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WHAT STARTS HERE CHANGES THE WORLD

Black Hole Mass Biases in Quasars

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Then: UT-Austin (PhD 1996, advisor: Bev Wills)

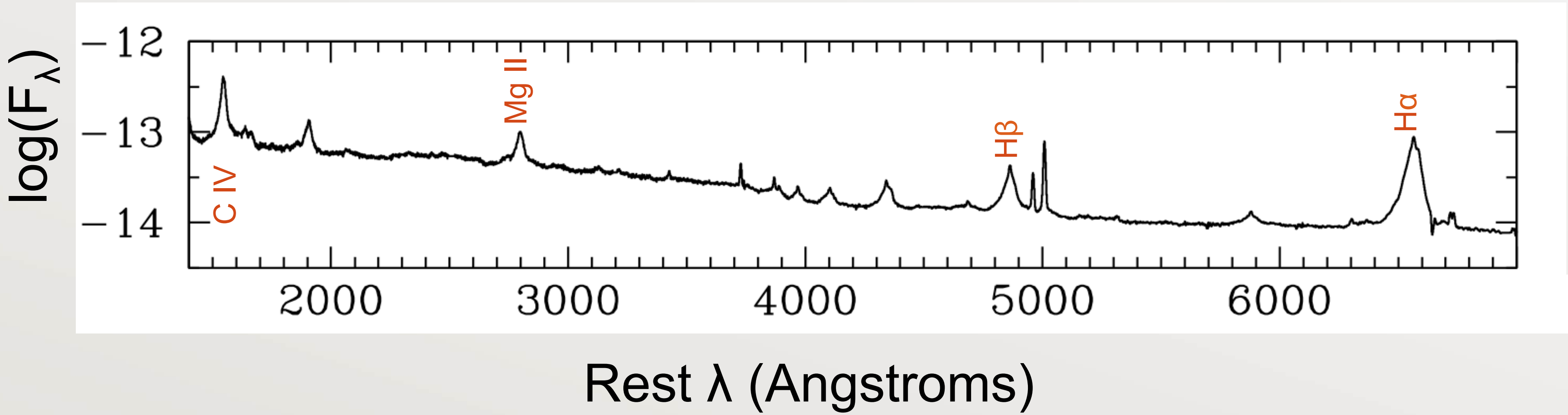
Now: University of Wyoming Professor

M_{BH} from Single-Epoch Quasar Spectra

- C IV for high redshift.
- Hβ for low redshift.

$$M_{BH} = \frac{f}{G} V^2 L^{1/2}$$

e.g., Vestergaard et al. (2006, 2009)

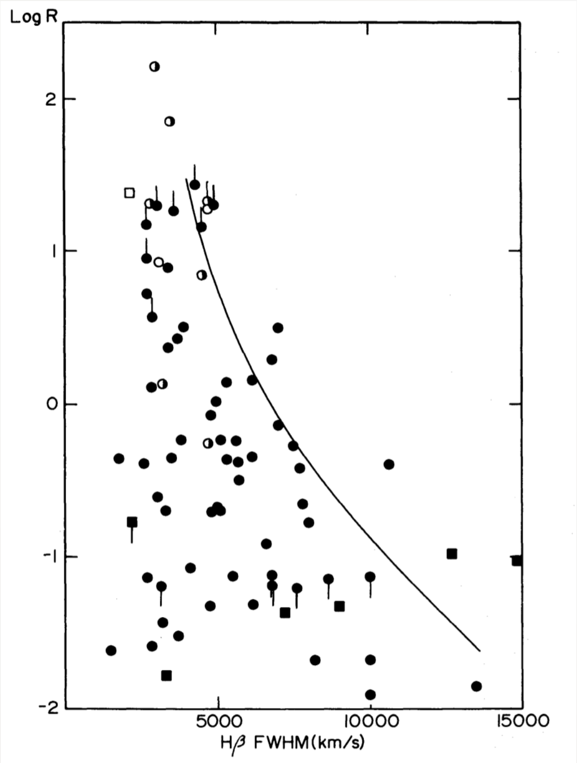


M_{BH} from Hβ: Orientation Issues

Wills & Browne (1986)

