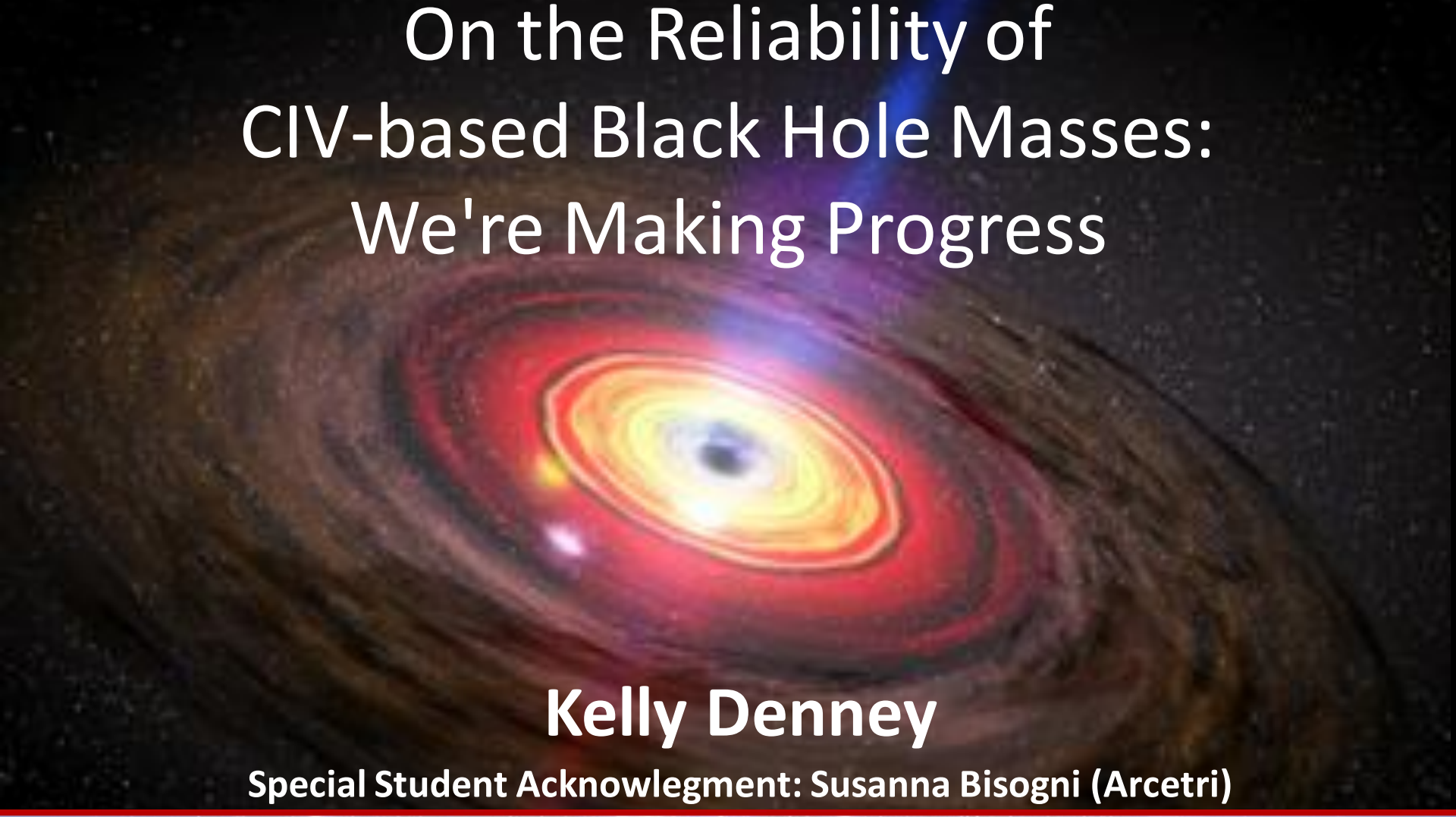
On the Reliability of CIV-based Black Hole Masses: We're Making Progress



Kelly Denney

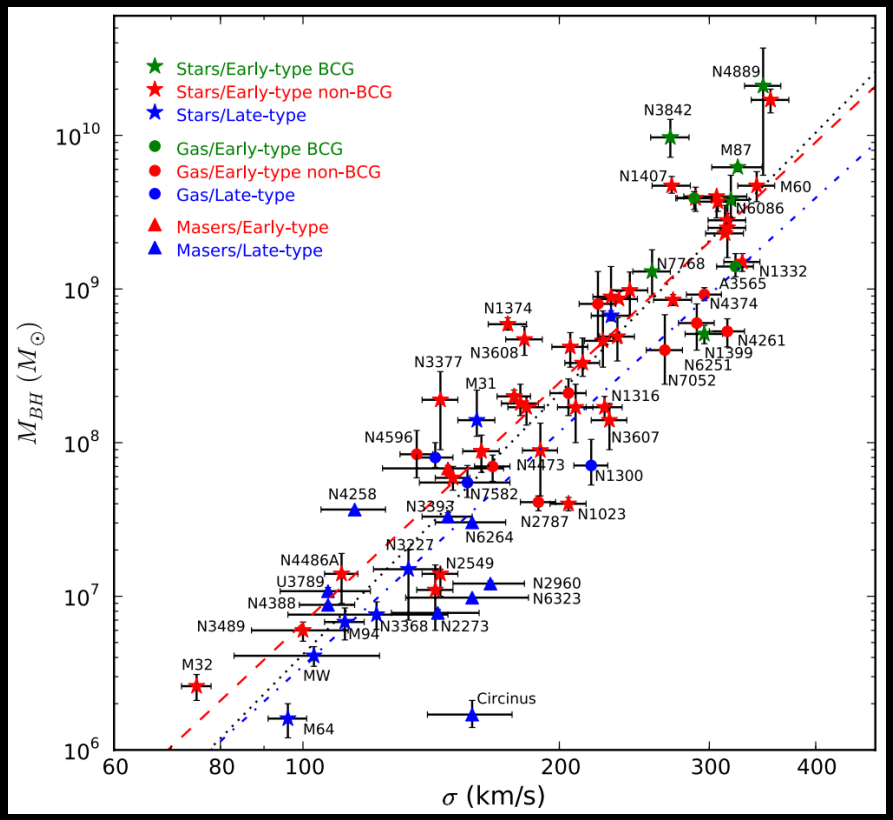
Special Student Acknowlegment: Susanna Bisogni (Arcetri)

