



The Pan-STARRS1 Search for the Highest Redshift Quasars

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Motivation : **why** pushing the redshift frontier

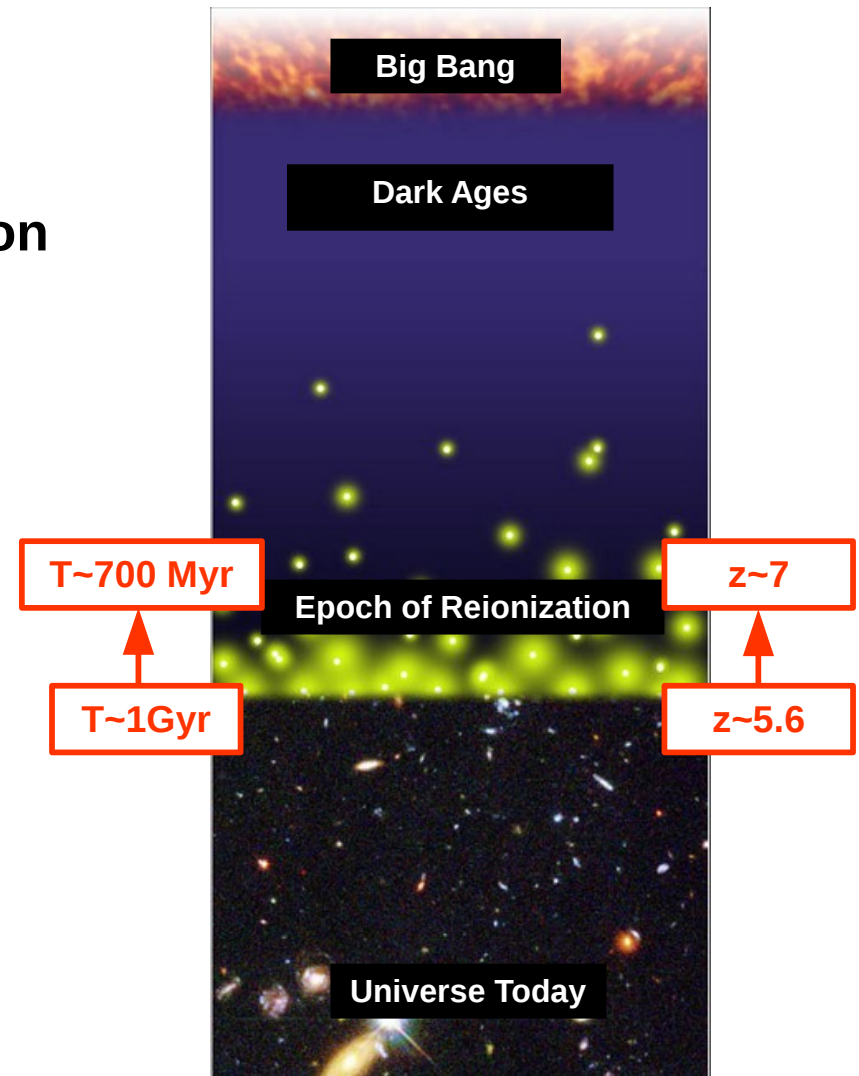
Current sample of >100 QSOs at $z \sim 6$

- Characterize early **Black Hole population**

$$M_{BH}(t) = M_{BH,0} e^{t/t_s} \quad t_s \approx 34 \text{ Myr}$$

$z \sim 6.3$	$\Delta T \sim 100 \text{ Myr}$
$z \sim 7.0$	
$M(BH)_{z \sim 6.3} \sim 20 M(BH)_{z \sim 7}$	

- Search for **first overdensities**



Motivation : **how** pushing the redshift frontier

Current sample of >100 QSOs at $z \sim 6$

zdrop-outs

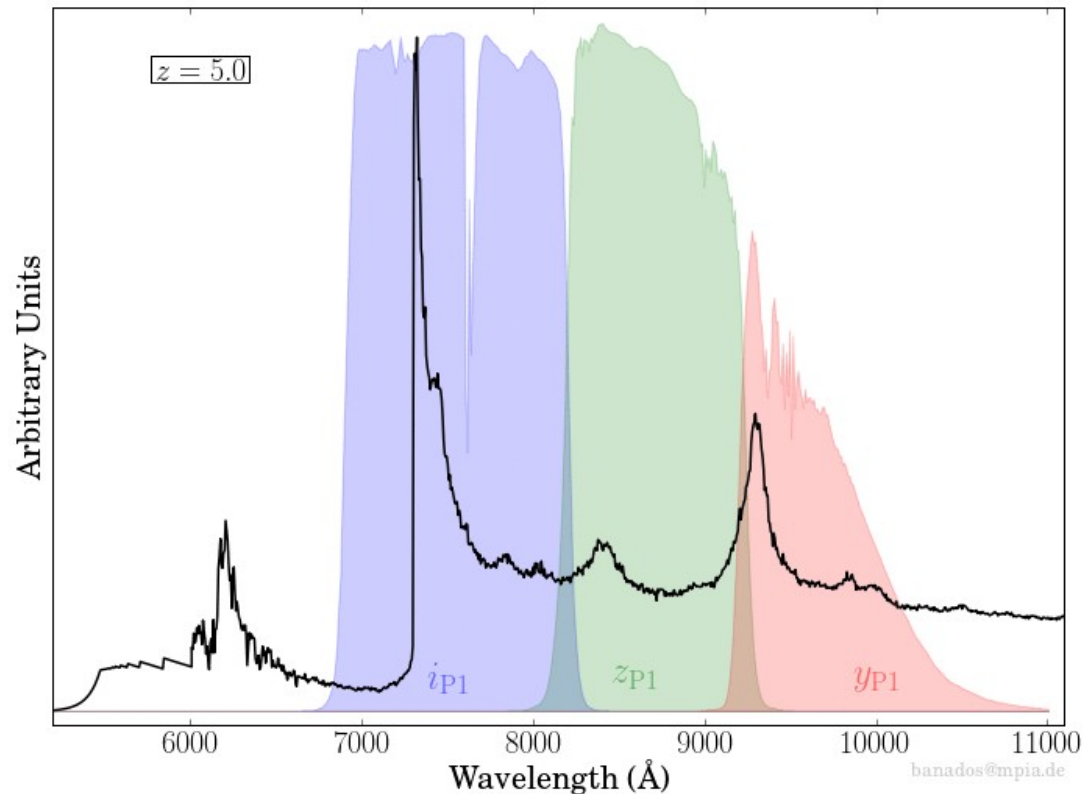
Quasar emission shifted out of z band

- **IR observations**

Number density: very low

$$N \approx 1 \times Gpc^{-3}$$

- **Large sky area**



Courtesy of Bañados E.

