Improving black hole mass measurements in quasars: characterizing the structure of the broad line region gas

By
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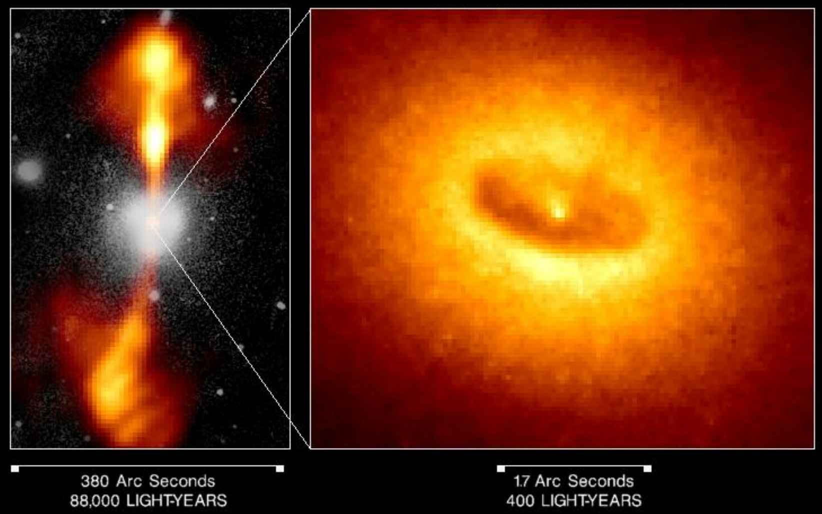
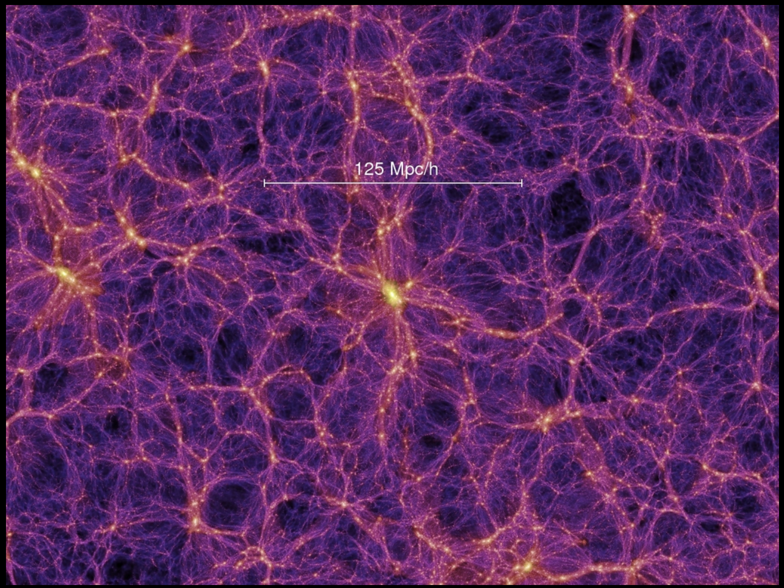
Outline

- How do we estimate black hole masses?
- Why is the velocity field so important?
- Improving the line width measure
- Polarization as an inclination measure?