DEPARTMENT OF ASTRONOMY

THE OHIO STATE UNIVERSITY

Motivation: Cosmic Structure Growth and the Coevolution of Galaxies and Supermassive Black Holes

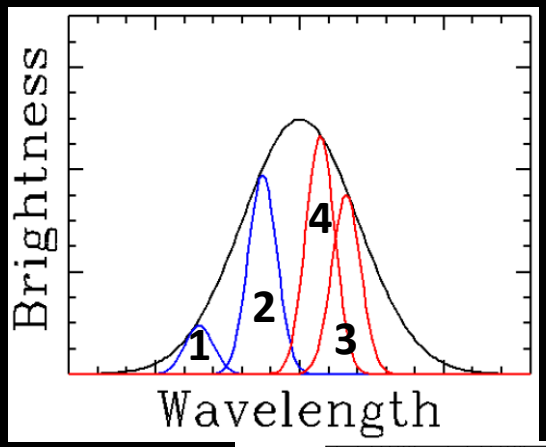
Millenium Simulation; Springel et al. 2005



McConnell & Ma, 2013, ApJ, 764, 184

Estimating the Black Hole Mass

- The Broad Line Region is under influence of BH Gravity, so broad line widths come from Doppler-broadening:

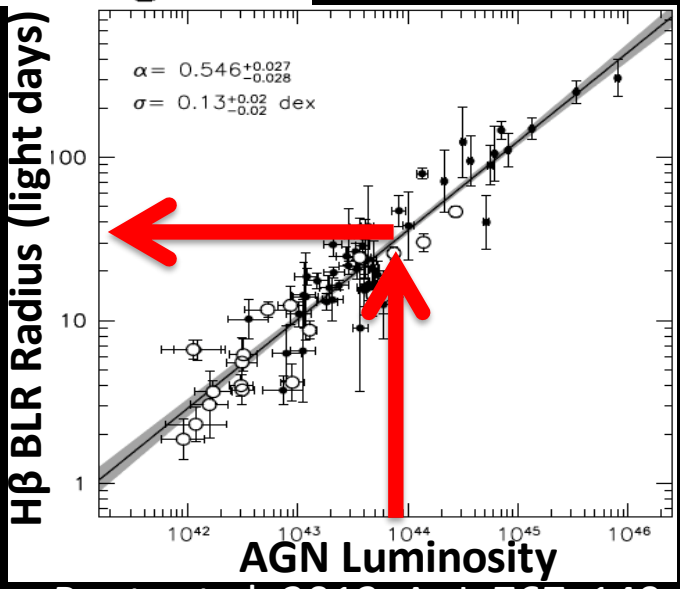


Reverberation

Scale Factor Time Delay

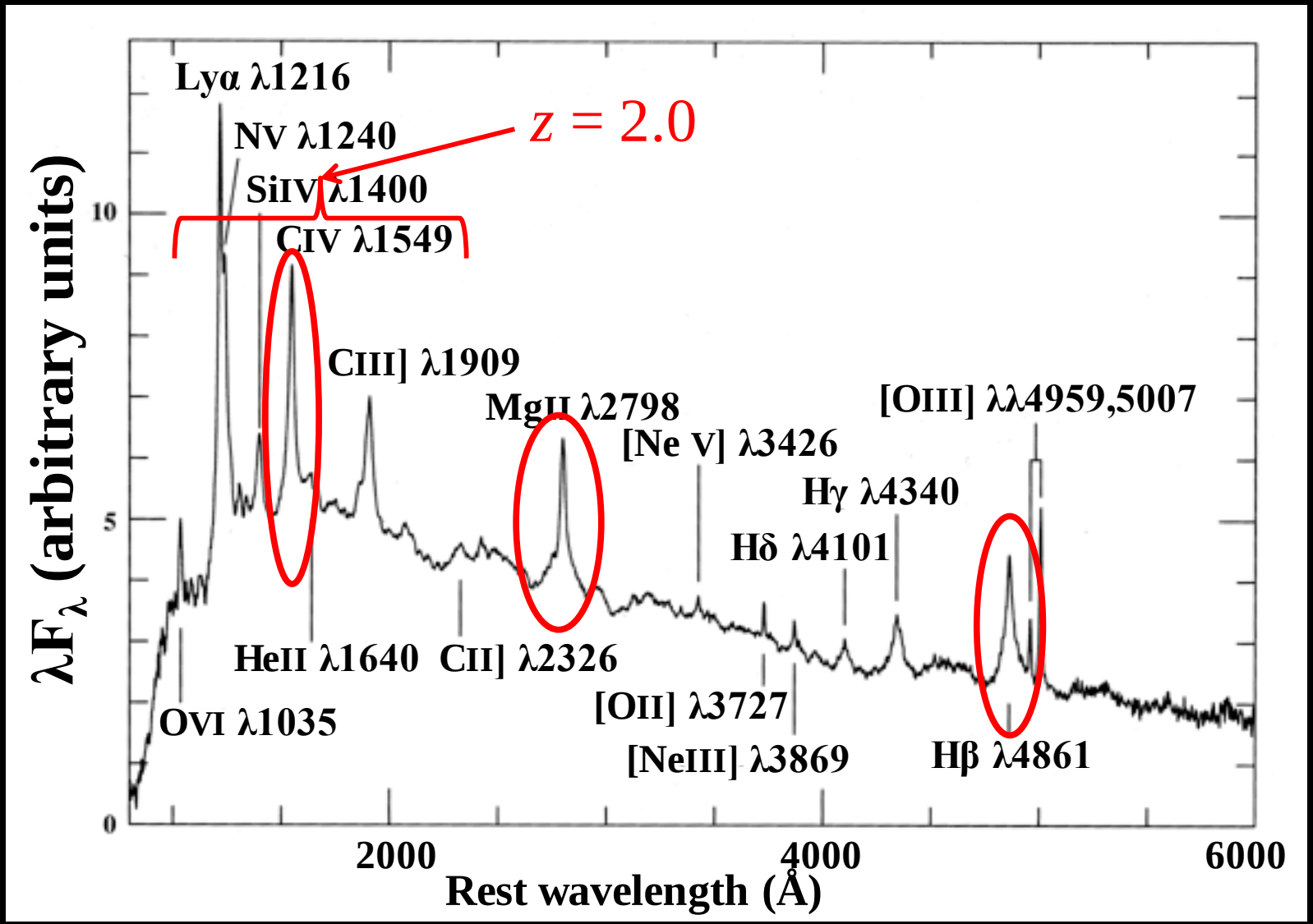
Line Width

$$M_{BH} = f \frac{RV^2}{G}$$



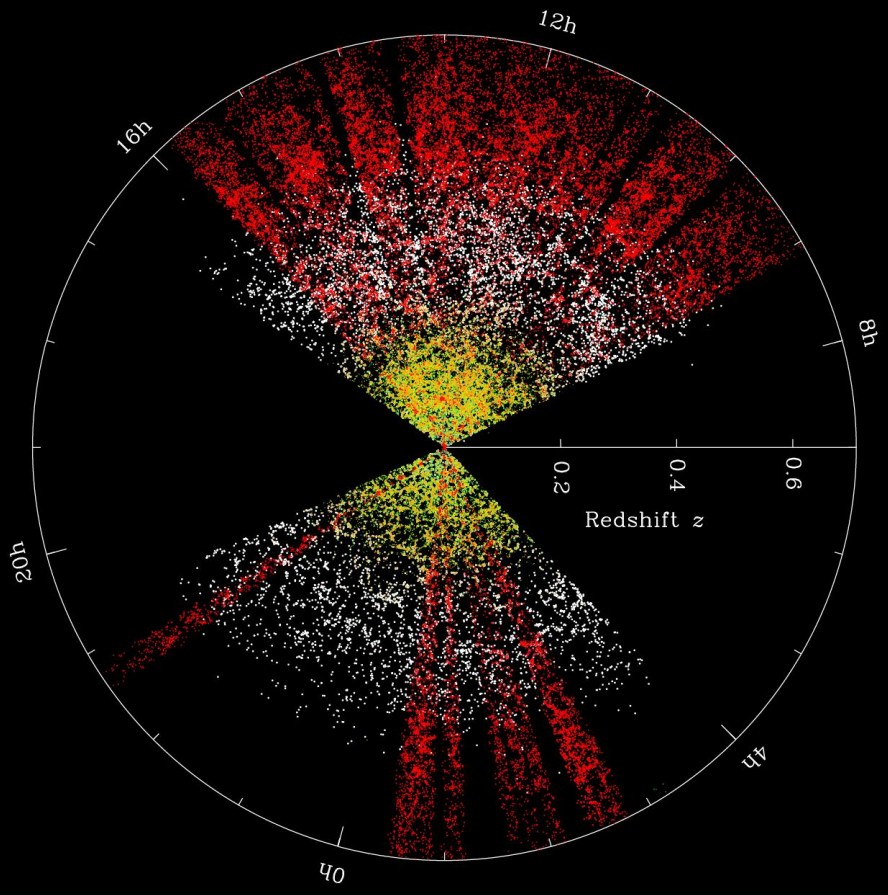
Bentz et al. 2013, ApJ, 767, 149

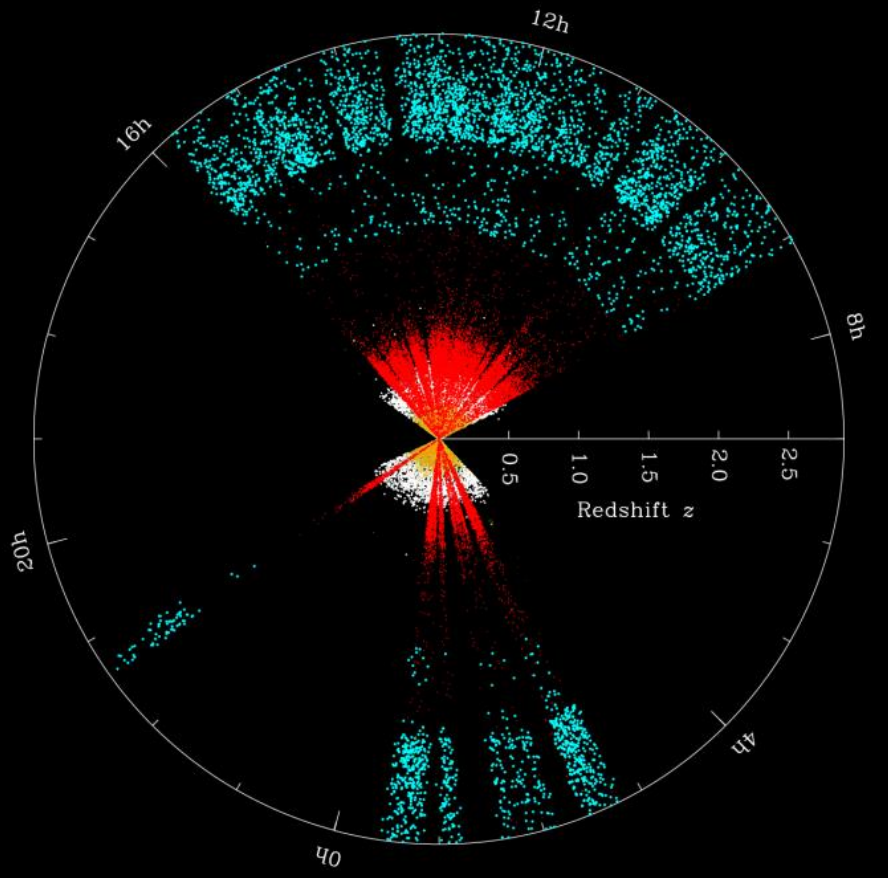
Emission Lines Used for SE Masses



Composite from the Large Bright Quasar Survey (Francis et al. 1991)

