On the quasar Main Sequence at high redshift:
AGN outflows and radioloudness relations

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Credit: ESO/M. Kornmesser

4D Eigenvector 1 (4DE1)

(or "an HR diagram for type-1 quasars?")

Proposed by Sulentic+00

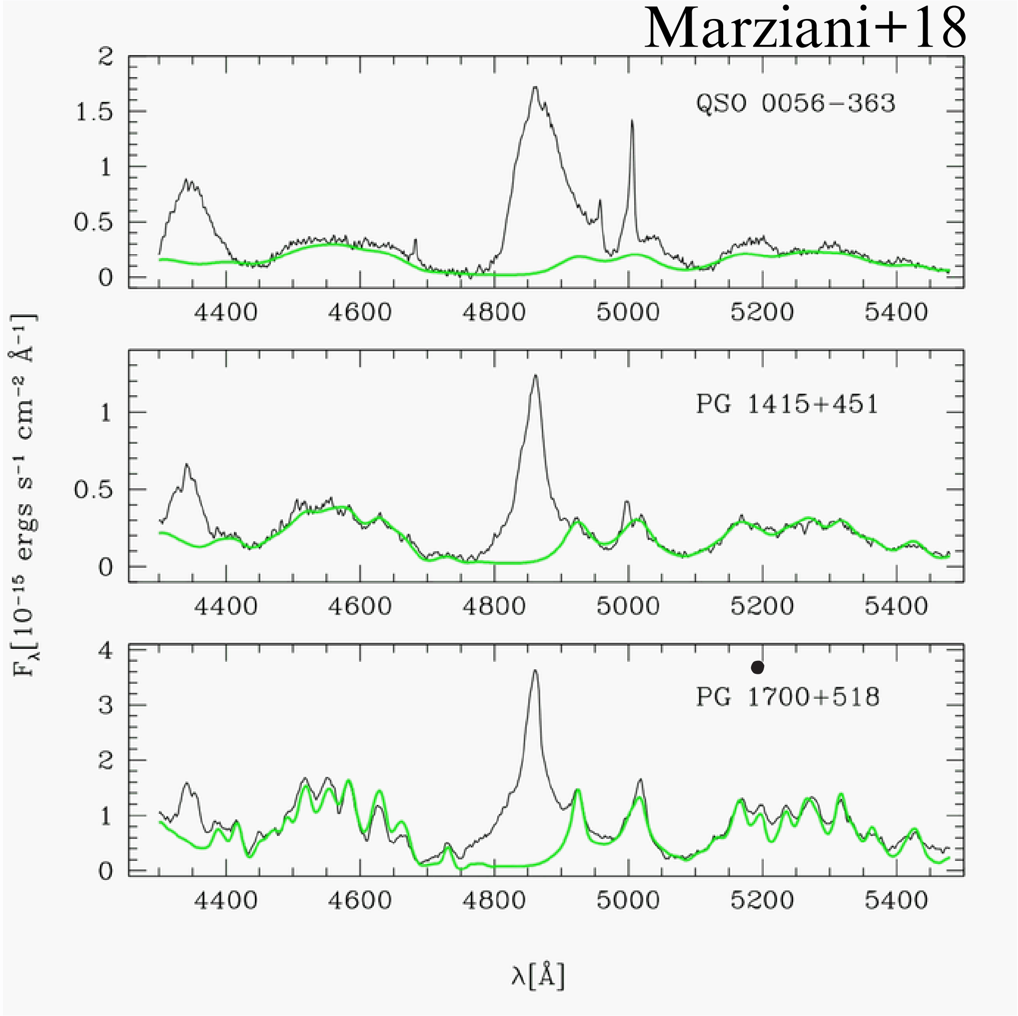
Goal: organize all the diversity seen in the spectra of quasars

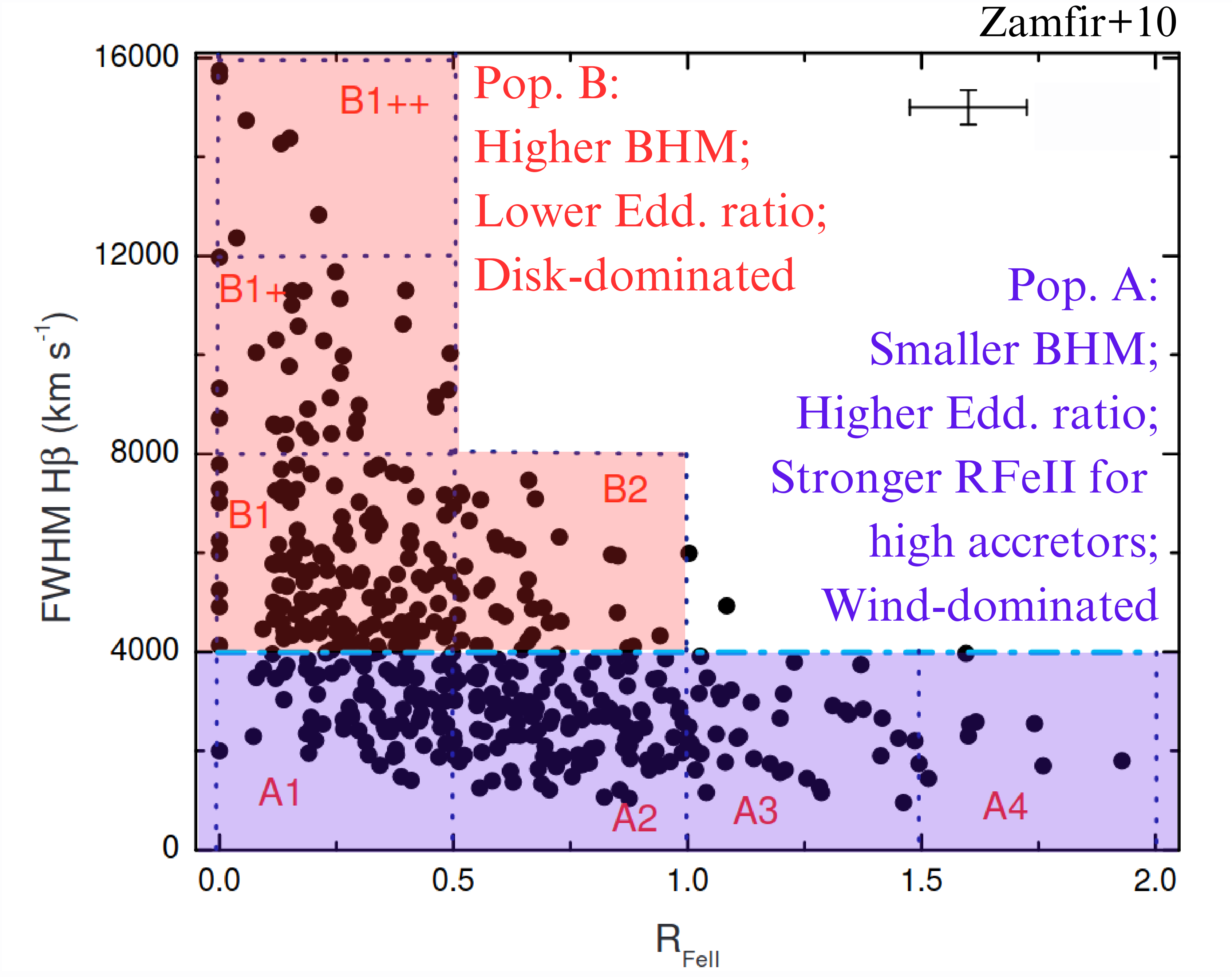
Four basic parameters:

- FWHM(Hβ,BC);
- RFeII=I(FeIIλ4570)/I(Hβ);
- Blueshifts of HIL, such as C IV and [O III];
- Soft X-ray photon index.

Low z (< 0.8)!!

Main Sequence (MS, 4DE1 optical plane) main physical drivers: Eddington ratio and orientation