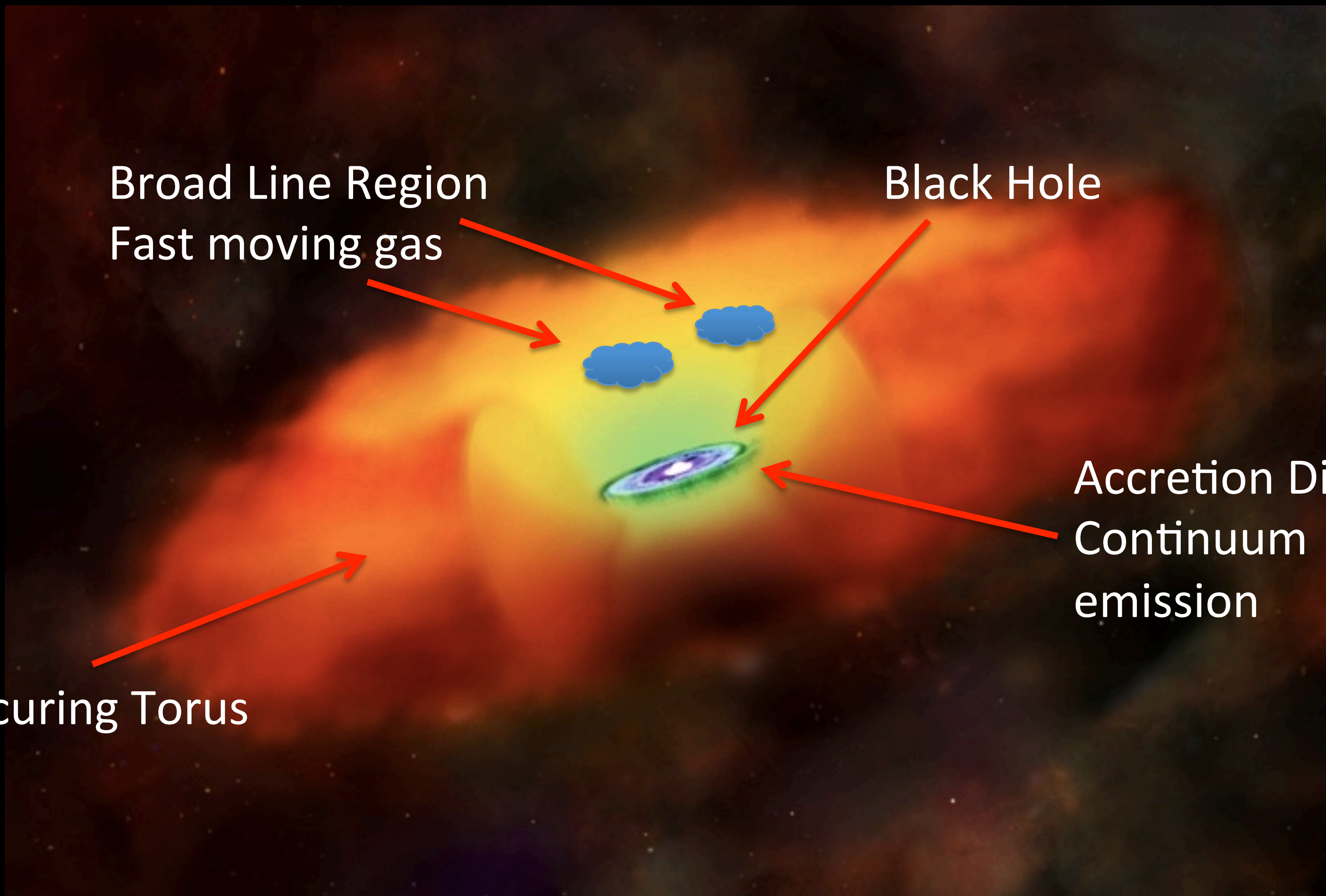
What can M_{BH} tell us about?





