The circumgalactic medium of QSOs (VI)

Marco Landoni - INAF OABr
Renato Falomo - INAF OAPd
Emanuele Farina - Max Planck Institute (Heidelberg)
Aldo Treves - Università degli Studi dell'Insubria (Como)
Riccardo Scarpa - IAC

Background

- How many type of quasar pairs exists ?
  There are "two types" of QSOs pairs

Physical

Gravitational bounded

$\Delta V_{\rm LOS} = 500 {\rm km\ s^{-1}}$

$pd \leq 500 {\rm kpc}$

Projected

Separeted on the sky by few arc-secs with different redshifts.

HERE WE CONCENTRATE ON **PROJECTED** PAIRS

QSOs absorption lines in pairs

- We exploit the background QSO *as a probe* of the cold circumgalactic medium of the foreground quasar.

- In particular, we analyse the absorption of Mg II and C IV systems imprinted in the spectrum of the background QSO in order to investigate the physical state of the cold gas and how the emission of the central engine affects its ionisation status.

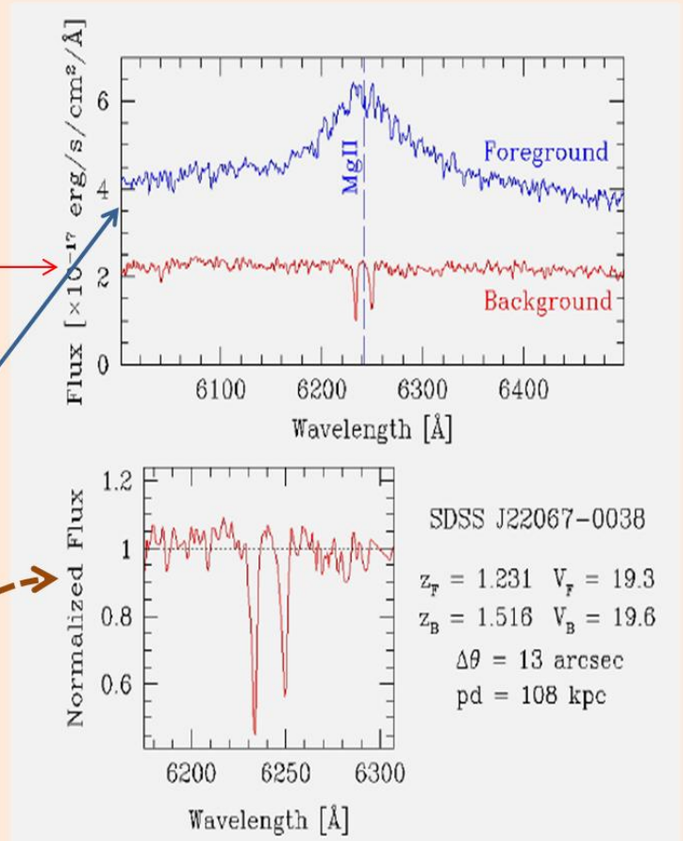
- We also compare the incidence and properties of Mg II /C IV absorption from the foreground QSO with those observed for quiescent galaxies (e.g. Chen et al) in order to make a reasoned comparison.

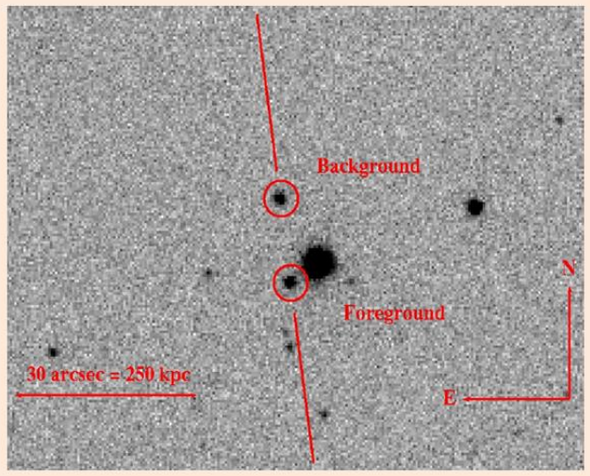
Quasar probing Quasar - Pictorial view

QSO close pairs

Background QSO

Foreground QSO





QSOs projected pairs - Selection

We selected quasar pairs from SDSS and adopting the following criteria:

1. Angular separation $\Delta\theta \leq 15''$ projected on the sky.

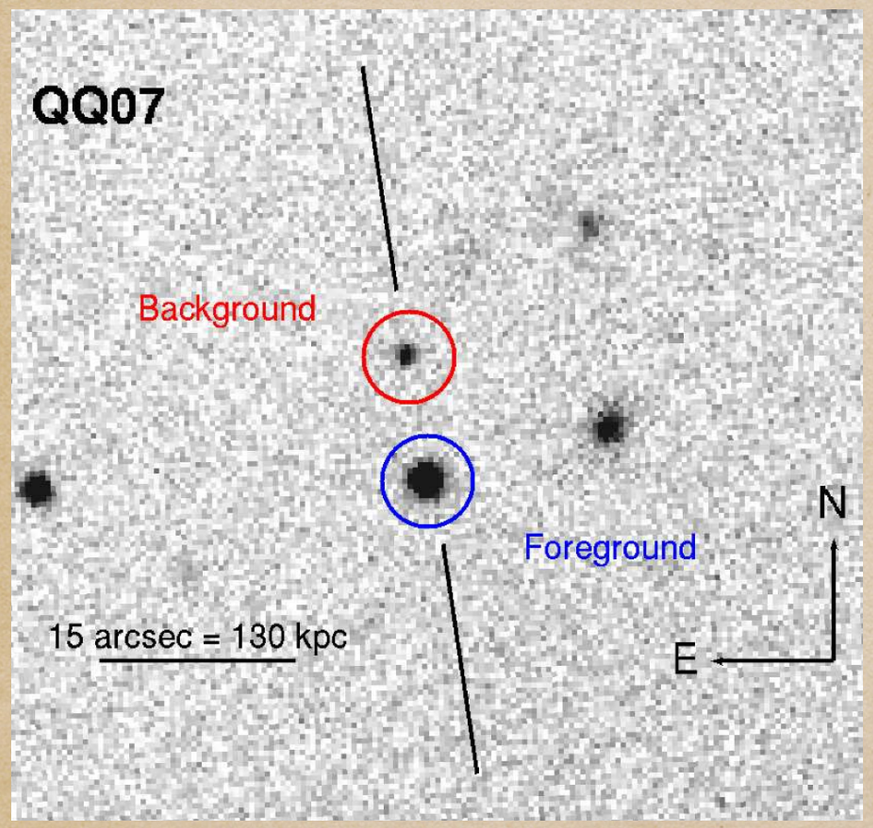
2. Redshifts of fore and background quasars combined so that the C IV and Mg II emissions and absorptions fall within the wavelength range observable.

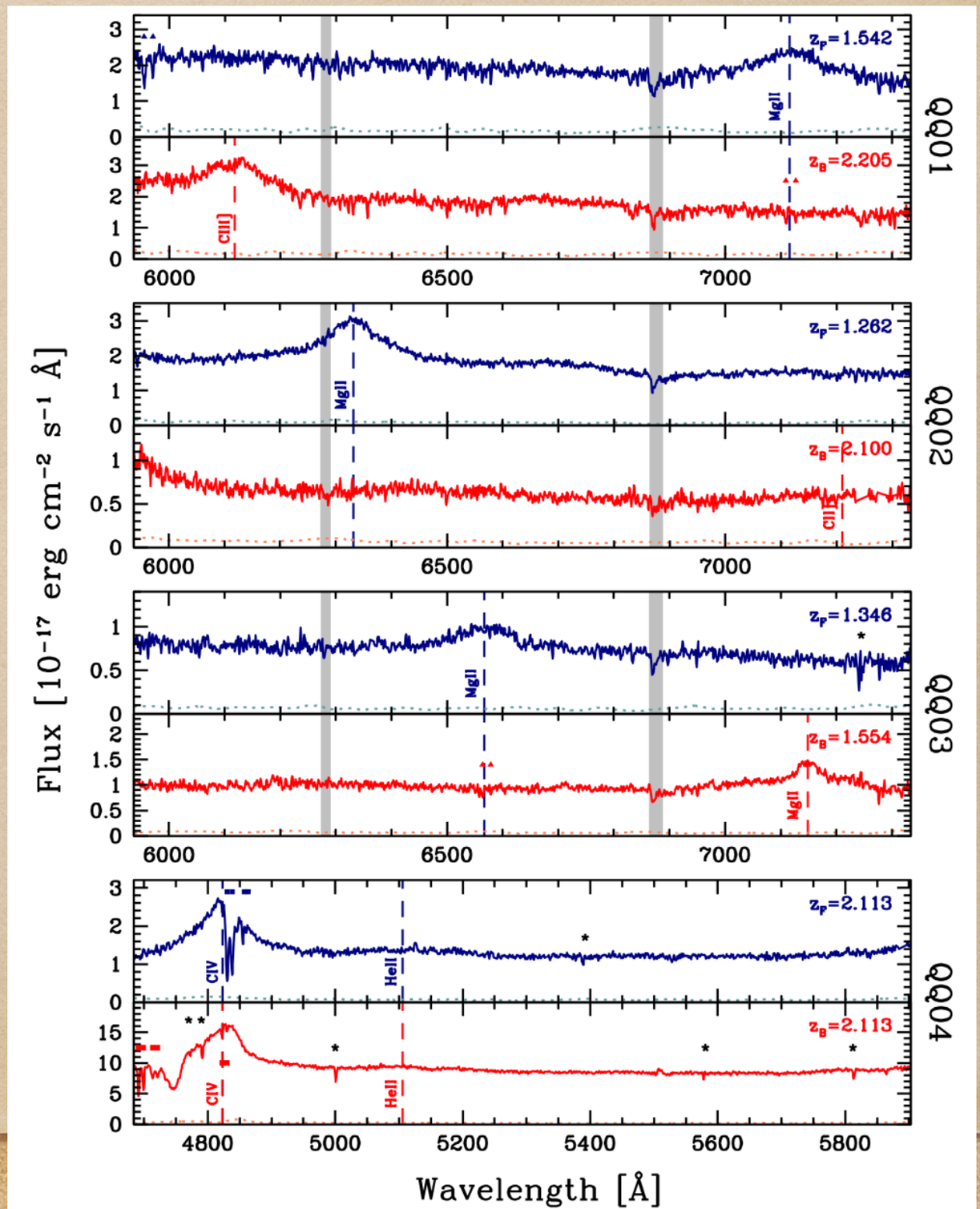
3. V < 21 in order to guarantee a reasonable signal-to-noise ratio of each spectra of the pair.