Mapping The Universe

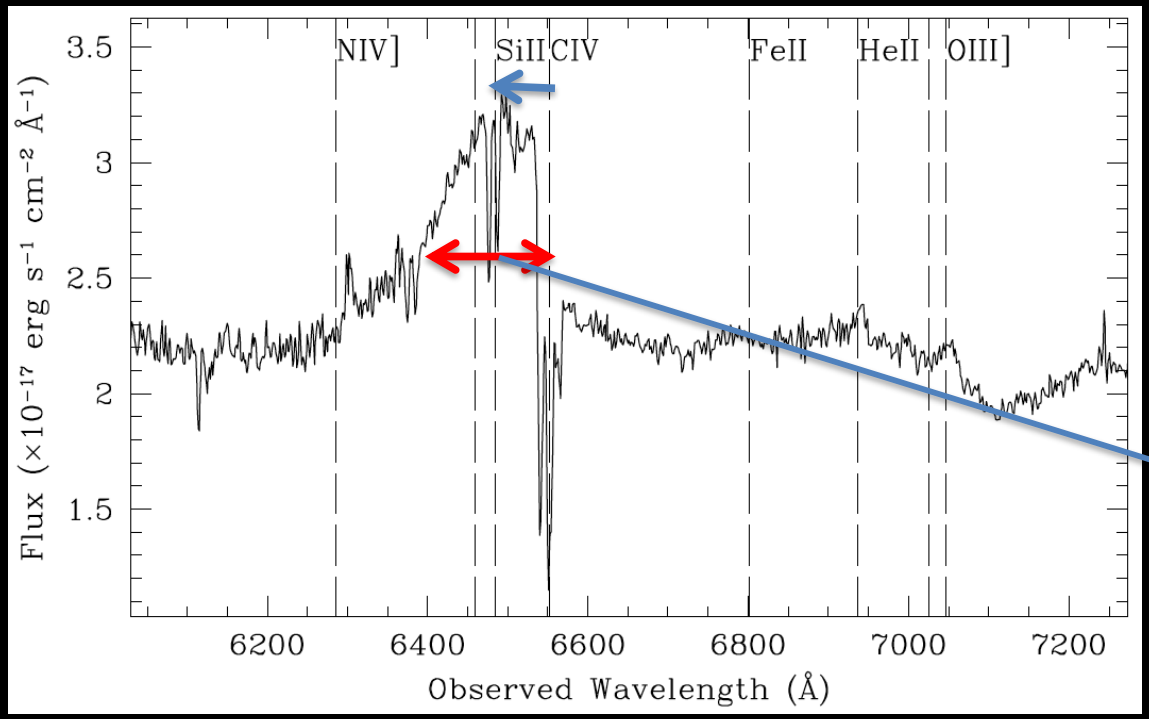


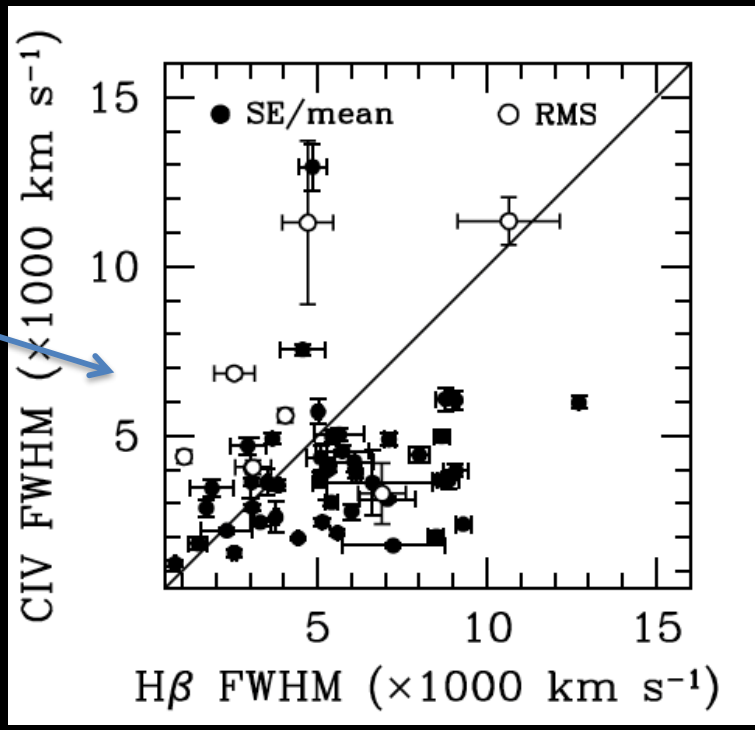


Diagrams courtesy of Michael Blanton (NYU)

- Very Distant quasars probe an enormous volume of the universe!