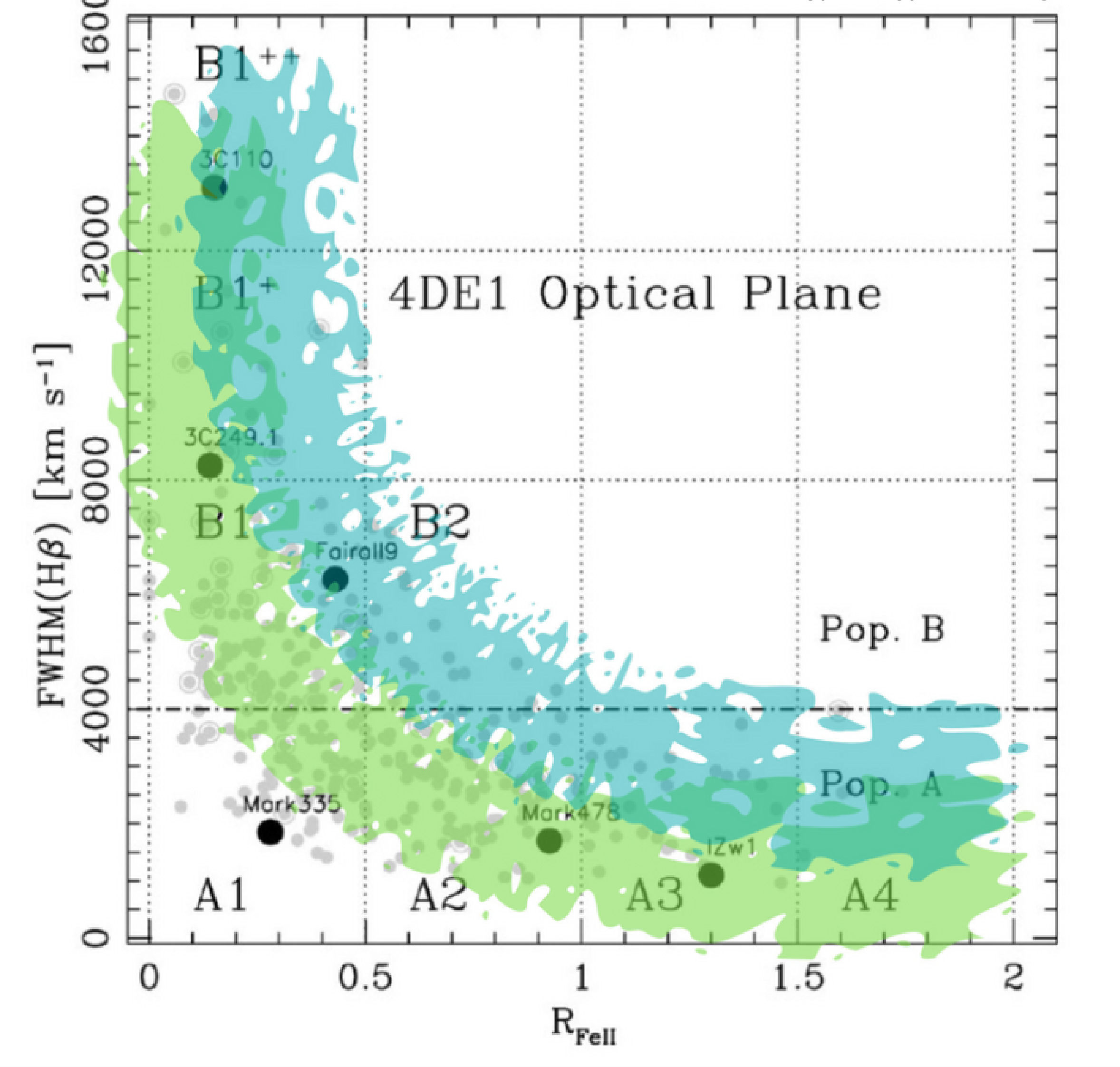




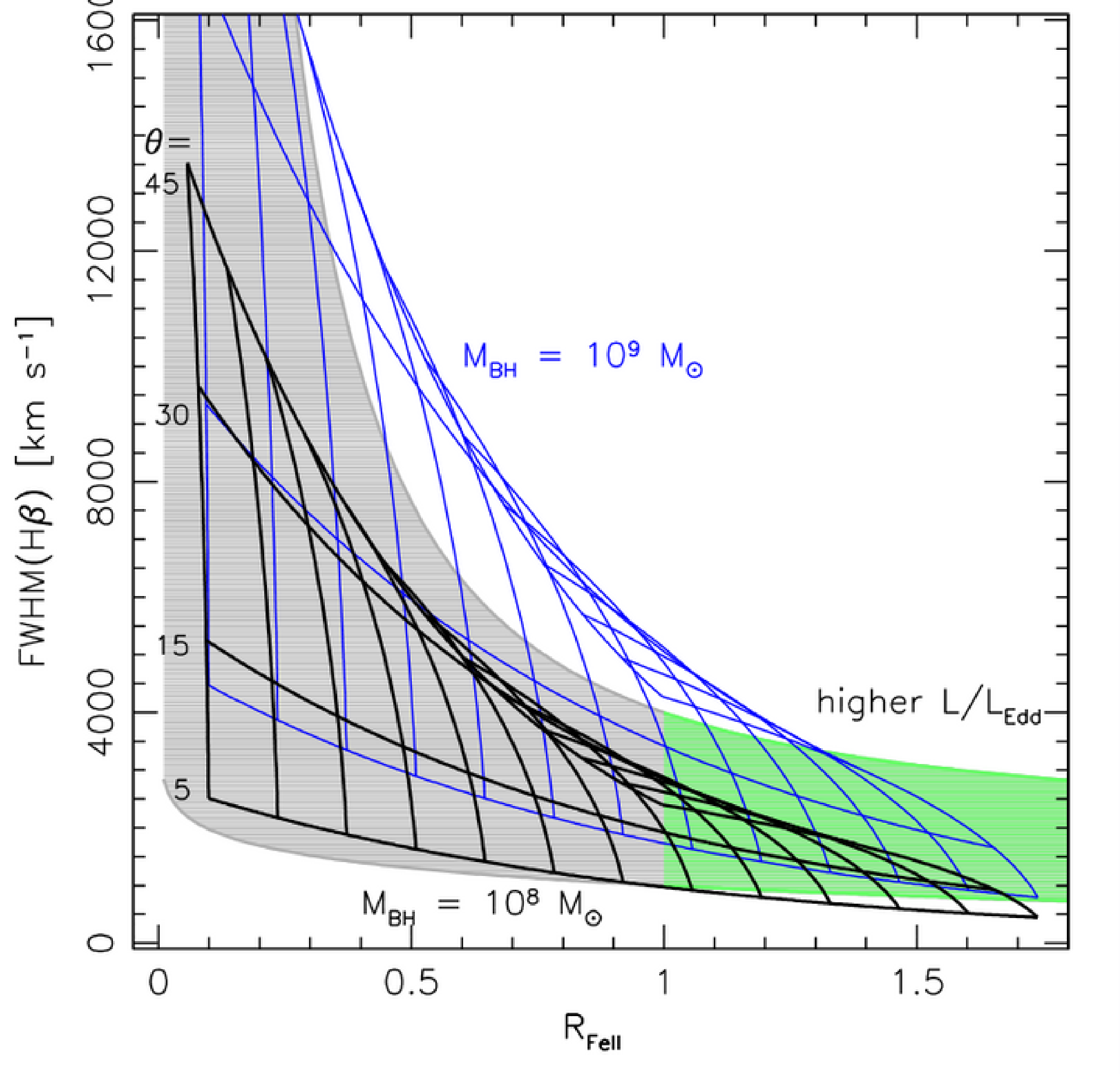
Goals

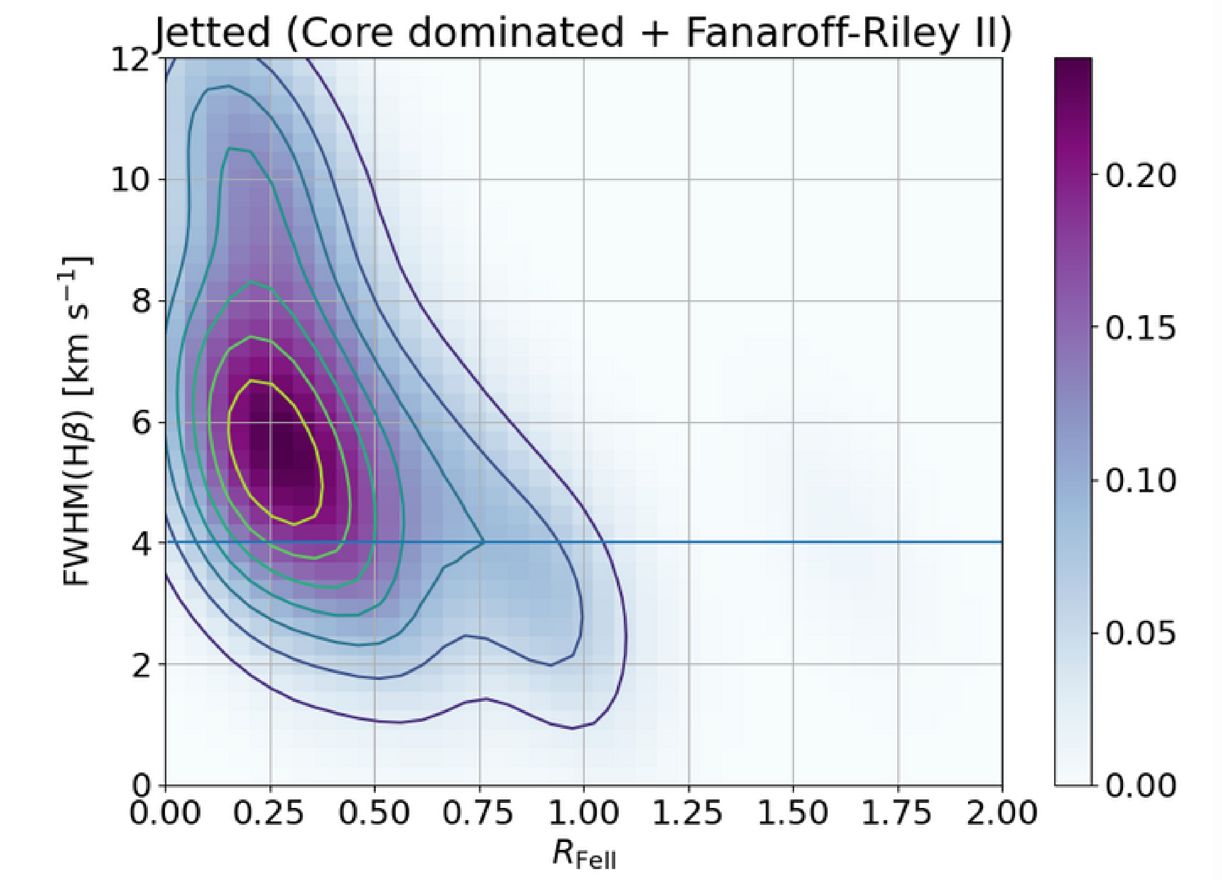
- How do the MS behave at high-z?
- Do RL and RQ have different physical properties?
- Are there spectroscopic differences between RL and RQ at high-z?
- Relations between radio and optical/UV properties
- Does the behave of outflows change between RL and RQ sources?

Marziani+18



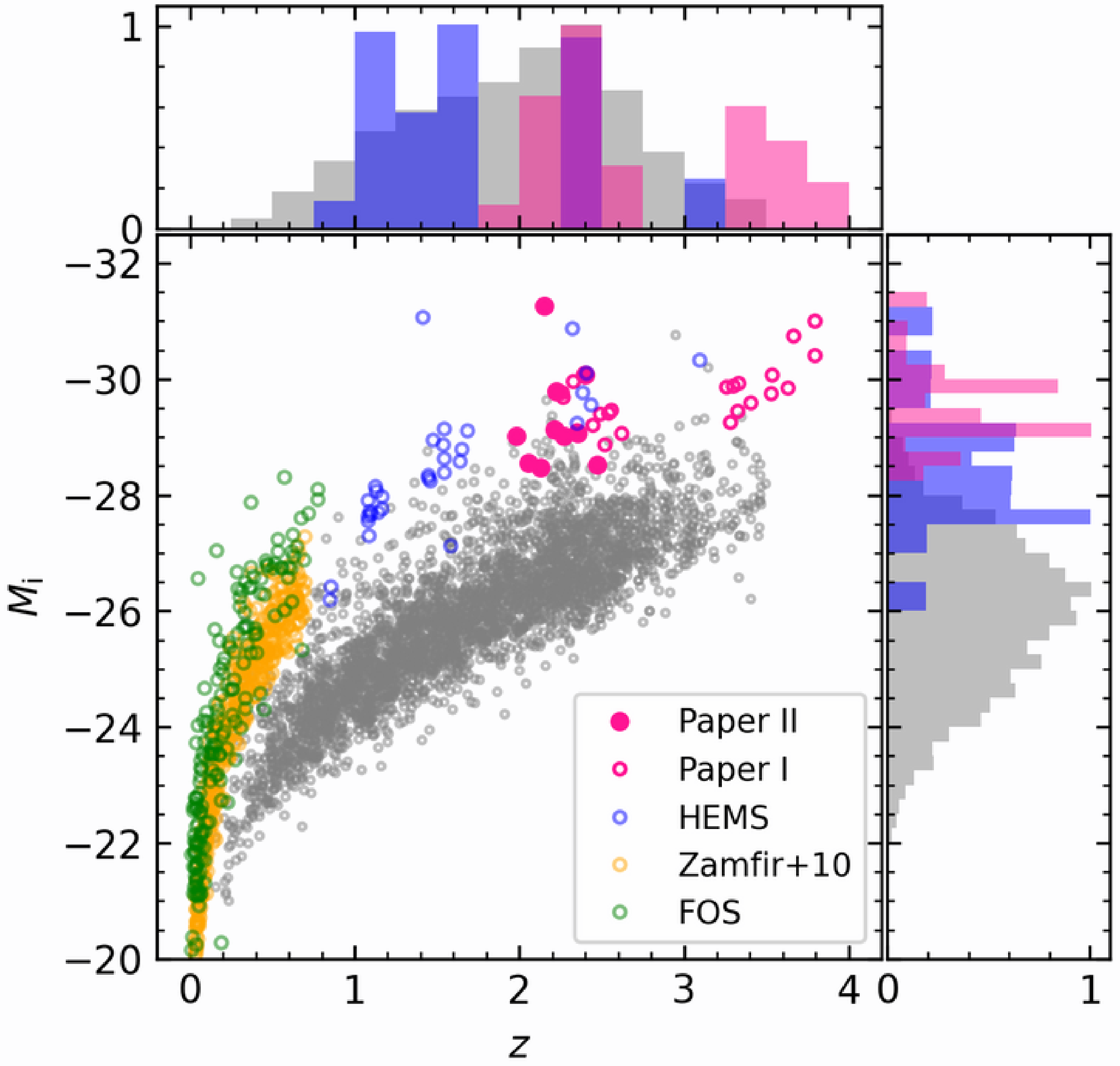
Marziani+22





32+52 high-L and high-z quasars
(1.2 ≲ **z** ≲ 3.9,
47 ≲ **log Lbol** ≲ 48,
9 ≲ **log MBH** ≲ 10,
-0.47 ≲ log L/L_Edd ≲ 0.32)

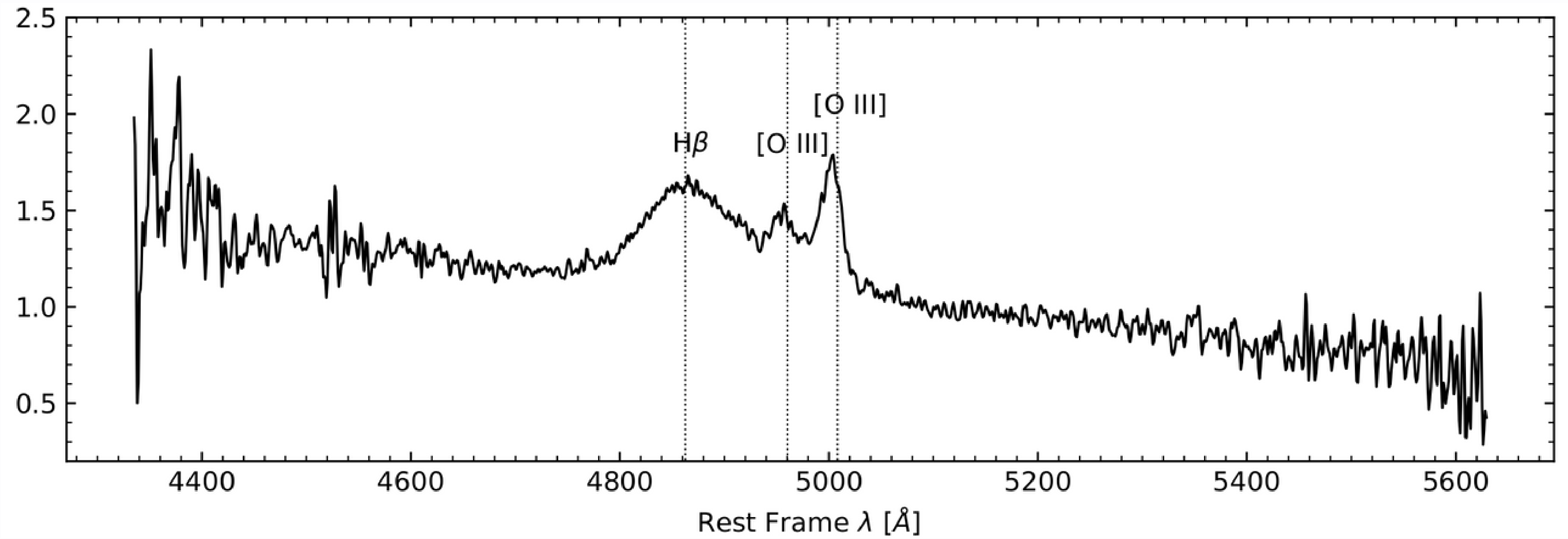
~ 130 Low-z
(z ≲ 0.5,
44 ≲ log Lbol ≲ 47,
7 ≲ log MBH ≲ 10,
-3.14 ≲ log L/L_Edd ≲ 0.28)



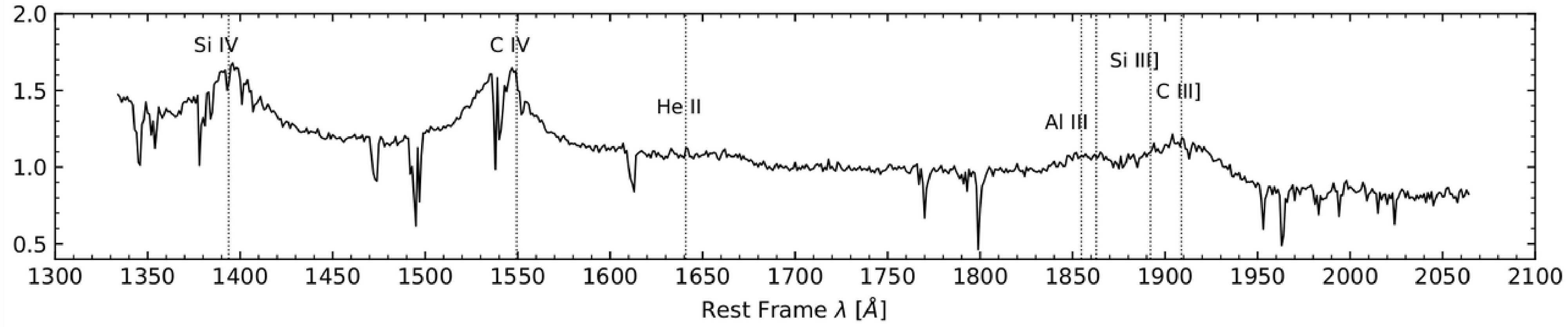
Marziani+03, Sulentic+06, Marziani+09, Zamfir+10, Sulentic+17, Deconto-Machado+23, Deconto-Machado+in prep.