Face On

Edge On

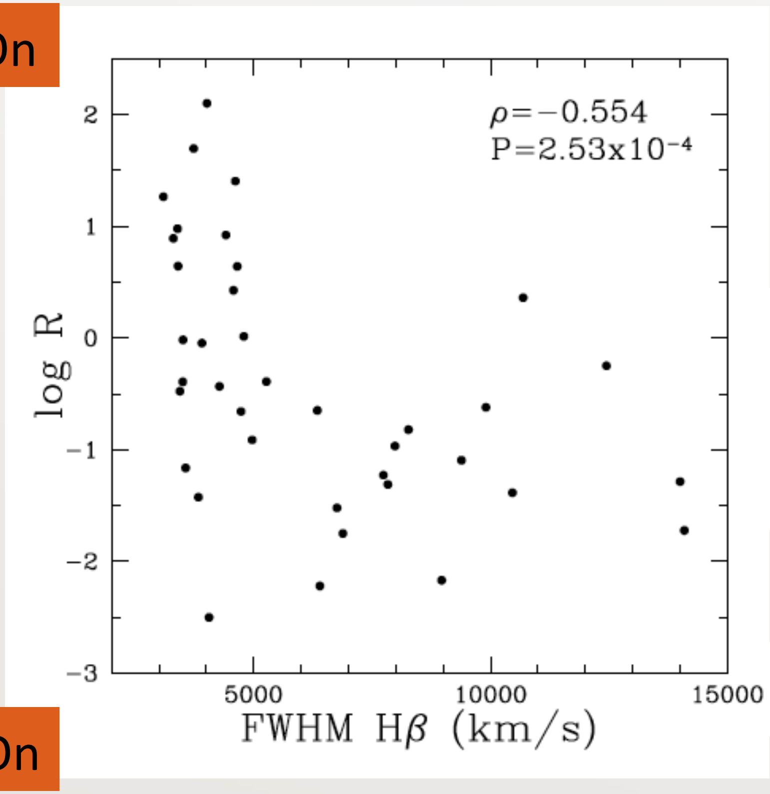


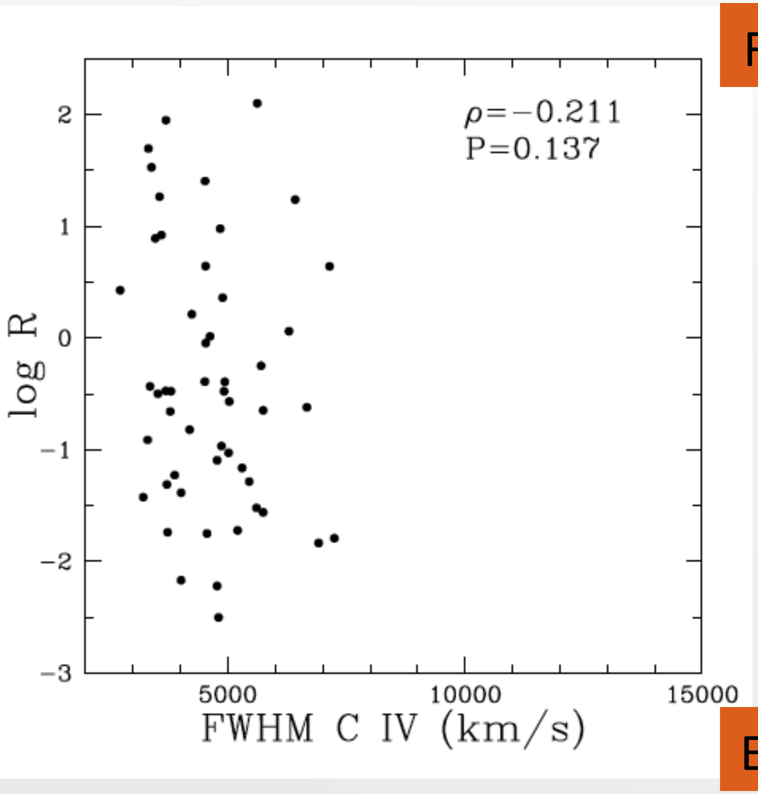
M_{BH} from Hβ: Orientation Issues

Runnoe et al. (2013a)

Face On

Edge On



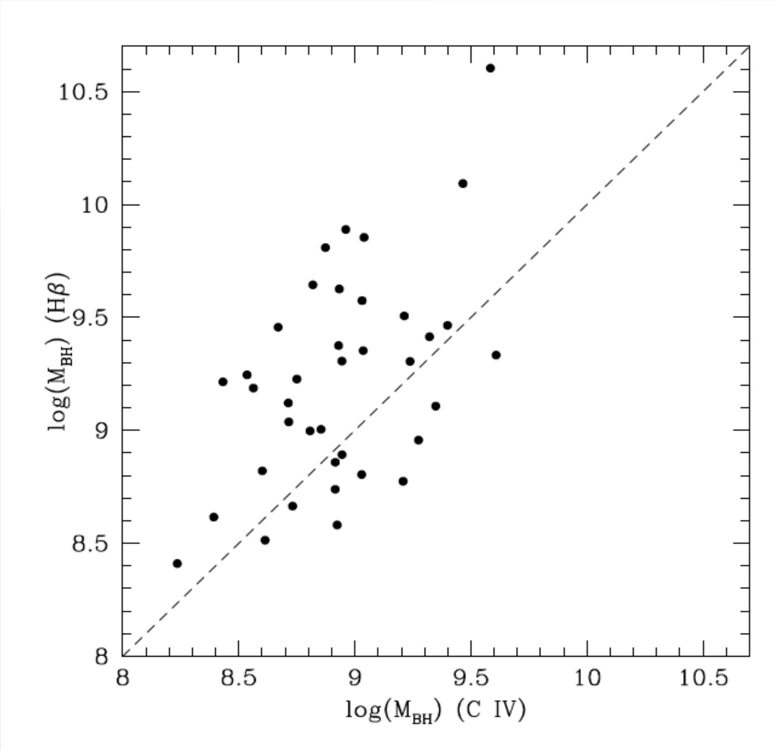


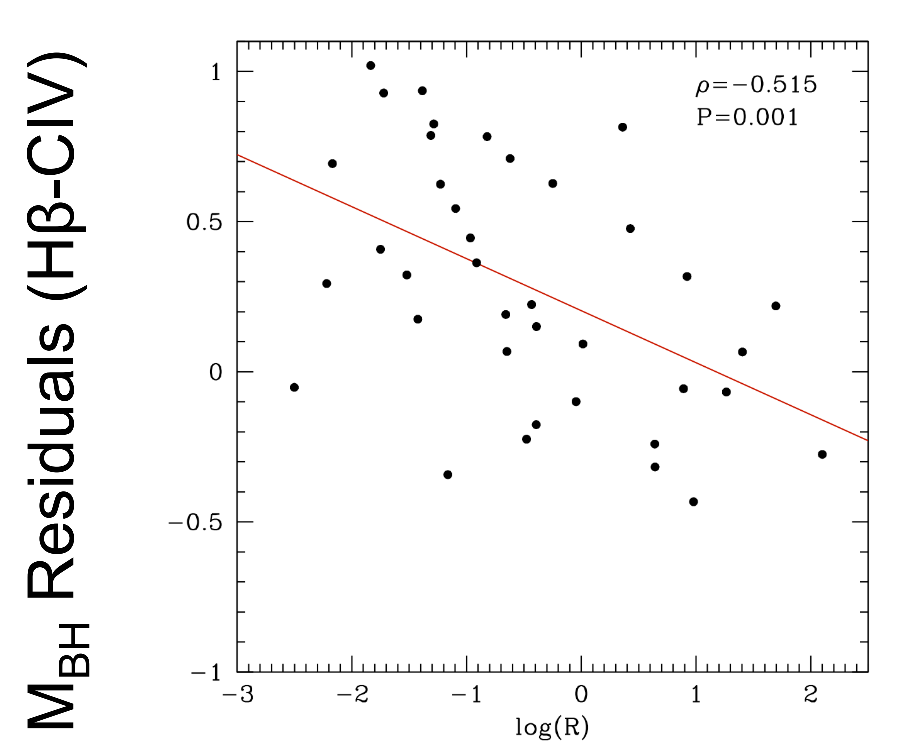
Face On

Edge On

M_{BH} from Hβ: Orientation Issues

Runnoe et al. (2013a)