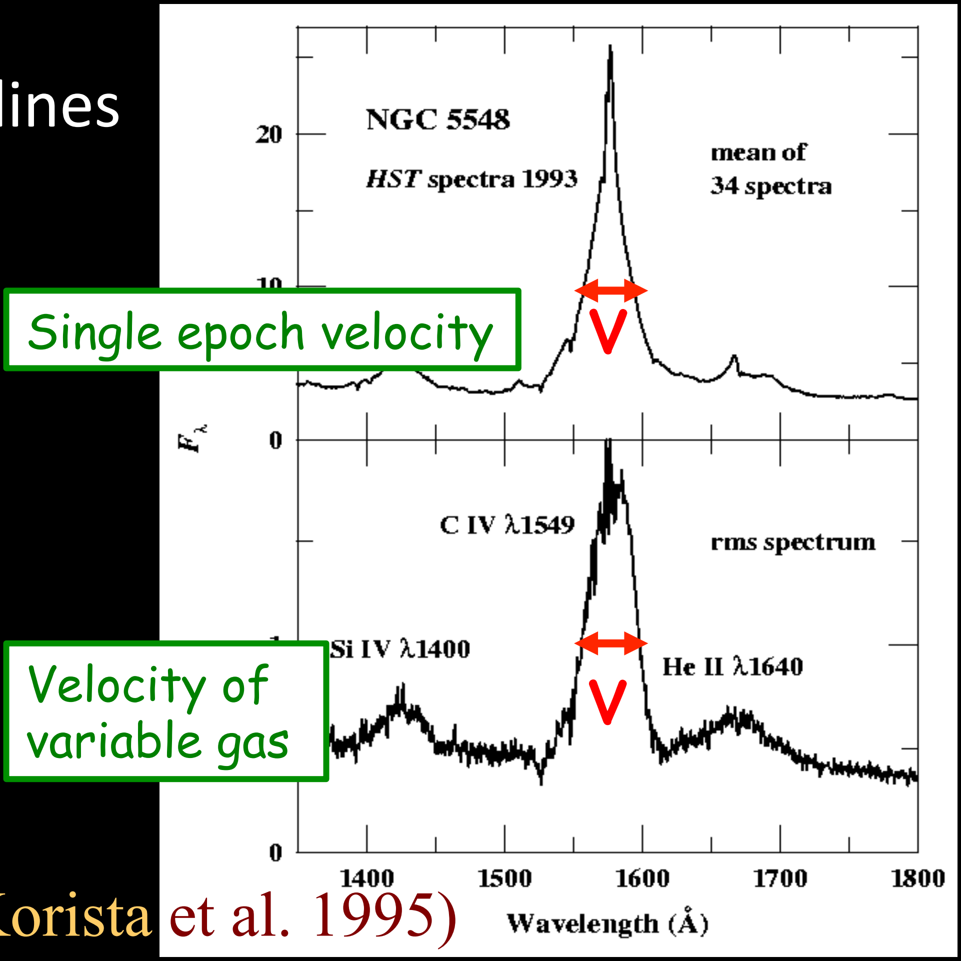
- Physics of active galactic nuclei
- Physical conditions in the early Universe
- Galaxy formation and evolution

A simple model for AGNs



Determining the virial mass

- Virial mass: $M_{BH} = f * R * V^2 / G$
- V from width of emission lines

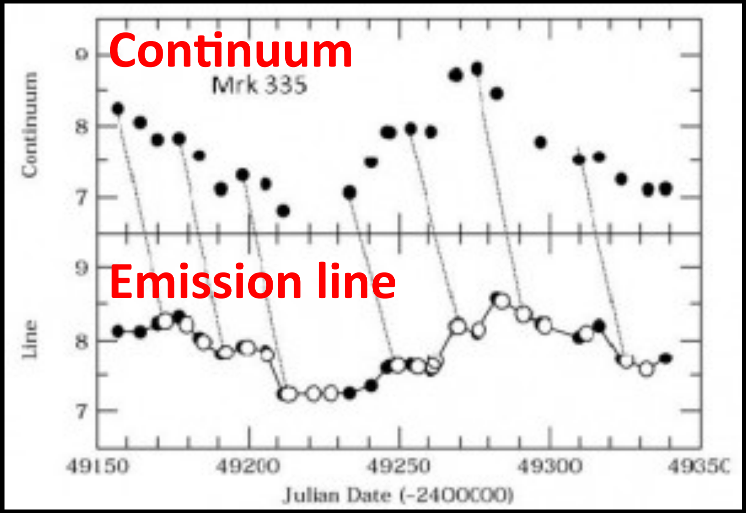


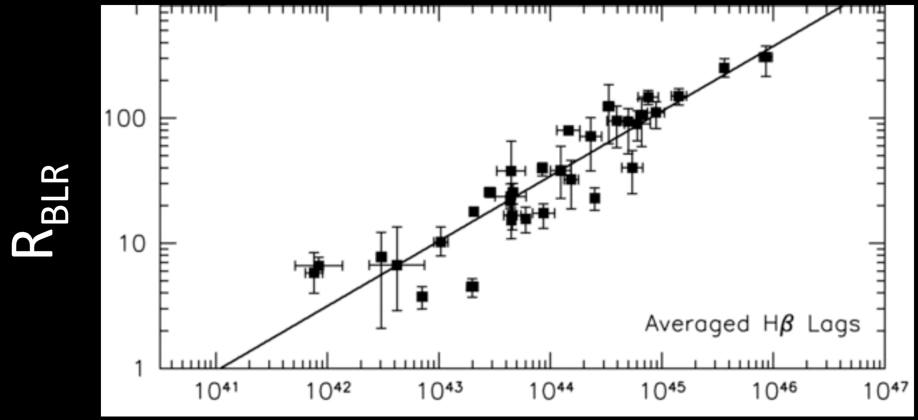
(based on Korista et al. 1995)