The Pan-STARRS1 Survey

- 1.8m telescope in Hawaii
- Survey in grizy, $\text{dec} > -30^\circ$

What is different from SDSS ?

- Coverage in the **south** → multiwavelength **follow up** with VLT, ALMA...
- **Deeper** in the redder filter ($\sim > 1$ mag in z)
- **y filter** enables high-z QSOs searches

Selection of z-dropouts

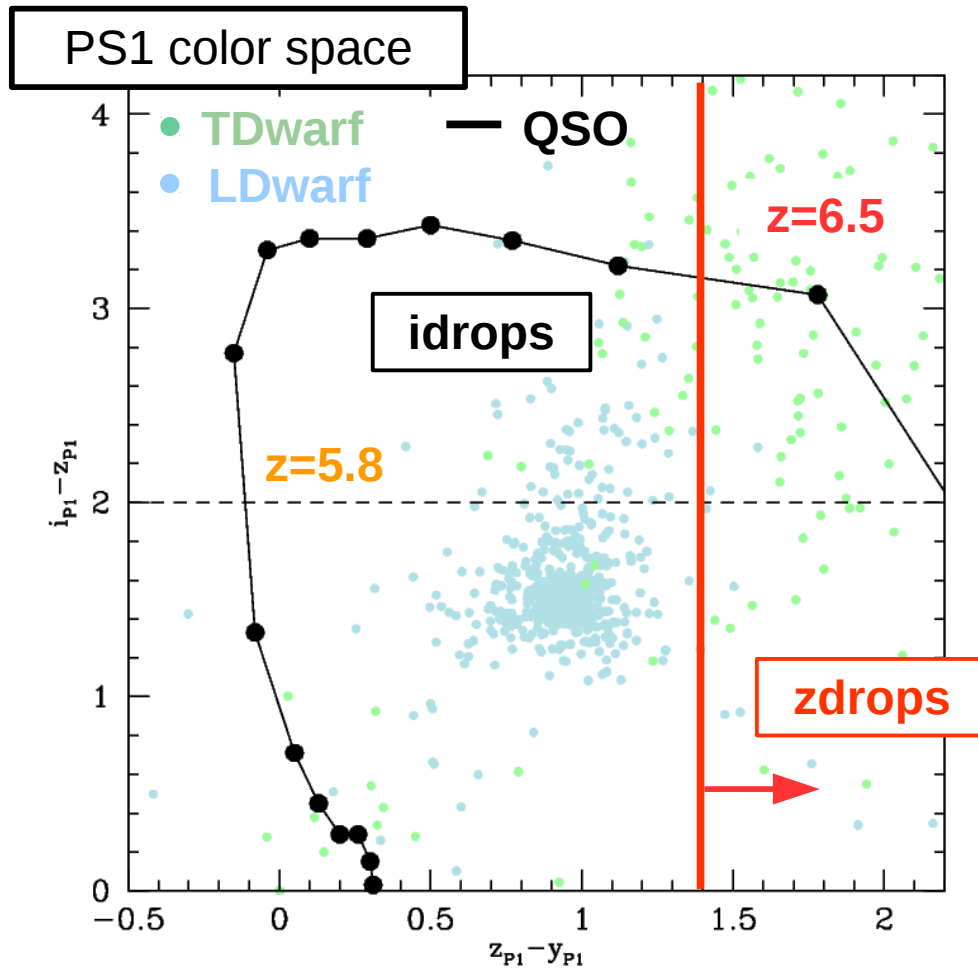
Database selection

- Color space

N° of sources

~3 439 696 157

Selection criteria color space



Mazzucchelli et al. in prep

Selection of z-dropouts

