Black Hole Mass Biases in Quasars

Mike Brotherton
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)
\( M_{BH} \) from H\( \beta \): Orientation Issues

Runnoe et al. (2013a)

\[ \rho = -0.554 \]
\[ P = 2.53 \times 10^{-4} \]

\[ \rho = -0.211 \]
\[ P = 0.137 \]
M_{BH} from H\beta: Orientation Issues

Runnoe et al. (2013a)

Using Vestergaard et al. SE Scaling Relations
$\mathcal{M}_{BH}$ from H$\beta$: Orientation Issues

Runnoe et al. (2013a)

Using Runnoe et al. H$\beta$ based masses corrected for log R.
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.
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).
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
$M_{\text{BH}}$ 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
Using FWHM C IV and Peak 1400/C IV to predict FWHM Hβ works much better! Resulting mass estimate also better.
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).
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.
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 $H\beta$ 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?