Determining the virial mass

- Virial mass: $M_{BH} = f * R * V^2 / G$
- V from width of emission lines
- R_{BLR} from
  1. Time lag (Reverberation mapping) or
  2. Luminosity (Single epoch masses)

Peterson (2001)





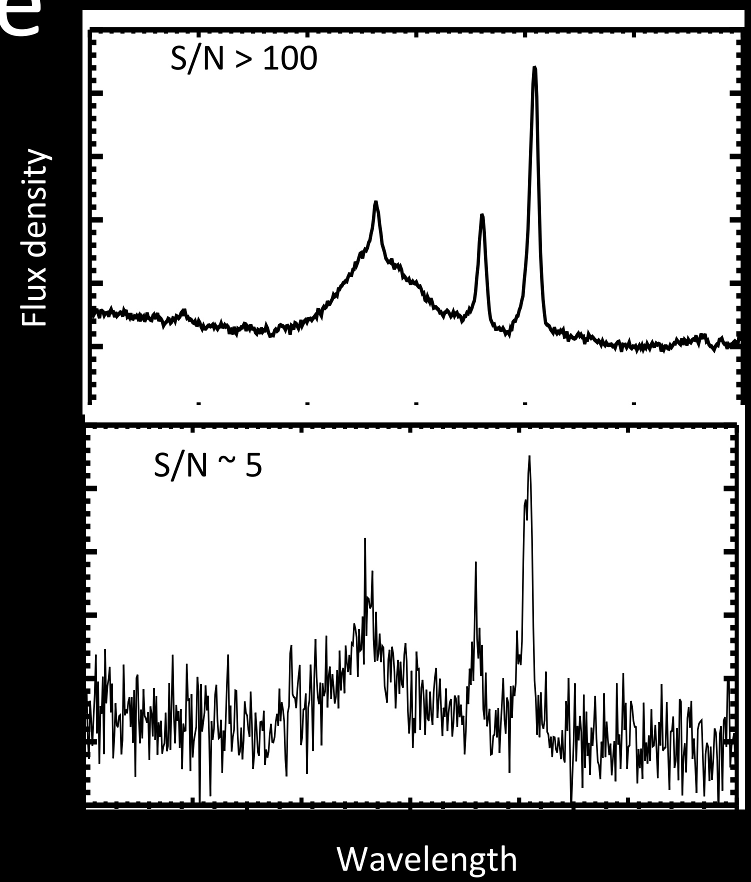
Bentz et al. (2009)

Uncertainties

- 0.5 – 0.6 dex in M_{BH} for single epoch masses
- R_{BLR} – L relationship is tight, only ~ 0.11 dex in intrinsic scatter
- Uncertainty dominated by our lack of ability to measure the true velocity field of the BLR
- Two of the main sources of uncertainties on velocity field:
  – Measuring emission line widths in (noisy) data (my work)
  – Unknown inclination and geometry of BLR – (Polarization?)