25.000 known pairs with pd in the range 50/1000 Kpc

(Hennawi & Farina 2015 in preparation)

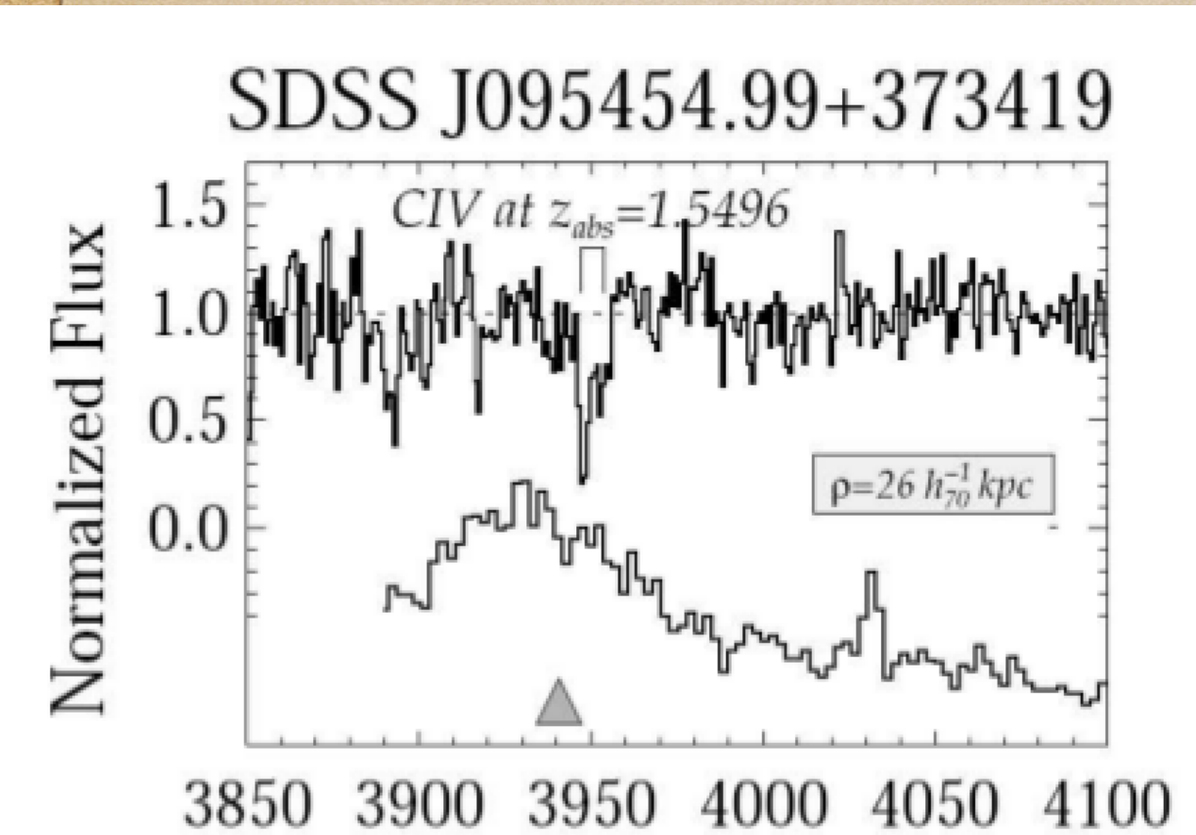
QSO projected pairs sample (Mg II)