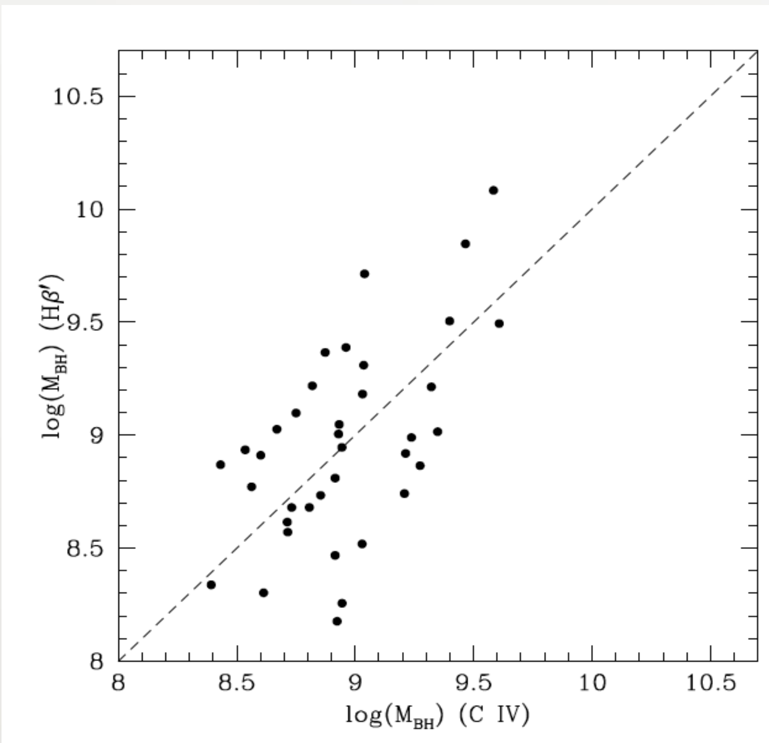
Using Vestergaard et al. SE Scaling Relations

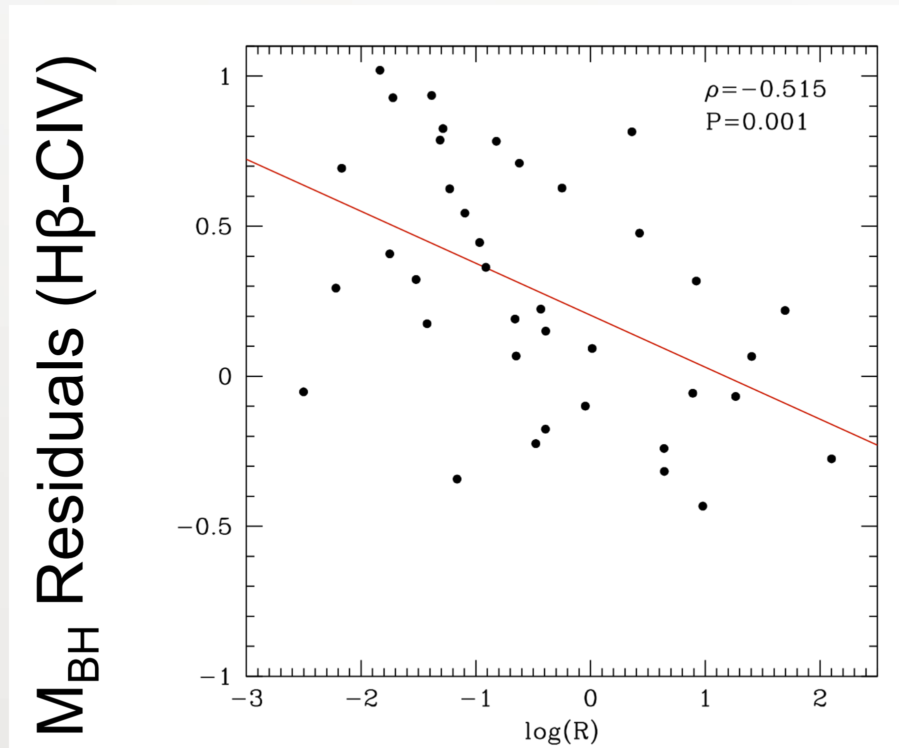
Edge On

Face On

M_{BH} from Hβ: Orientation Issues

Runnoe et al. (2013a)





Edge On

Face On

Using Runnoe et al. Hβ based masses corrected for log R.

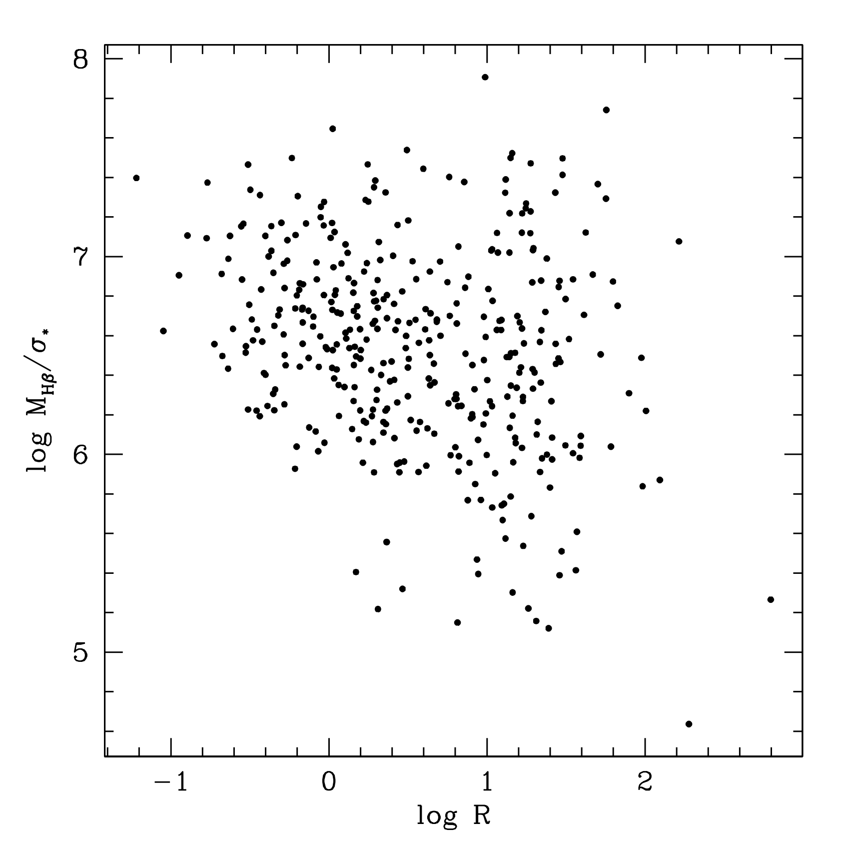
M_{BH} from Hβ: Orientation Issues

Brotherton, Singh, & Runnoe (in prep.)