ISAAC + reanalysis of HEMS and FOS samples

optical: VLT (infrared)



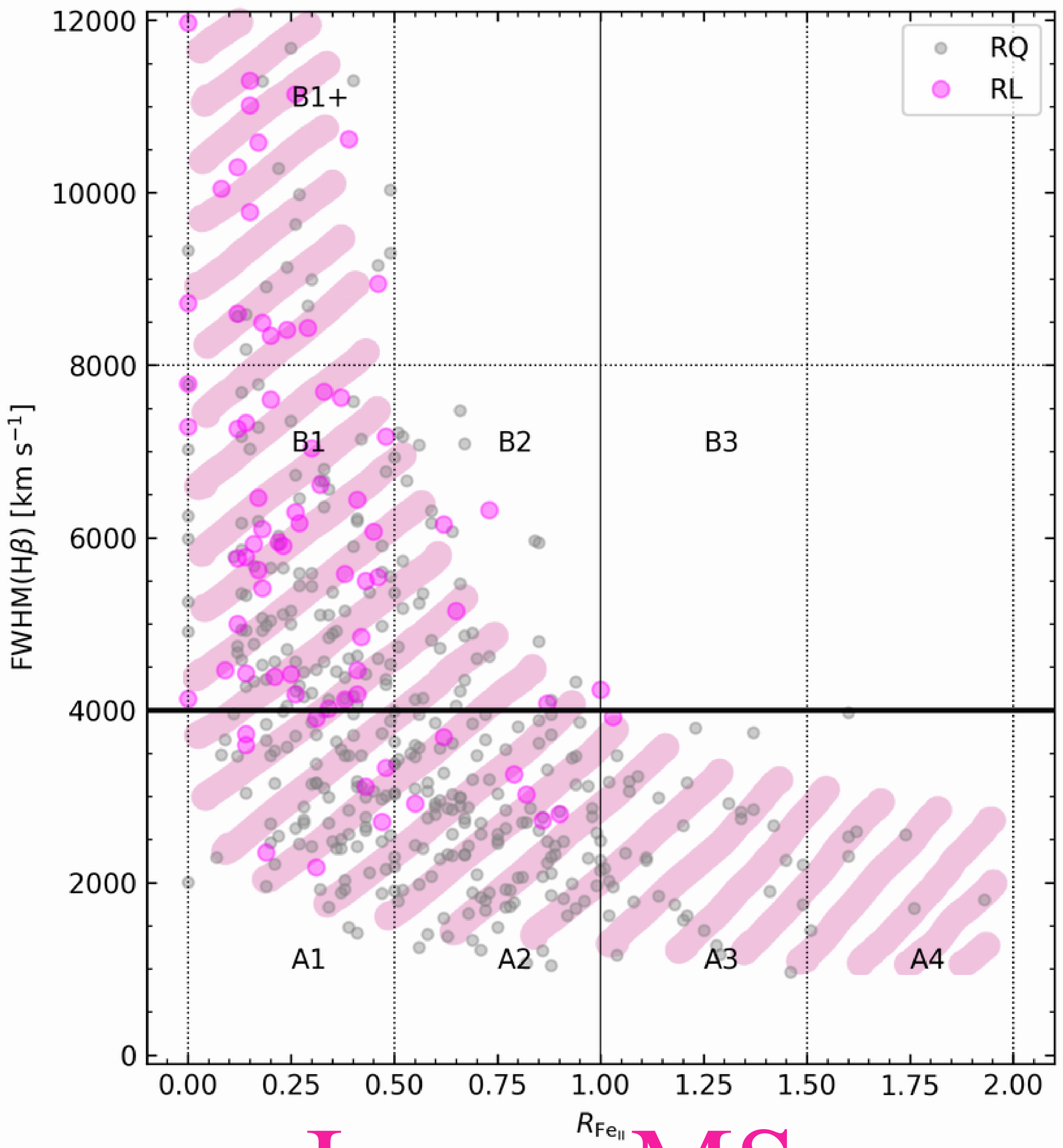
UV: archival data (optical)

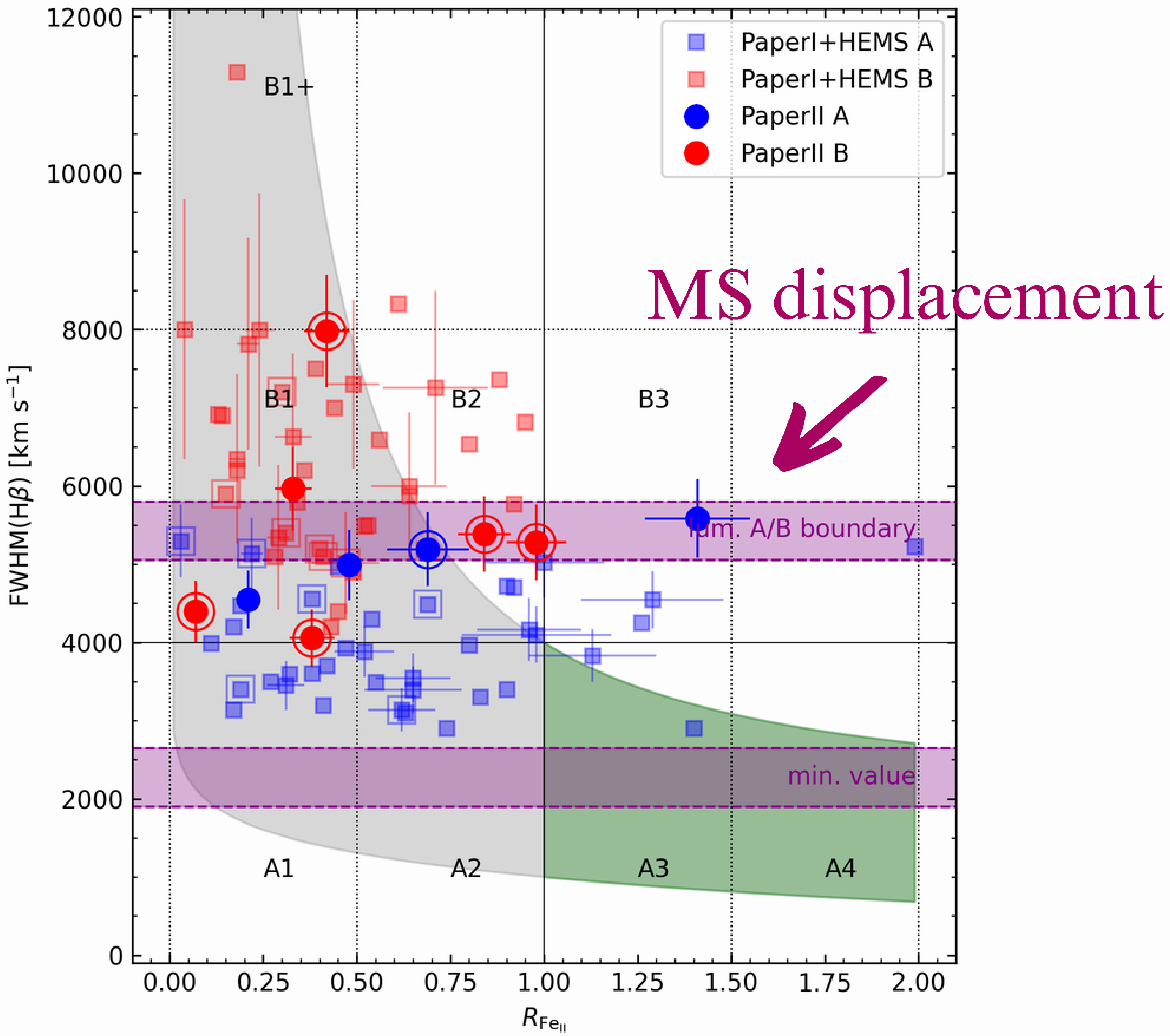


radio: mainly from NVSS and FIRST
(we define the **radioloudness parameter** as the ratio between the specific flux at 1.4 GHz and in the g-band)

The 4D Eigenvector 1 sequence persists at high-z

sources from Zamfir+10





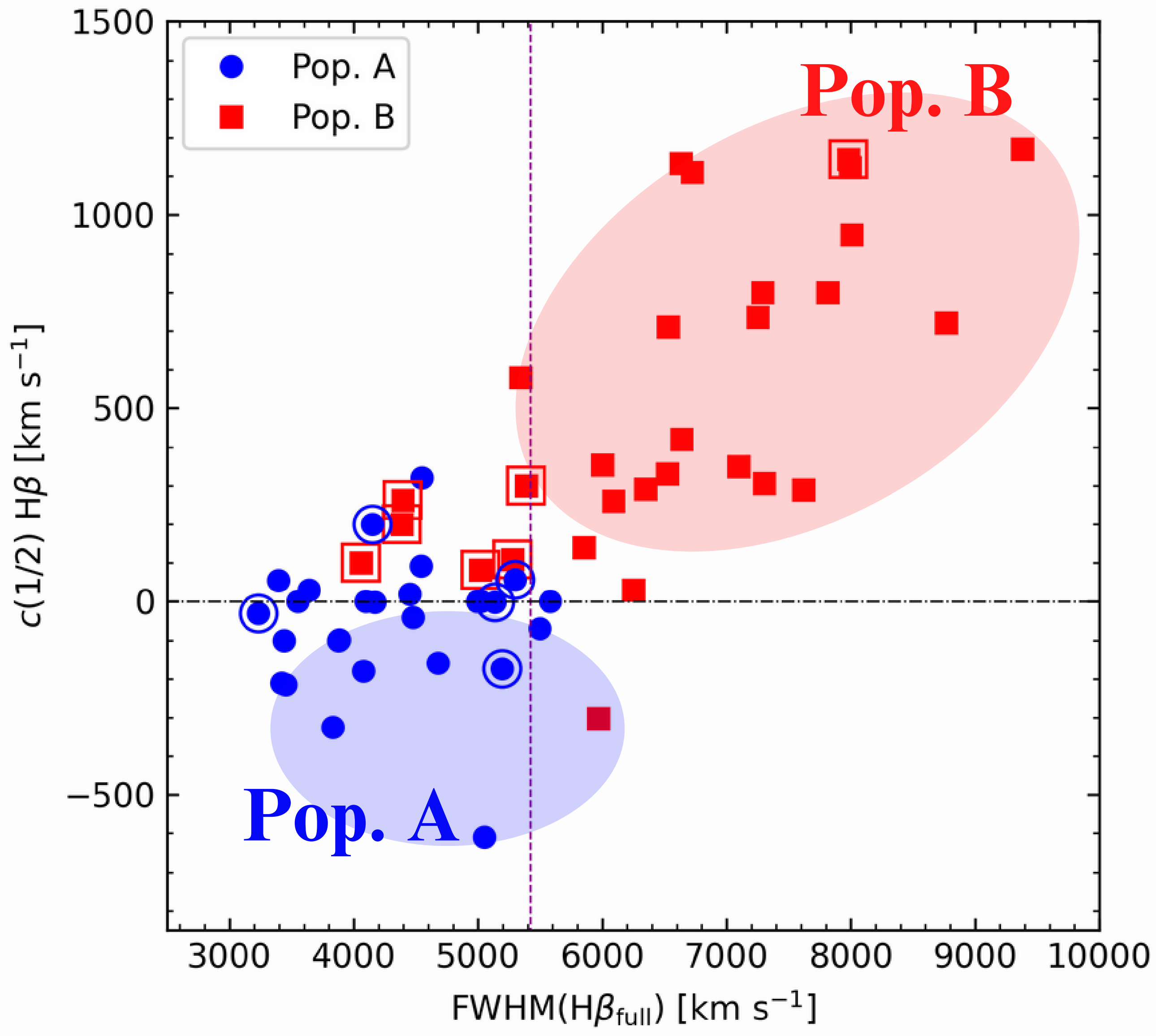
Low-*z* MS

High-*z* MS

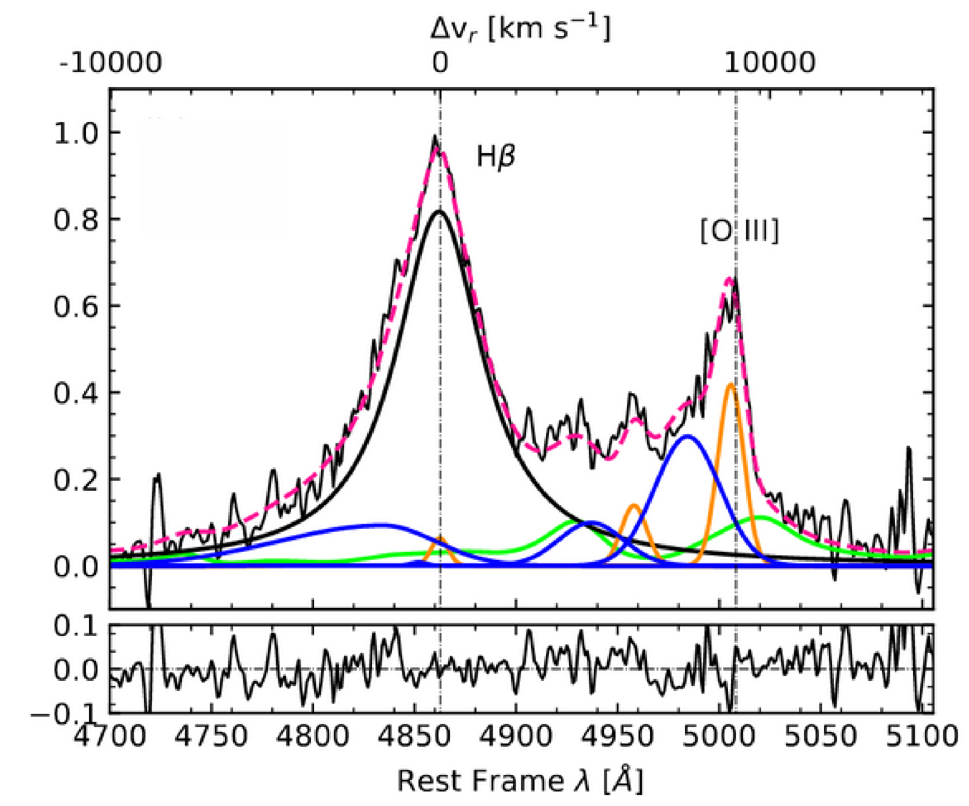
The dichotomy between Pop. A and

Pop. B is still preserved at high z

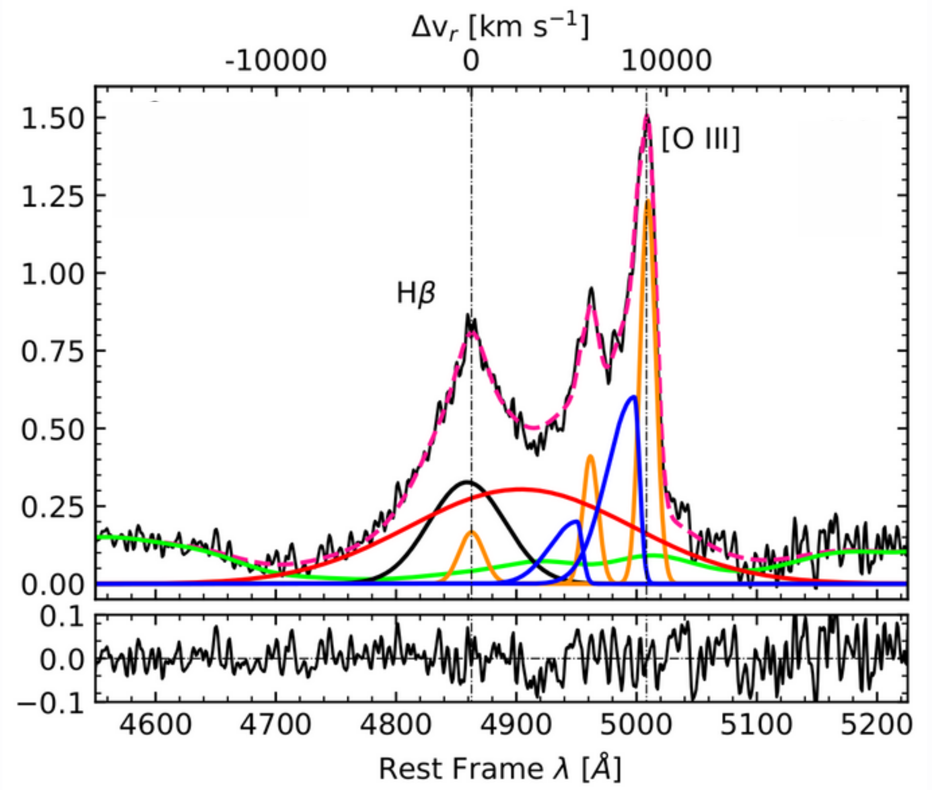
Hβ



Pop. A (higher accretors)