At High Redshift We Need CIV

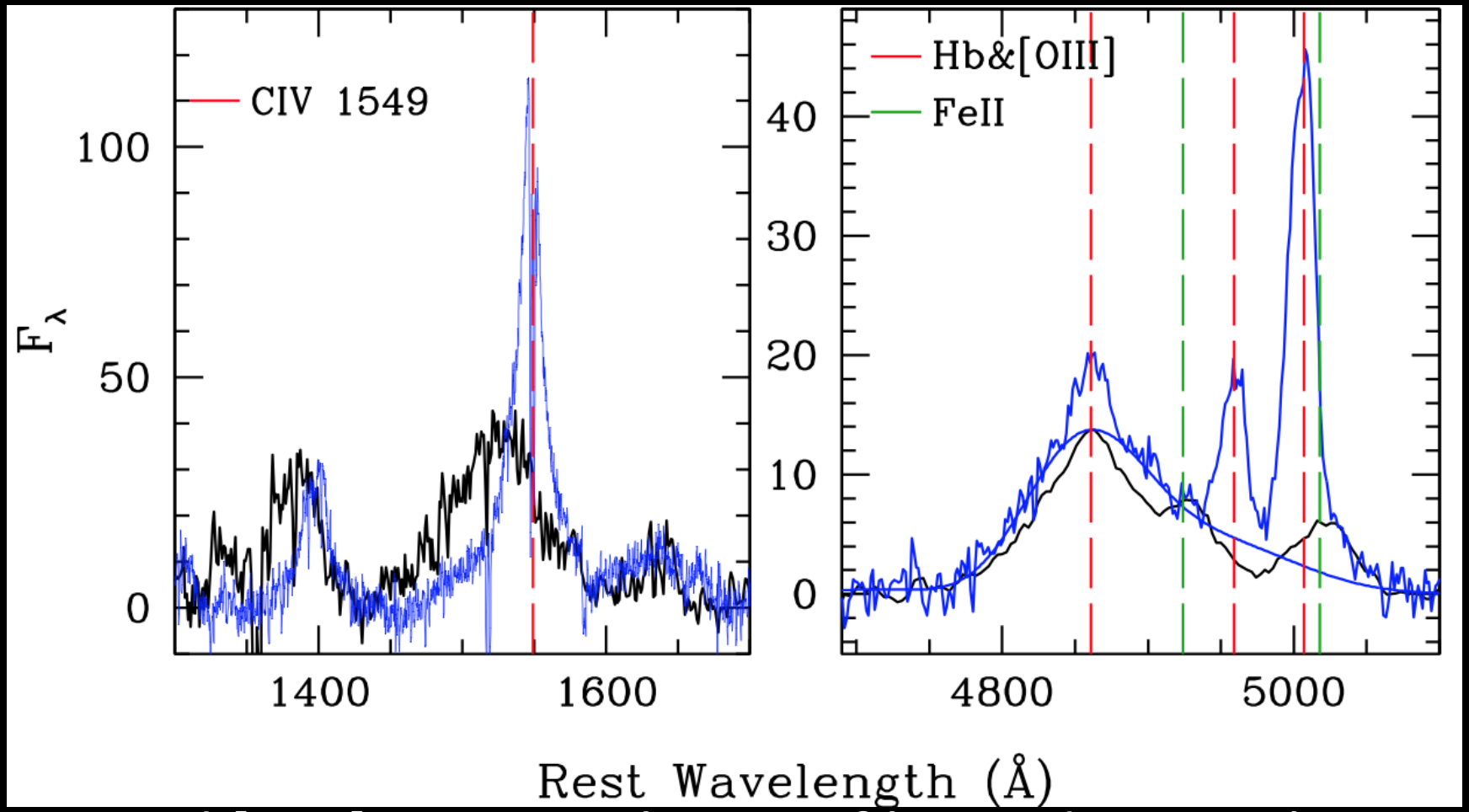




Denney et al. 2013, ApJ, 775, 60

- Concerns with CIV:
  - Blueshift/asymmetries (outflows?), absorption,
  - Line width inconsistencies with Hβ when using FWHM.

Quasar Diversity in Emission Lines



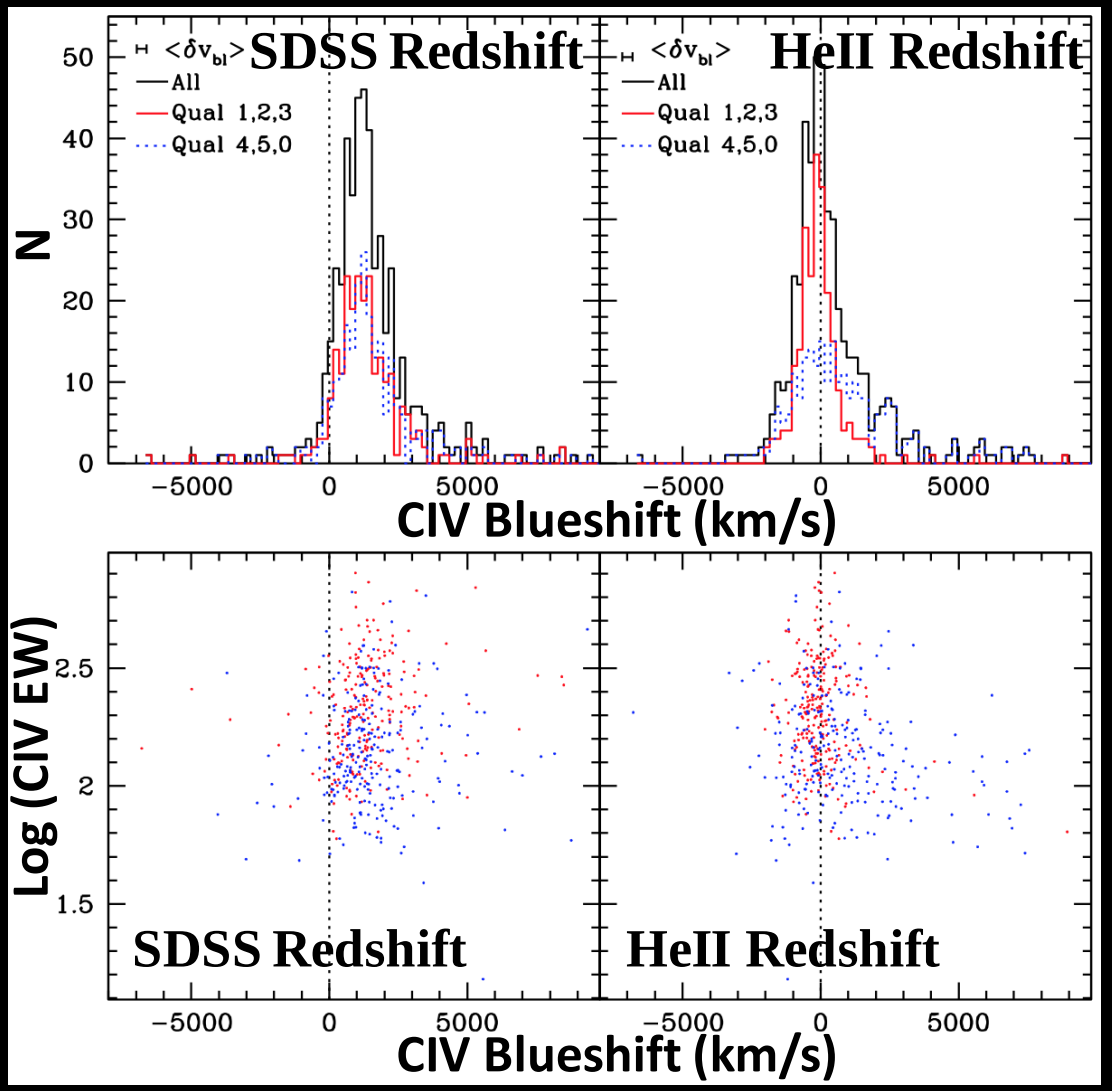
- CIV and [OIII] emission line profiles and strength:
  - Both broad AND narrow lines change coherently

  (EV1 parameter space, likely = accretion rate differences)

Quasar Diversity in Emission Lines 1: The Blueshift is only as good as the Redshift

Diverse emission line properties affect redshift precision and accuracy

- Likely due to the dependence on a composite spectrum.
- **Result: blueshift is not as ubiquitous as previously believed**



Denney et al. 2016, in prep.

Quasar Diversity in Emission Lines 2: What's "Width" That Velocity?