How to look for Hβ-based black hole mass orientation bias when C IV is not available?

Use stellar velocity dispersion, here estimated for about 400 radio-loud quasars with z < 0.75 from [O III] FWHM in SDSS spectra. Log R from FIRST (note issues, e.g., Jackson & Browne 2012, CSS sources).

Sample shows strong correlation, but a little weird compared to Wills & Browne (1986). Also see Shen & Ho (2014), Runnoe talk.

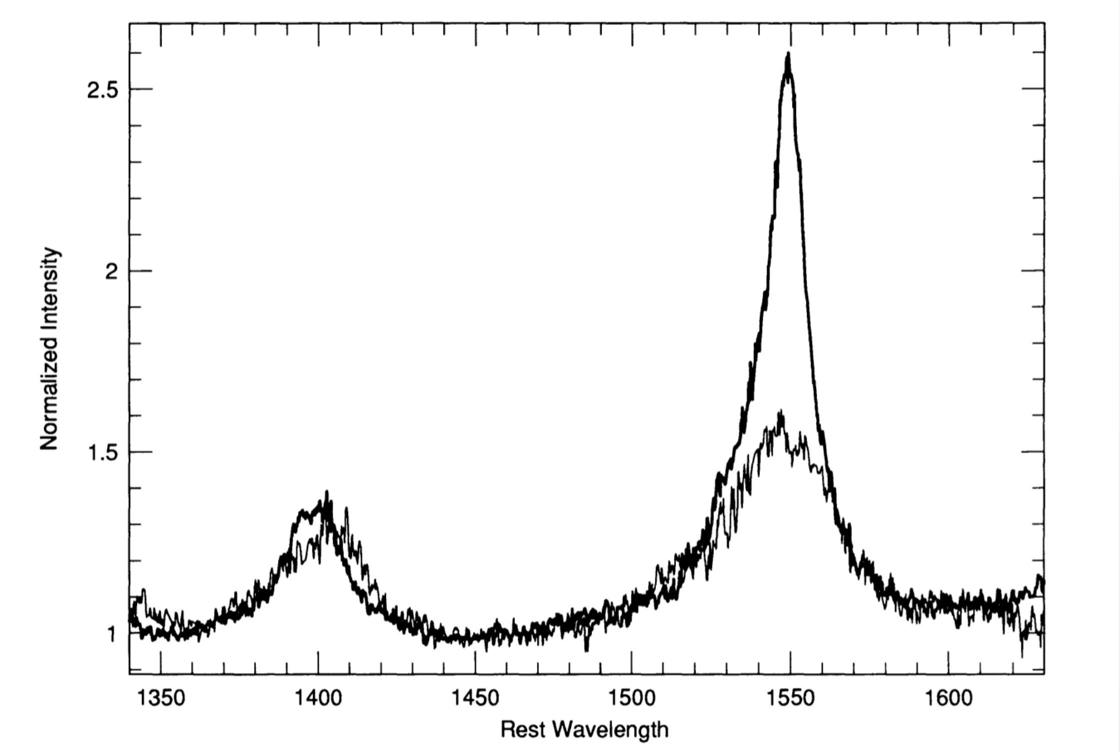


Edge On

Face On

M_{BH} from C IV: Eigenvector 1 Issues

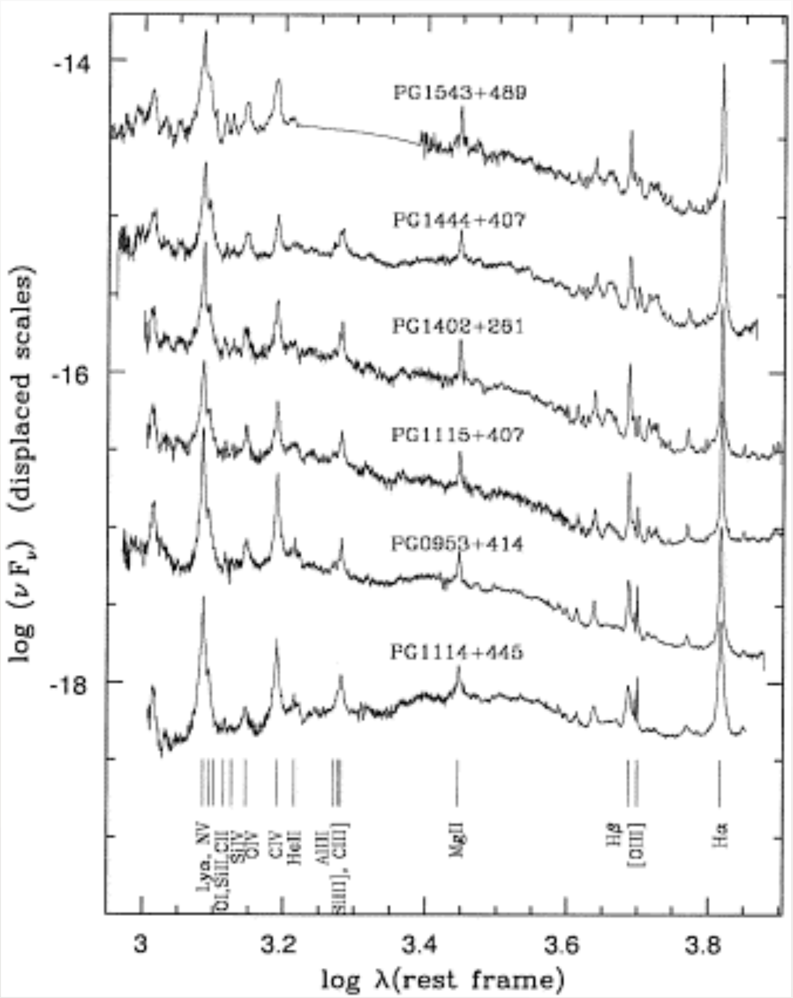
Wills et al. (1993)



Continuum-normalizes spectra of two composite spectra with different average FWHM C IV. Difference is due to change in low-velocity emission (i.e. the “Intermediate Line Region” or ILR, part of EV1).

