# Black Hole Masses, Outflows and Hot Dust at High-Redshift


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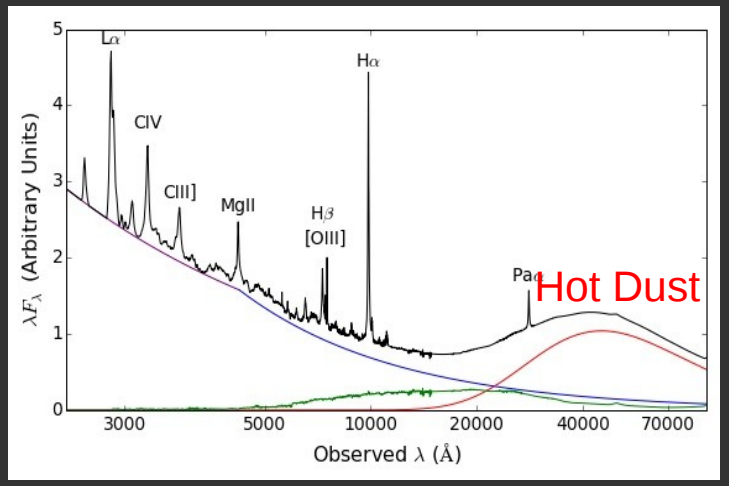
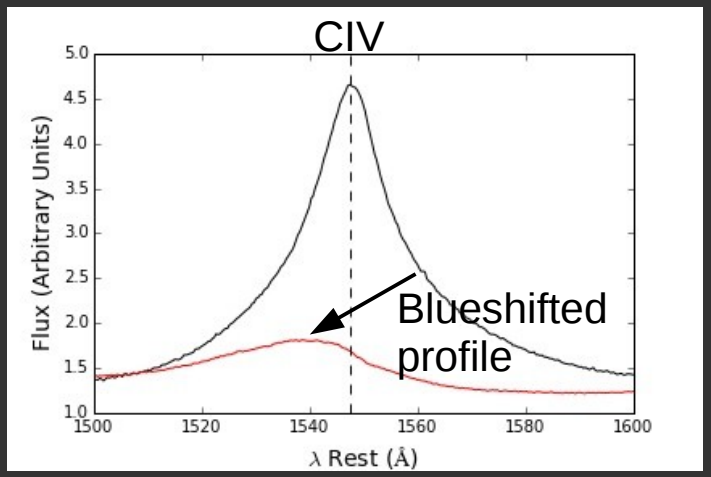
# Motivation

