Evidence for quasar evolution in the first billion years

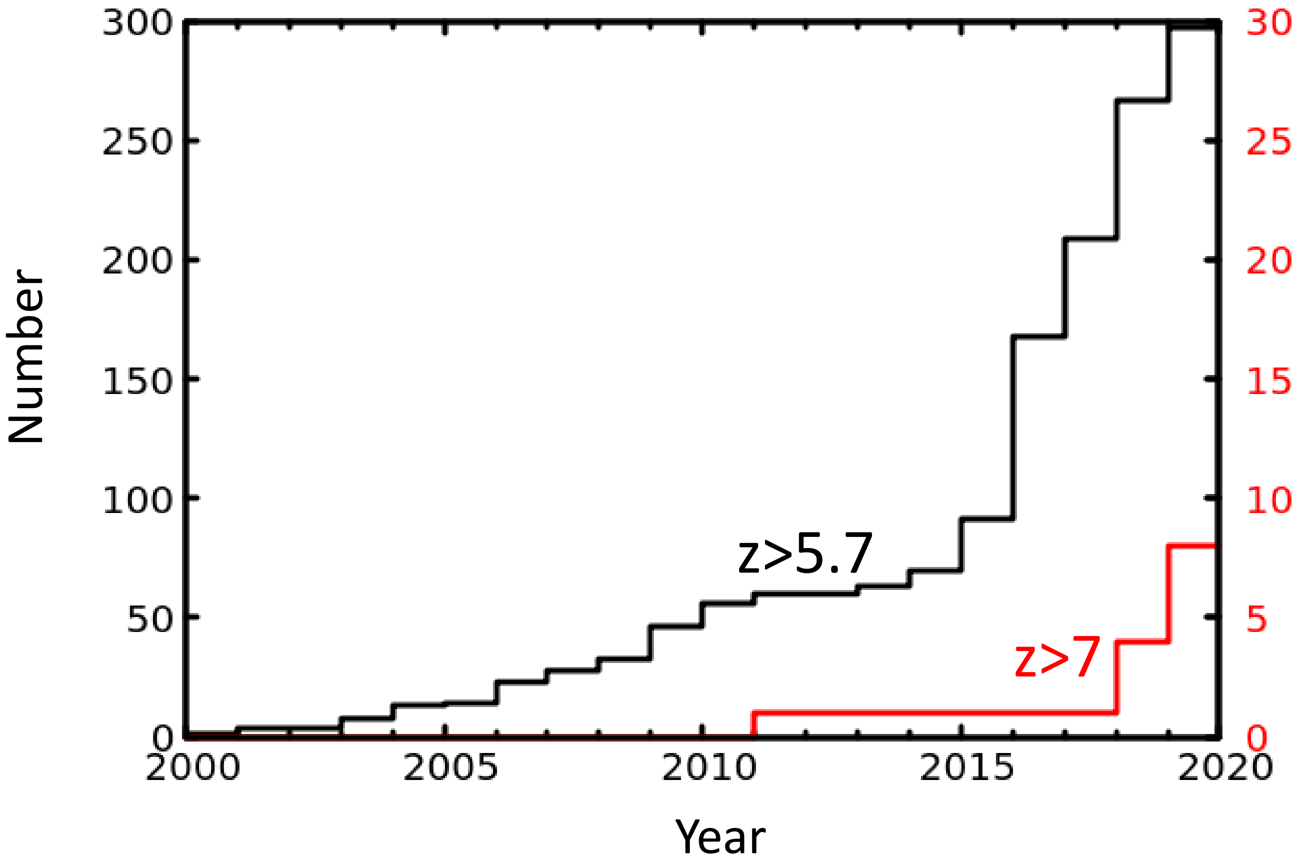
Sarah Bosman

University College London

Meyer, Bosman & Ellis 2019, MNRAS, 487, 3305

KICC 10th Anniversary Symposium – Cambridge 19/9/2019

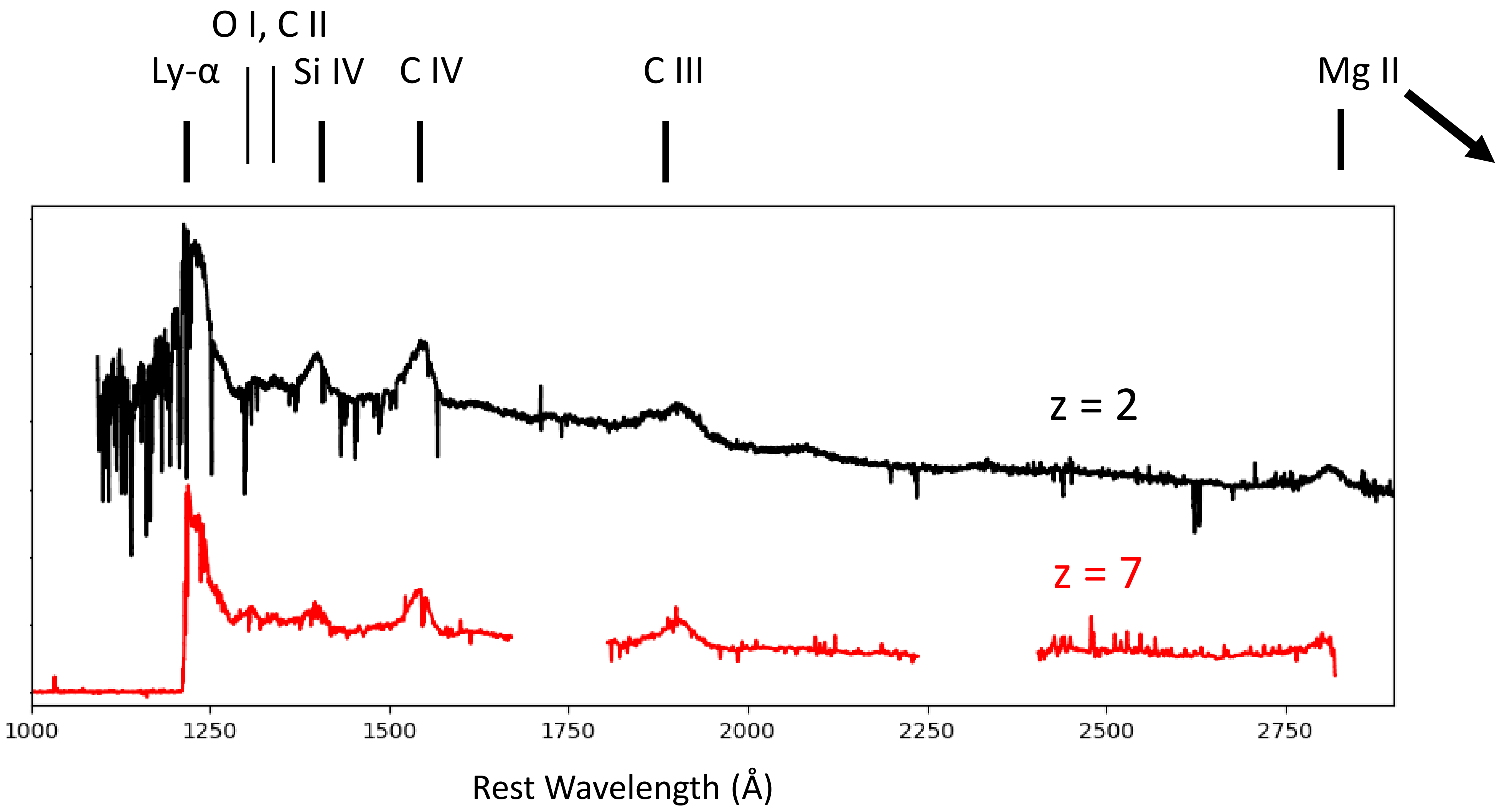
Growing numbers



The end of the beginning:

O(1000) quasars in the first billion years expected in LSST, Euclid

Quasars across cosmic time



Close to systemic

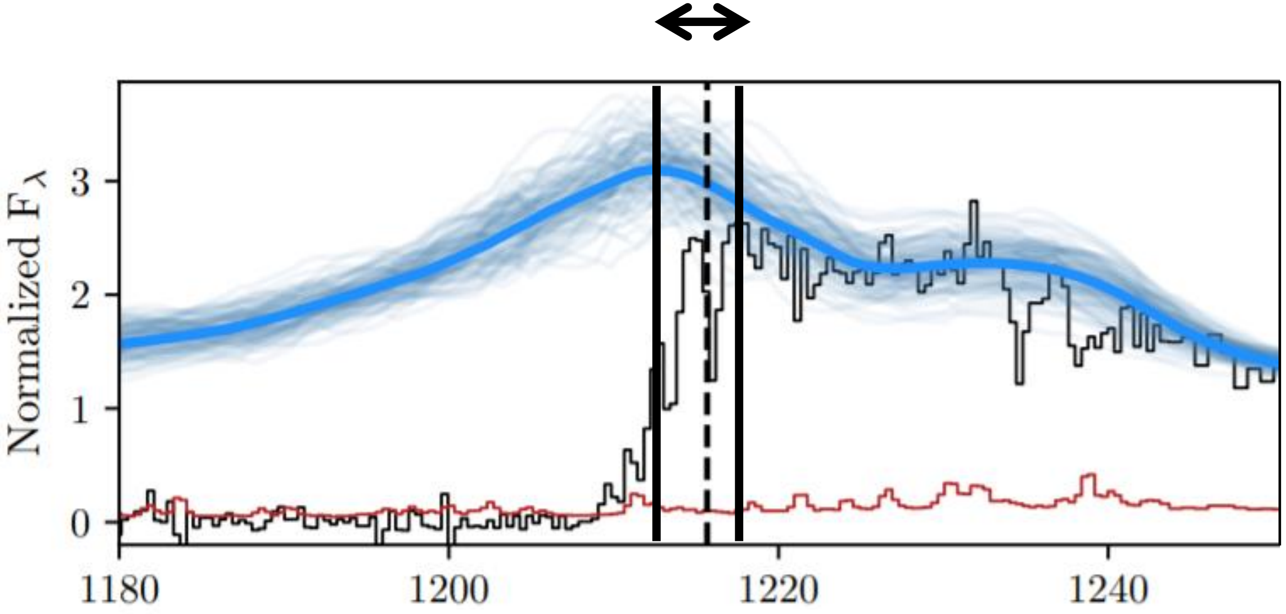
Width ~ BH mass

Beyond reach at z > 7

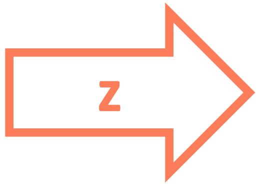
Much harder to access than optical features at z > 4

Redshift determination

$\Delta z \sim 0.1$



Davies et al. 2019



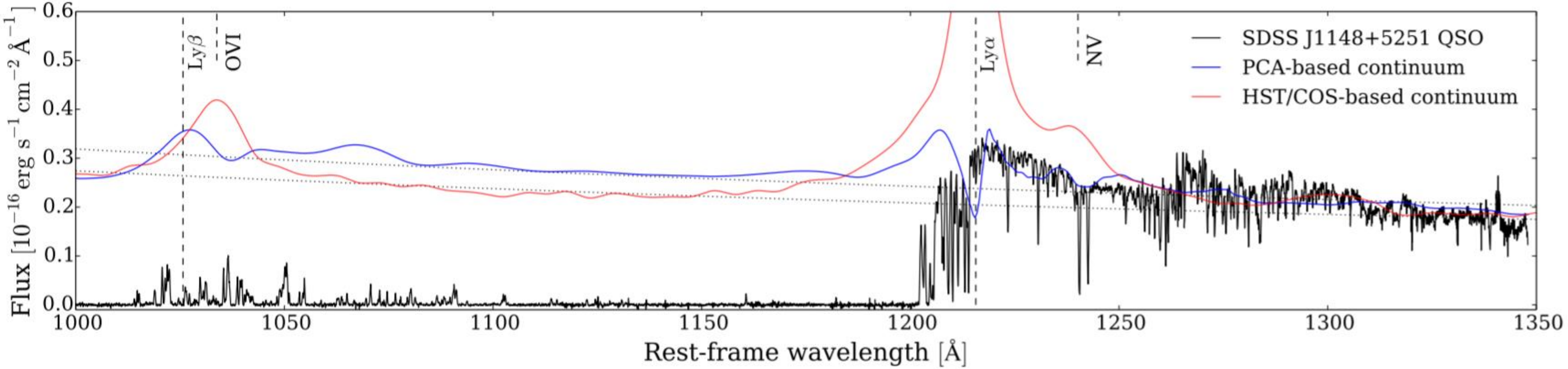
Studies of hosts (Feruglio et al. 2018)

Quasar's sphere of influence, near zone (Eilers et al. 2017)

Statistical errors in cosmological applications (e.g. BAOs, correlations, etc)

How can we best measure z from next-gen optical spectra surveys ?

Intrinsic evolution and continuum predictions



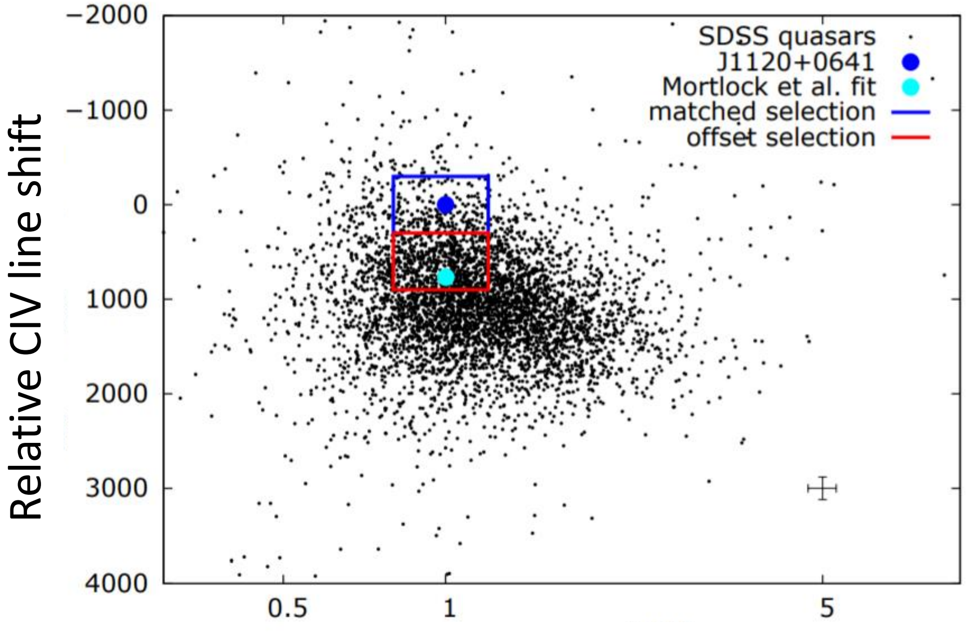
Kakiichi, SB et al. 2018

Continuum level necessary for studies of Lyman-α transmission:

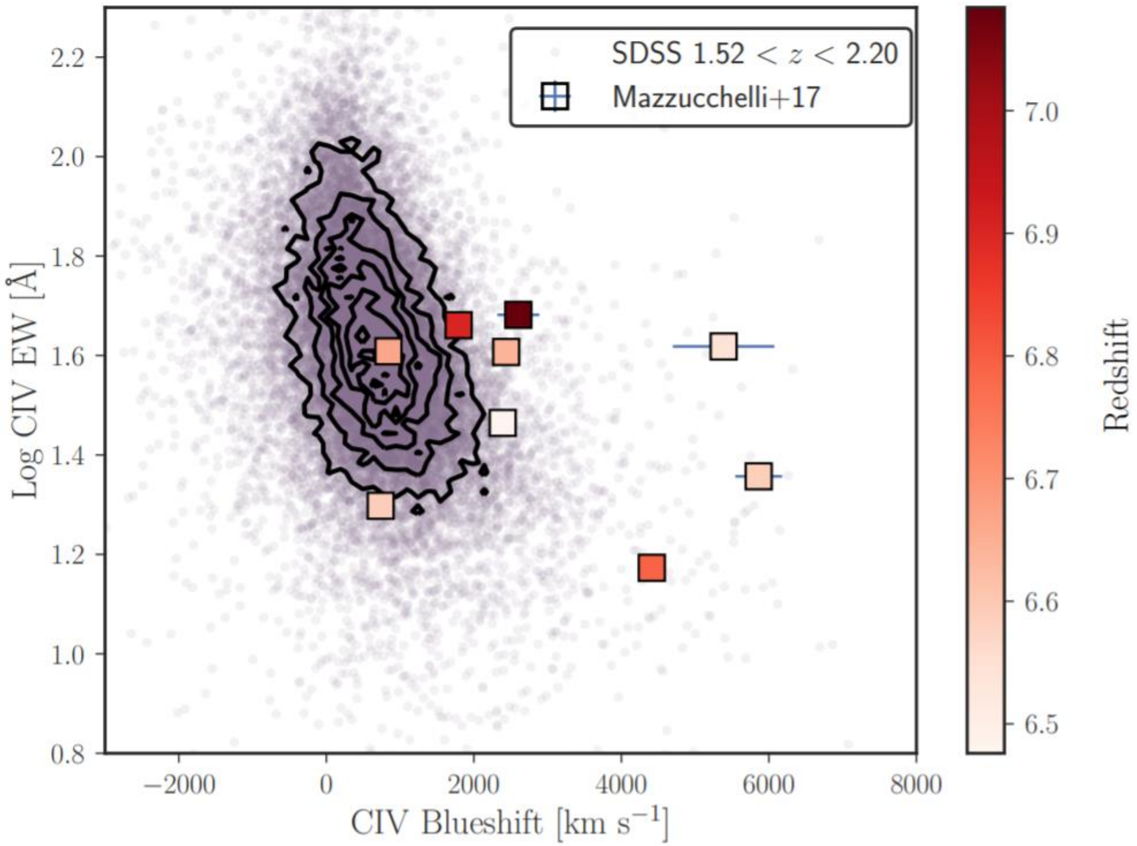
- Mean opacity
- Small scales
- Cross-correlations

Are PCA extrapolations from low-z justified?