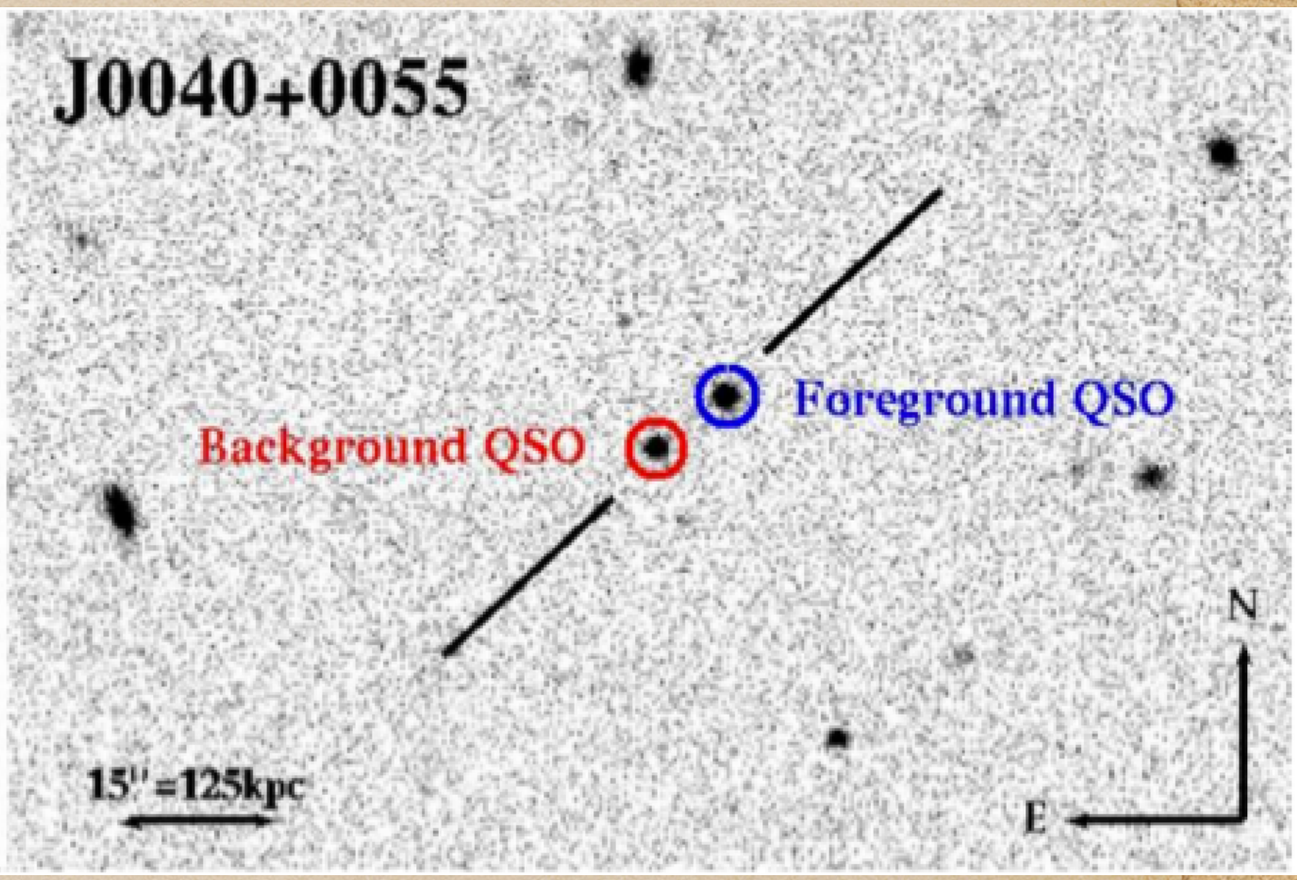




Farina et al 2014

QSO projected pairs - sample from SDSS (C IV)





Farina et al 2014

CASE 1

The Mg II absorption lines

We decided to study the Mg II doublet (2796 A, 2803 A) since:

- Falls in the **optical window** at intermediate redshift.
- Probes photoionized gas at $T \sim 10^4$
- Traces a wide range of neutral H I column densities ($N_{H_I} = 10^{16} \sim 10^{21}$)

Transverse or Line-of-sight absorption

Transverse: Detected on the background QSO. It is considered associated to the foreground QSO if lies within 1000 km/s from the redshift of the foreground QSO.

Line-of-sight: Detected on the foreground (or background) QSO and associated to the halo of the QSO itself.

In the FORS2+GTC sample we detected 8 transverse Mg II and **zero** line-of-sight absorption systems.

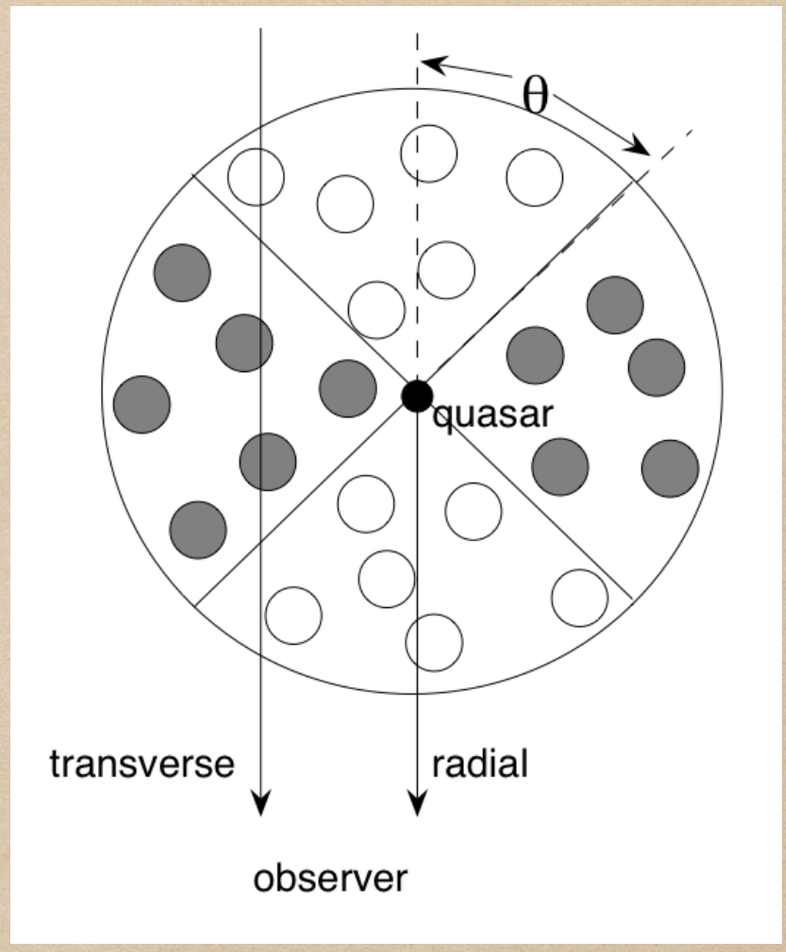
Farina et al 2014

Why this difference ? A physical interpretation

- Quasar luminosity of about 10^46 erg/s
- Cool gas around quasar in clouds of 1pc and density of 10^-2 atoms cm^-3.

Then…

- The emission of QSO can heat the gas up to 10^5 K at a distance up to 100 Kpc.
- The ionising flux is also emitted in cones and then is anisotropic.