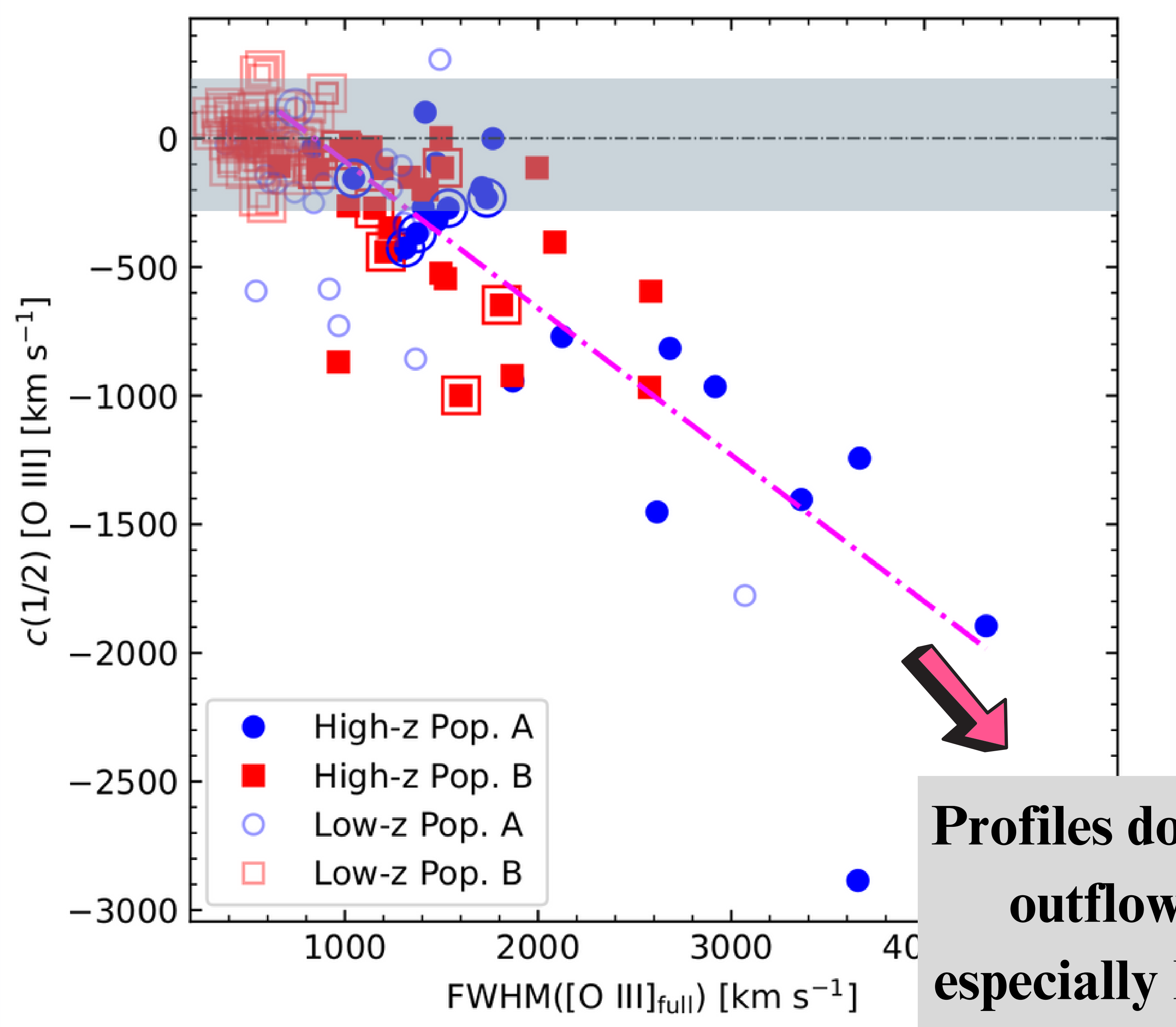
Pop. B (lower accretors)



As at low z, Pop. A (higher accretors, $L/L_{Edd} \gtrsim 1.$) and Pop. B (lower accretors, L/L_{Edd} ~ 0.2-0.3) at **high z** follow different trends in Hβ!

- VBC needed for Pop. B (50% of the full profile, ~ 10000 km/s);
- At high z, outflows are also detected in Hβ.

While at low z, we only find [O III] outflows in Pop. A, at high z they are found also in Pop. B sources

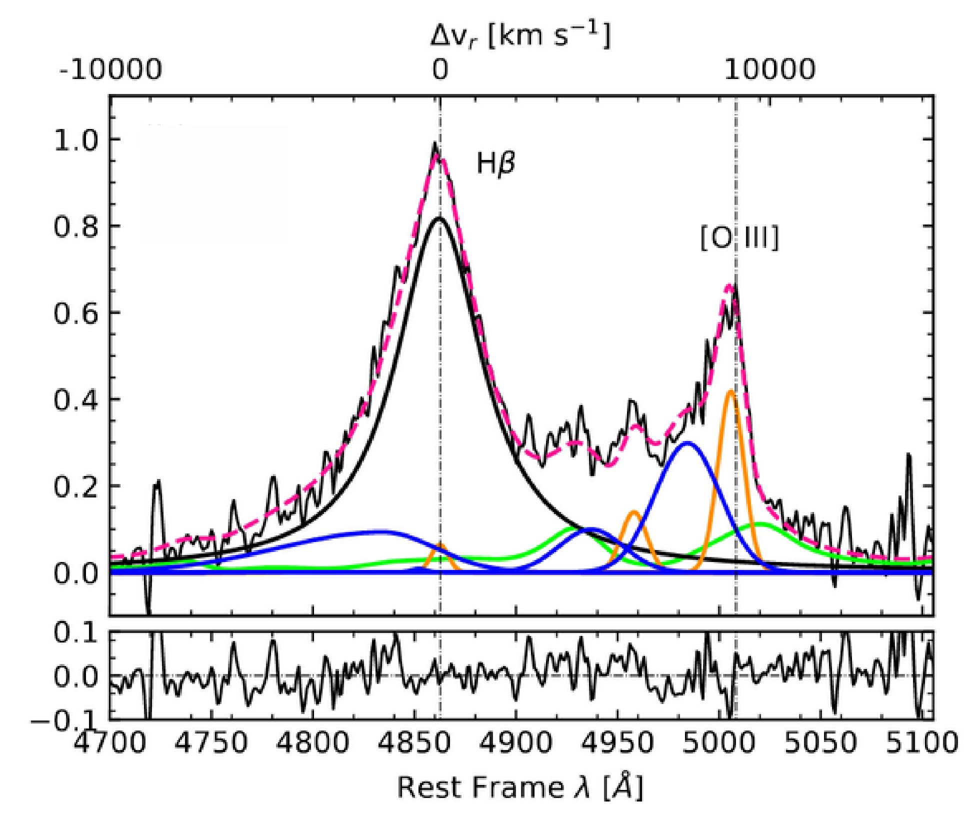


Profiles dominated by outflowing gas, especially RQ Pop. A

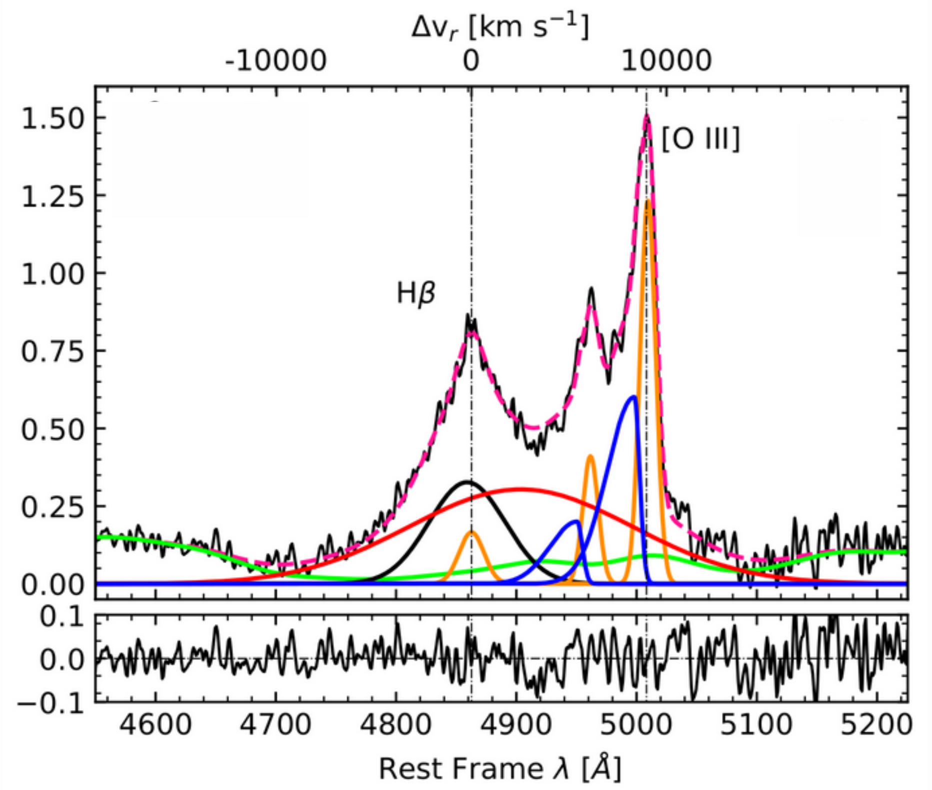
$c(1/2) \approx (-0.57 \pm 0.06)\mathrm{FWHM} + (481 \pm 115)$ [km/s]

Centroid velocity at 1/2 flux intensity

Pop. A (higher accretors)



Pop. B (lower accretors)