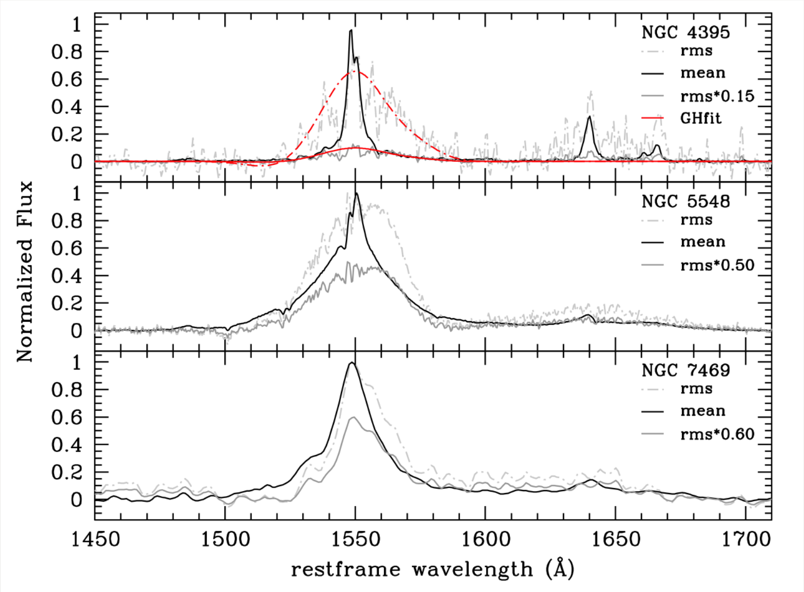
M_{BH} from C IV: Eigenvector 1 Issues

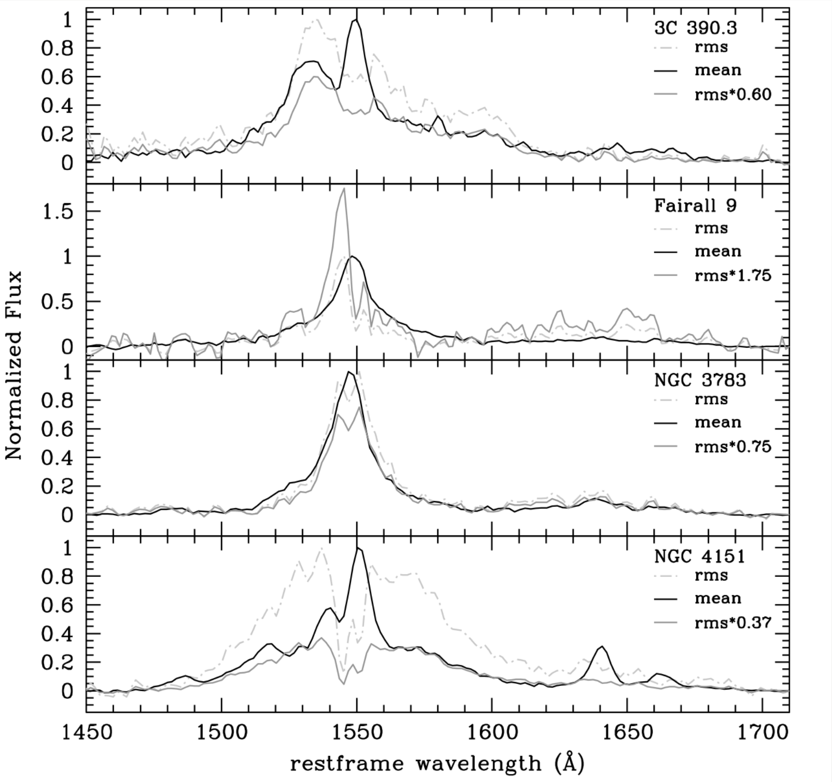
- Problems with Single-Epoch C IV Emission Line
  - Reverberation Mapping shows that C IV is broader than Hβ
  - Often in single-epoch spectra, C IV is NARROWER than Hβ
  - Low-velocity C IV gas does not reverberate (not virial?) -> scatter in SE FWHM of C IV
  - Part of "Eigenvector 1" relationships, correlates with optical narrow line region (NLR) emission, also with other UV parameters



M_{BH} from C IV: Eigenvector 1 Issues

Denney (2012)