Database selection + cross-match

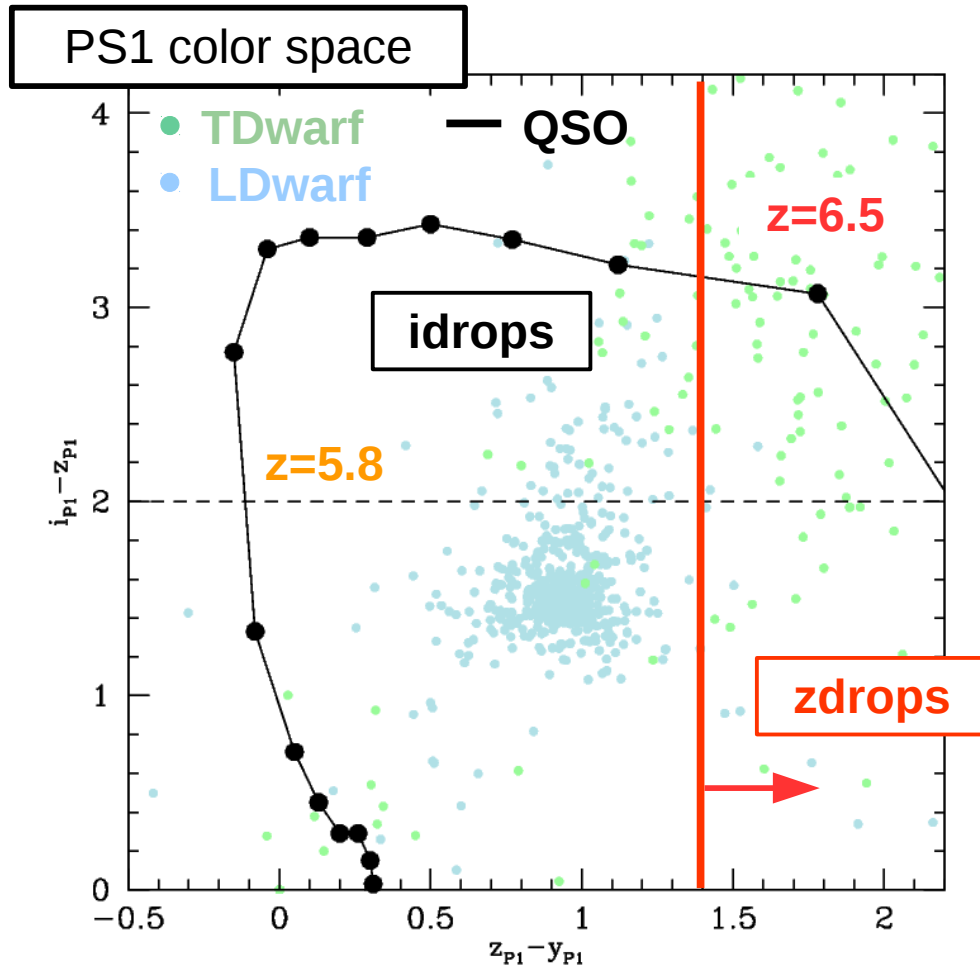
- Color space

N° of sources

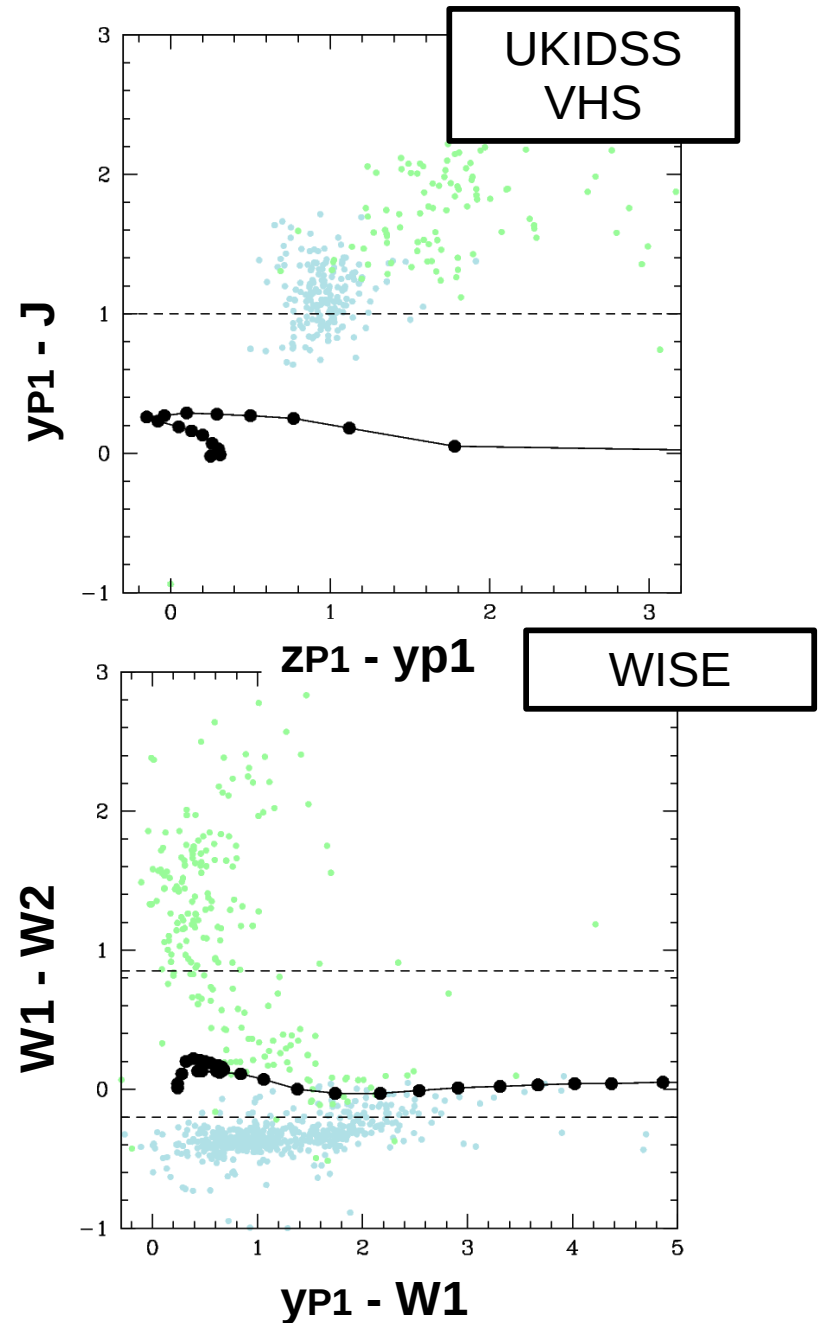
~3 439 696 157

~200 000

Selection criteria color space



Mazzucchelli et al. in prep



Selection of z-dropouts

Database selection + cross-match

- Color space
- SED fit

N° of sources

~3 439 696 157

~200 000

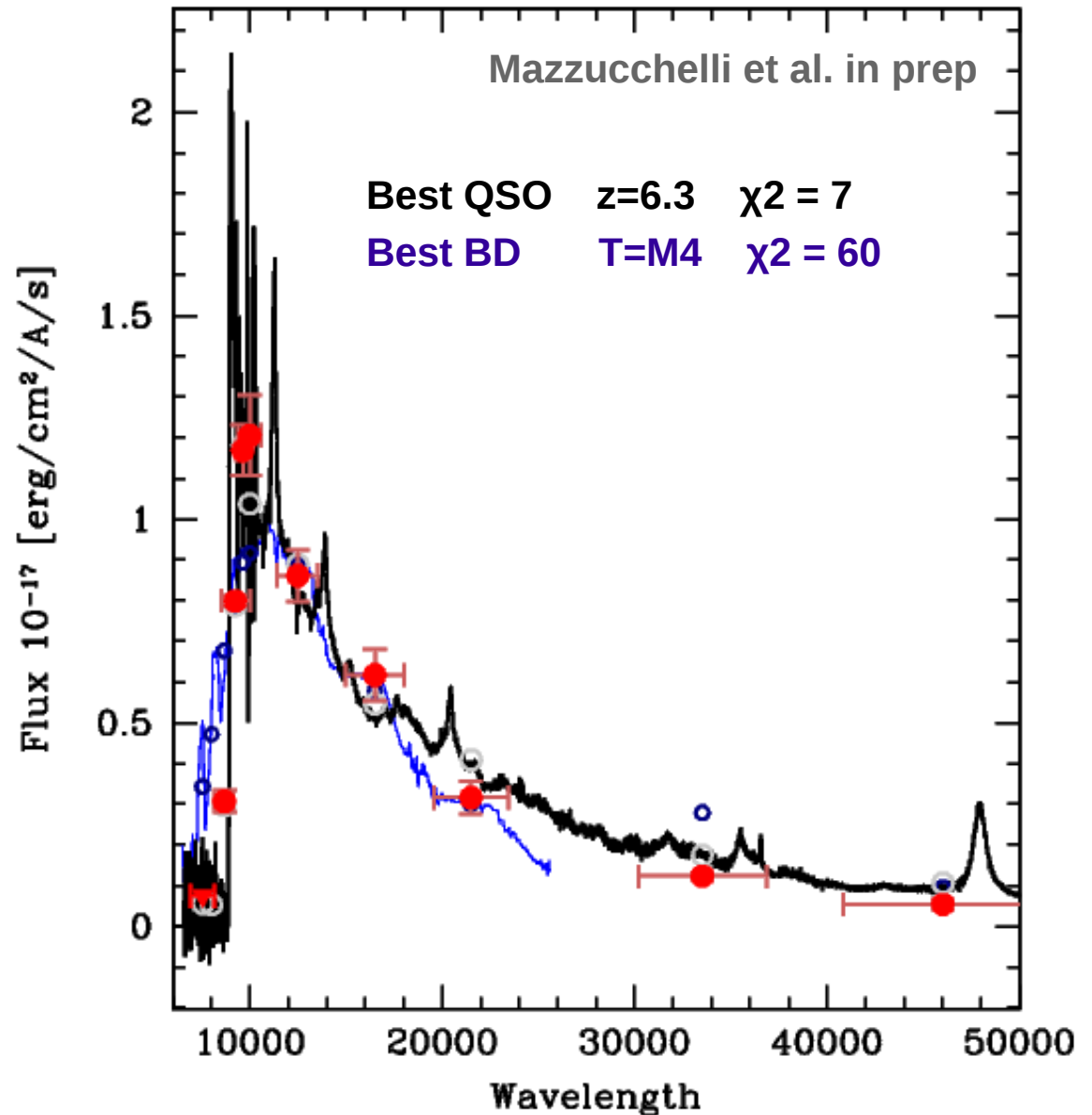
SED Fit Method

QSO Templates

- Observed composite templates
- IGM absorption
- Redshift: $z: 5.5-9.0$
 $\Delta z = 0.1$