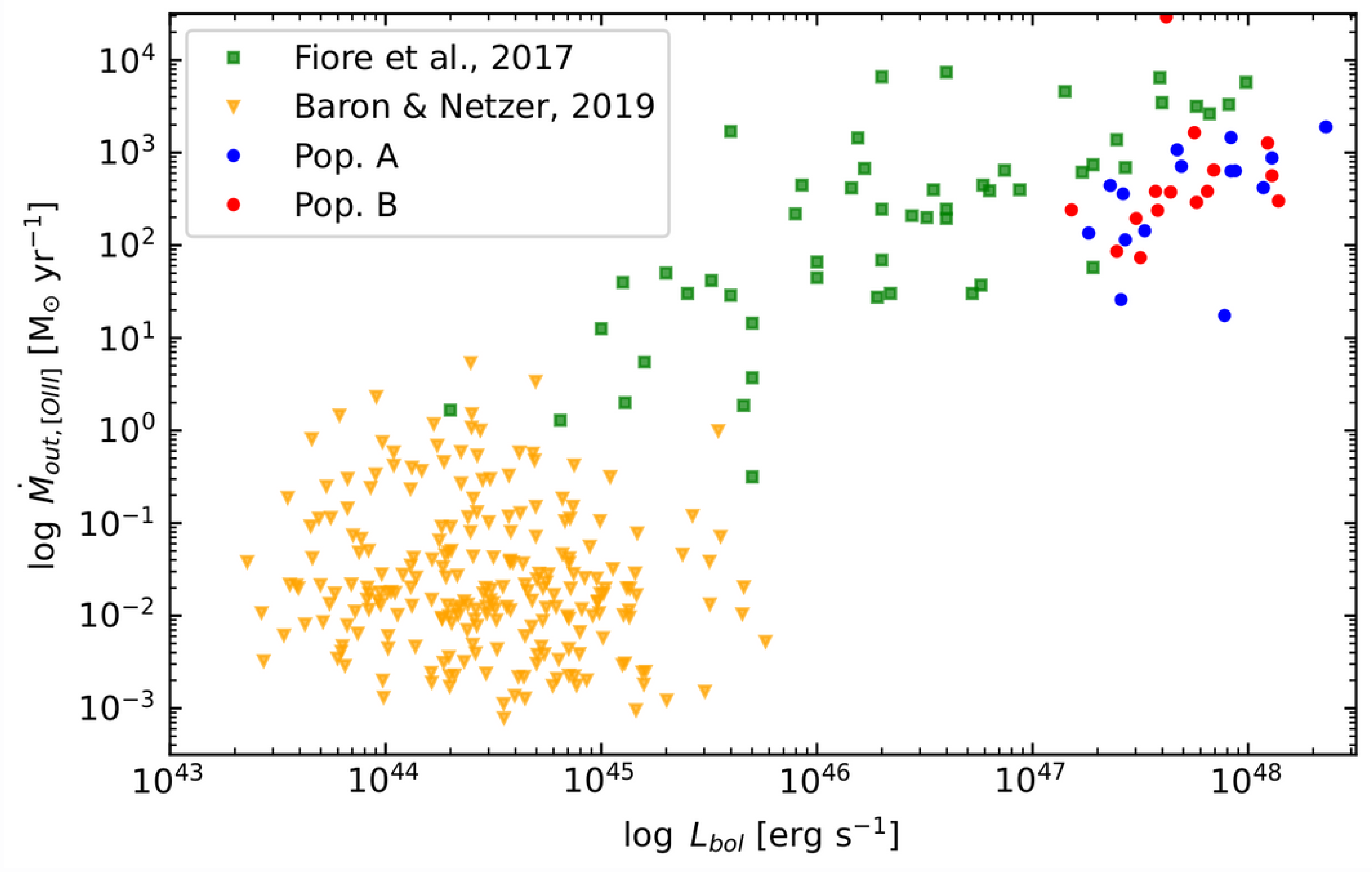


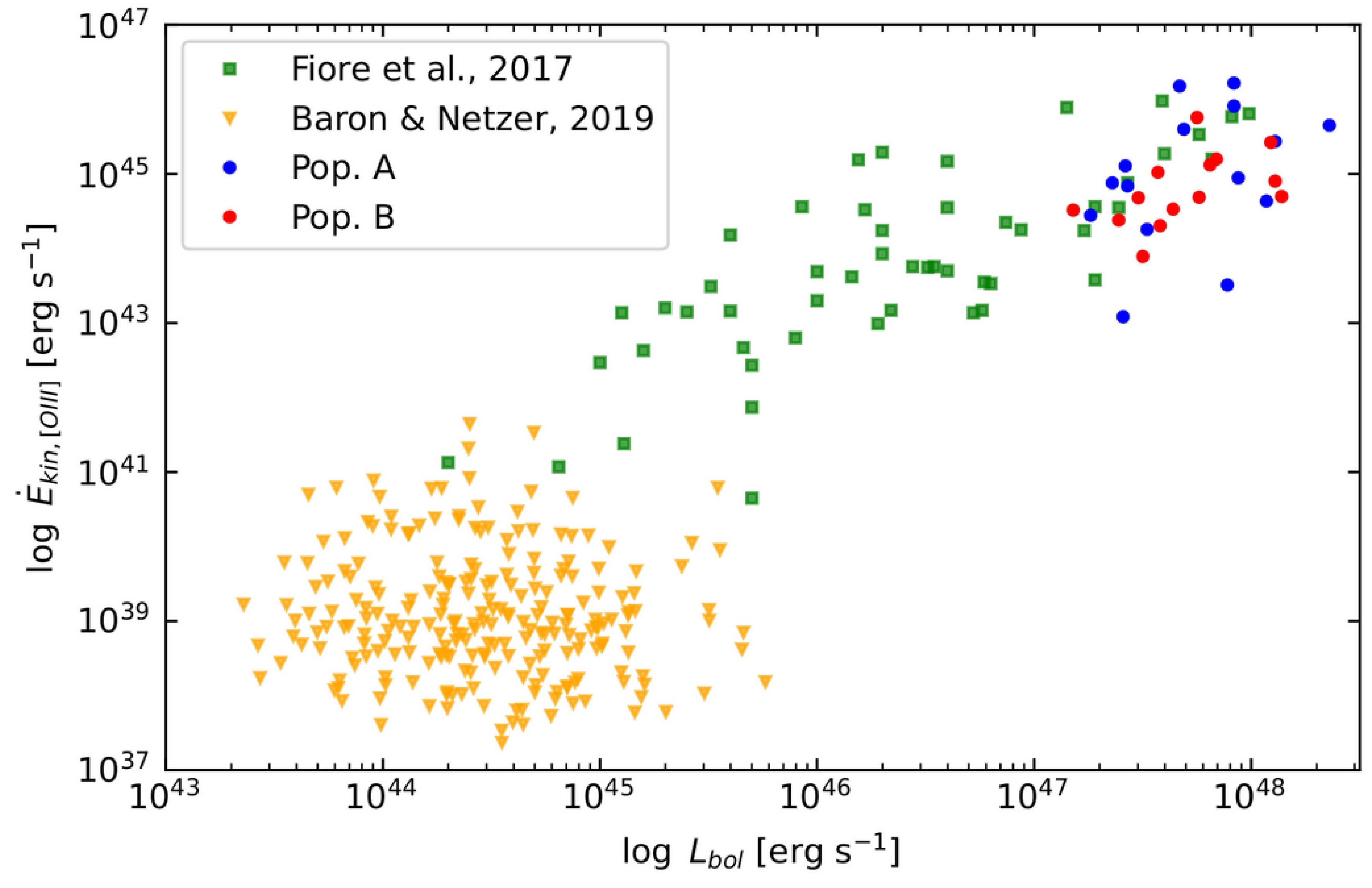
Fiore+17

Mass outflow rates between 10^1 and 10^3 solar masses/yr

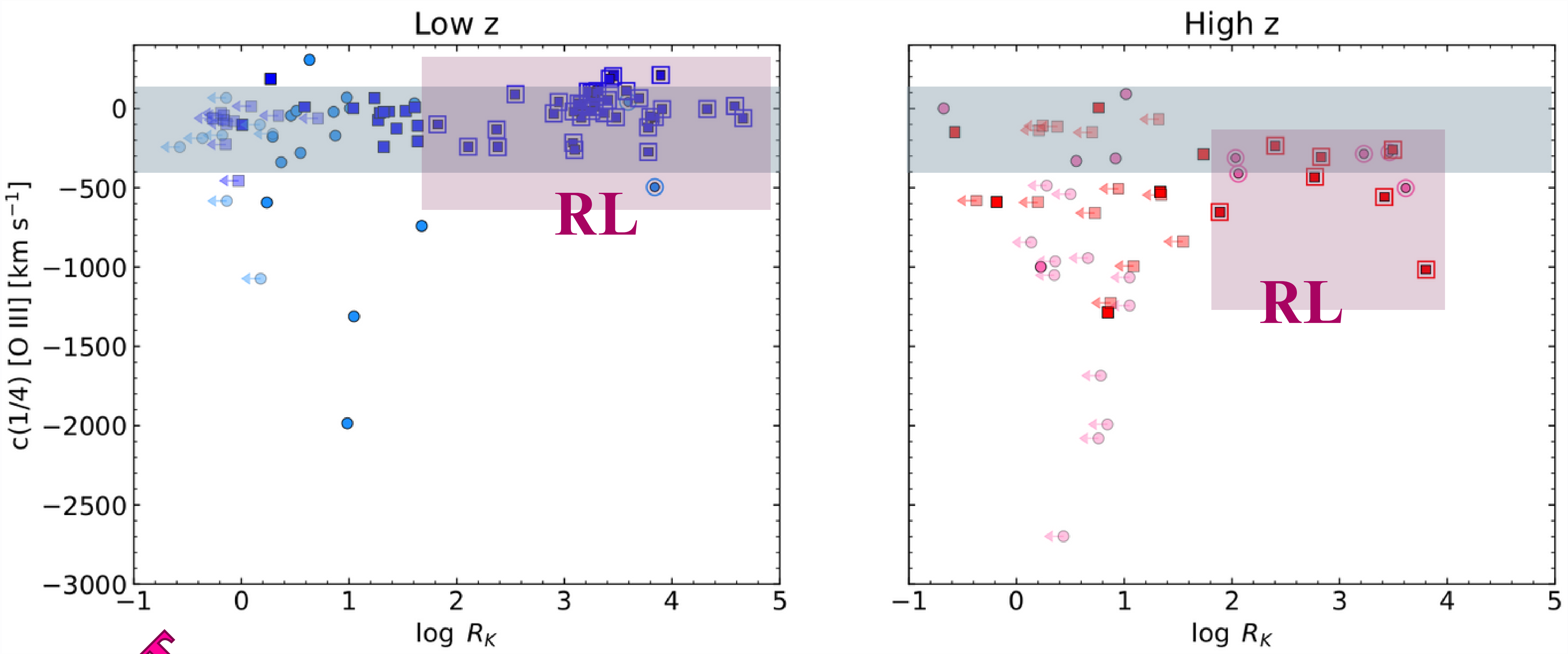
Kinetic powers between 10^{43} and 10^{46} erg/s

Averaged outflow efficiency: 0.02

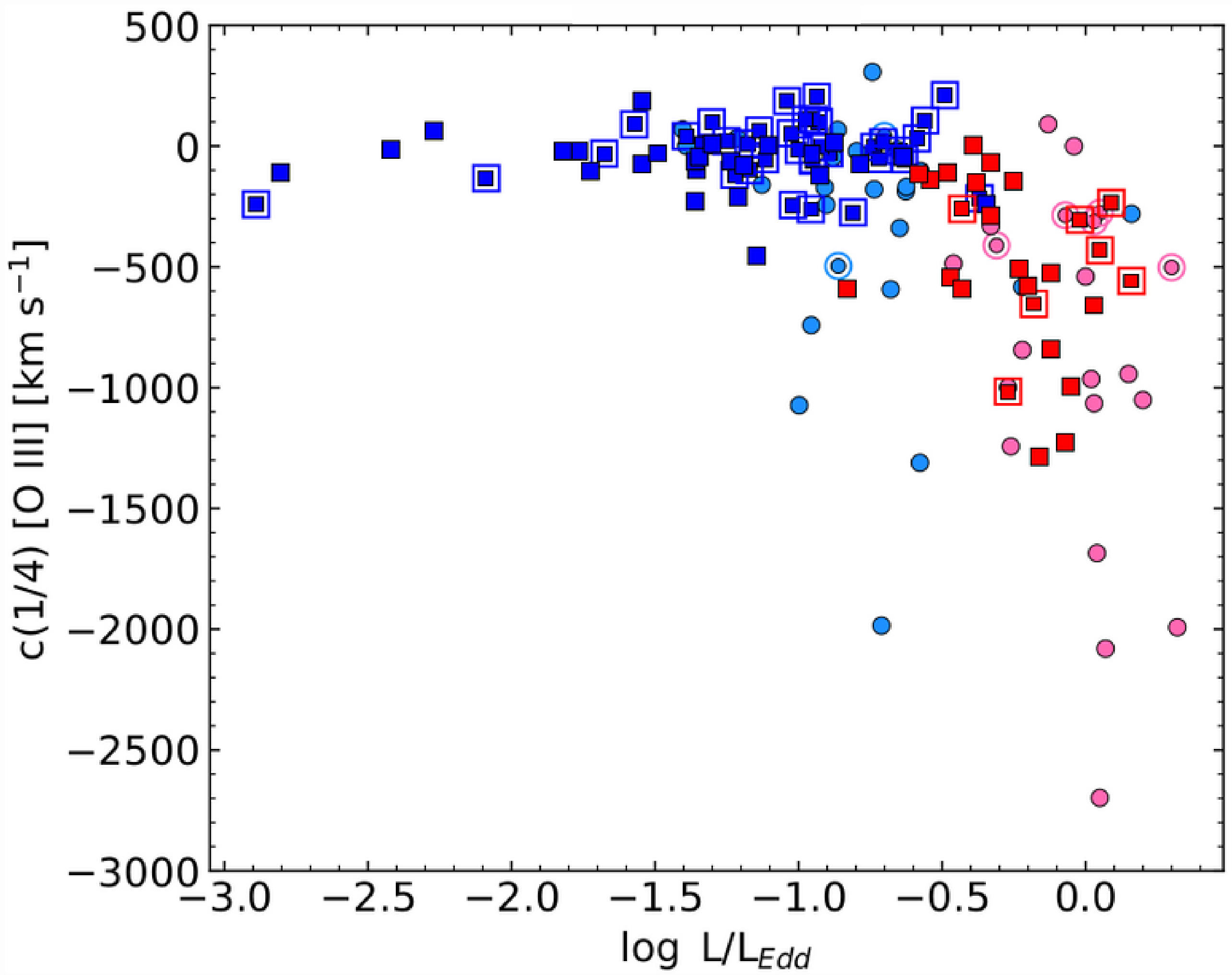




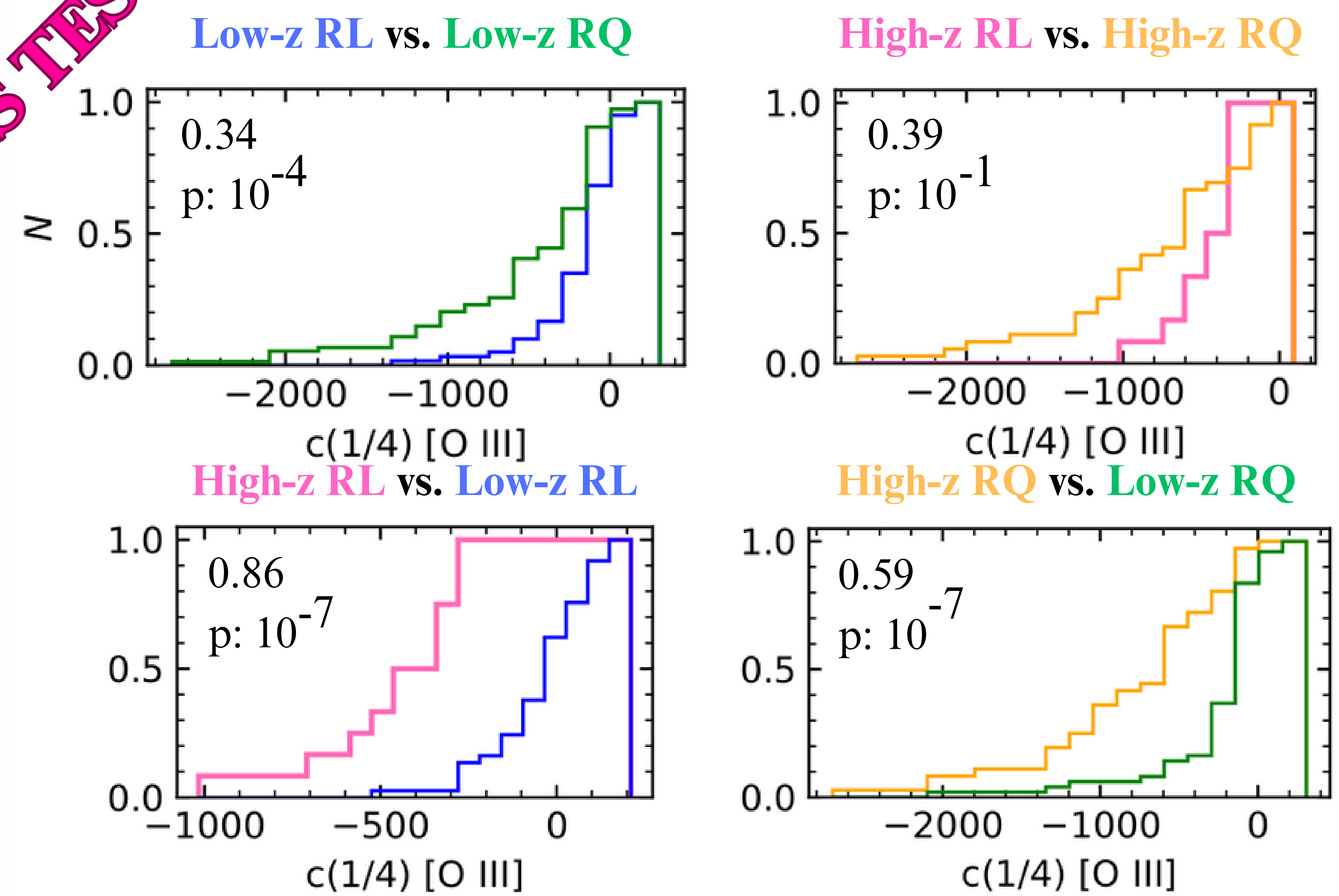
[O III]