- Single-epoch mass:

$$M_{BH} = f \frac{RV^2}{G}$$

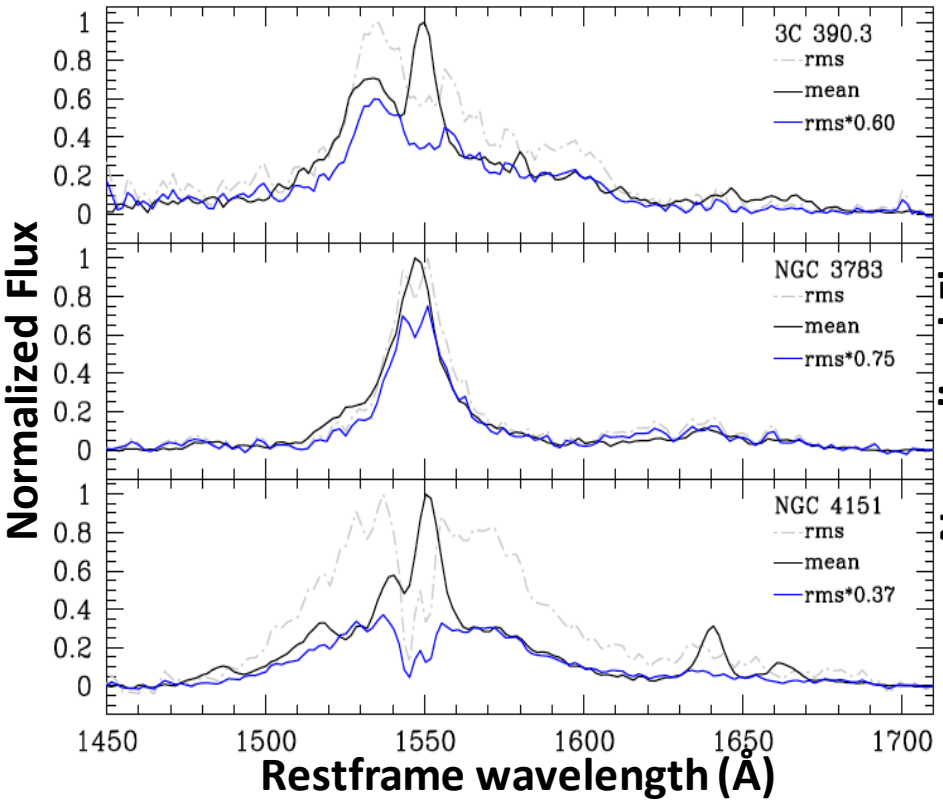
But what is V?

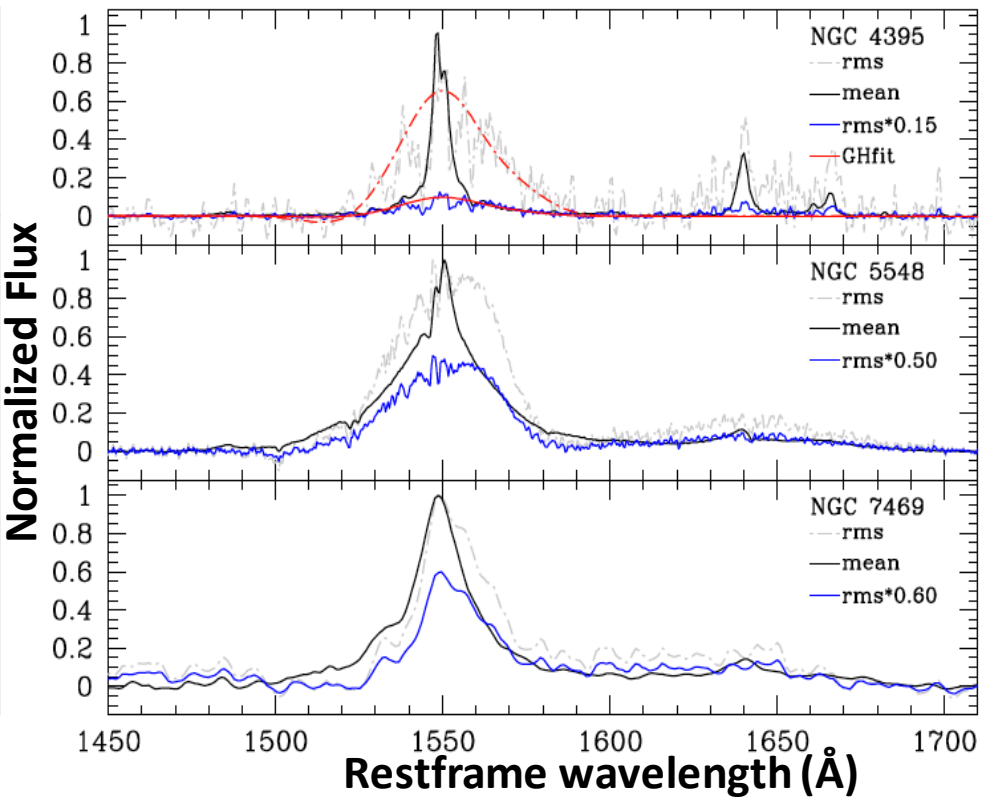
- Physically:
  - The velocity dispersion of the BLR gas at the distance from the black hole, R, probed by reverberation mapping
- Observationally:
  - The line of sight velocity characterized by a line width measured from a single spectral profile that is a superposition of all line photons emitted between the AGN and us.

What's "Width" That Velocity?