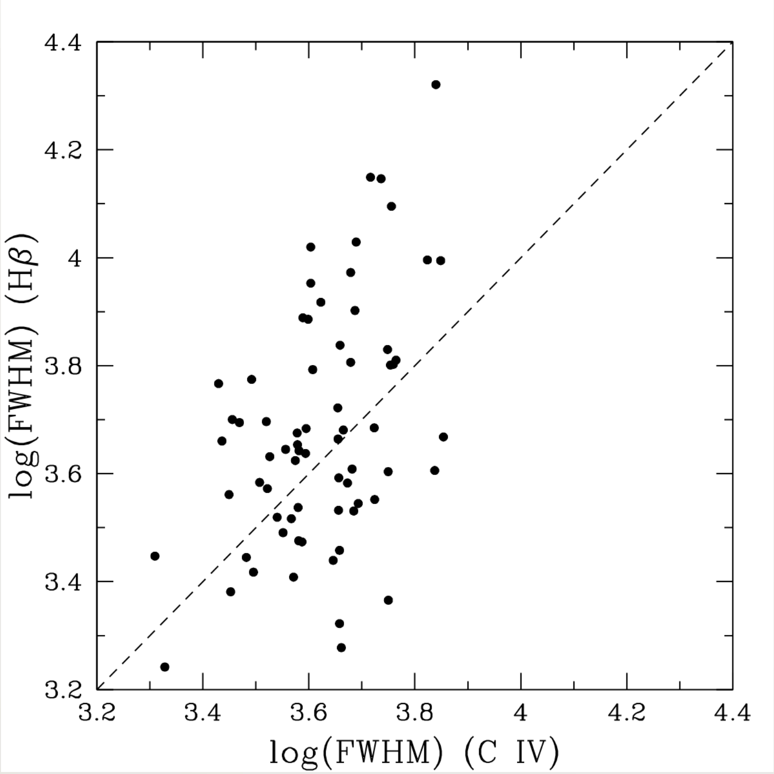


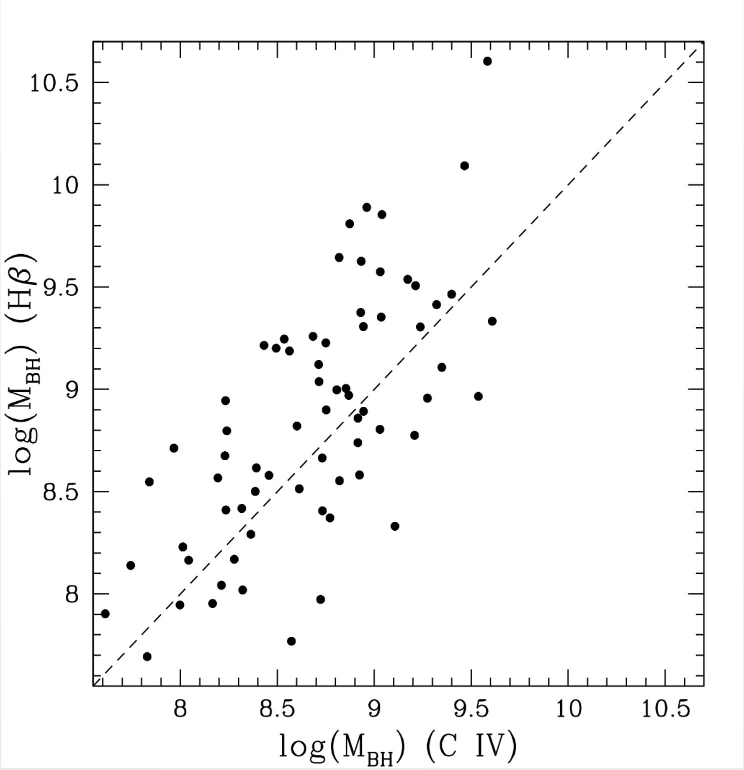


C IV rms profiles broader than mean profiles.

M_{BH} from C IV: Eigenvector 1 Issues

Runnoe et al. (2013b)



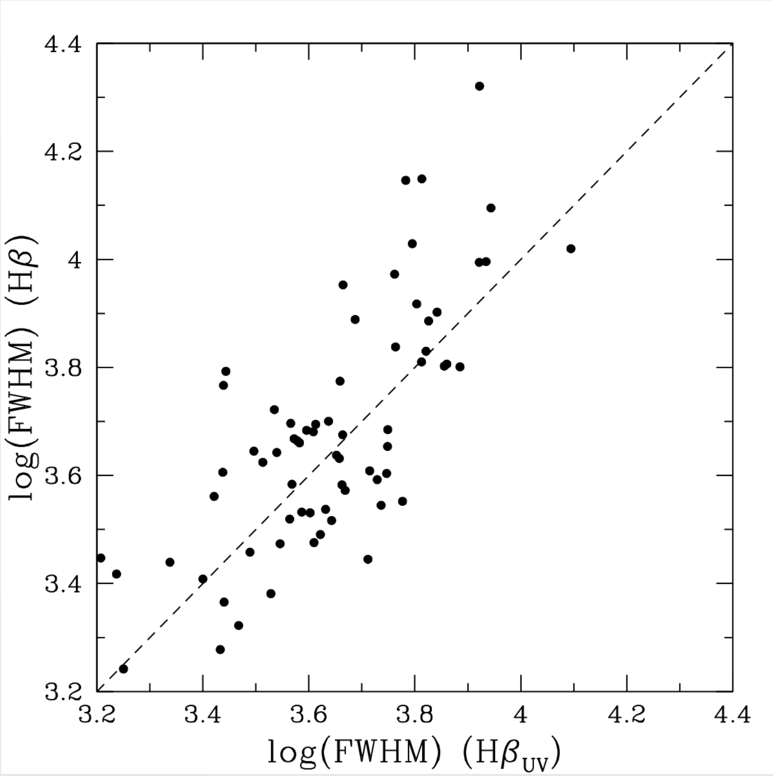


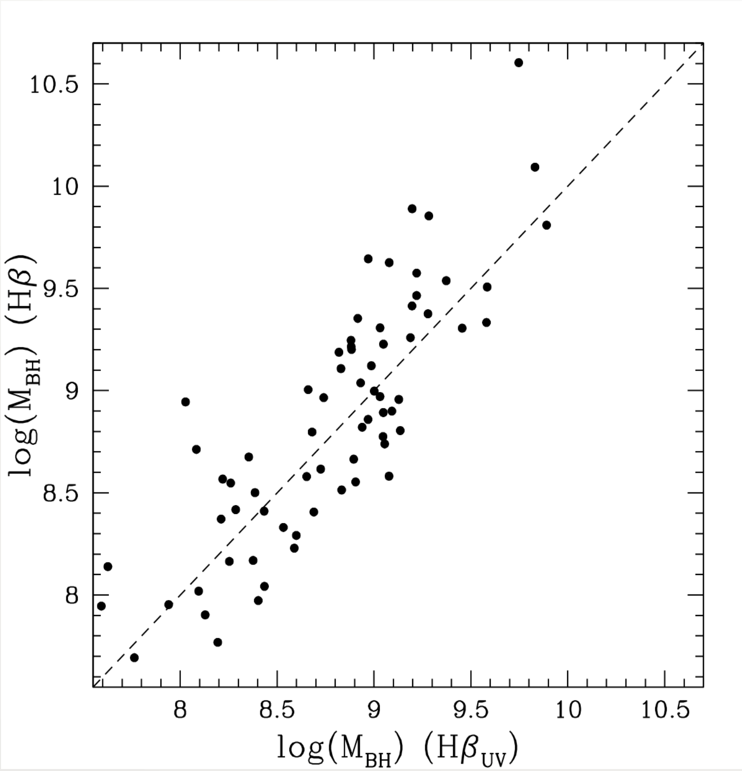
Line widths correlated, but not well.
Difference correlates with Peak 1400/C IV.