BDs Templates

- Observed BDs Spectra
- Photometric correction for WISE magnitude



Selection of z-dropouts

Database selection + cross-match

- Color space
- SED fit
- Automatic rejection of outliers
- Visual inspection

Photometric Follow up

- 2.2mMPG, NTT @ La Silla
- 3.5m @ CAHA

Spectroscopic Follow up

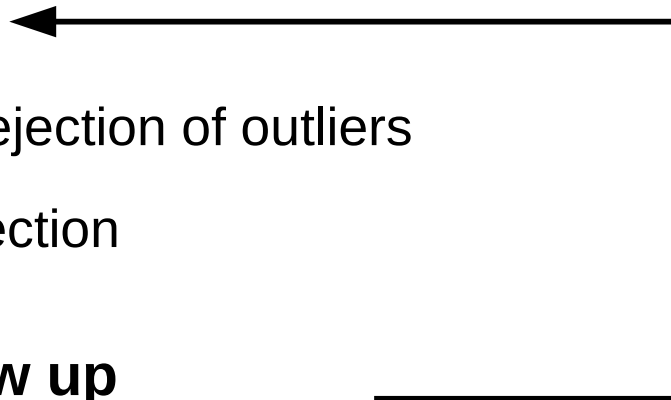
N° of sources

~3 439 696 157

~200 000

~500

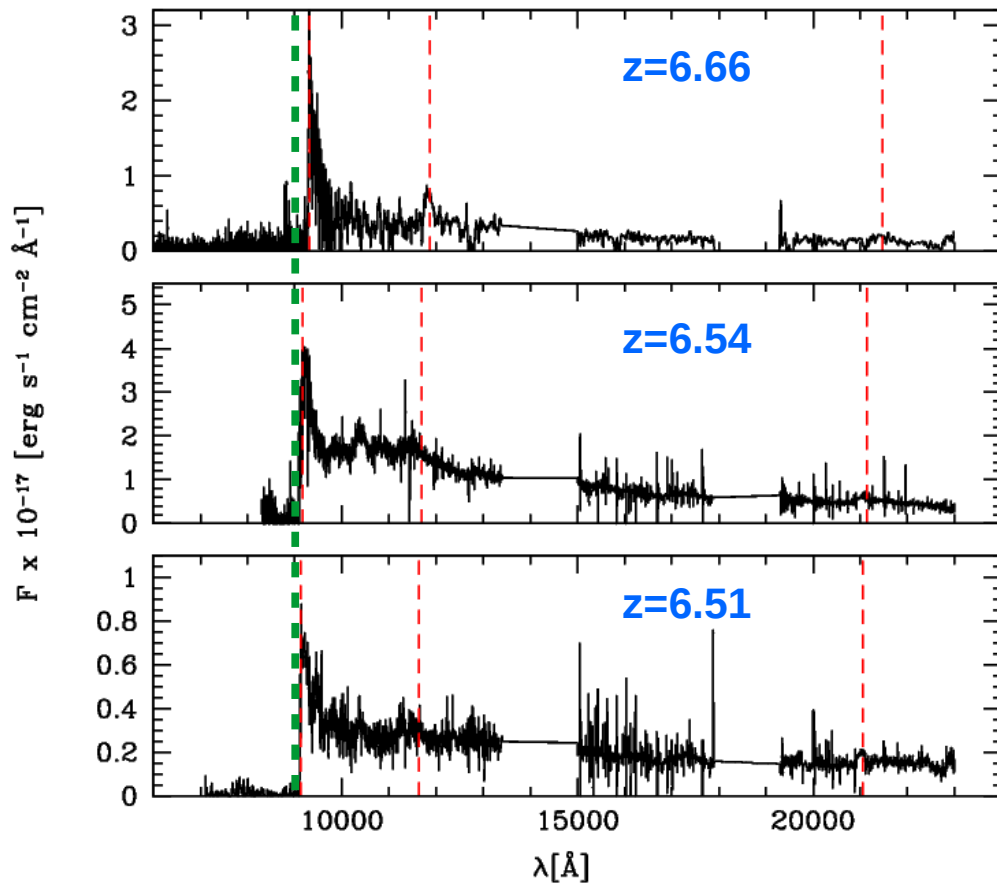
~10



PS1 QSOs at $z > 6.4$: the Sample

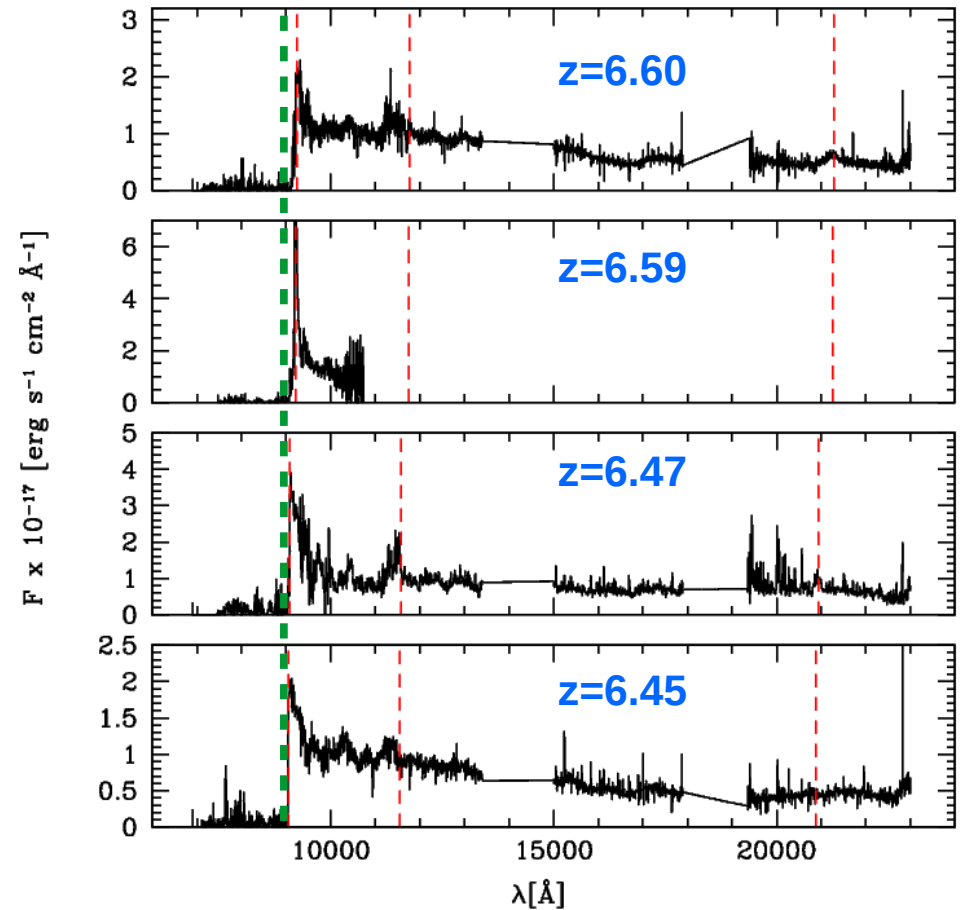
7 PS1 QSOs at $z > 6.4$

Lya @ $z=6.4$



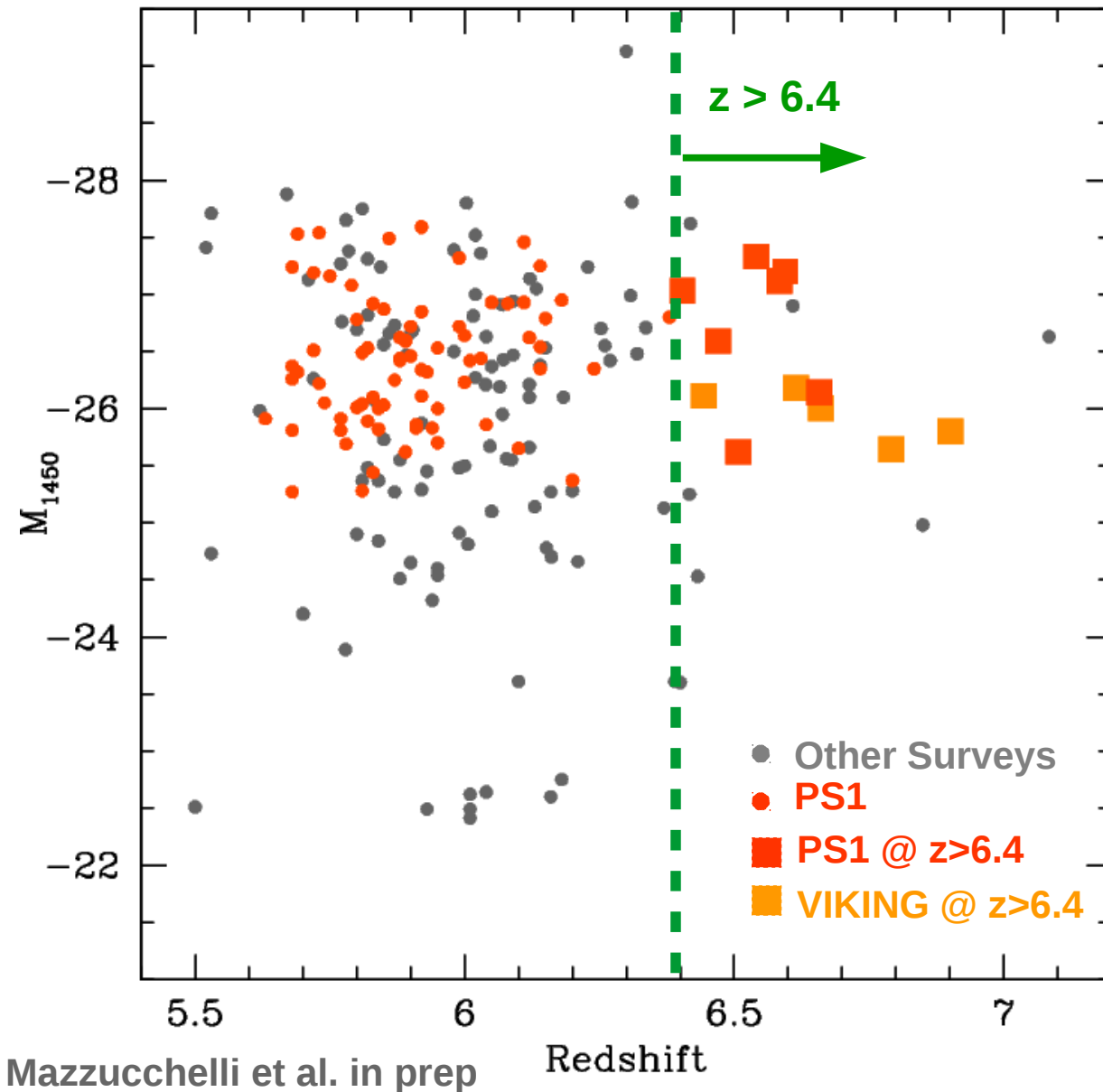
Venemans et al. 2015

Lya @ $z=6.4$



Mazzucchelli et al. in prep

PS1 QSOs at $z > 6.4$: Magnitude and z distribution