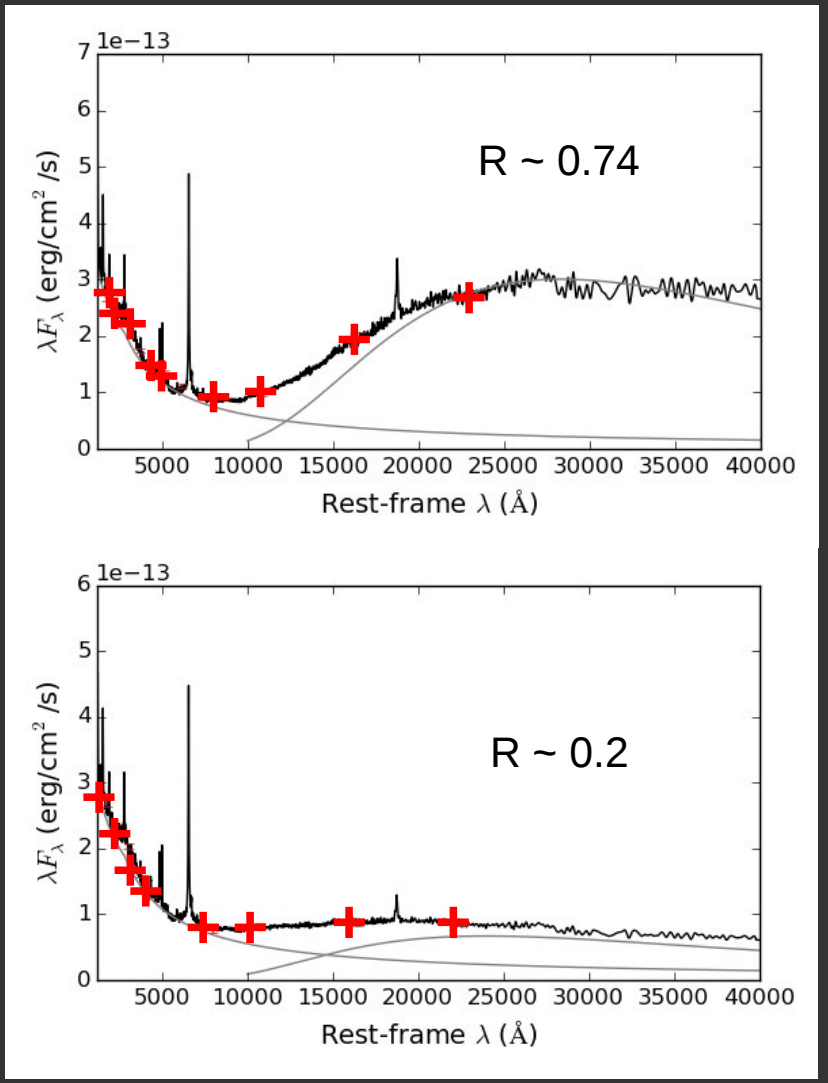
- Our goal is to study the **hot dust** which is closest to the central source, and at the same time **outflows** in the BELR.
- The shape of the rest-frame **near-infrared SED** reflects the temperature and covering factor of the hot dust. Meanwhile, outflows in the BLR are reflected in the blueshifting of broad, high-ionisation rest-frame **UV emission lines**.
- How do these two physical components relate to one another, and how do they relate to fundamental properties of quasars (e.g. M$\odot$, L/L$_{Edd}$)? Are properties dependent on orientation effects or indicative of a particular evolutionary phase.
- With spectra and photometry from large area, multi-wavelength surveys we can study these properties for 10,000s of luminous quasars during the epoch of peak quasar activity ($2 < z < 3$).

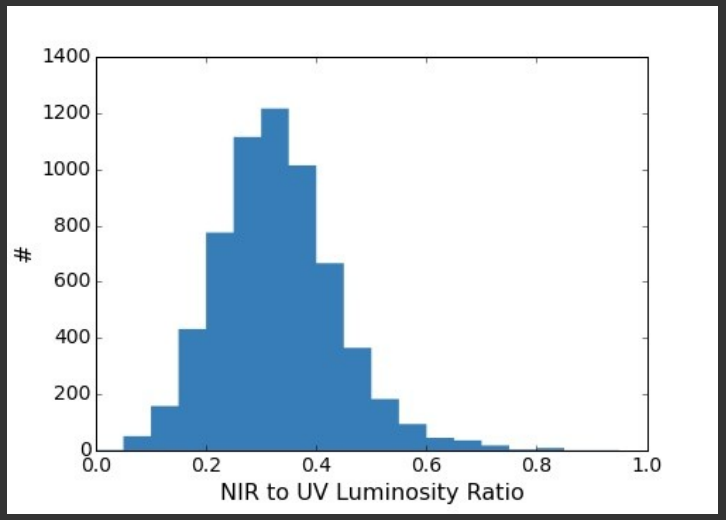


# Hot Dust Emission

- Fit SED model to SDSS, UKIDSS and WISE photometry.
- A simple black-body (free parameters temperature and normalisation) reproduces the near-IR SED very well, which suggests emission from optically thick material exterior to BELR.
- T ~ 1400K, consistant with pure graphite dust a sublimation temperature.
- Significant diversity in hot dust abundance observed