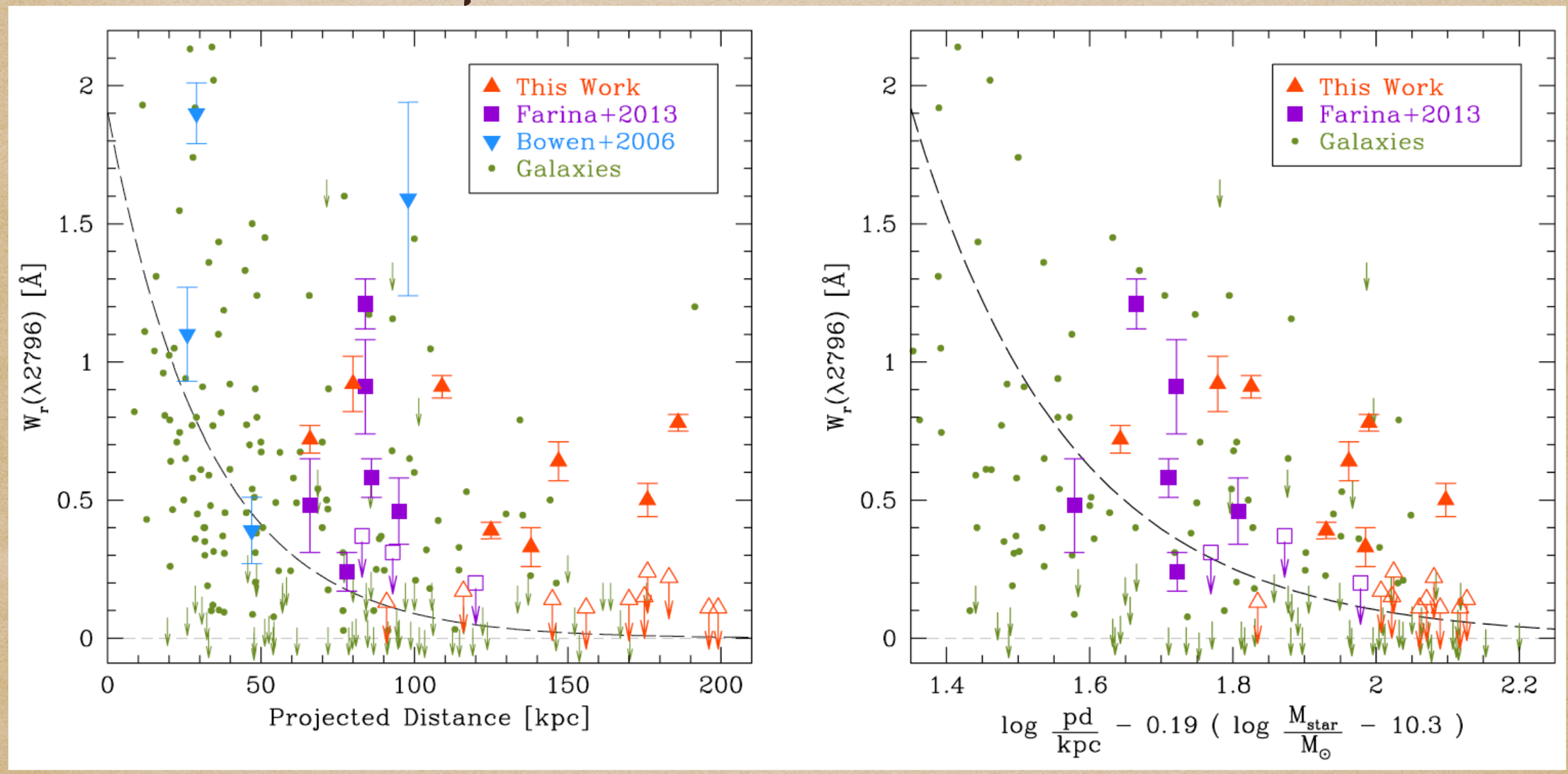


Not ionized, MgII survives

Ionized, MgII is destroyed

Anisotropy between transverse and LOS absorption.

Transverse absorption of Mg II . Scaling relation EW-pd and stellar mass normalisation