Improving the emission line width measure

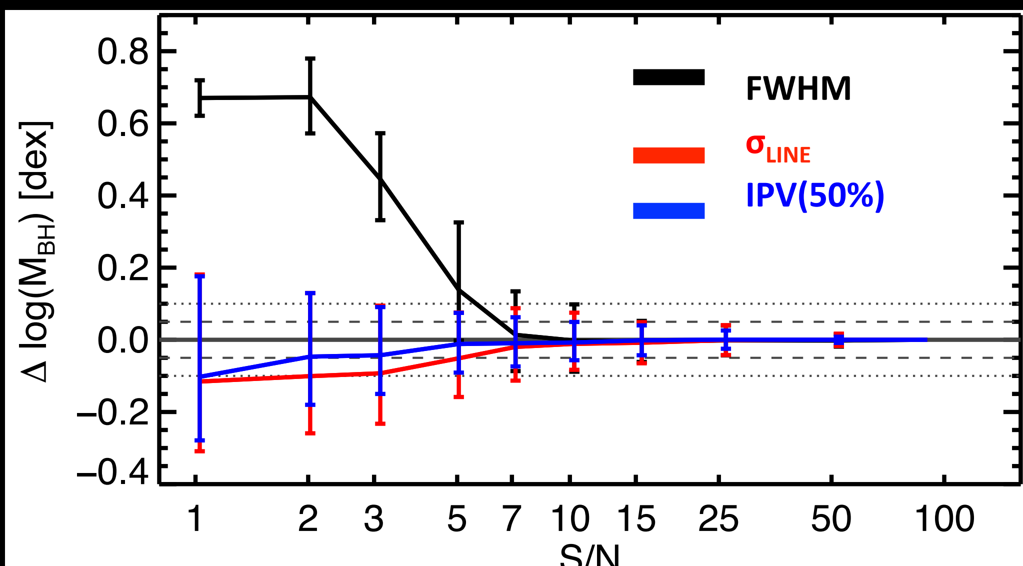
- 18 high S/N spectra (H-beta and CIV)
- 9 S/N levels between 1 and 50 per pixel
- 500 degradation realizations
- Spectral decomposition and line width measure for each degraded spectrum
- Compare accuracy and precision of FWHM, line dispersion and IPV width
- Measure directly on data and on smooth functional fits

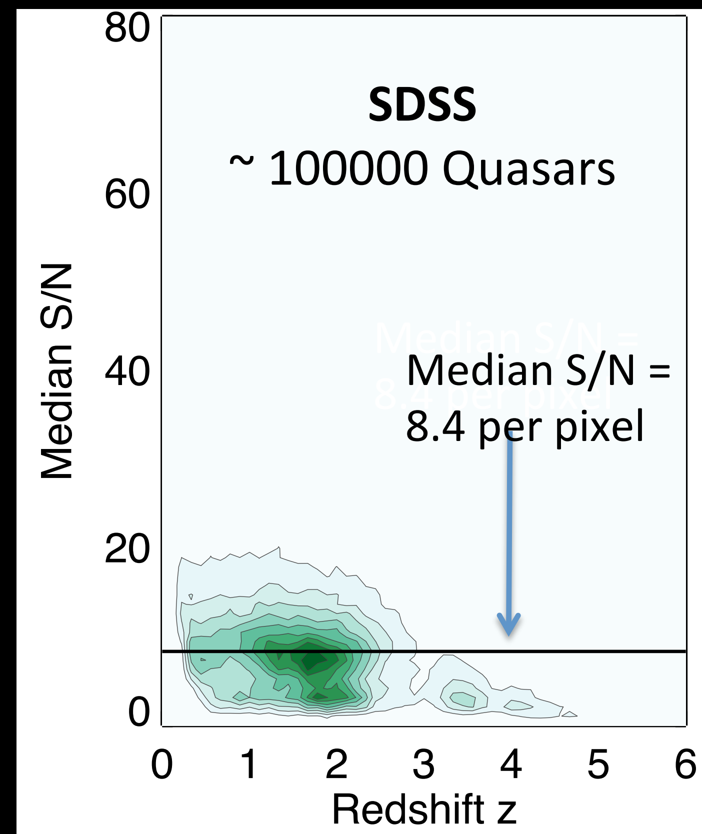


- Goal: To obtain the most accurate and precise line width measure that is simple to measure in a automated fashion

Results of my work

- FWHM is strongly affected by noise, not accurate at S/N < 20 per pixel
- Line dispersion is not accurate at S/N below 10 per pixel
- With IPV, the typical accuracy and precision is within 0.01 dex and 0.11 dex at S/N ≥ 5 per pixel