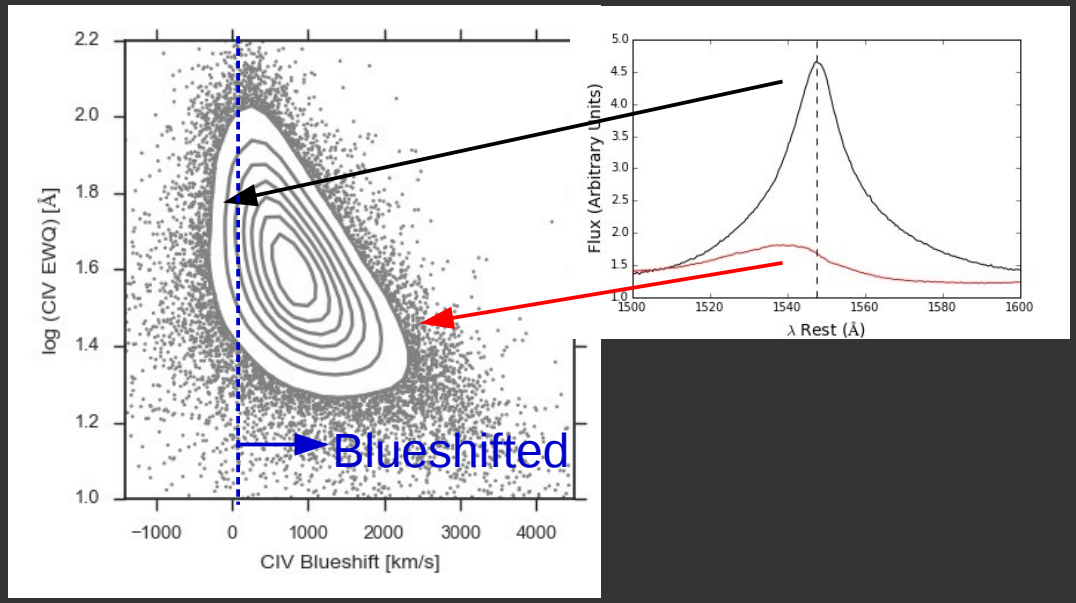


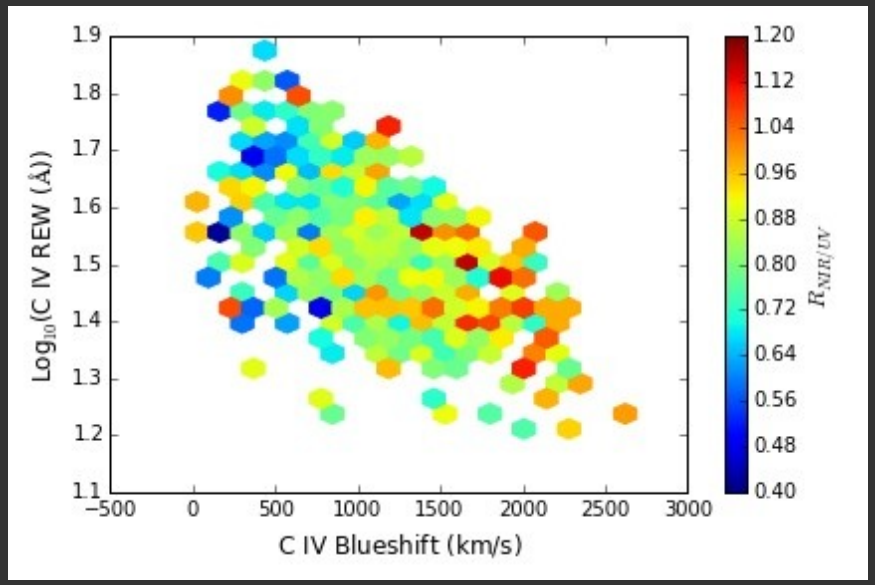

R = Ratio of NIR (1 – 3μm) to UV (0.2 – 0.9μm) luminosity

# CIV Emission

- CIV exhibits a broad range of morphologies, including significant blueshifts of up to several 1000km/s.
- Usually interpreted as evidence for strong outflows, resulting from presence of a radiation line-driven accretion-disk wind.