First hints of evolution: C IV

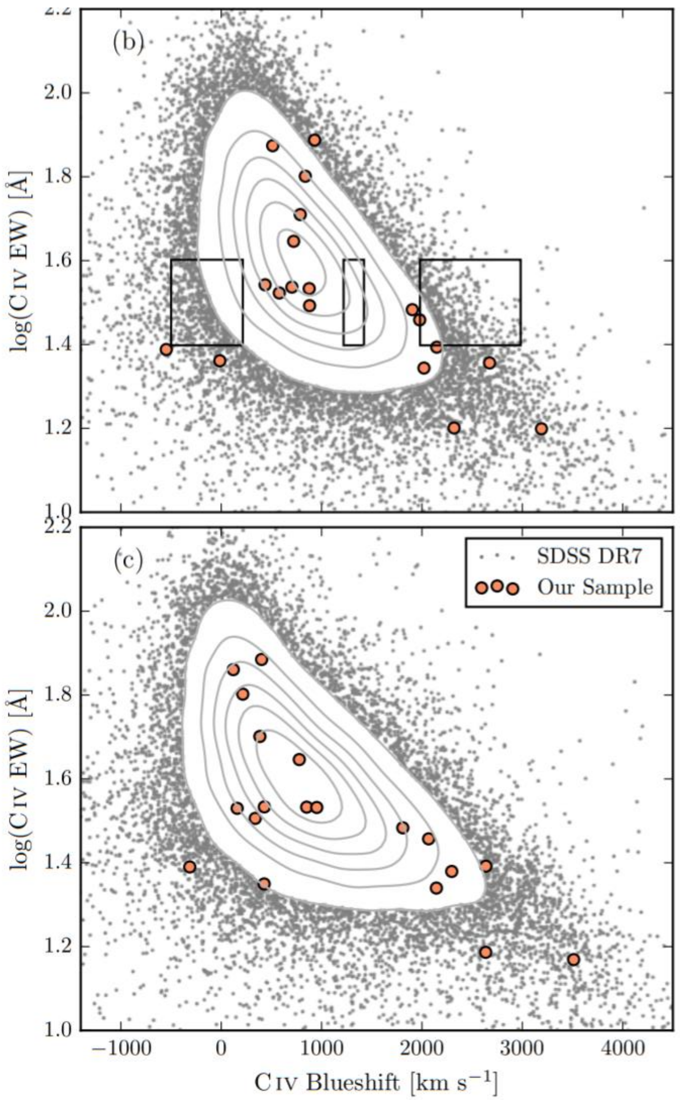


SB et al. 2015

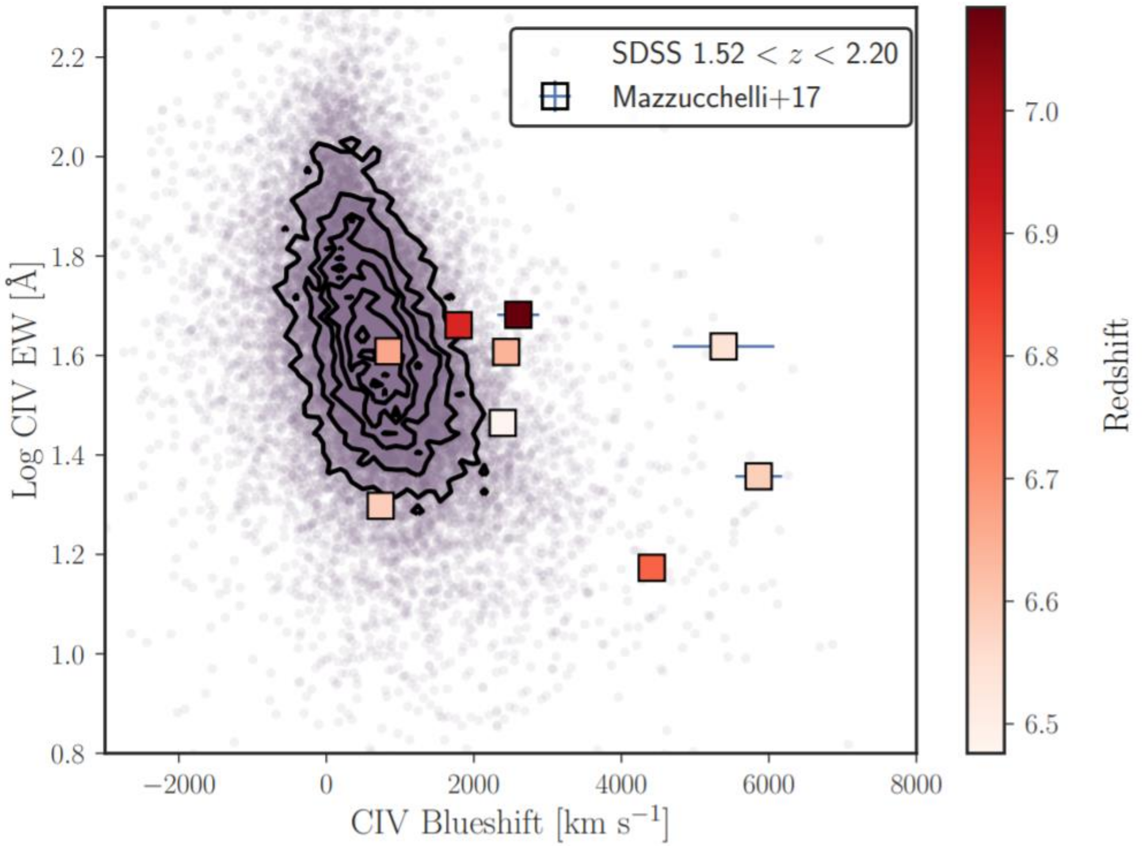


Mazzucchelli et al. 2018

First hints of evolution: C IV

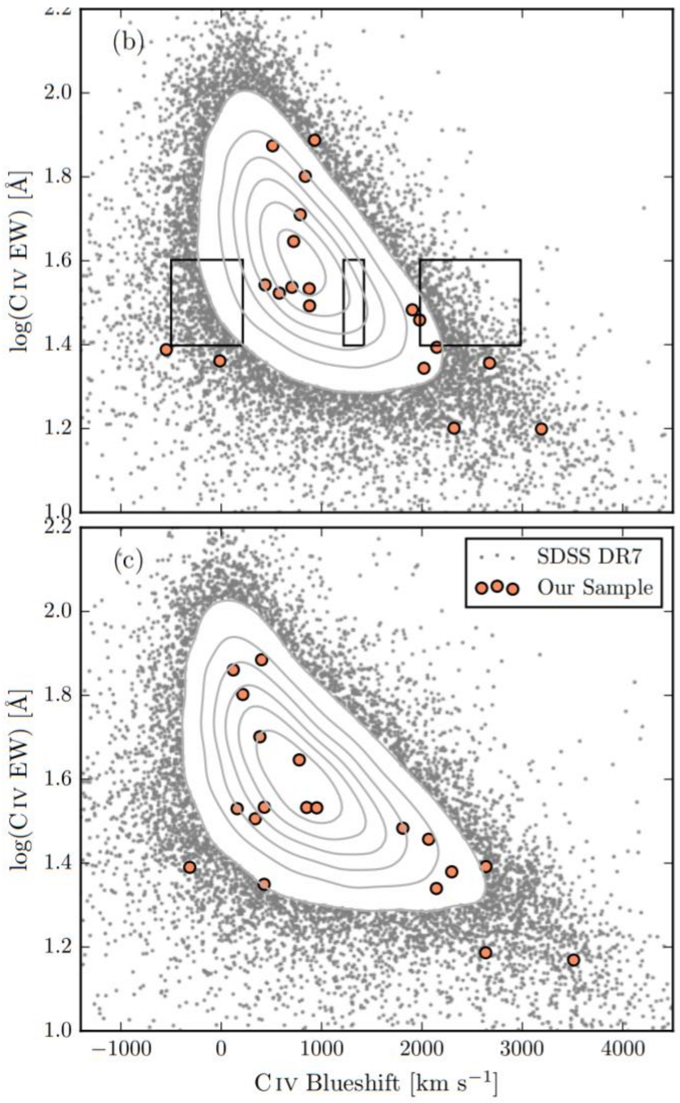


Coatman et al. 2016



Mazzucchelli et al. 2018

Inconsistent definitions



Emission line shift compared to what?

Systemic z known from observations of host?
Mg II? Lyman-α?
Combined physical/PCA + z fit?

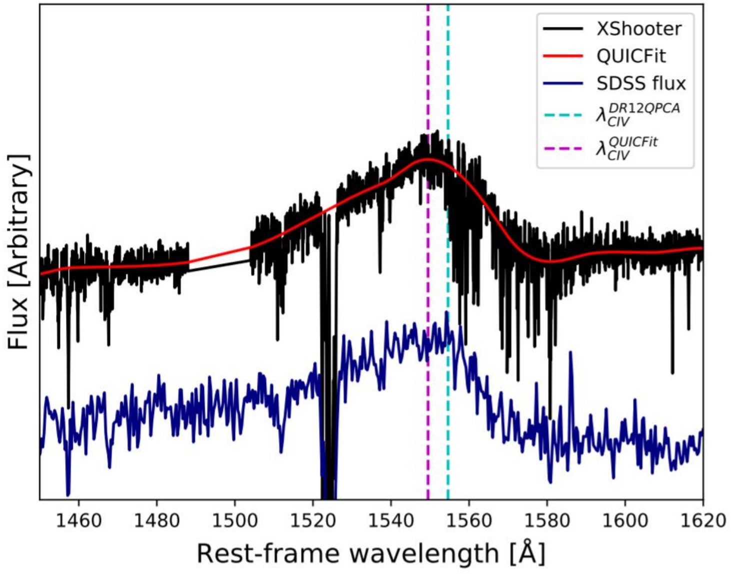
What is the line centre?

Peak of flux or peak of fit? Covariance matrix?

Analytic fit: how many gaussian components? Includes asymmetry?

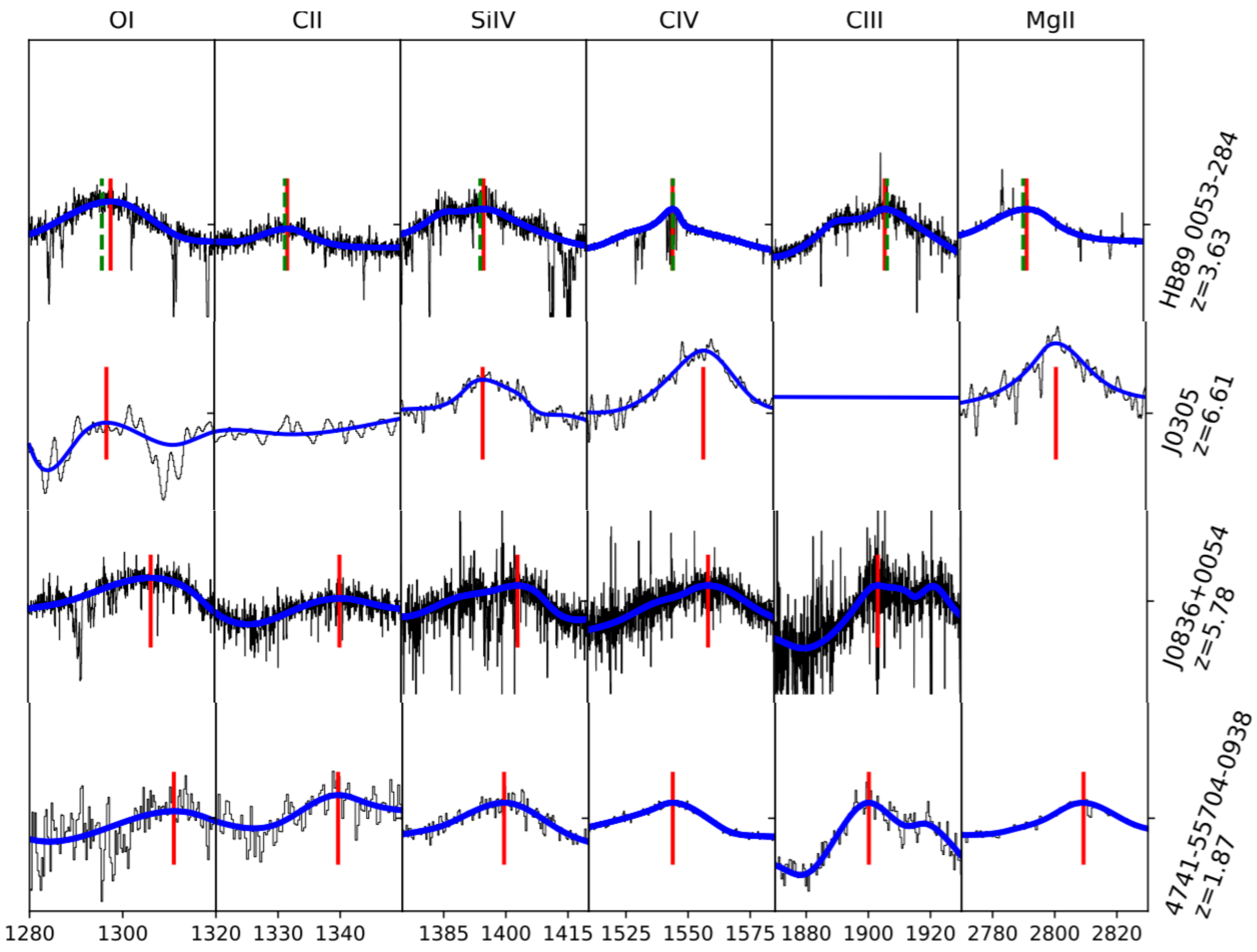
Fit a PCA/ICA: what training sample? How many components?

Method sensitive to resolution and SNR?