Scatter: 0.40 dex

M_{BH} from C IV: Eigenvector 1 Issues

Runnoe et al. (2013b)



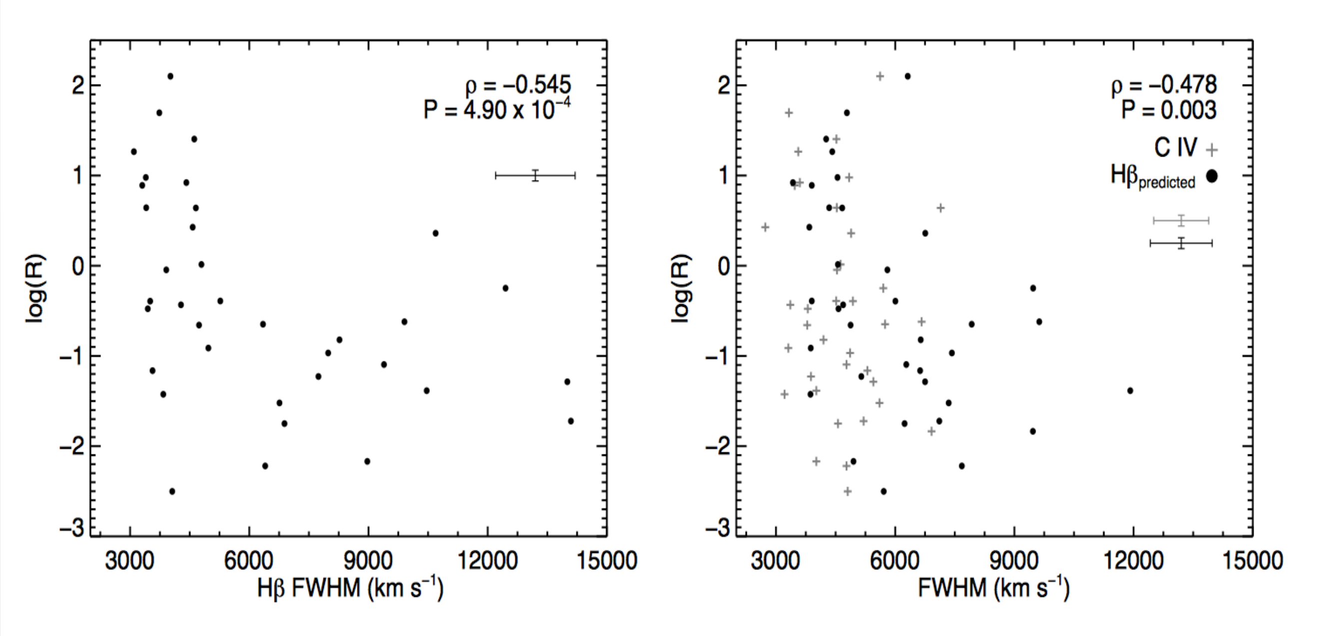


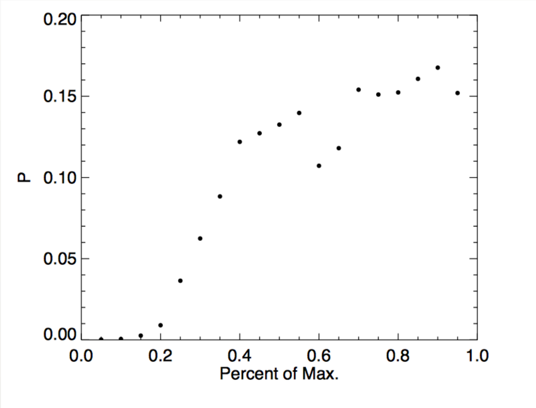
Using FWHM C IV and Peak 1400/C IV to predict FWHM Hβ works much better! Resulting mass estimate also better.

Scatter: 0.32 dex

An aside: C IV Orientation Issues

Runnoe et al. (2014)



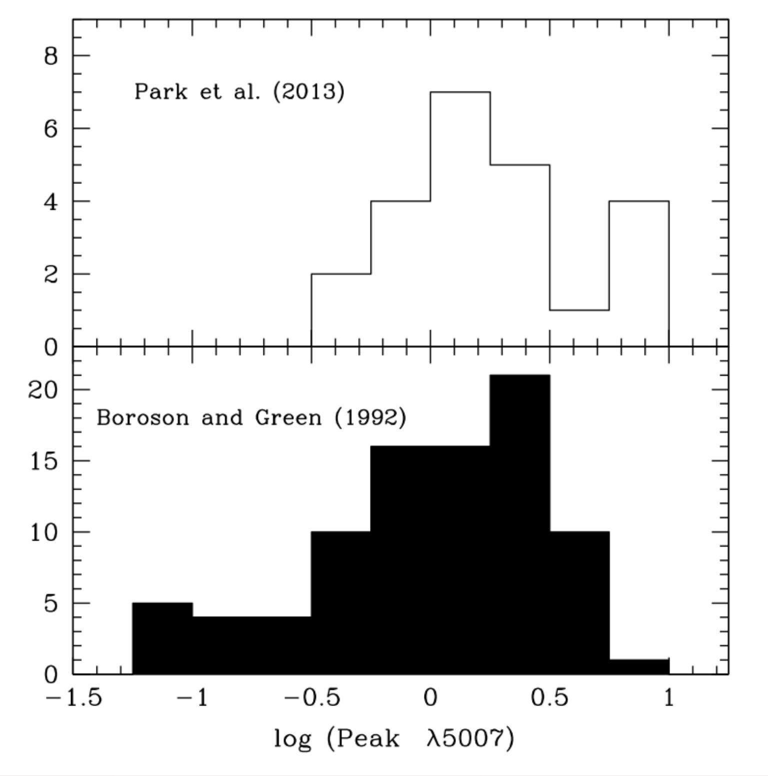


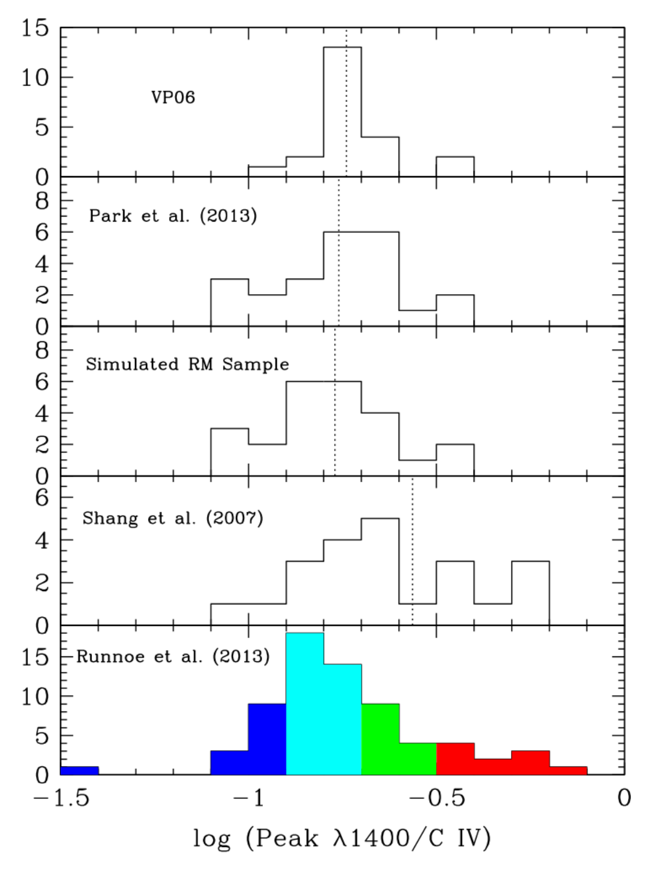
For Bev's HST Radio-loud sample, original Wills-Browne plot on left, new version on right using a formula to predict Hbeta FWHM based on C IV FWHM and EV1 proxy peak 1400/C IV (to measure contamination).