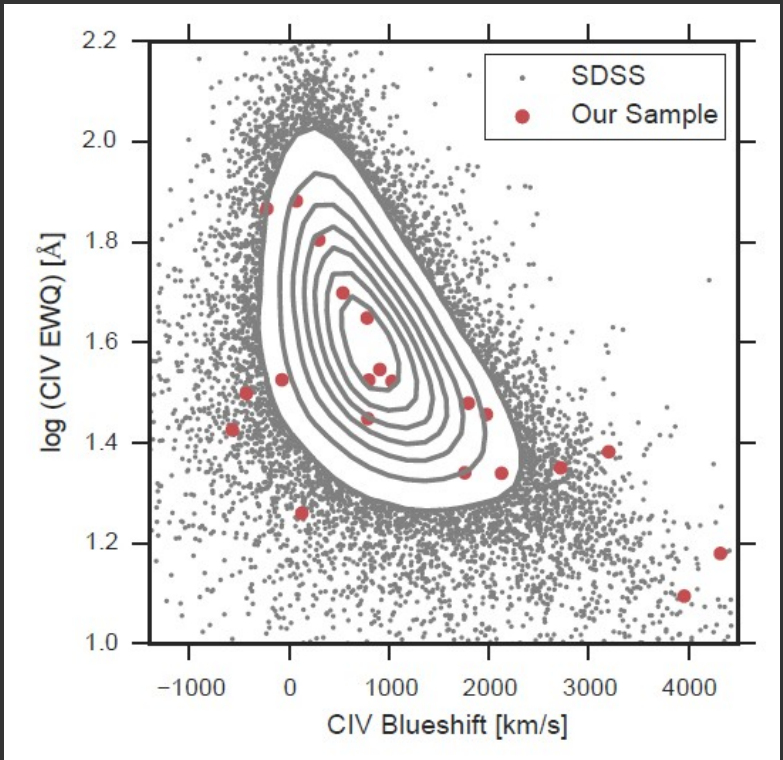



- Find that CIV blueshift correlates with amount of hot dust (e.g. Wang+14).
- Relating to MBH and L/LEdd will help us to test models that explain this result (e.g. orientation effect, dust in outflows).