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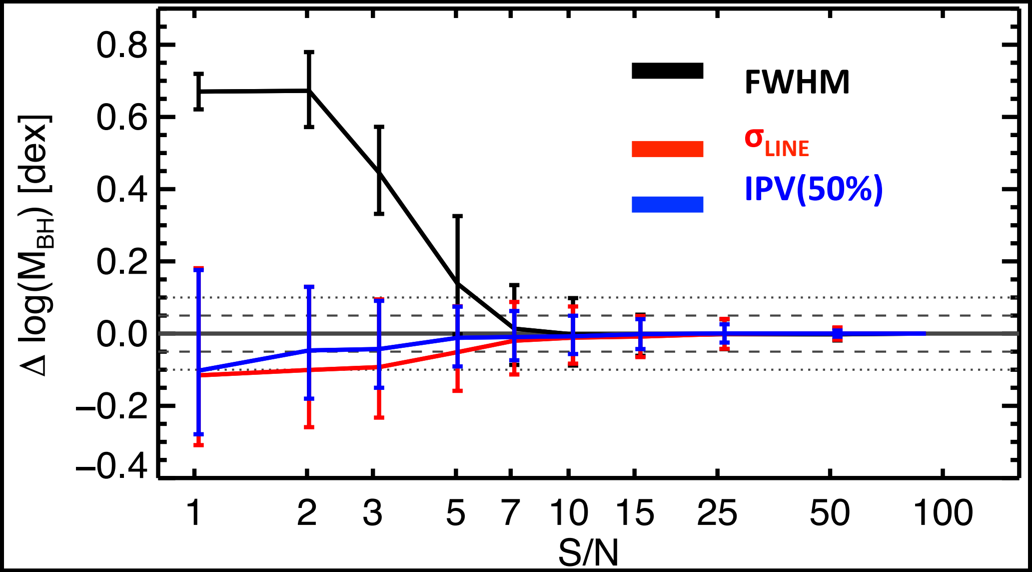
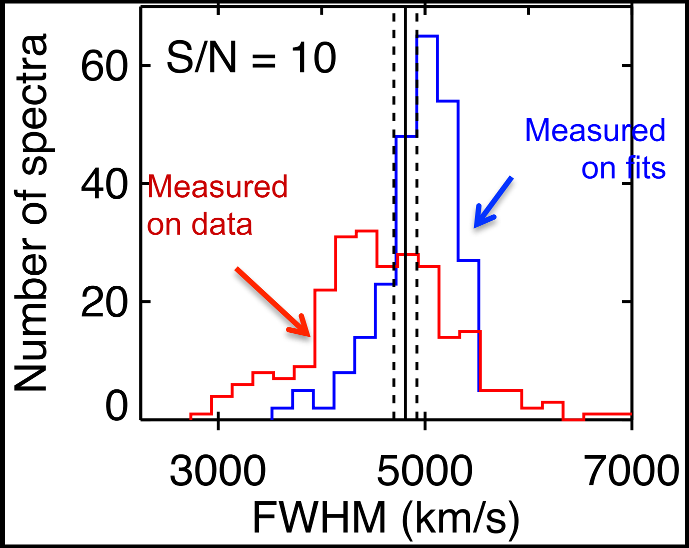
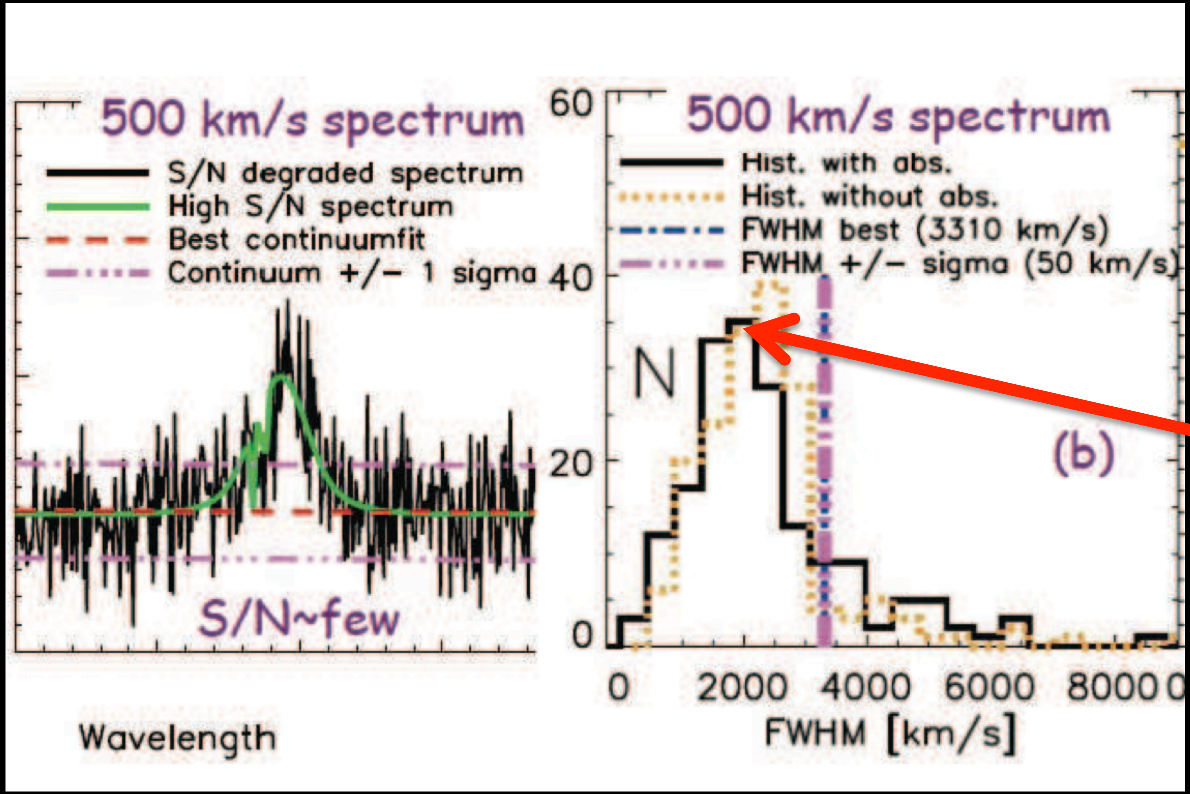
- With IPV, the typical accuracy and precision is within 0.01 dex and 0.11 dex at S/N ≥ 5 per pixel
- IPV is most robust to noise and in addition easy to measure in an automated fashion
- Measuring on smooth functional fits introduces new systematics