Probability of log R vs V correlation as a function of peak fraction. The broad wing component behaves like Hbeta.

M_{BH} from C IV: Eigenvector 1 in RM Samples

Brotherton et al. (submitted)



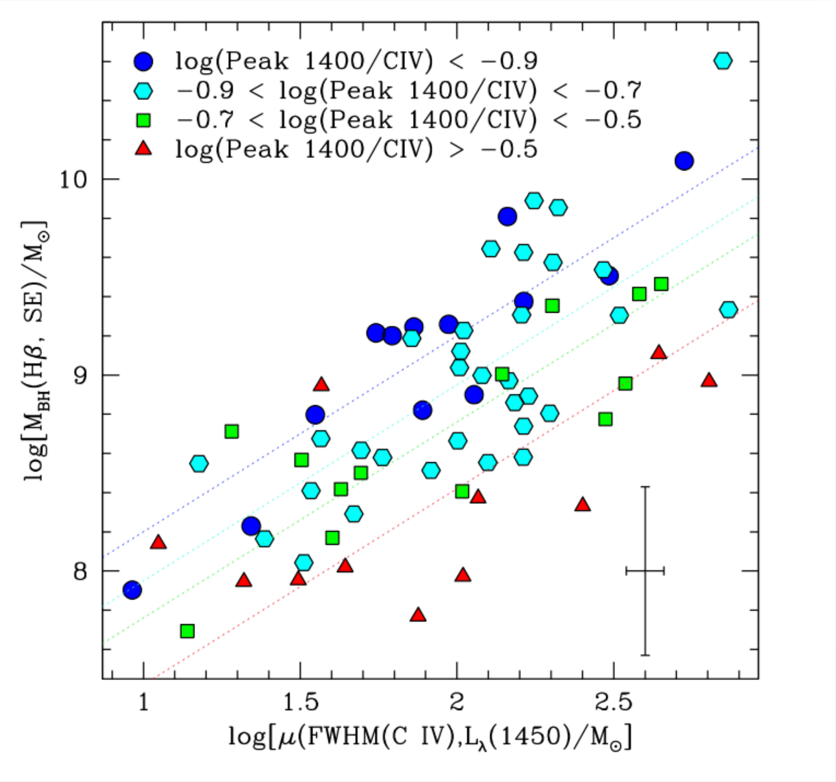


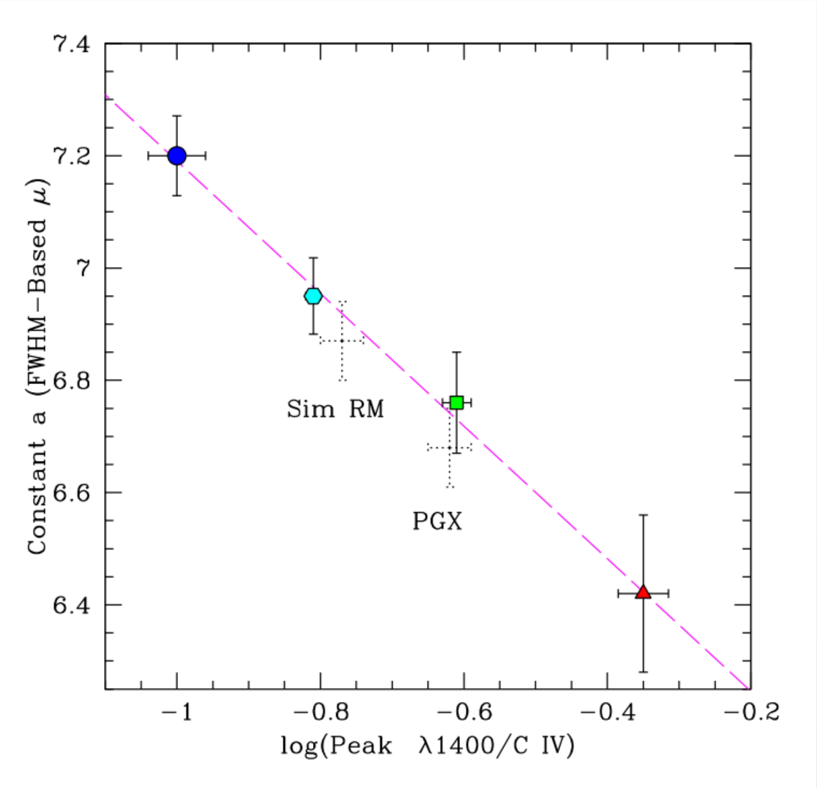
RM samples for C IV based black hole mass estimation are biased toward large [O III]/Fe II values.

RM samples for C IV based black hole mass estimation are biased toward small 1400/C IV values.

M_{BH} from C IV: Eigenvector 1 in RM samples

Brotherton et al. (submitted)





A sample bias in EV1 creates a corresponding shift in black hole masses. For Vestergaard & Peterson (2006) and Park et al. (2013) the C IV scaling relations predict masses about 0.2 dex or 50% too high.

M_{BH} SE Scaling Relations: Conclusions

Orientation effects exist, likely a *sin i* factor due to the inner BLR being a flattened disk of some sort. This affects Hβ strongly, but only the broad, virial part of C IV (Runnoe et al. 2014). This can be corrected for in radio-loud quasars, and perhaps also radio-quiet quasars in the future.

Eigenvector 1 (i.e., the amount of contamination of a non-virial ILR component in C IV) creates scatter and biases in black hole mass estimates. Can also be corrected for by using EV1 indicators in optical and/or UV.

Can we get SE masses within a factor of 2?