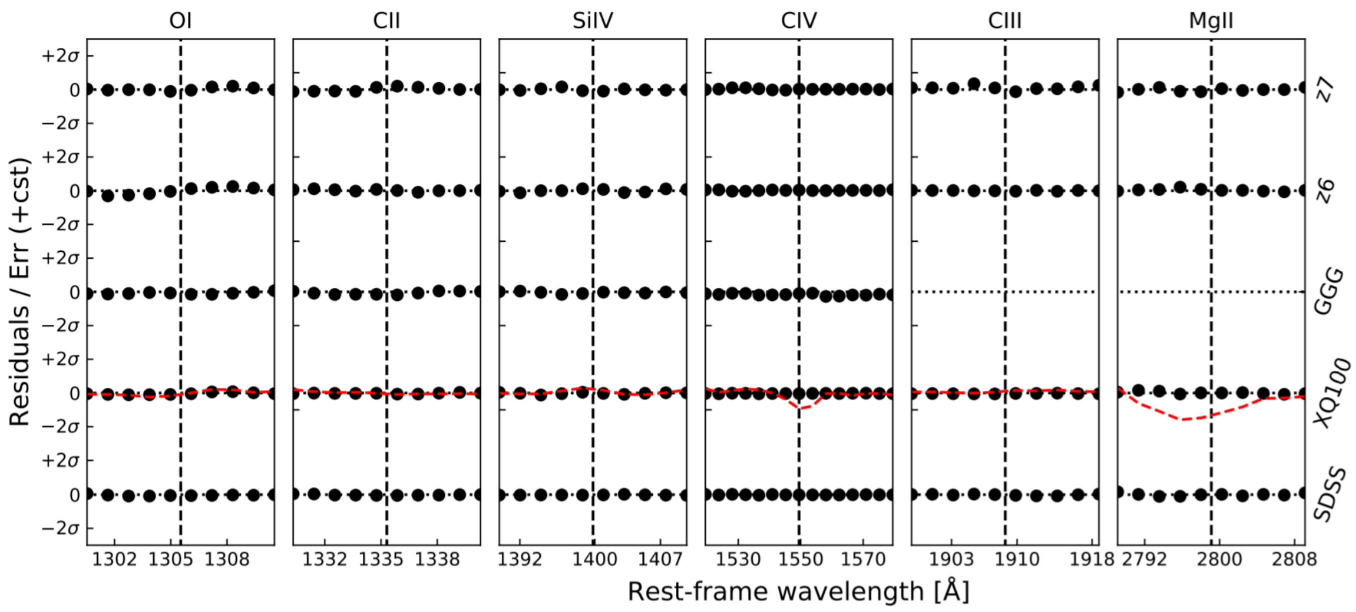
Larger sample, controlled experiment

- 394 quasars from 1.5 < z < 7.5, same luminosities
  - SDSS, XQ100, GGG + individual z > 5.5 quasars
- Homogeneous, (nearly) model-independent approach
  - Line shapes fit as slow-varying spline, *QUICFit*



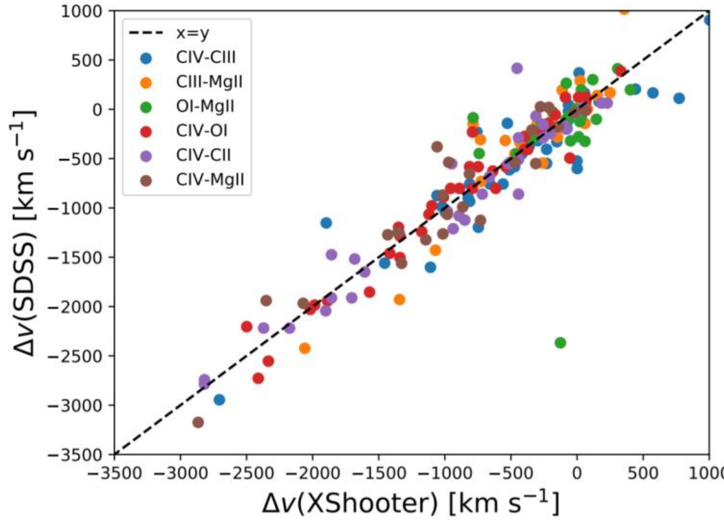
Meyer, SB & Ellis 2019

Check systematics

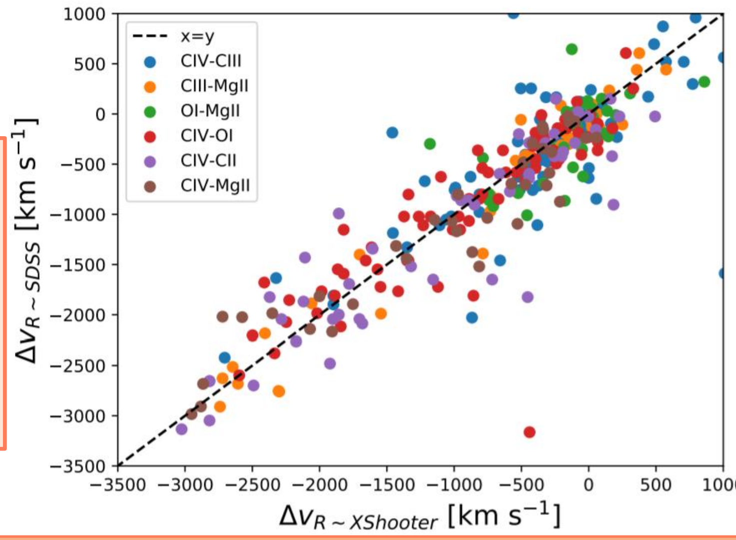


Stack fit residuals at all line locations and all samples

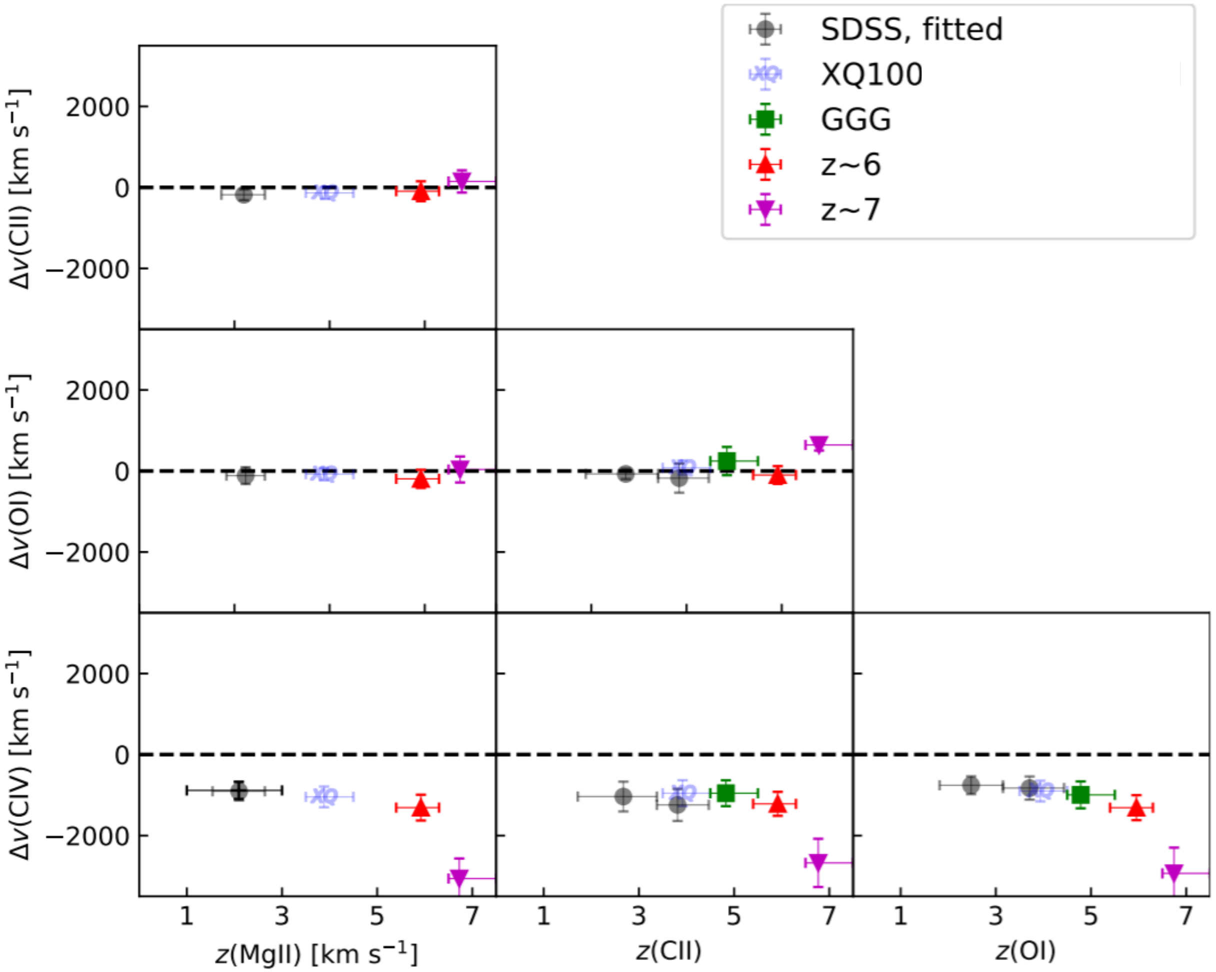
Use quasars observed in multiple surveys