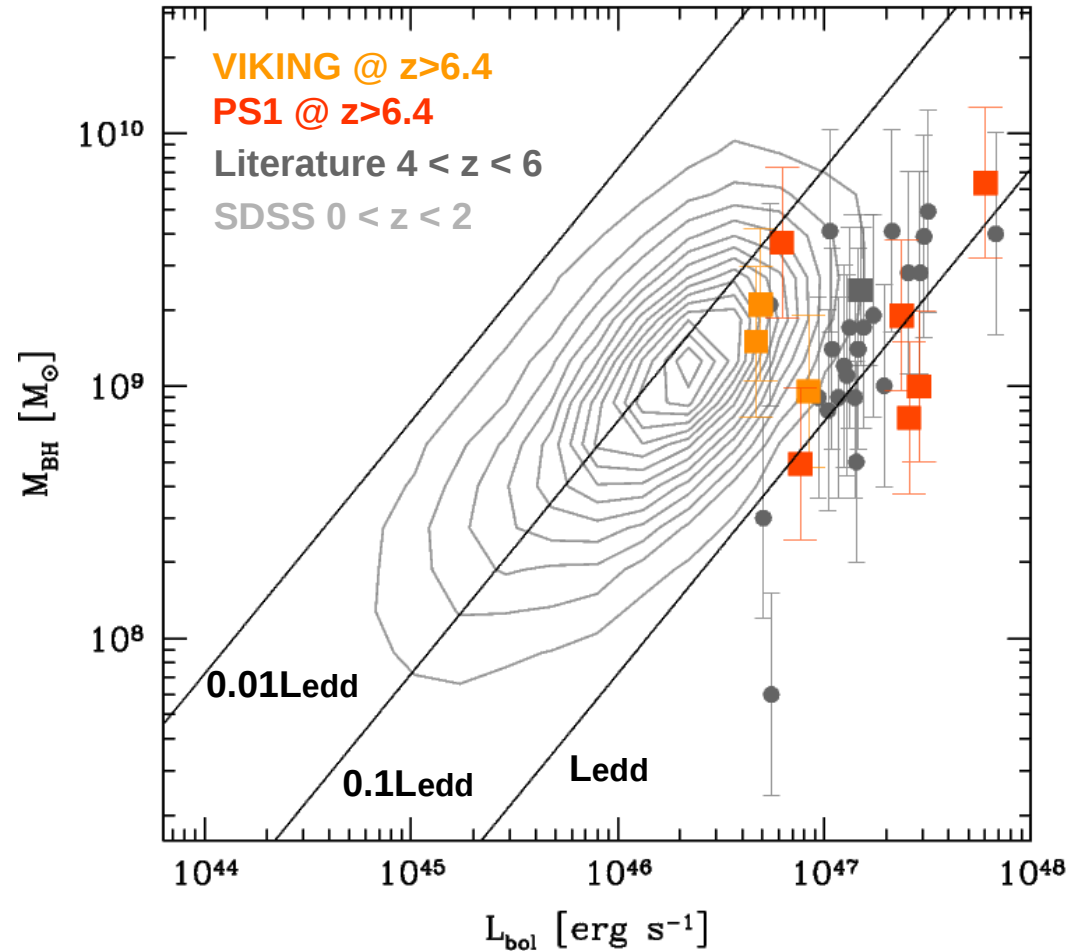
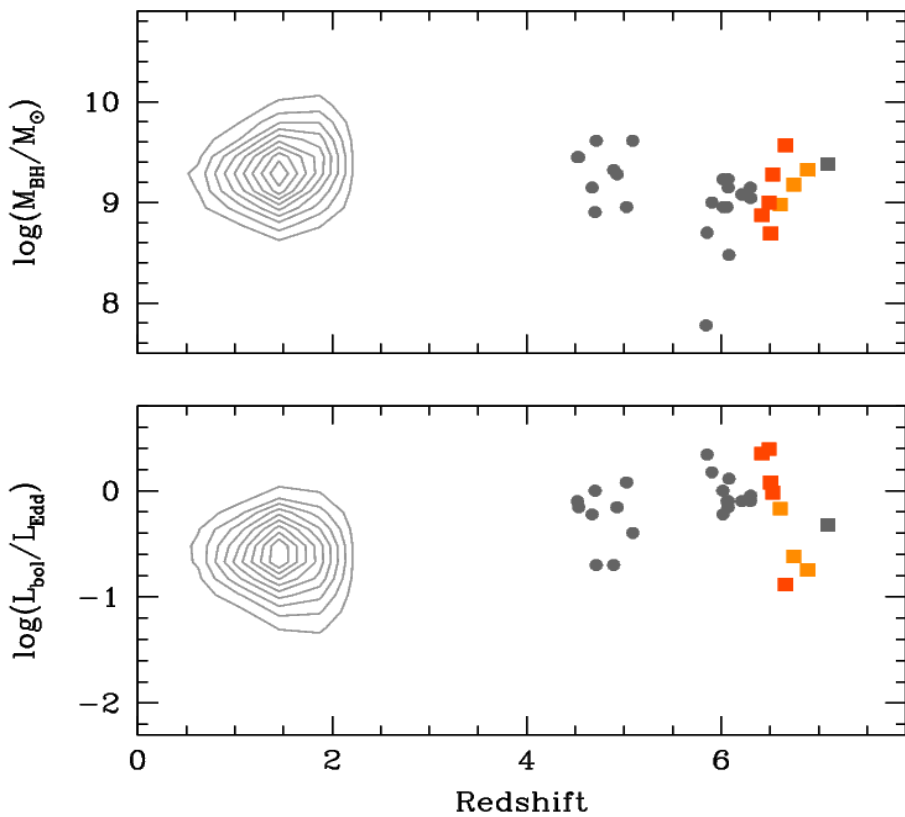


PS1+VIKING QSOs

Sample study of
QSOs at $z > 6.4$

Banados et al. 2016 subm.
Mazzucchelli et al. in prep.
Venemans et al. 2015
Venemans et al. 2013

PS1 QSOs at $z > 6.4$: MBH and L_{bol}

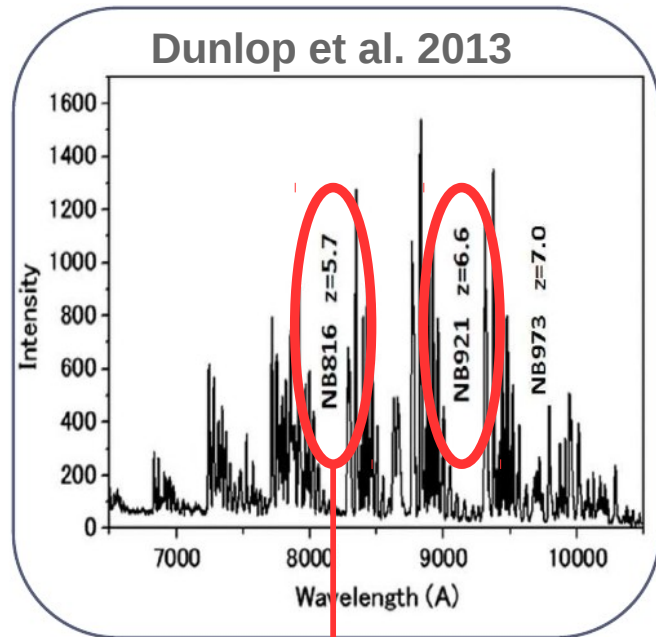


Mazzucchelli et al. in prep.