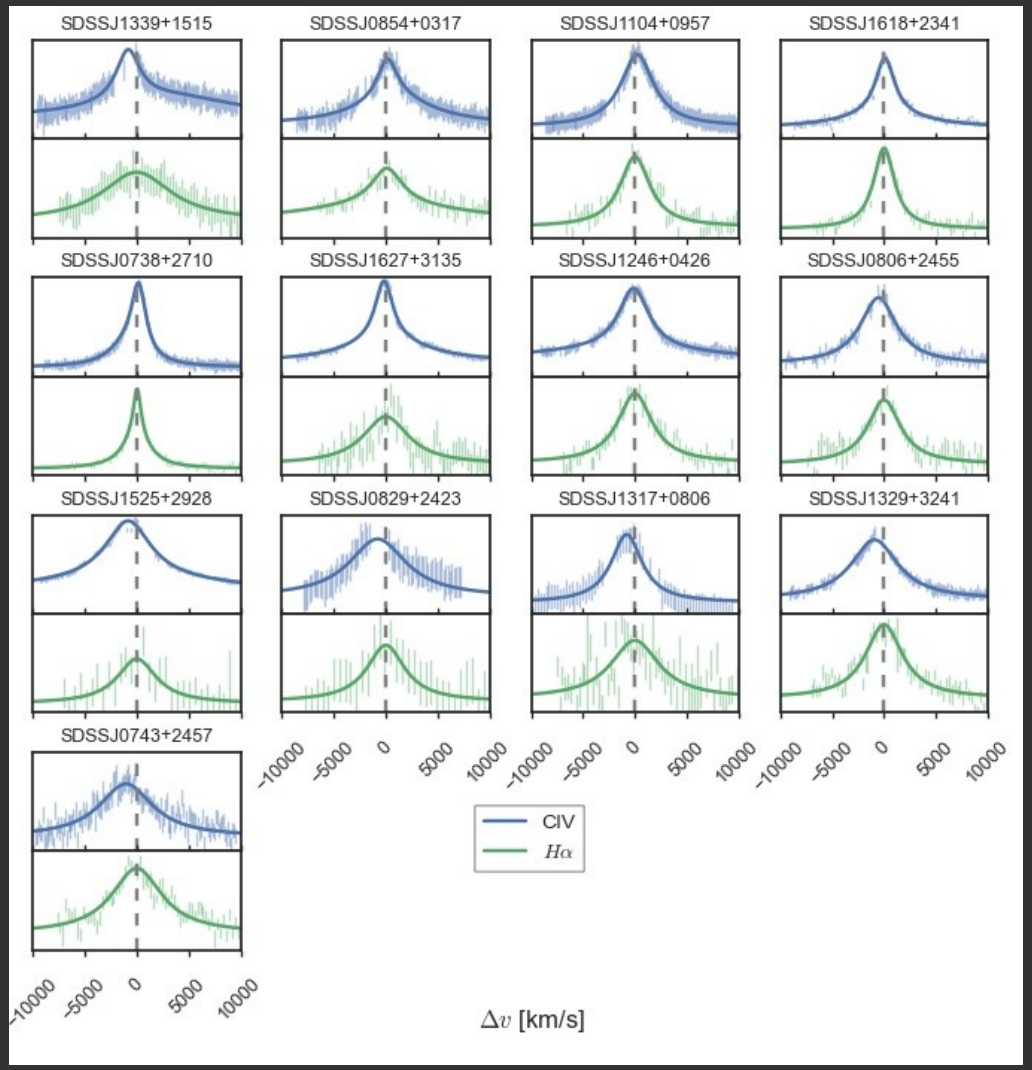
# Black Hole Masses

- At 2 < z < 5 CIV is used in virial scaling relations to estimate MBH (Shen+11). But virial assumption clearly invalid when significant contribution from non-virial wind component, which questions reliability of MBH estimates.
- Obtained near-IR spectra with LIRIS on 4.2m WHT for 22 quasars at 2 < z < 2.7 with a range of CIV emission line properties. Gives us independent virial BHM estimate using low-ionisation Hα emission line.



# Line Profiles

- With this data, can directly compare Ha and CIV profiles, and virial BH mass estimates derived from them.