Effects of unrecognized absorption

- Add narrow line absorption prior to degradation
- Absorption is very hard to detect in degraded spectra
- Absorption leads to systematic biases
- Conclusion: need high S/N and high resolution data to be able to account for absorption



Offset of > 0.2 dex in M_{BH} due to absorption alone

Uncertainty due to inclination

$$\Delta V_{\rm obs} \approx \left(a^2 + \sin^2 i\right)^{1/2} V_{\rm Kep},$$

$$V_{Kepler} = \frac{V_{Obs}}{\sqrt{(a^2 + \sin^2 i)}};$$

$$M_{BH} = f \times RV_{Kepl}^2 / G$$

- a can be H/R of disk or $V_{TURBULENT}$ / V_{KEPLER}
- i is inclination of disk. Face-on: i=0°

a	inclination	V_{KEP}/V_{OBS}	$(V_{KEP}/V_{OBS})^2$
0.1	10	5	25
0.1	80	1	1
0.3	80	1	1
0.3	60	1.1	1.2
0.3	50	1.2	1.4
0.3	45	1.3	1.7
0.3	40	1.4	2
0.3	30	1.7	2.9
0.3	20	2.2	4.8
0.3	10	2.9	8.4

If 0.1 < a < 0.3 and inclination is unconstrained:

ΔM_{BH} can be up to a factor of 25!

Collin et al. 2006

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Assume a = 0.3:

$\Delta i \sim 70°$ -> $\Delta M_{BH} < 8.4$

$\Delta i \sim 30°$ -> $\Delta M_{BH} < 4.2$

$\Delta i \sim 20°$ -> $\Delta M_{BH} < 2.4$

Collin et al. 2006

Issues to be resolved

- How accurately can we measure the inclination from polarimetry? We only need $\Delta i = 20° - 30°$.
- How accurate an indicator of the BLR inclination is the inclination obtained by polarization?
- How demanding are these observations in terms of observation time and spectral (spatial?) resolution to be reliable?
- Compare with inclinations from radio observations:
  - Is radio tracing the BLR inclination?
  - How often is the radio inclination aligned with the polarimetric inclination?
- How does the above points change if we look at the statistics for large samples of objects?