Artificially degrade data quality to match the worst sample



Results

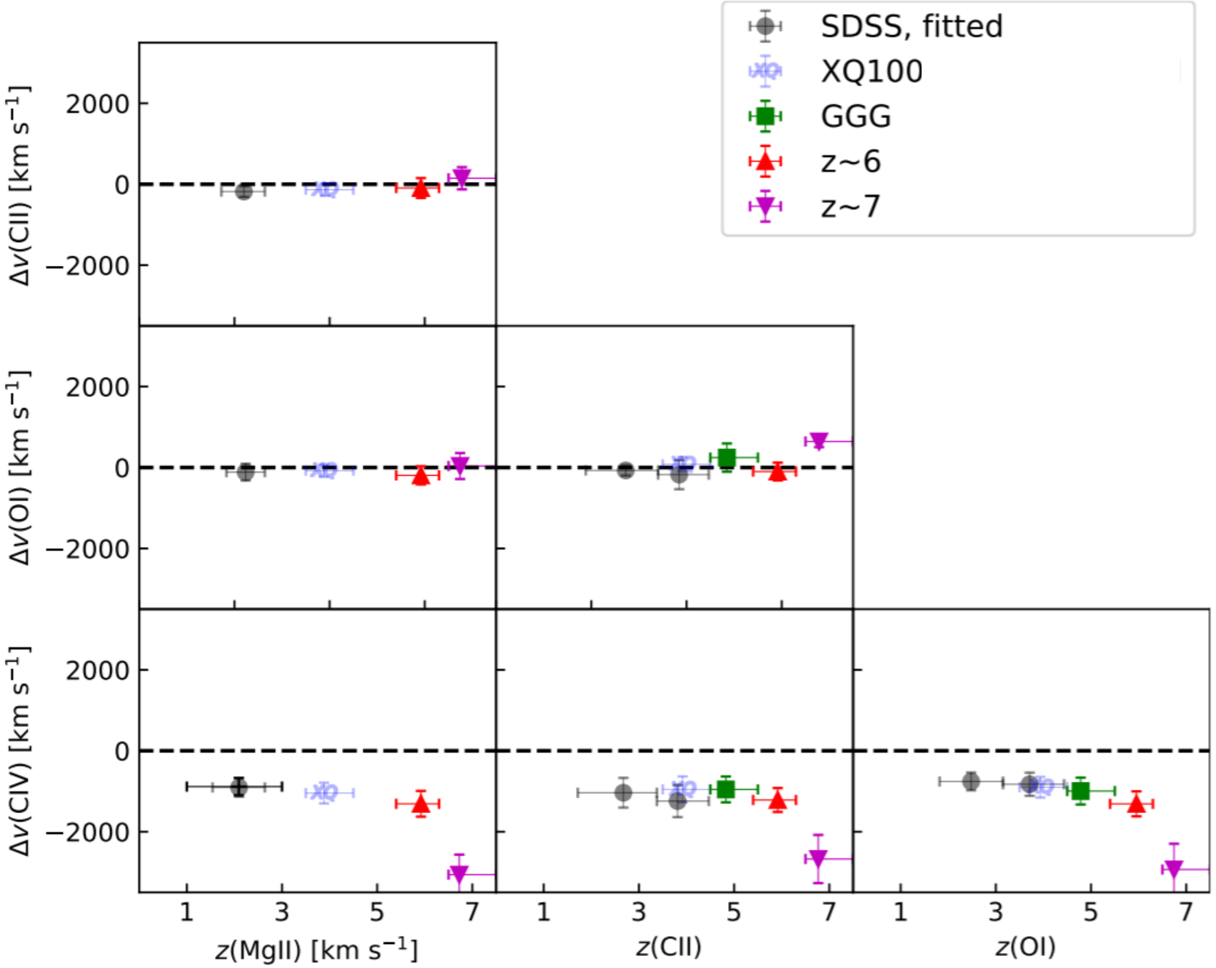


O I, C II, Mg II trace each other at all z

C IV shift grows by x3 from z = 1 -> 7, ***regardless of line of reference***

Meyer, SB & Ellis 2019

Results



In the optical up to z = 6.1 !

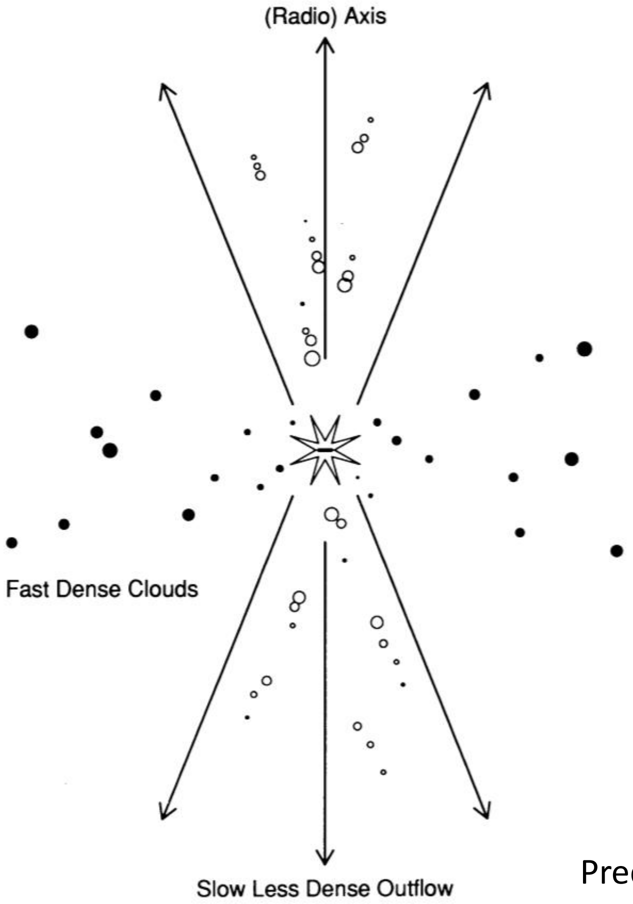
Visible in IR up to z = 16 !

O I, C II, Mg II trace each other at all z

C IV shift grows by x3 from z = 1 -> 7, ***regardless of line of reference***

Meyer, SB & Ellis 2019

Interpretation I: selection bias

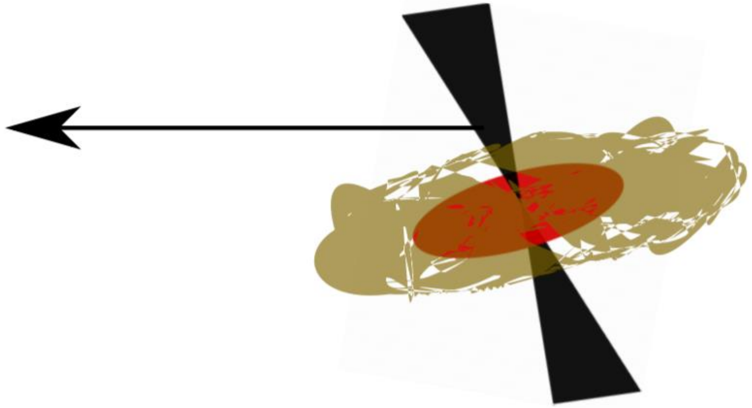


Wills et al. 1993 : C IV broad line originates in **polar outflows**

Higher inclination leads to **lower observed luminosity**

High-z quasars chosen for spectroscopy are the brightest: **largest intrinsic L and face-on**

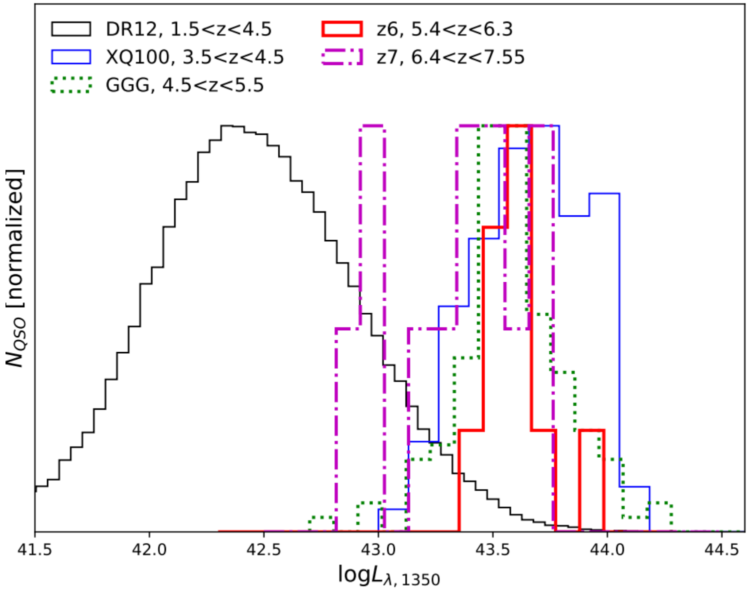
At later times, same observed luminosity includes **brighter objects with larger inclinations: lower C IV blueshifts on average**



Predictions: C IV anomaly weaker for fainter high-z quasars
Bright high-z quasars more radio-loud
Maximal C IV blueshift constant across z
No new physical processes: **PCA decompositions ok**

Interpretation II: intrinsic effects ?