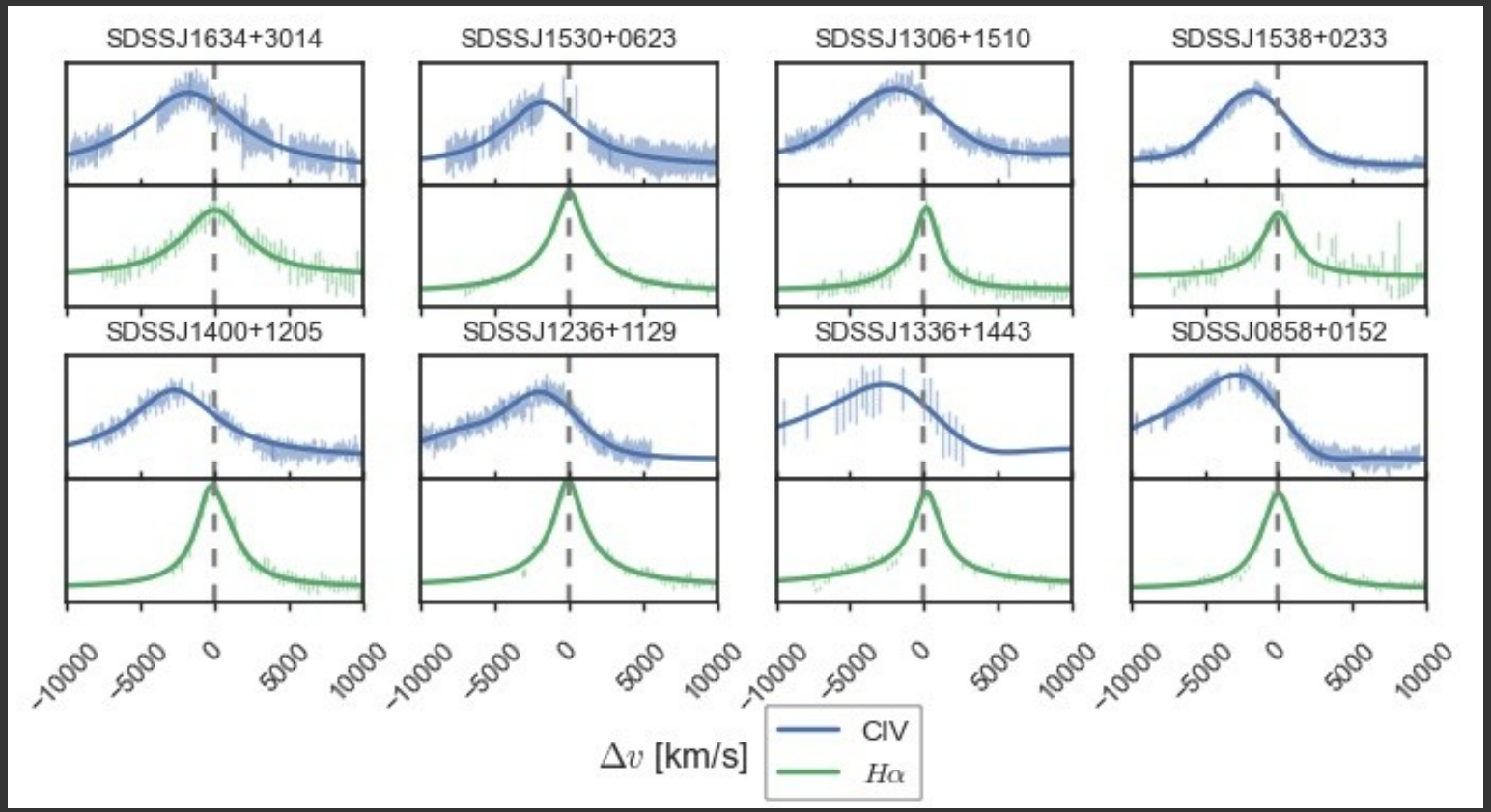

CIV blueshift ~ 0 km/s

CIV blueshift ~ 1000 km/s

# Line Profiles

- With this data, can directly compare Ha and CIV profiles, and virial BH mass estimates derived from them.