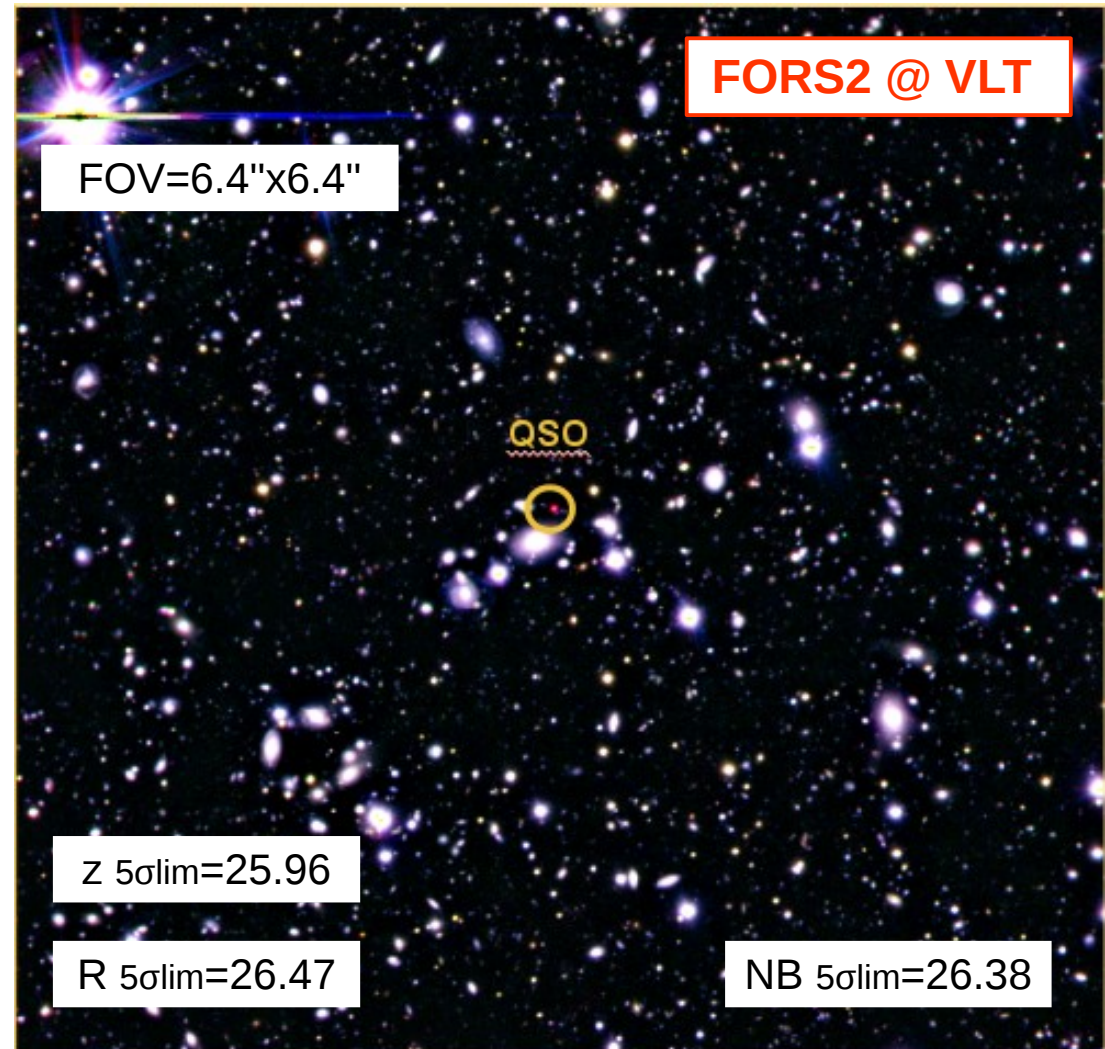
PS1 QSOs at $z > 6.4$ show Eddington ratios ~ 1

Study of QSO Environment: NB Search @ $z=5.7$

Search for **Lya emitting galaxies** around QSOs through **Narrow Band Deep Imaging** in clean atmospheric windows



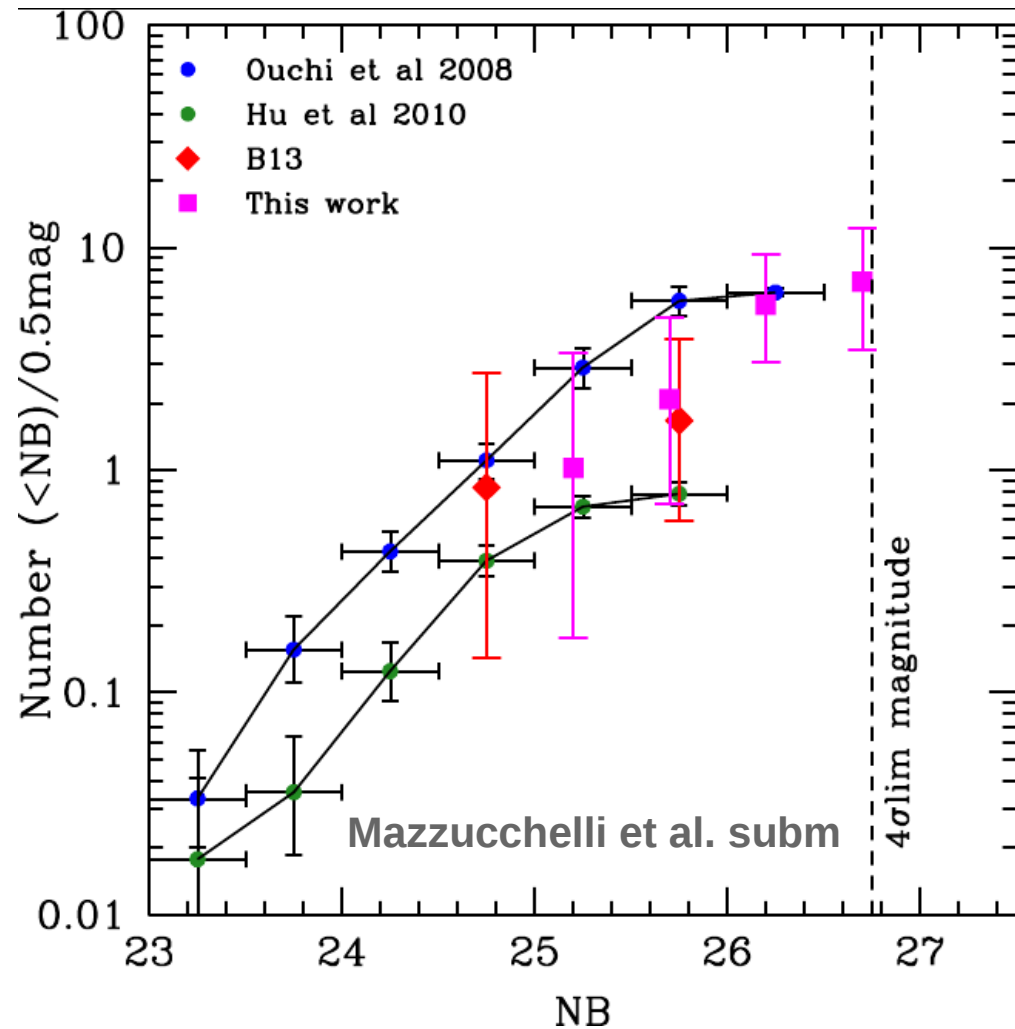
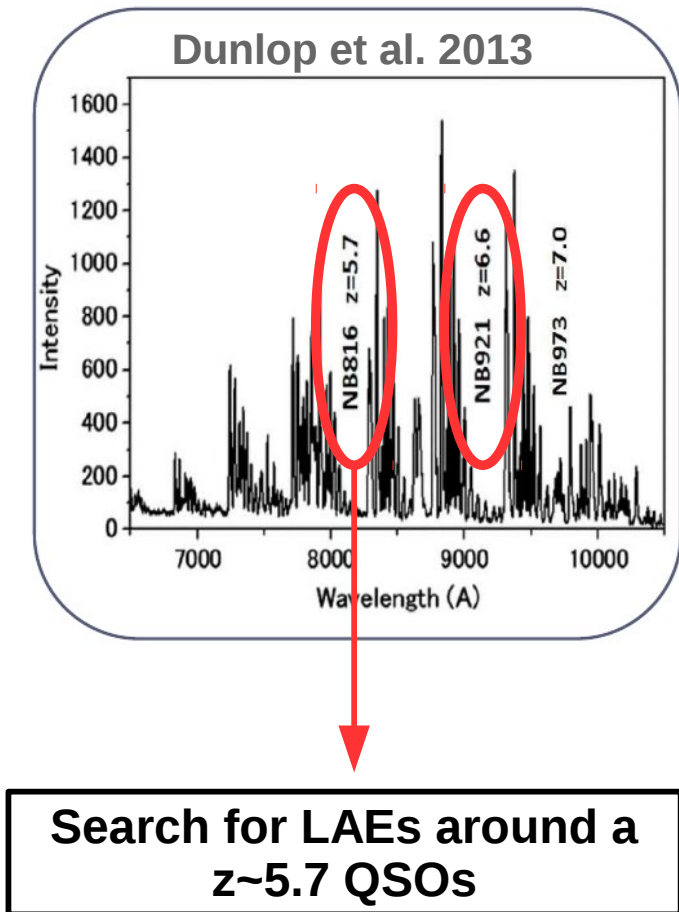
Search for LAEs around a $z\sim 5.7$ QSOs