Velocity centroid vs. Eddington ratio



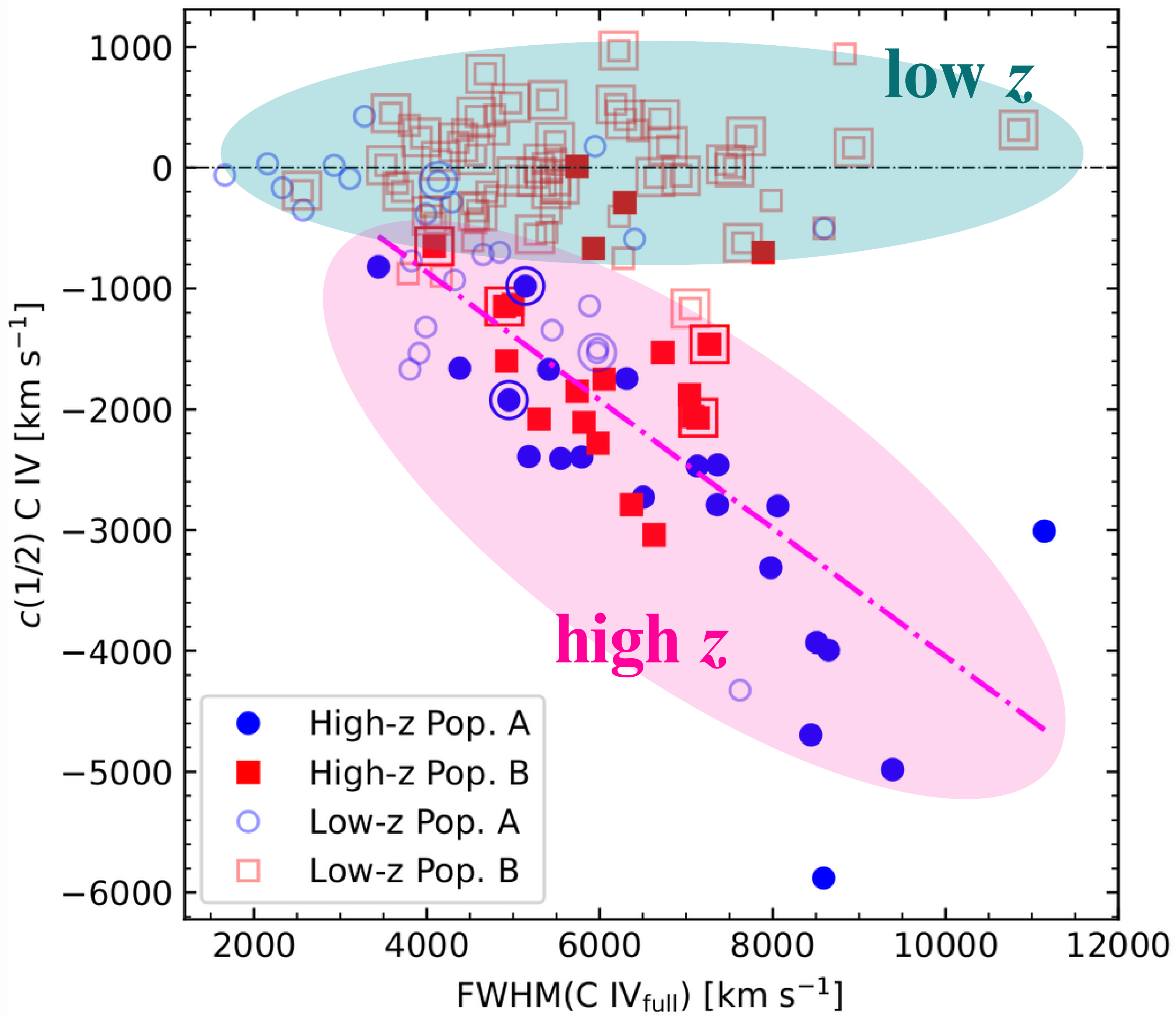
KS TEST



Radioloudness seems to somehow contribute to smaller outflows, however the strongest outflows in [O III] are caused by accretion

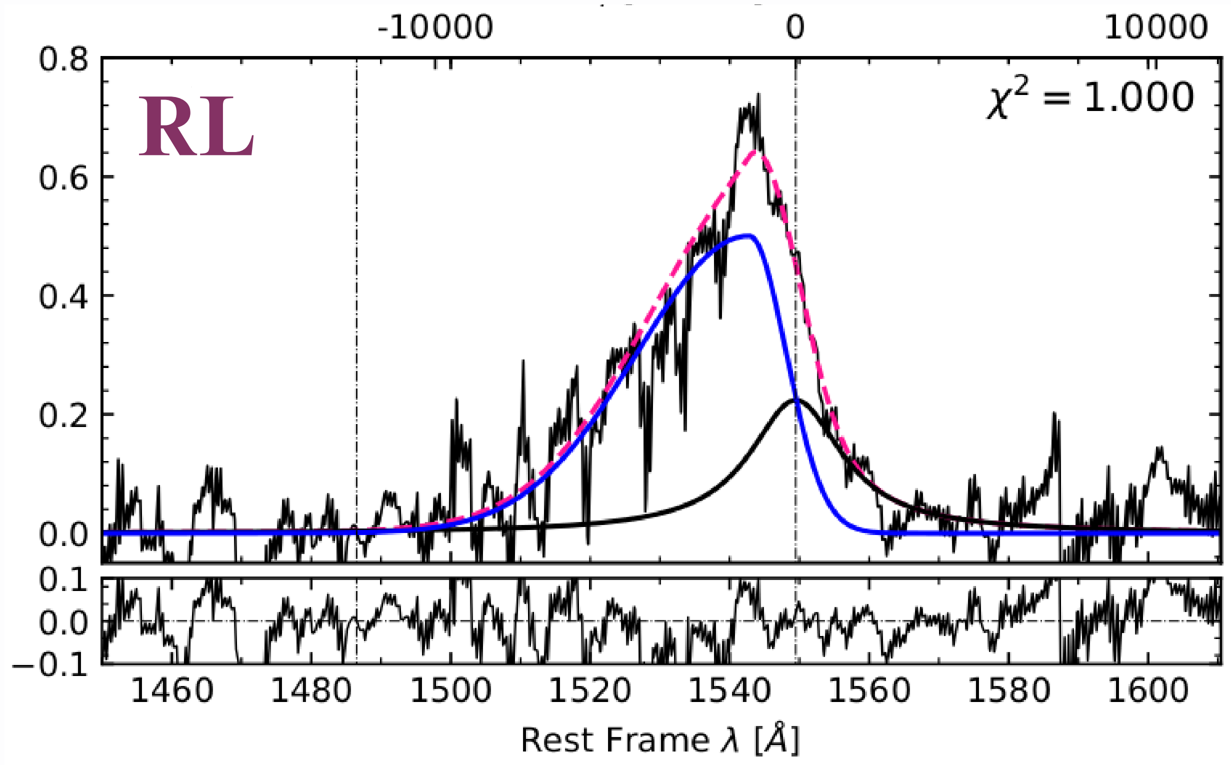
- **RL have smaller outflows compared to RQ;**
- **High-z RL/RQ have stronger outflows than low-z RL/RQ.**

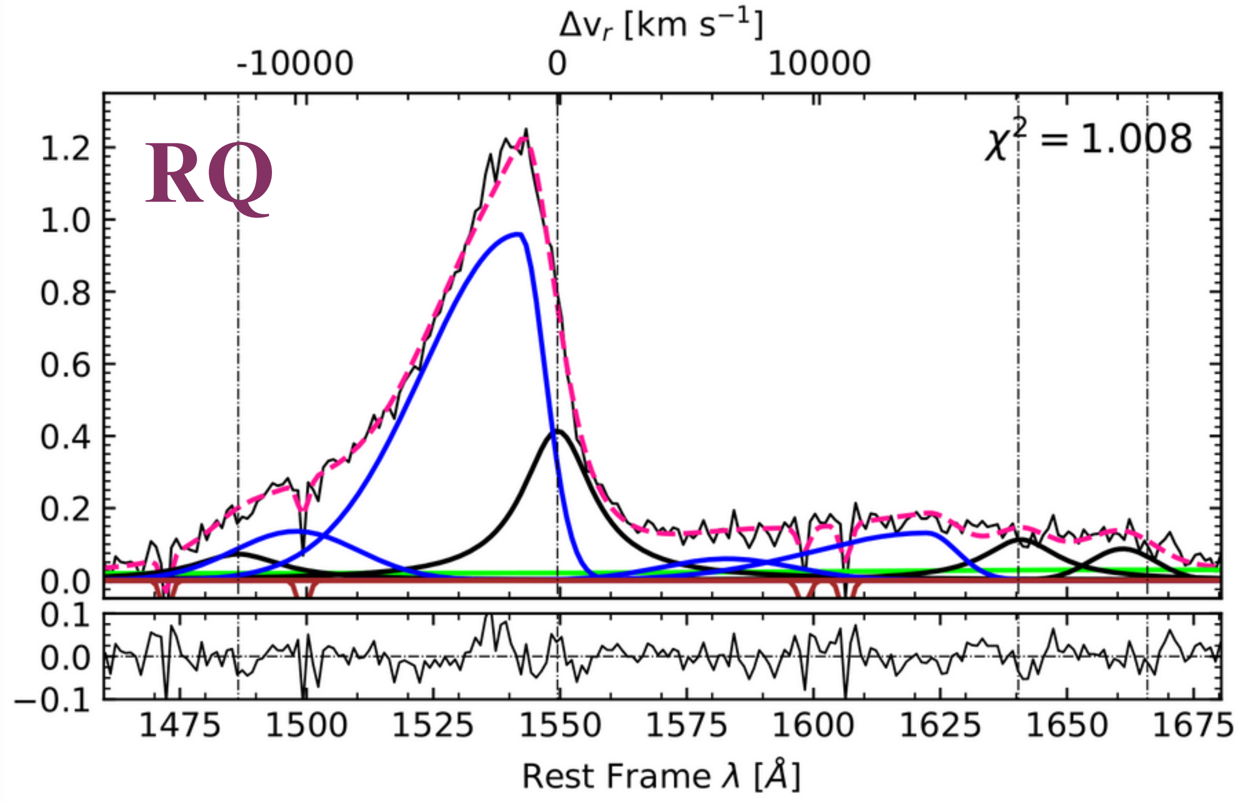
C IV: a magnified version of [O III]?



$$C(1/2) \approx (-0.53 \pm 0.09)\mathrm{FWHM} + (1259 \pm 642)\ [\mathrm{km/s}]$$

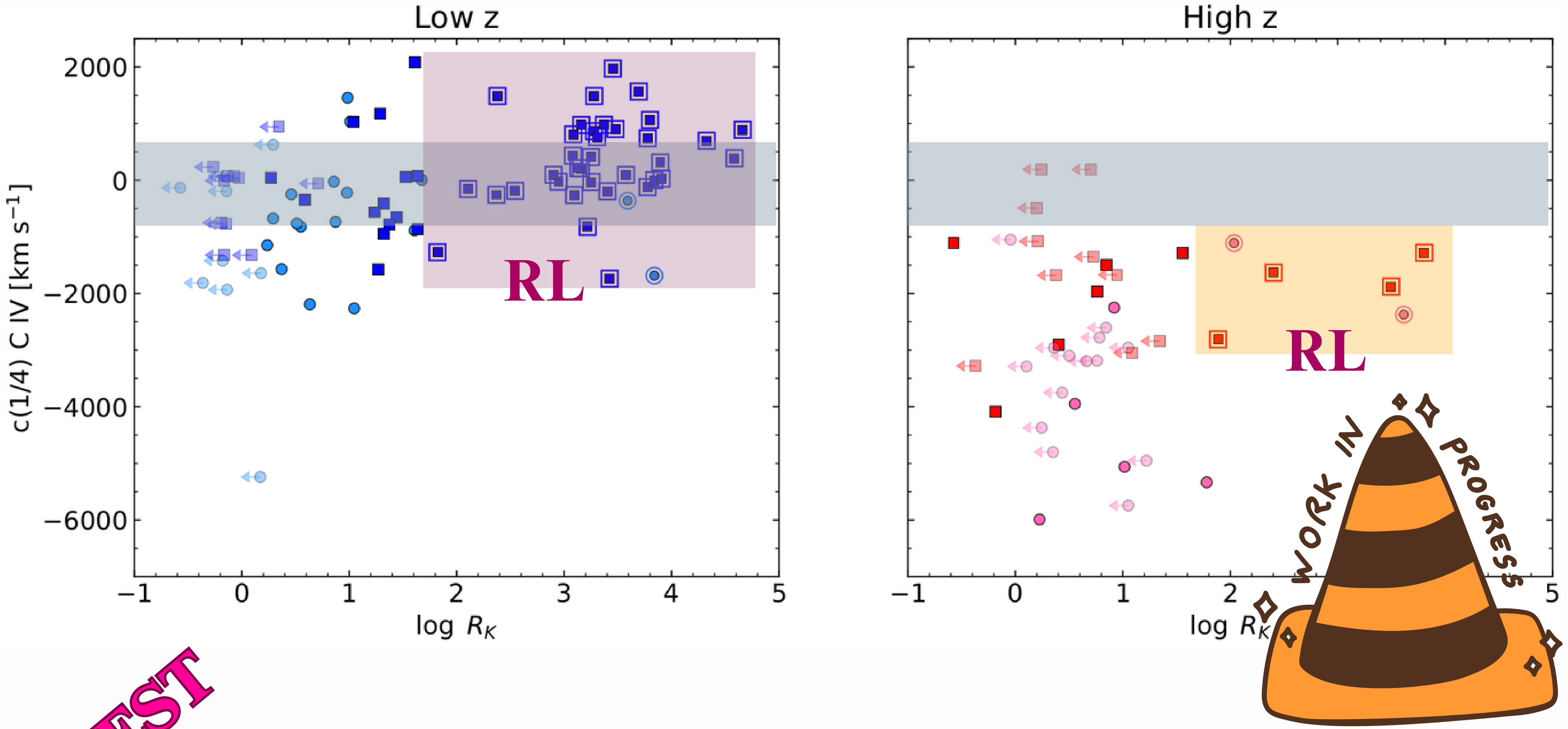
[O III] and C IV seem to follow a very similar, strong correlation between FWHM and blueshifts (outflows);



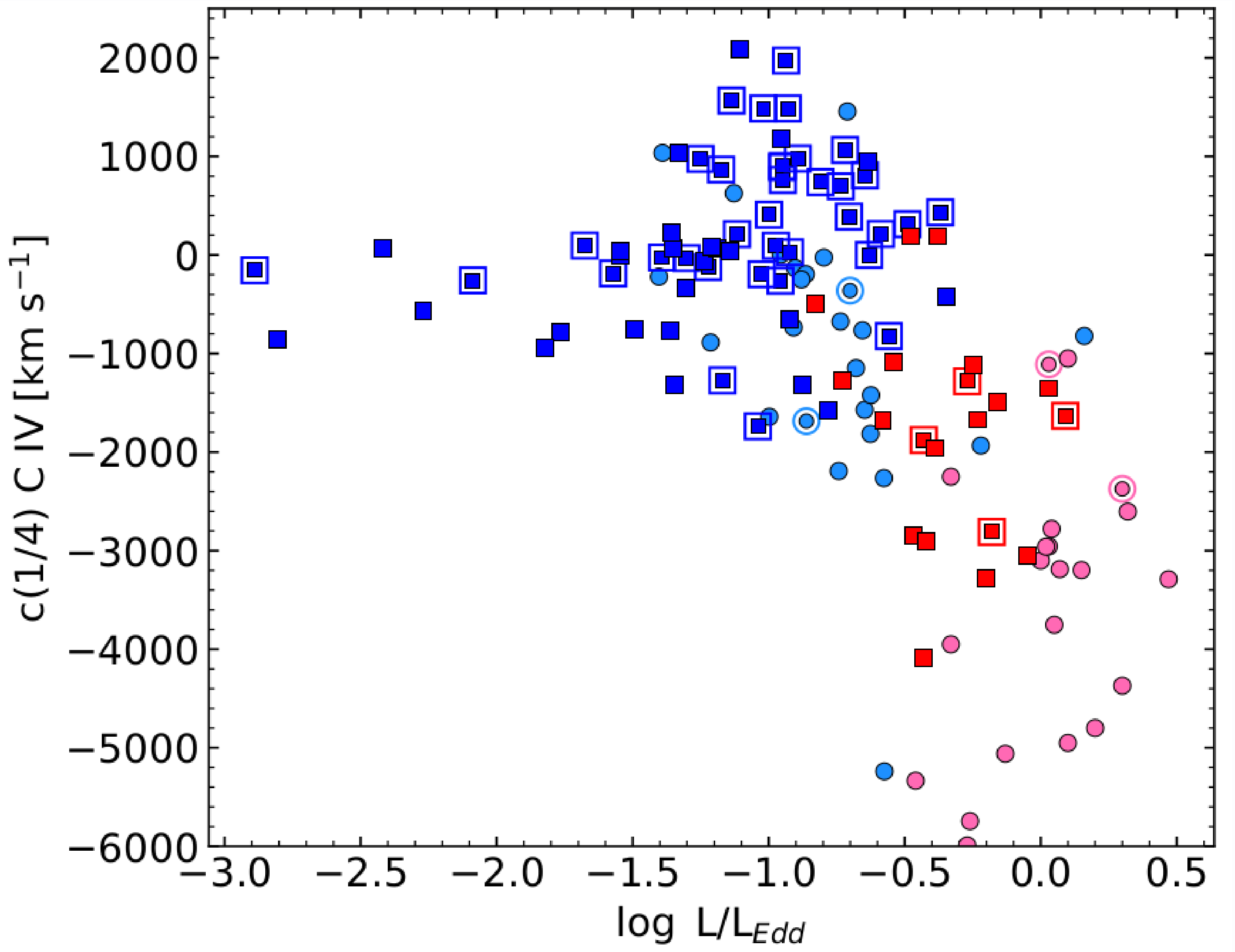


BLUE is the predominant component in both Pop. A (higher-) and Pop. B (low-accretors)

C IV: a magnified version of [O III]?