– we see all line-of-sight emission, not only that reverberating

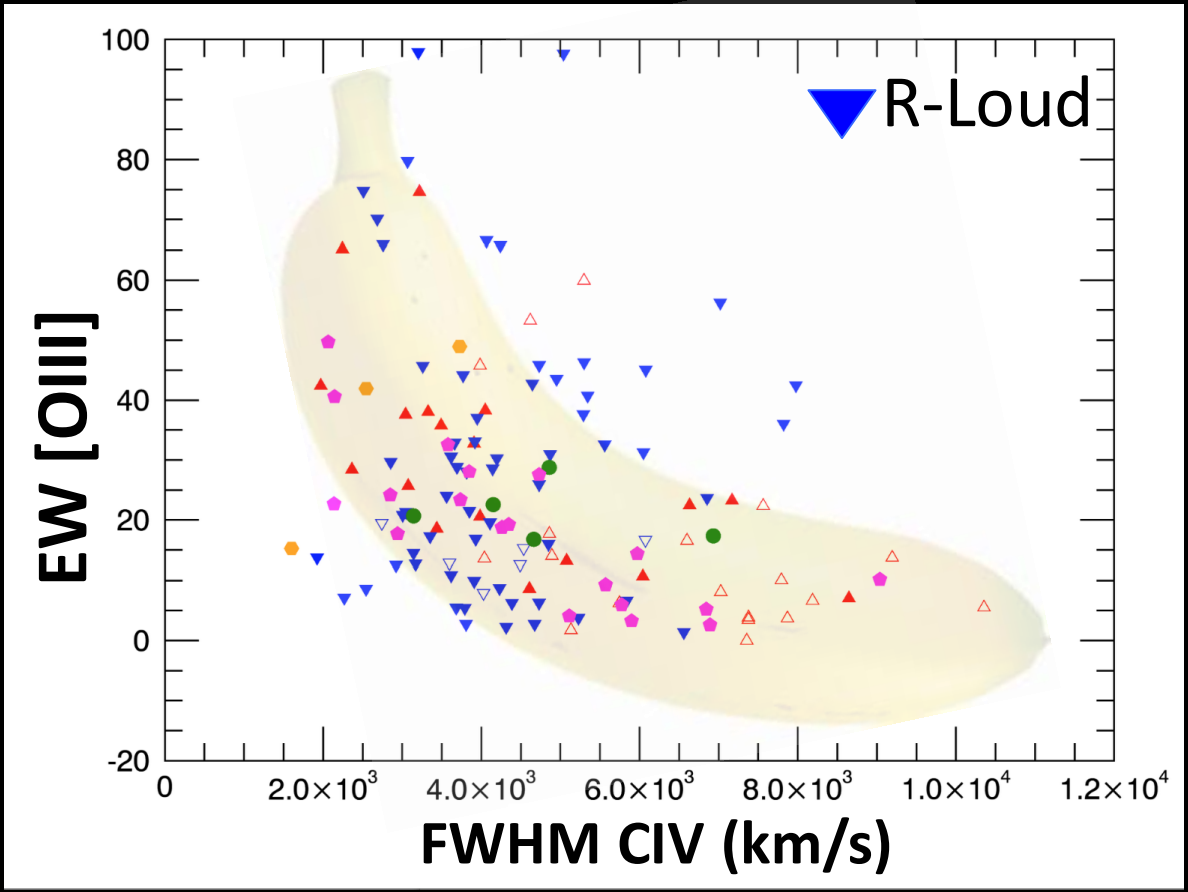
This leads to biases in Velocity





Adapted from Denney, 2012, ApJ, 759, 44

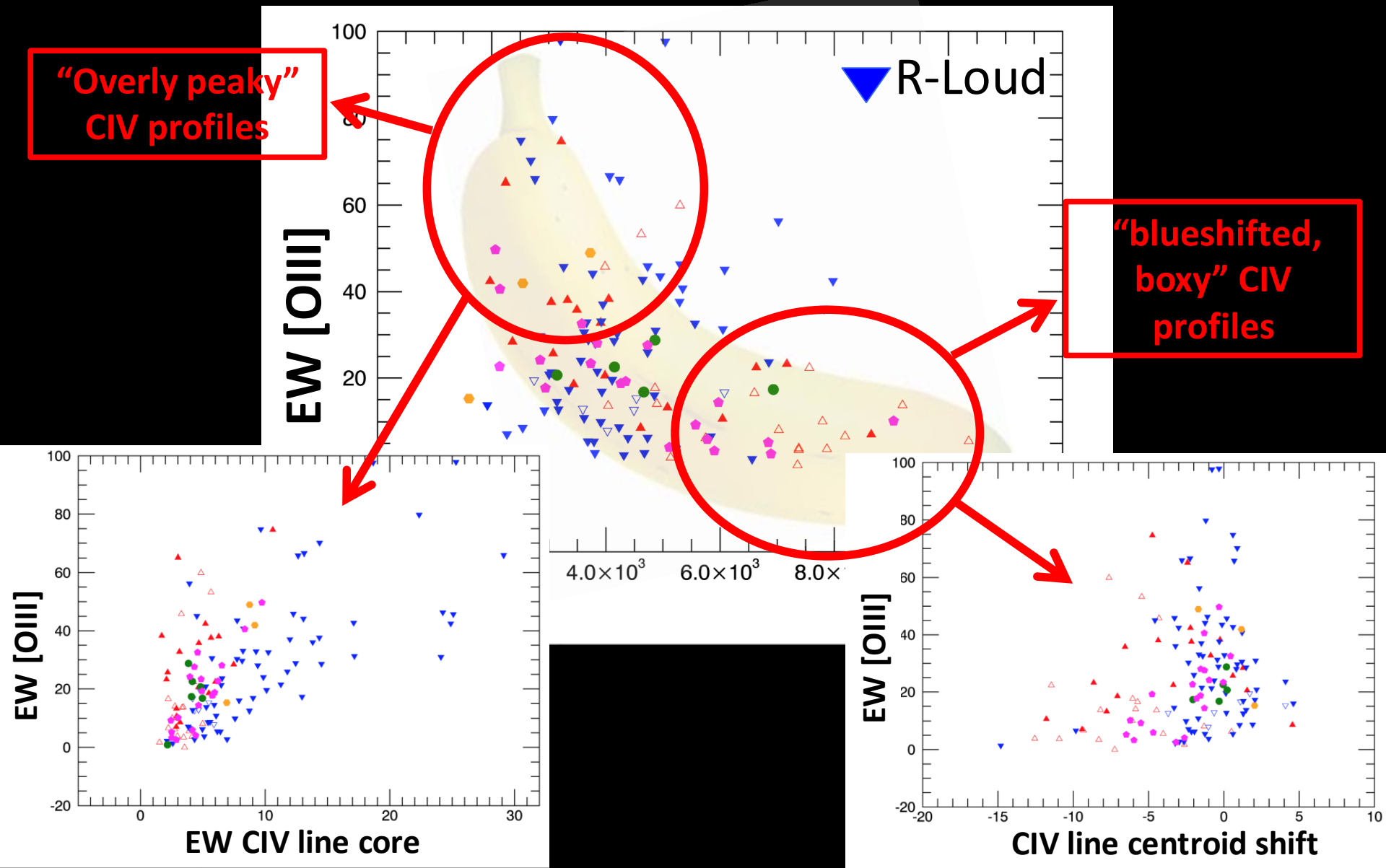
De-Biasing CIV FWHM: Smashing the Banana