What is different at z > 6 ?

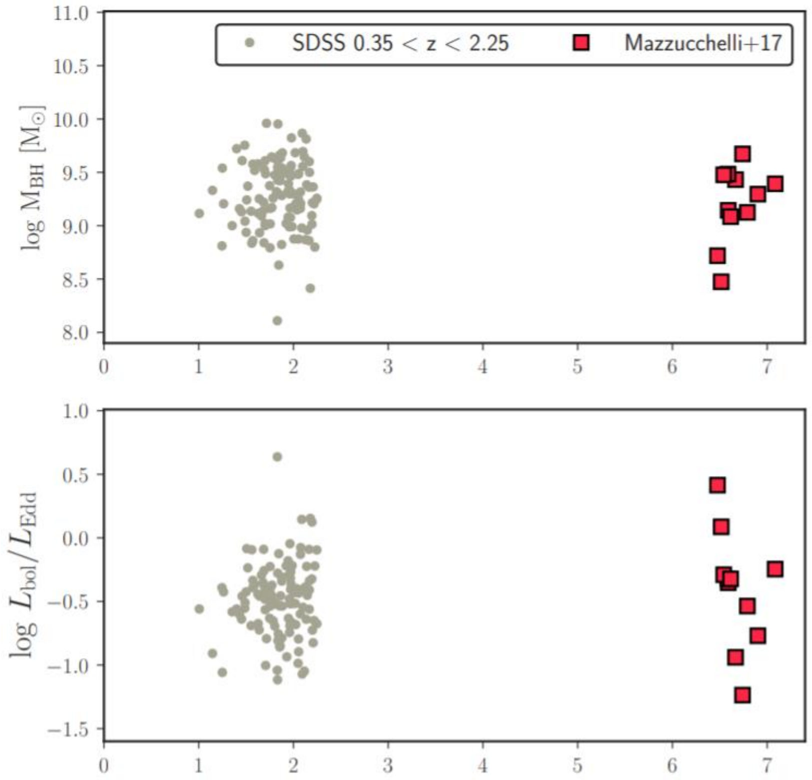


Meyer, SB & Ellis 2019

Luminosity is matched across samples

BH masses and **Eddington ratios** based on Mg II are consistent

Metallicities based on broad lines EW are consistent to first order (?)



Mazzucchelli et al. 2018

Interpretation II: intrinsic effects ?

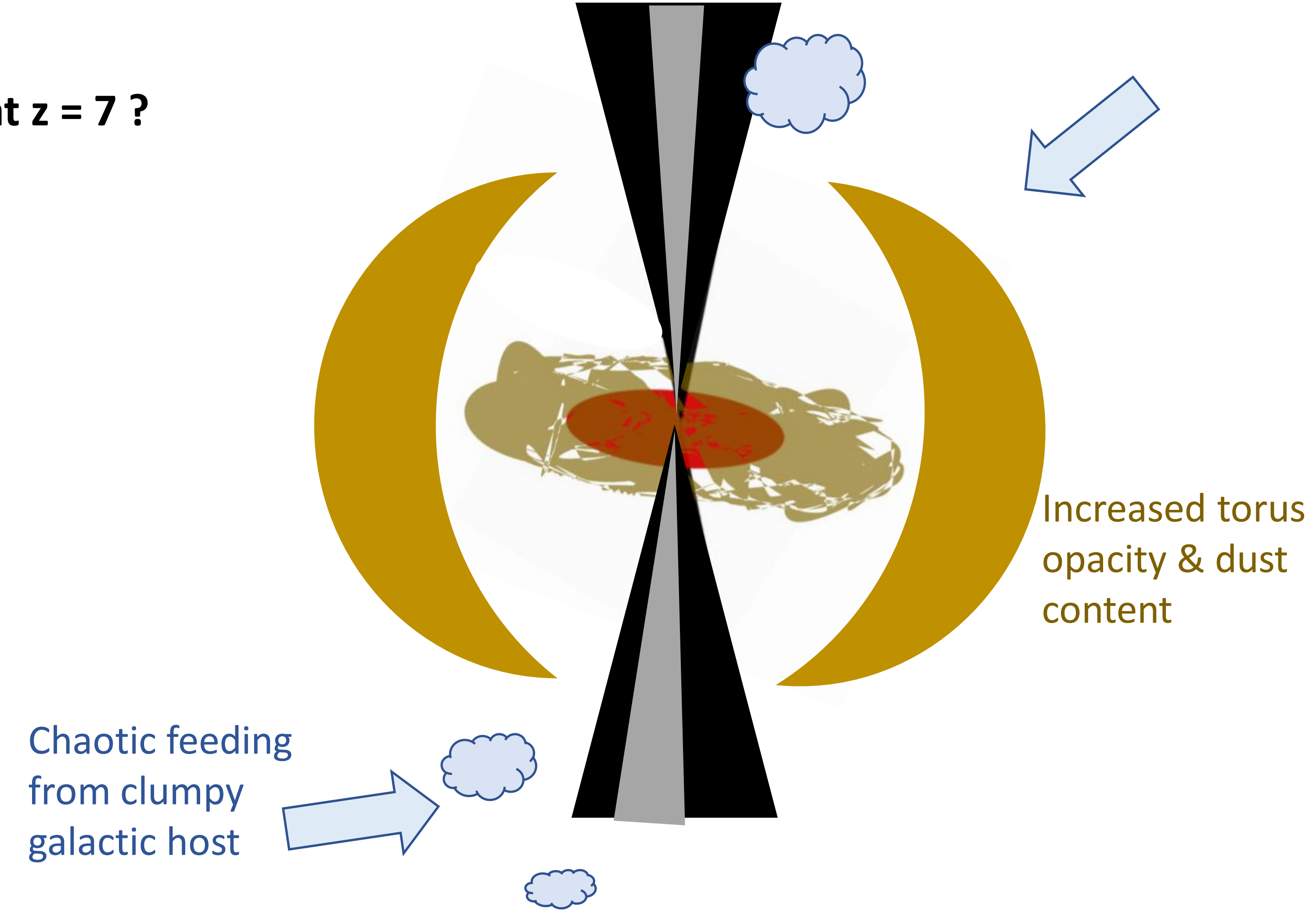
What is different at z = 7 ?

Obscuration?