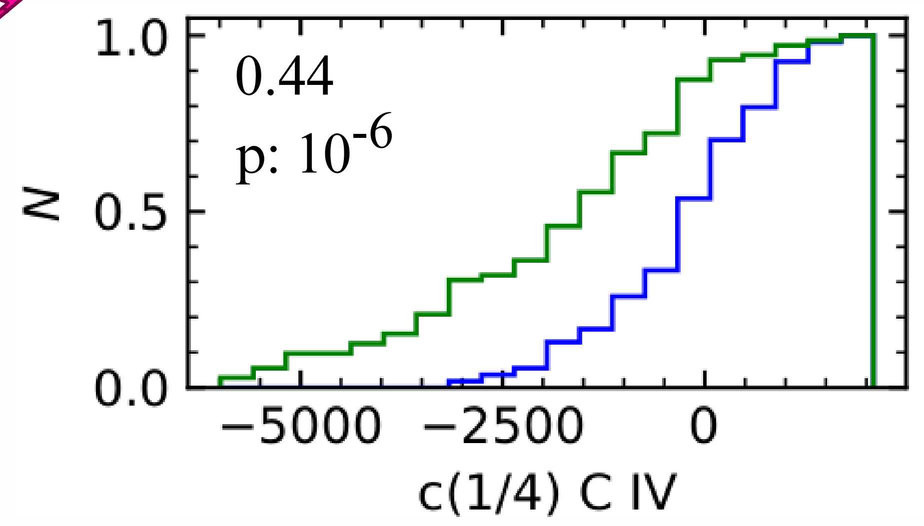


Velocity centroid vs. Eddington ratio

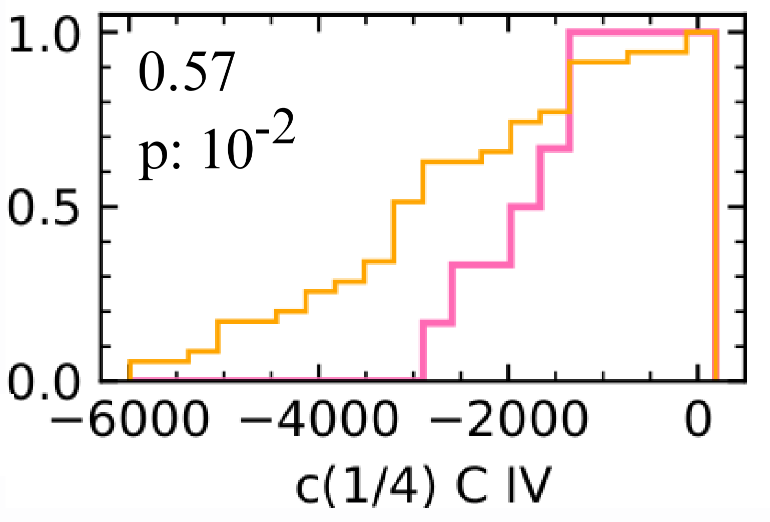


KS TEST

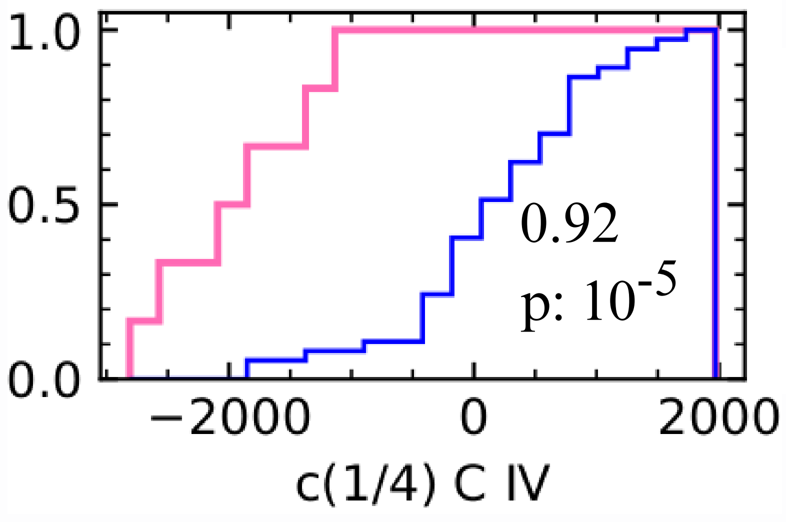
Low-z RL vs. Low-z RQ



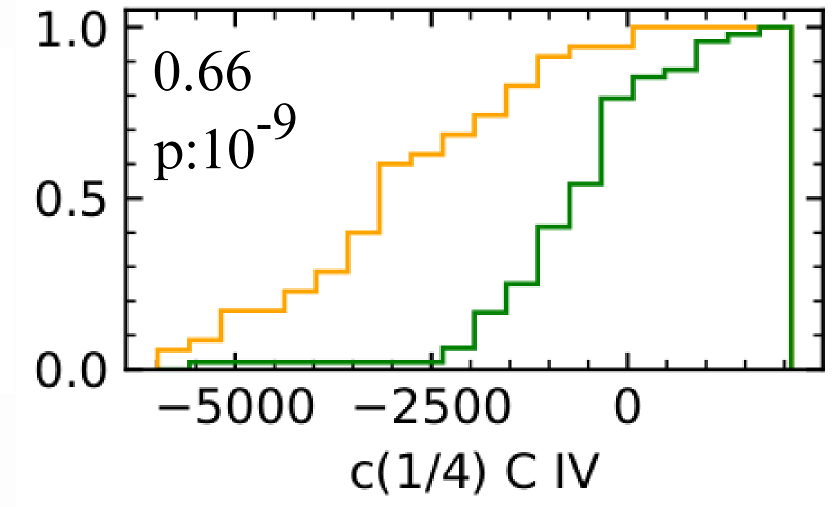
High-z RL vs. High-z RQ



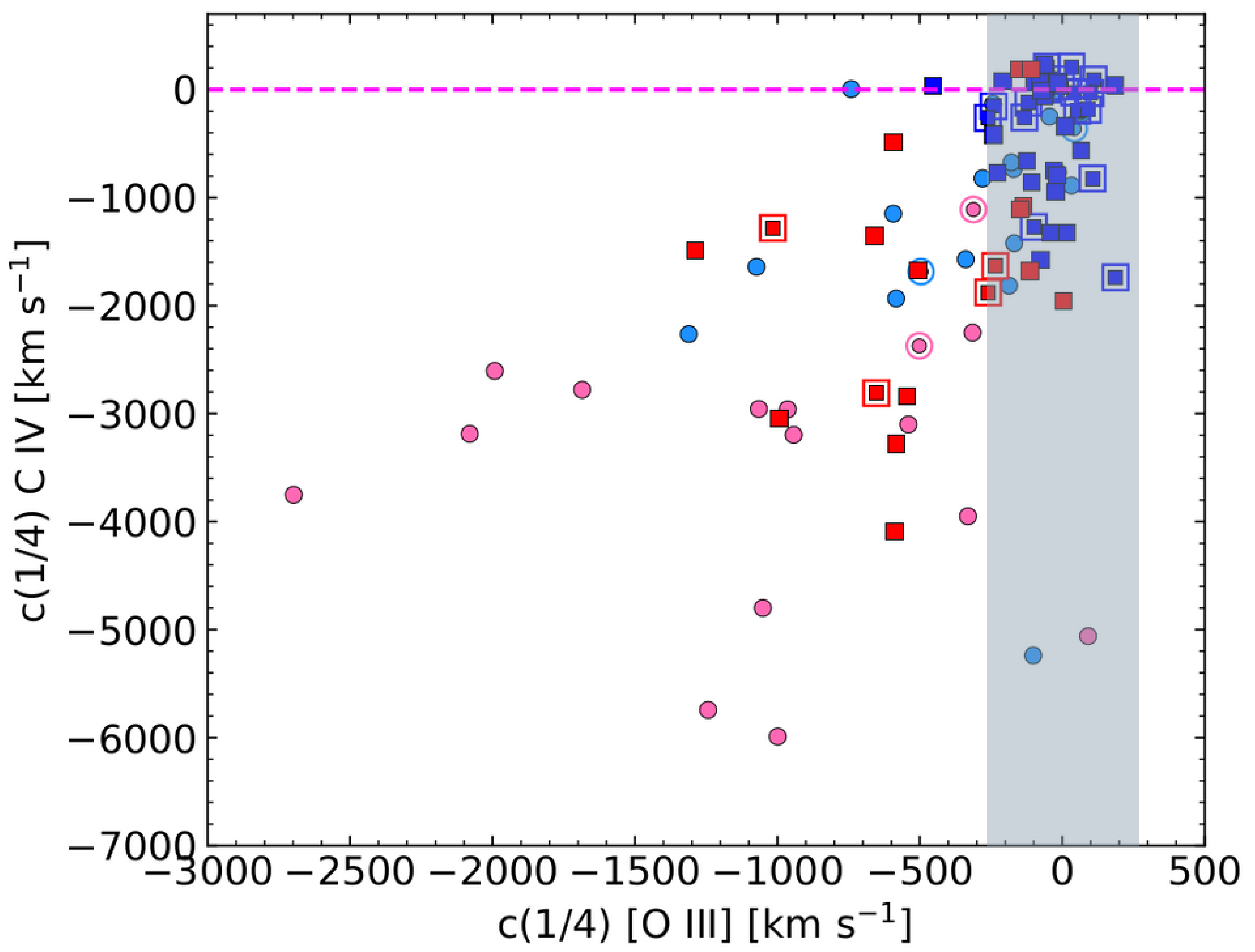
High-z RL vs. Low-z RL



High-z RQ vs. Low-z RQ



C IV x [O III]



At high z,
sources that present strong blueshifts (outflows) in [O III] will also present it in C IV!

Possible physical connection between inner (C IV) and outer ([O III]) outflows?!

Conclusions

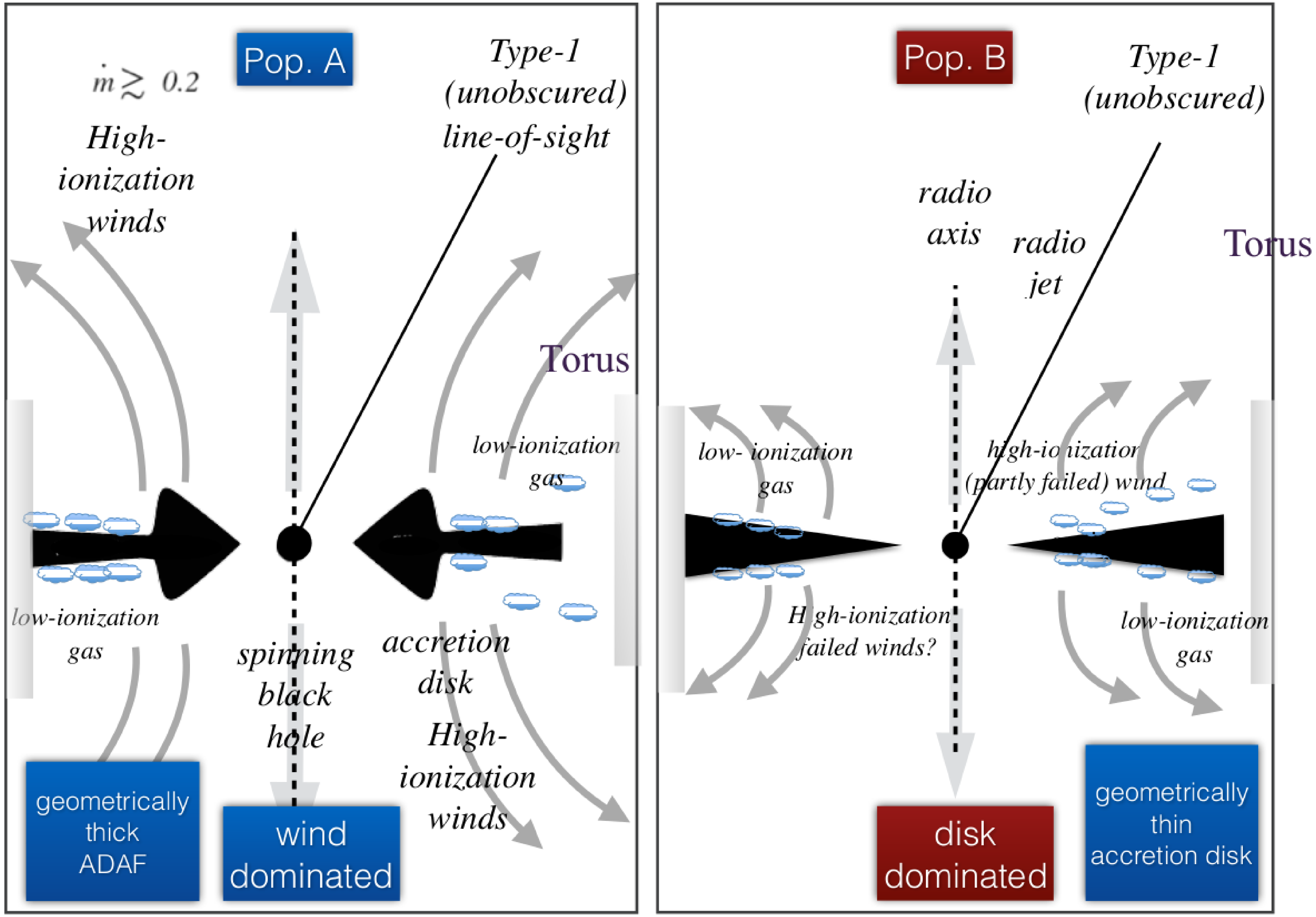
- The **4D Eigenvector 1 sequence persists at high-z**. The existence of Pop. A and Pop. B is preserved.
- Our analysis shows that the **behaviour of quasars of high-luminosity** all along the MS is **strongly affected by powerful outflows** involving a **broad range of spatial scales** in both the BLR and NLR;
- **[O III]** and **C IV** seem to follow a **very similar, strong correlation** between **FWHM and blueshifts (outflows)**;
- While at low z only high-accretors (Pop. A) show evidence of significant outflows, **at high z** the **outflow signature is detected** in **disk-dominated Pop. B quasars as well**.
- **RL sources** seem to present **weaker outflows** than the RQ ones in the **same redshift range**. However, **higher redshift** imply **stronger outflows**, which indicates that **the impact of the radioloudness on the winds is much smaller than the one of accretion**.