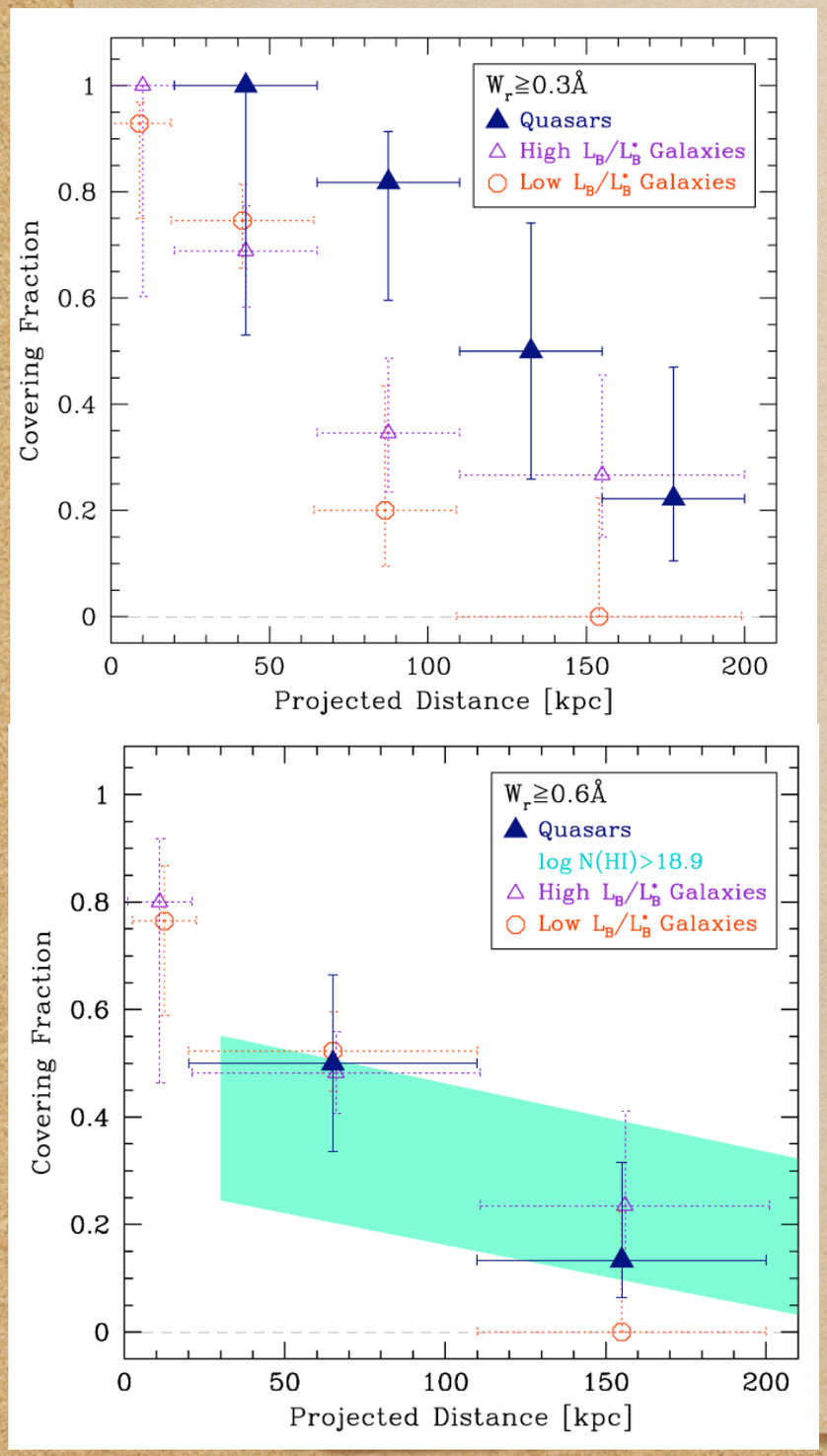


1. Anticorrelation between EW and Wr at 8-sigma for galaxies and 2-sigma for QSO

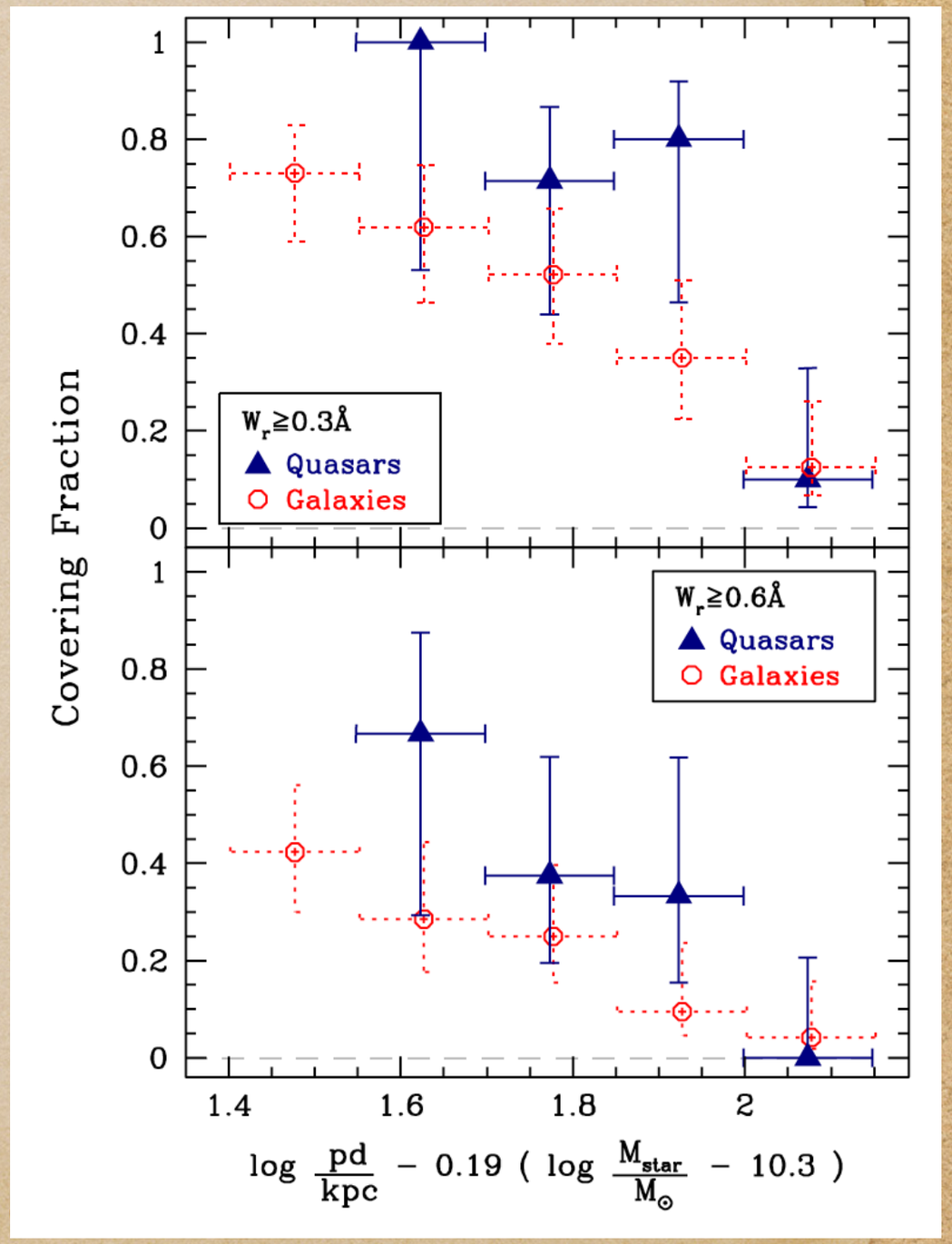
2. The anti correlation is **enhanced** if **stellar mass** is considered. The hypothesis of the underlying same population is ruled out at 77% confidence level.