SMBH feeding with O(Eddingdon) accretion rate is more obscured at high z

Trebitsch+19 : high-z quasars only UV-bright ~8% of the time/angle

Smaller opening angle along jet-aligned channels



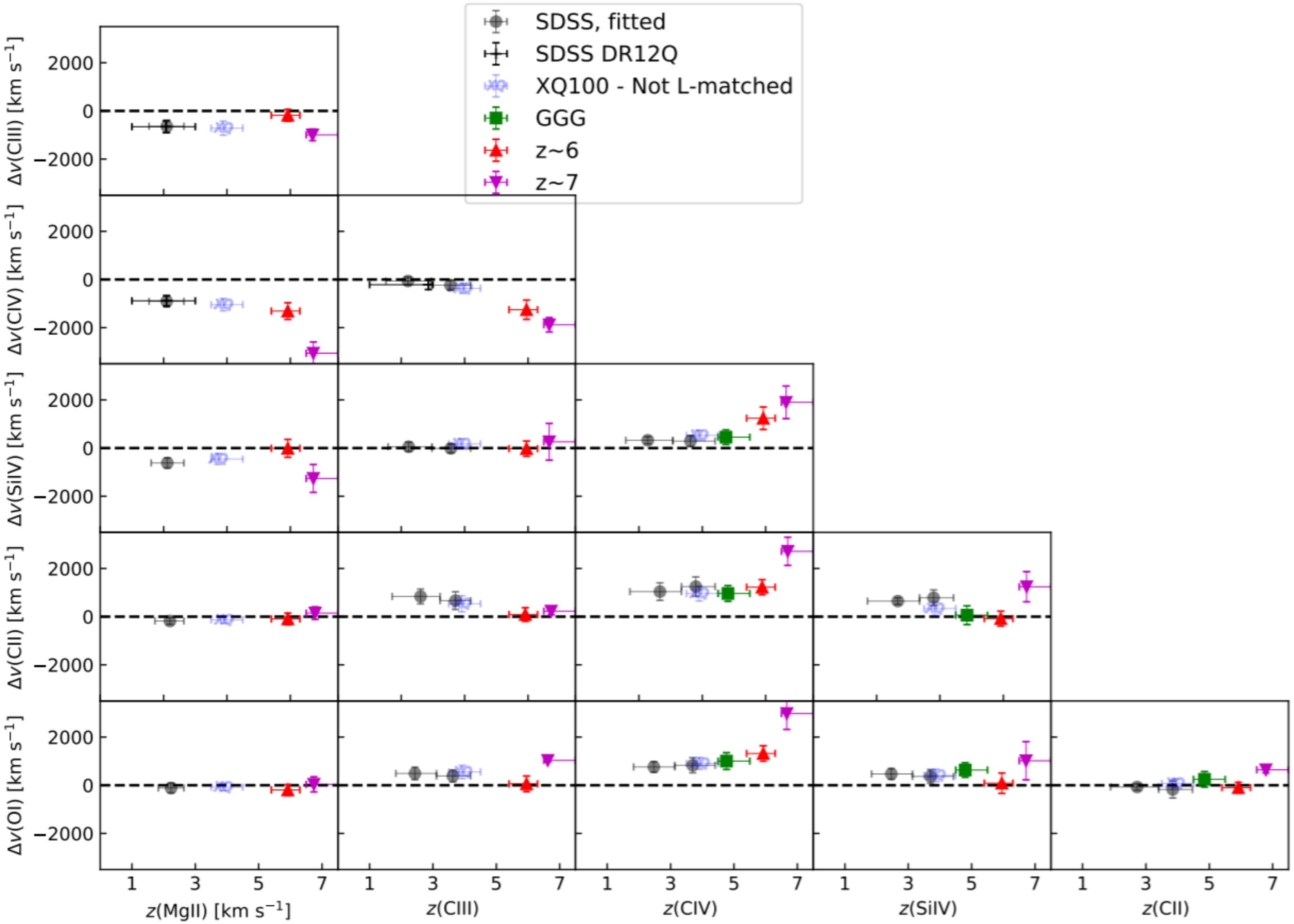
Conclusions

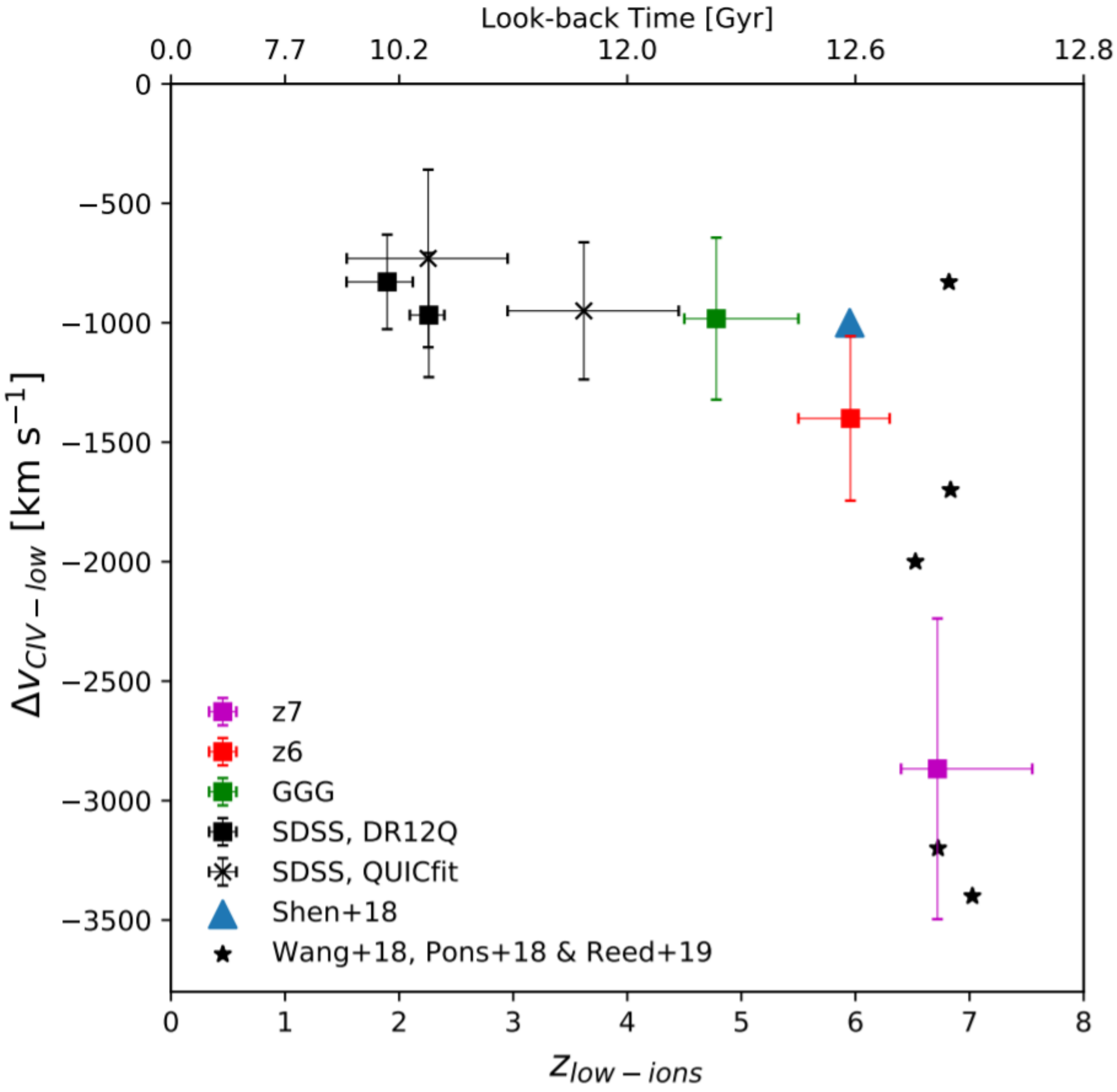
- C II, OI lines follow Mg II at any redshift: a **better way to measure quasar z from optical spectra alone** up to z = 6, IR up to z = 16

- The blueshift of the CIV line **increases by factor 3 from z = 1 to z = 7**, accelerating beyond z > 6

- Why? Maybe a **selection bias** on the most luminous objects: more face-on with **C IV polar outflows** ?
- Or new physical processes in quasars at high z?

Additional slides


SDSS, fitted
SDSS DR12Q
XQ100 - Not L-matched
GGG
z~6
z~7
Δv(CIII) [km s−1]
Δv(CIV) [km s−1]
Δv(SiIV) [km s−1]
Δv(CII) [km s−1]
Δv(OI) [km s−1]
z(MgII) [km s−1]
z(CIII)
z(CIV)
z(SiIV)
z(CII)


Look-back Time [Gyr]
0.0
7.7
10.2
12.0
12.6
12.8
0
−500
−1000
−1500
−2000
−2500
−3000
−3500
$\Delta v_{CIV-low}$ [km s^{-1}]
z7
z6
GGG
SDSS, DR12Q
SDSS, QUICfit
Shen+18
Wang+18, Pons+18 & Reed+19
0
1
2
3
4
5
6
7
8
$z_{low-ions}$