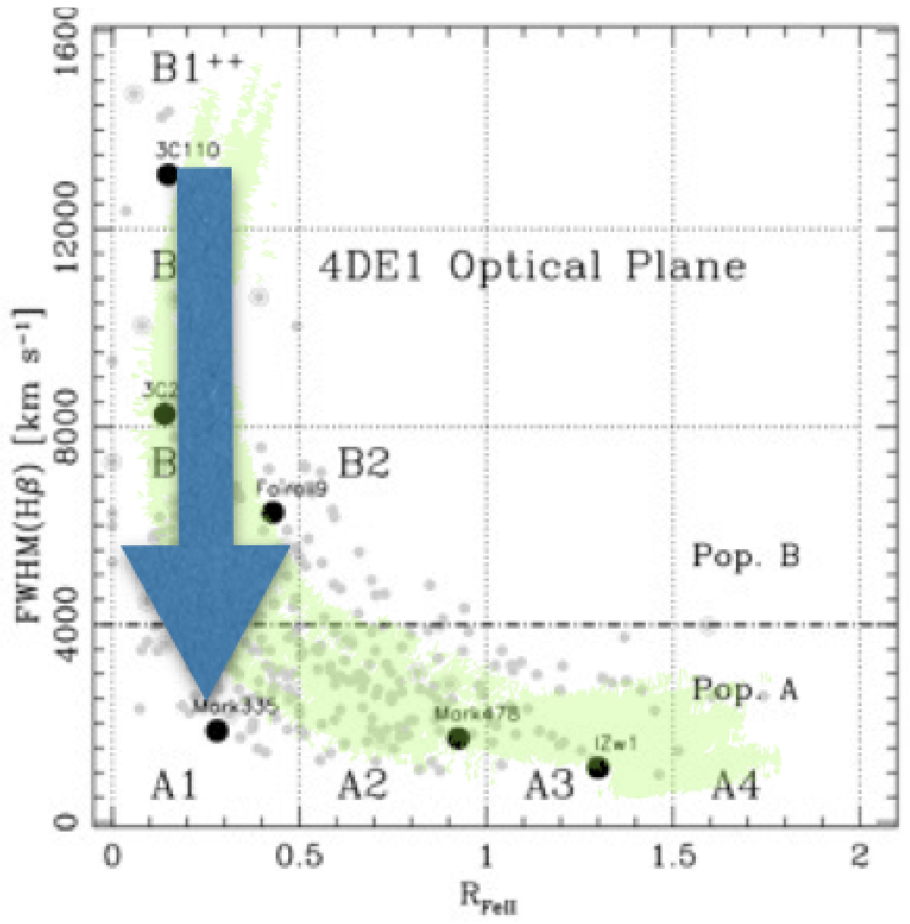
Thank you for your attention!

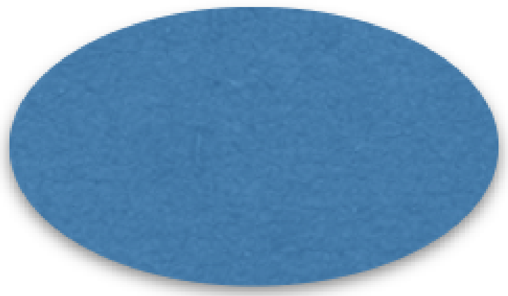
Pop. A/B transition: geometrically thick/thin disk?

Not drawn to scale

Abramowicz et al. 1988, Shakura & Sunyaev 1973

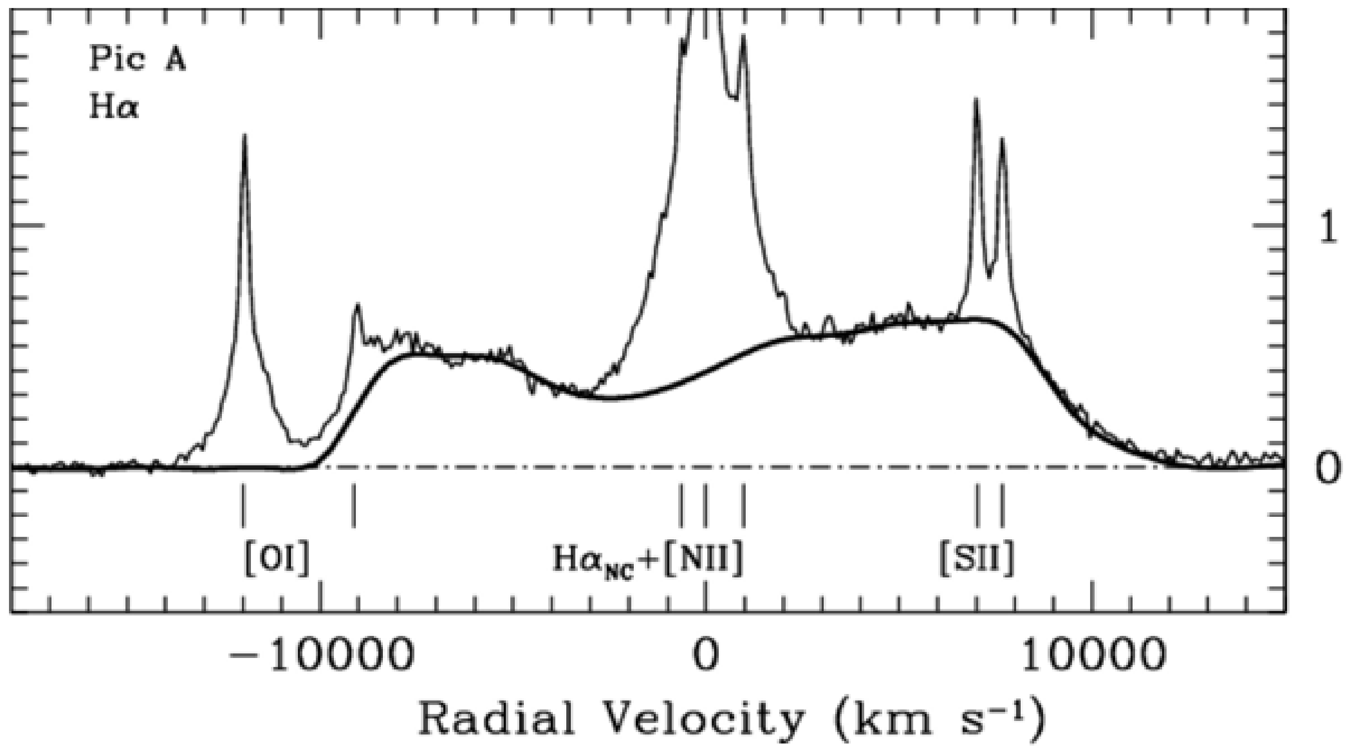


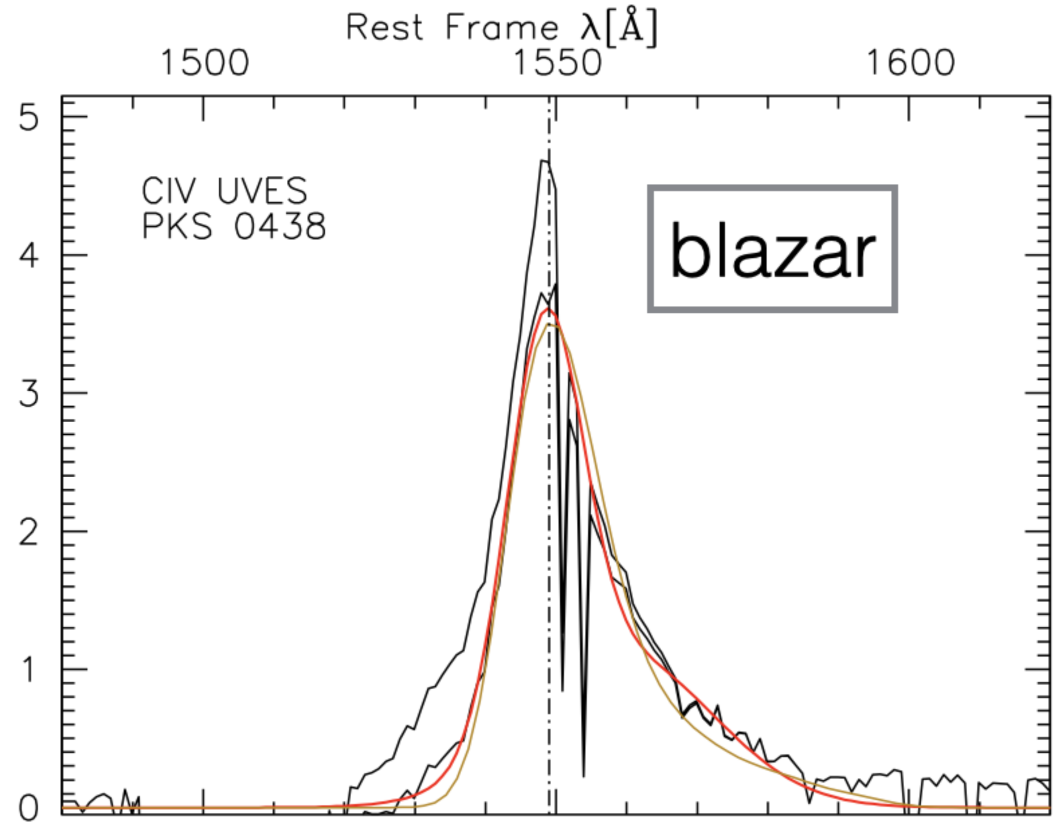




i=30-40

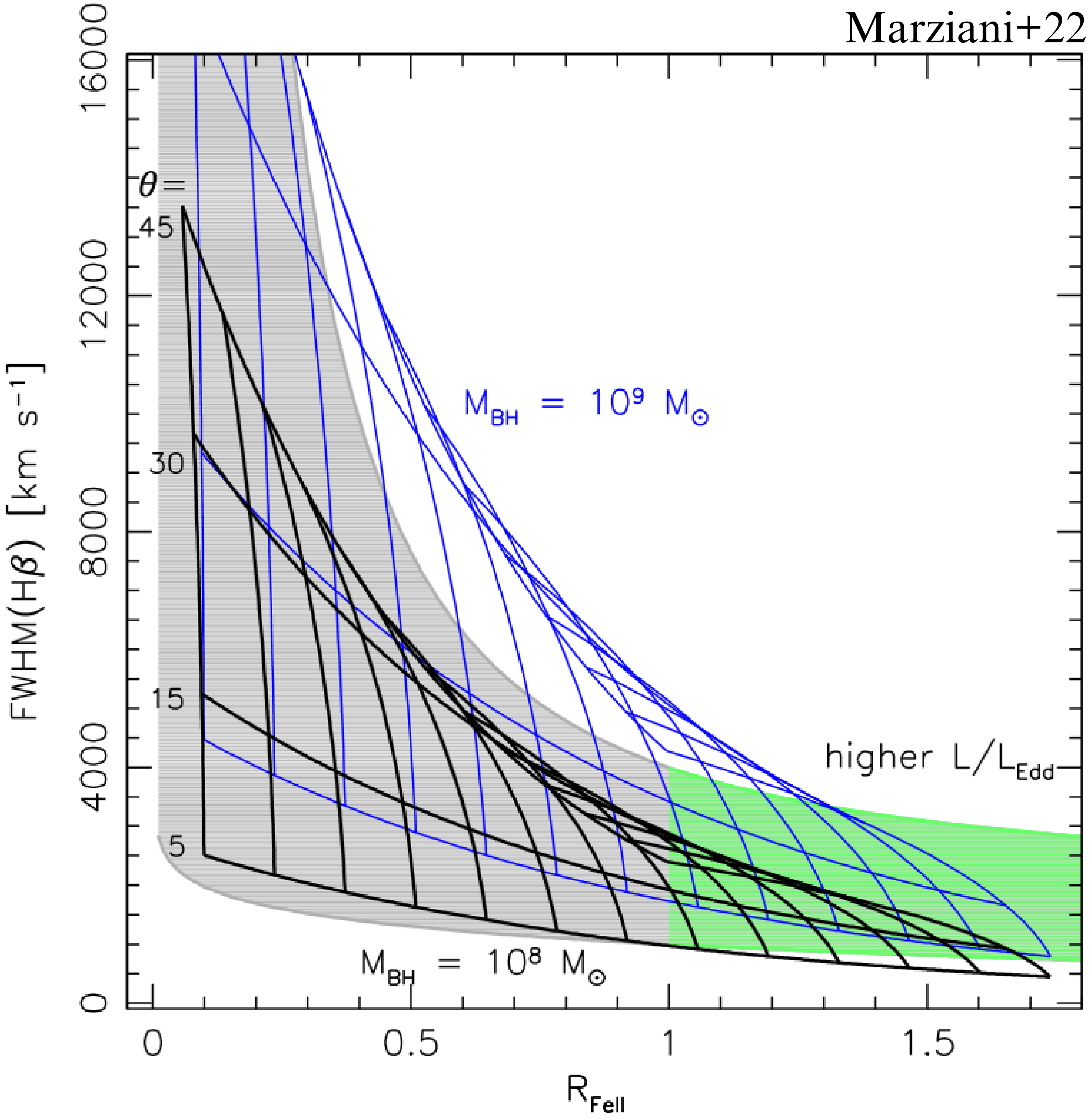
i=0





blazar

Marziani+22



- Orientation yields an almost vertical displacement from broader to narrower profiles, passinf from viewing angle Θ ≈ 50 to Θ ≈ 5

- Eddington ratio is roughly proportional to RFeII

Eddington ratio & orientation, fixed BHM