Farina et al 2014

Transverse absorption of Mg II . Covering fraction



Taking into account the stellar mass



Farina et al 2014

The case of MgII - summary

1. QSOs are surrounded by a large amount of Mg II with covering fraction about 1.0 at pd < 60 kpc.
2. Weak anti correlation between Mg II and impact parameter enhanced considering the stellar mass which plays a crucial (not the unique one) role.
3. QSO emission is not isotropic (difference between the number of LOS and transverse systems).

CASE II (Work in progress)

The C IV absorption lines

In order to make further steps to understand the connection between CGM, quasar activity and their environments we **extended** our study to C IV absorption systems following the same observation strategy illustrated for the Mg II.

The C IV doublet is:

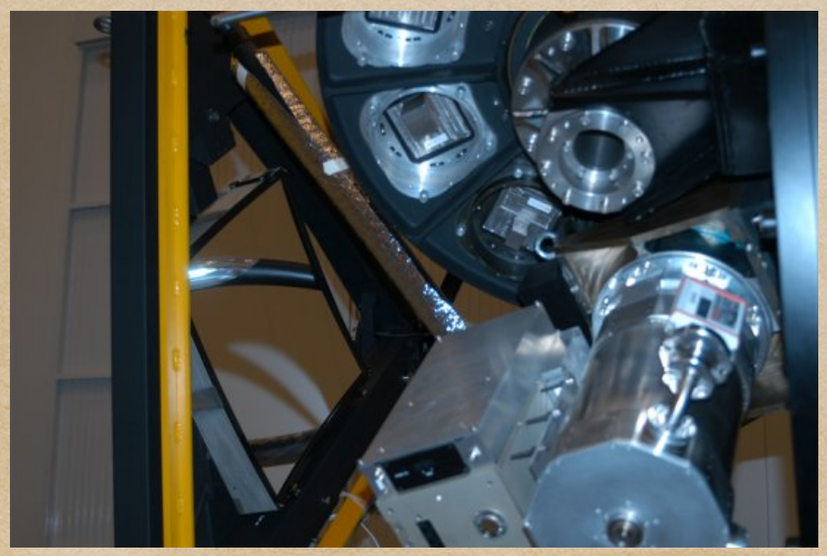
1. A tracer for **highly-ionised gas**
2. Detectable at **high impact** parameter

with respect to Mg II or H I case (low-ionised region).

3. An unique tools to understand the **processes of QSO formations and evolutions** that deposit enriched material far from the host galaxies.

Quasar probing Quasar at GTC with OSIRS.

- **Largest** (10.5 m) optical telescope
- F/16
- FoV 20’ ⌀
- Located at Roque de los Muchachos Observatory on the island of la Palma (2300 mt above sea level).