Mazzucchelli et al. subm

Study of QSO Environment: NB Search @ $z=5.7$

Search for **Lya emitting galaxies** around QSOs through **Narrow Band Deep Imaging** in clean atmospheric windows

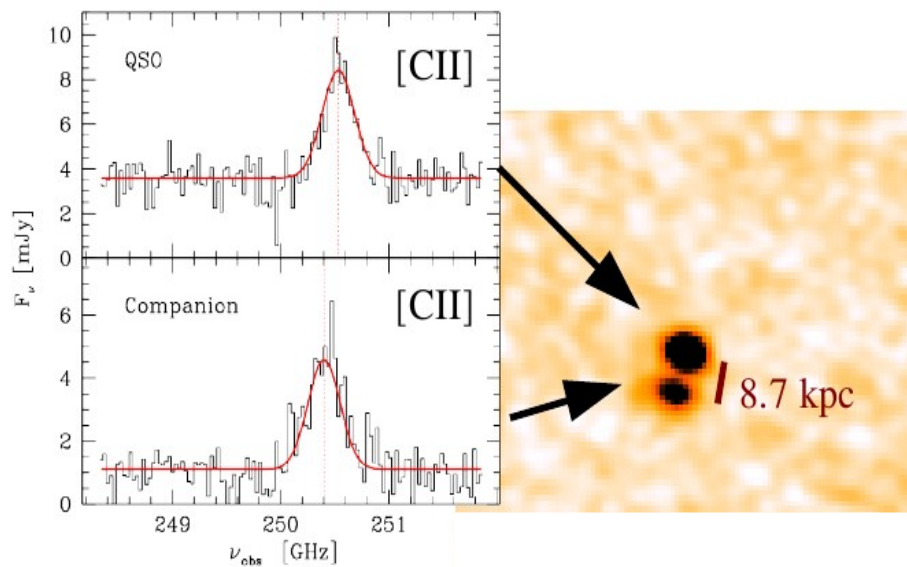


No evidence for LAEs overdensities

A Gas Rich Companion Galaxy

ALMA Cycle 3 Survey of **Dust Continuum and [CII] Emission**
in 35 $z \sim 6$ QSOs (PI:Walter)

Discovery of **gas rich and highly star forming companion galaxies**

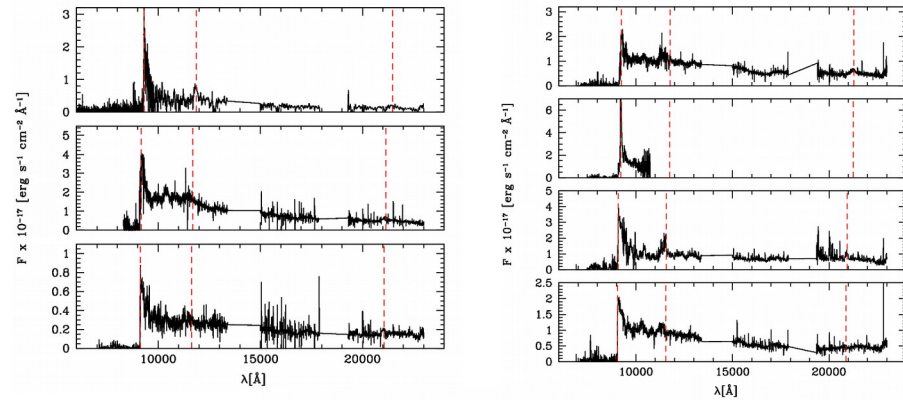


$L[\text{CII}] \sim 10^9 L_{\text{sun}}$
 $L_{\text{IR}} \sim 10^{11} L_{\text{sun}}$
 $\text{SFR} \sim 100 M_{\text{sun}}/\text{yr}$

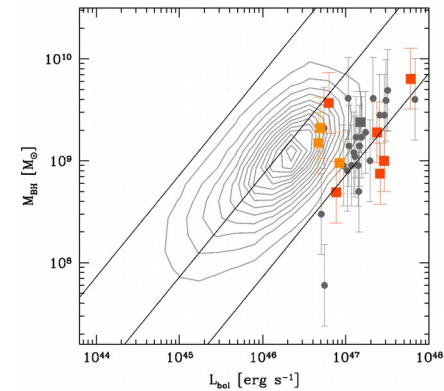
Highly **overdense region** in the Early Universe

Conclusions

- The discovery of 7 new PS1 QSOs at $z > 6.4$



- They show $L_{bol}/L_{edd} \sim 1$



- Environment studies

No evidence for LAE overdensities

Gas rich companions