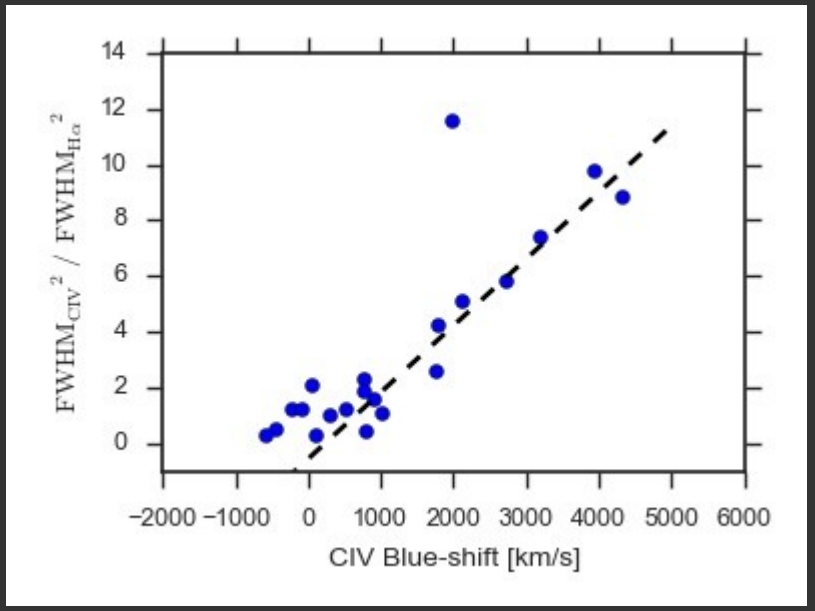
CIV blueshift ~ 2000 km/s

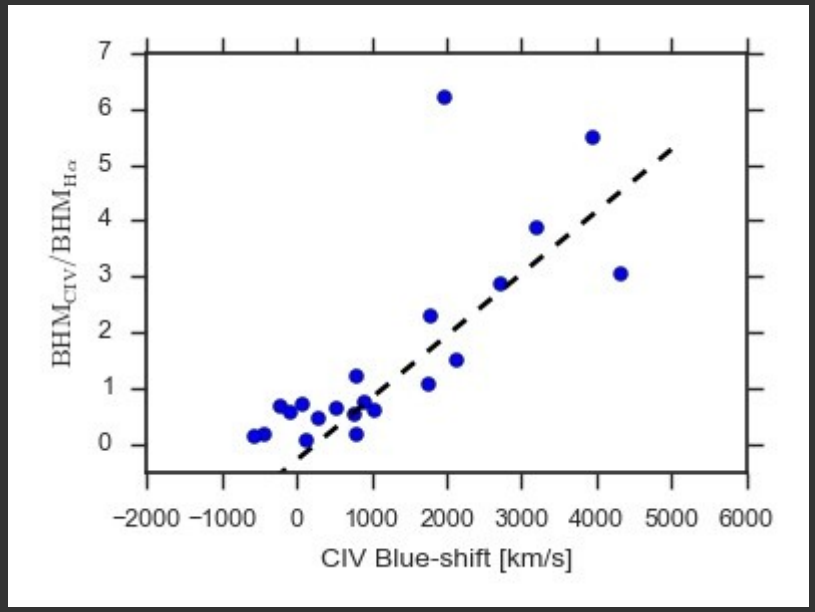



CIV blueshift ~ 4000 km/s

# Black Hole Masses

- CIV-based virial BH mass estimates are overestimates when CIV is blueshifted, and bias is tightly correlated with the blueshift.



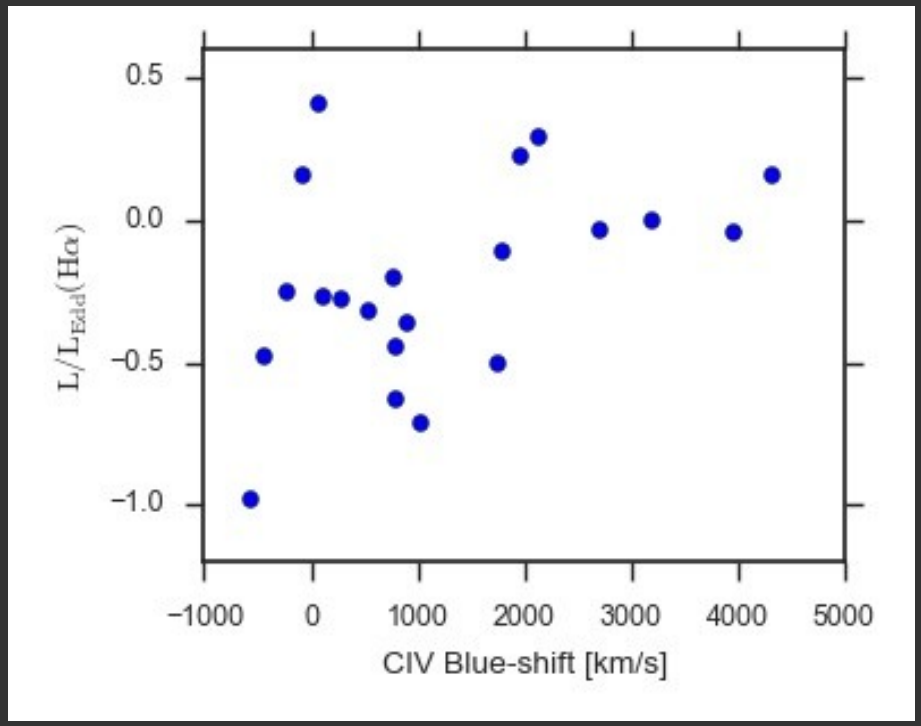




- Now extending sample to include ~300 quasars at $2 < z < 5$ from literature, ~80 from NTT large program (PI: J. Hennawi) and 32 from recent NTT program (PI: L. Coatman) specifically targeting high CIV blueshift objects.
- Will use sample to derive corrections to widely used CIV virial BHM estimate as function of CIV-blueshift and EQW.

# Eddington Ratio

- We find that high blueshift objects have low MBH and high $L/L_{Edd}$, and are being scattered in to our flux-limited sample during an evolutionary growth phase of rapid accretion.
- High accretion rates are driving strong outflows in BELR.

- CIV blueshift < 1500 km/s:
  - Median $L/L_{Edd}$ 0.47
- CIV blueshift > 1500 km/s:
  - Median $L/L_{Edd}$ 0.96



# Conclusion

- We have showed how objects with evidence for strong outflows have enhanced hot dust emission.
- We have shown how these objects are accreting at around their Eddington luminosities.
- A natural interpretation is that we are seeing the dust in the outflow during this phase.
  - High Eddington ratios can drive stronger outflows, and at the same time flatten the geometry of a dusty wind (Keating+14), exposing more of inner edge to a relatively face-on line of sight and hence enhancing hot dust emission.
- CIV virial BHM estimates significantly overestimate true mass when wind component of line is significant.