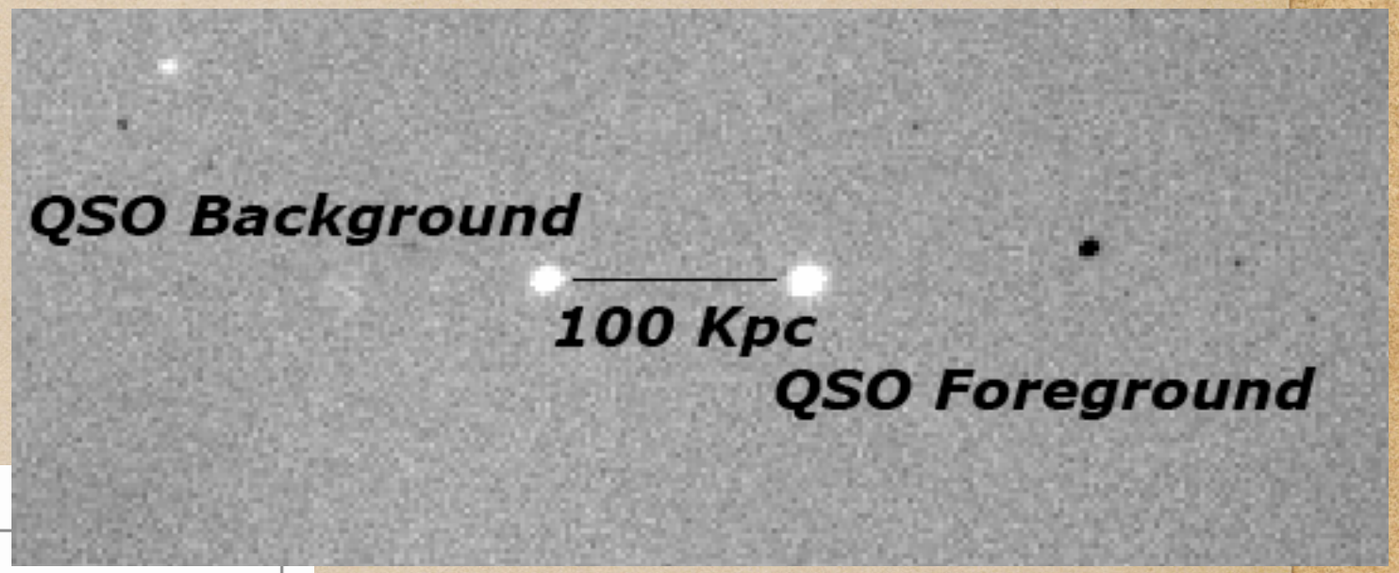


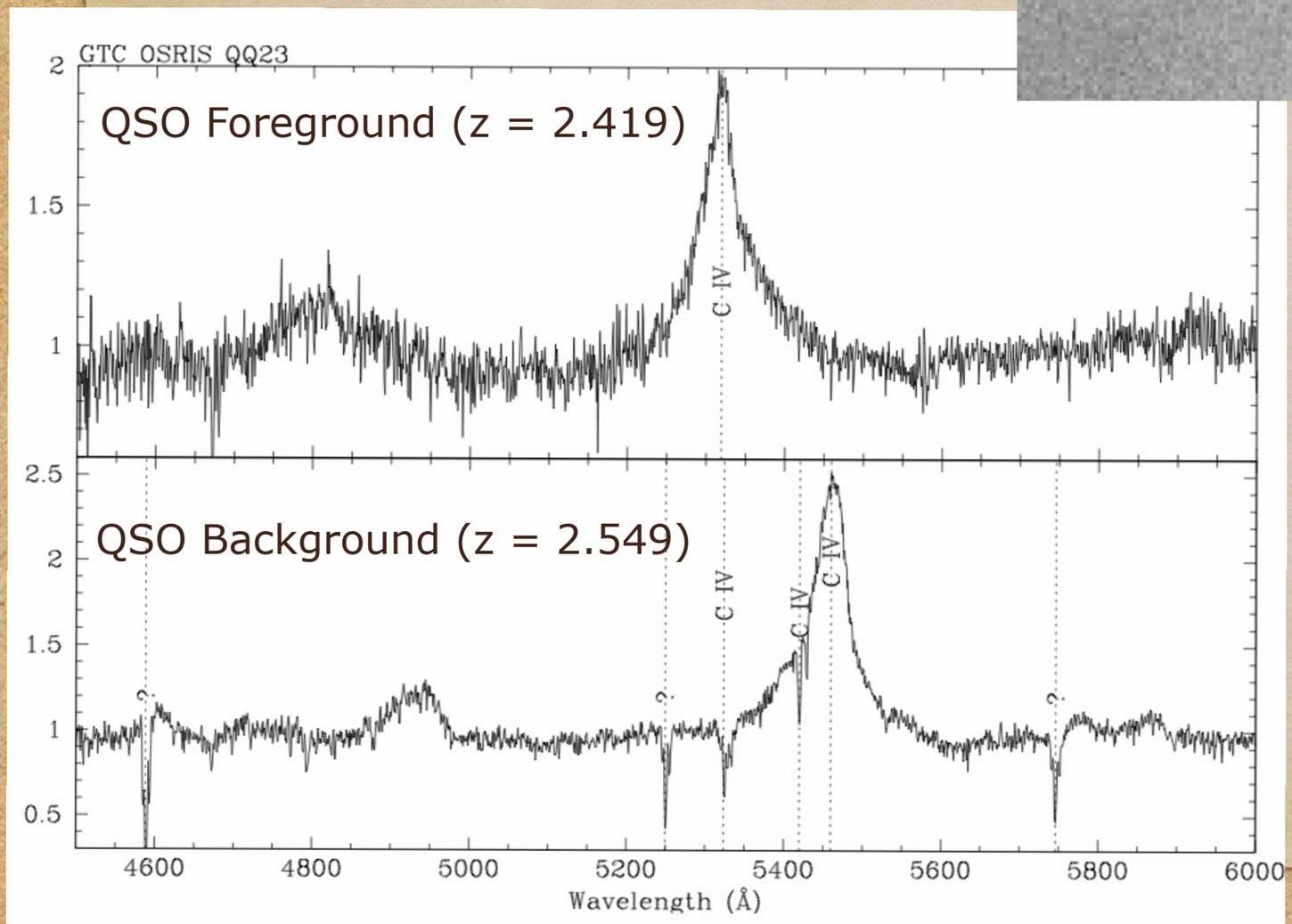
- Focal reducer instrument
- Imaging & Spectroscopy
- Longslit spectroscopy with VPHG gratings. R2500V and R2500U (used in our program) provide R of about 2500 and high throughput.

Quasar probing Quasar at GTC with OSIRS.

- We obtained spectra for about 30 QSOs pairs in the redshift range z 1.90 2.50.
- The program has been completed 2 weeks ago.
- Average SNR of 20 in each spectrum of each pair. This allow to better detected faint spectral feature with even smaller equivalent width.

A sample pair with OSRIS@GTC





- Transverse and LOS CIV absorption systems are detected.
- 100 Kpc of projected distance. C IV absorption systems survive as expected from models.

Forthcoming and conclusions

- C IV program, carried out with the biggest telescope in the world, has been completed 2 weeks ago.
  Data reduction is also almost completed.

- We will compare the result of C IV with those of Mg II in order to understand the physical status of highly ionised gas around quasars at large impact parameter.