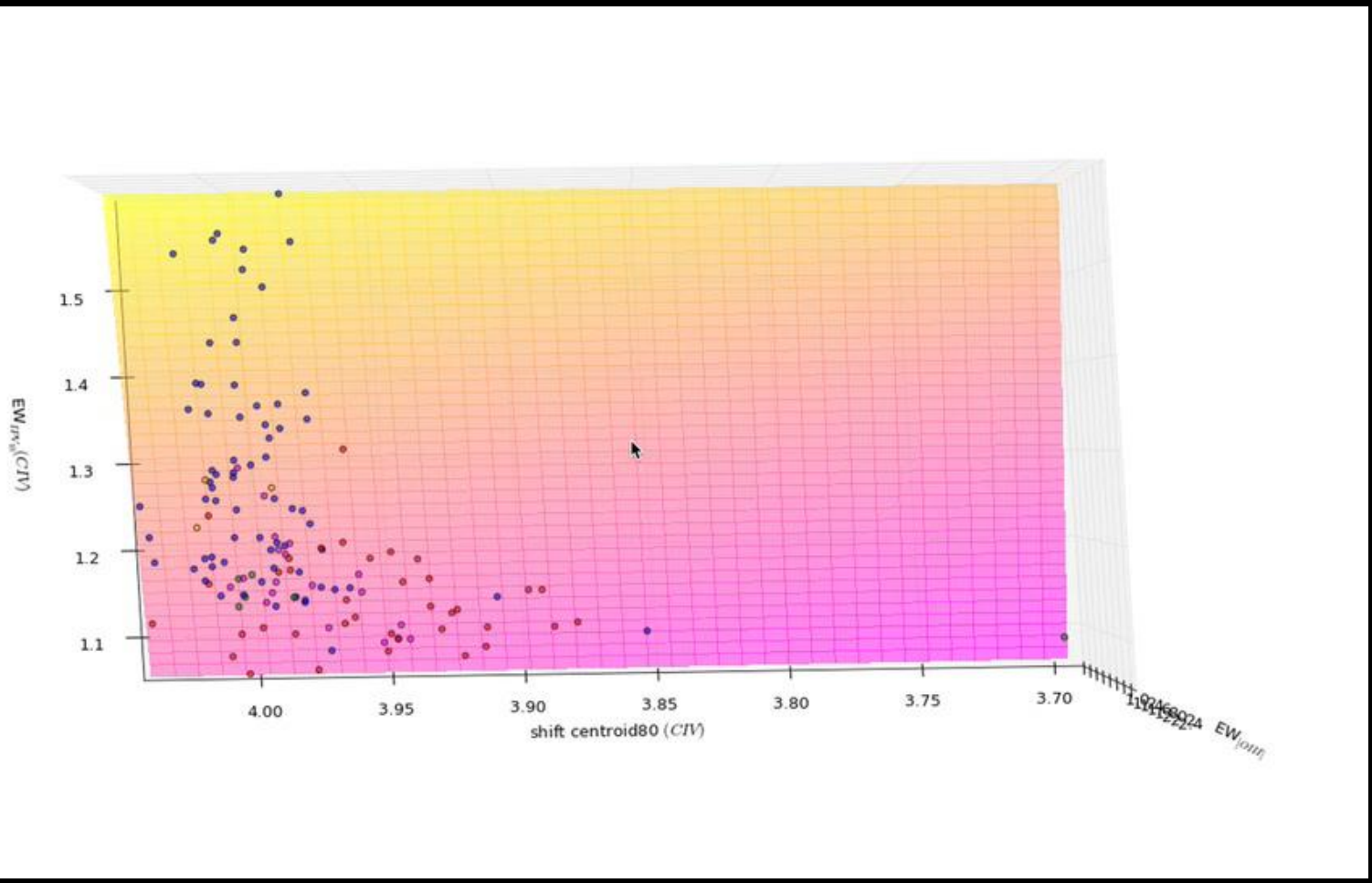
Preliminary work by Susanna Bisogni:

- FWHM of CIV (a broad line) "correlates" with [OIII] (a narrow line) – It shouldn't if the FWHM is probing the virial BLR velocities.

De-Biasing CIV FWHM: Smashing the Banana



Smashing the Banana in 3D with PCA



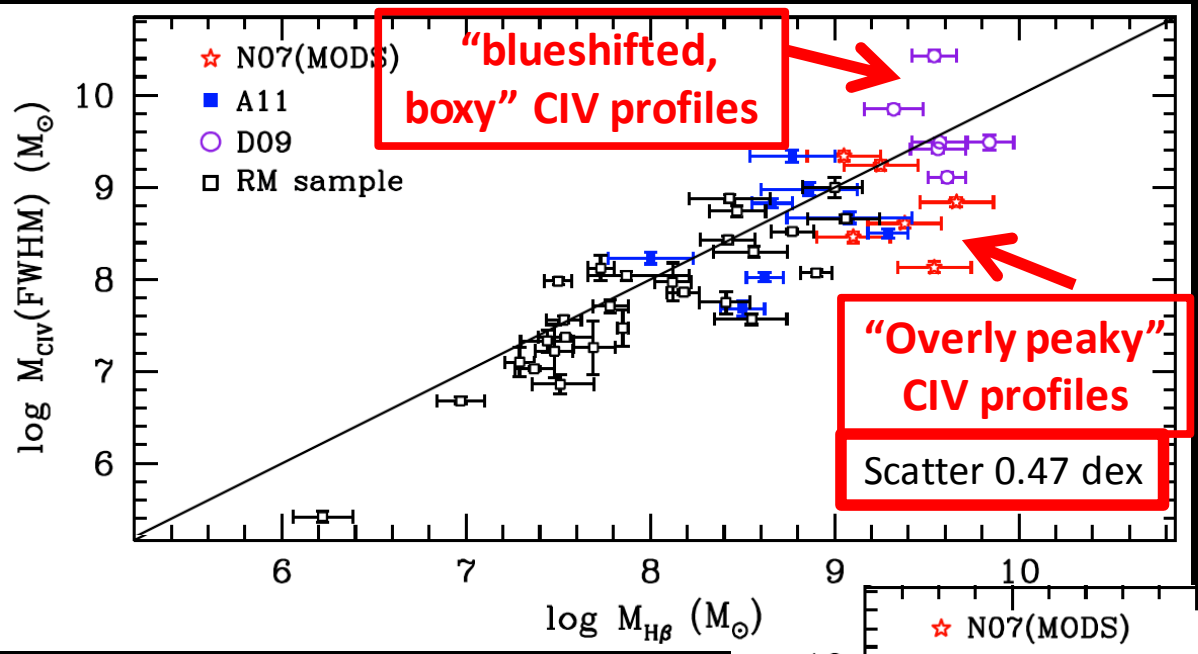
- Use Principal Component Analysis to isolate the 2 CIV profile parameters that correlate best within this parameter space.
- Use the results to fit a 3D plane to correct the bias in FWHM from both sources of non-reverberating gas.

Conclusions

- We'd like to be confident that CIV-based BH mass estimates are reliable to more easily probe the high-z Universe for studies of galaxy evolution and structure growth.
- RM studies shed light on the current problem with CIV SE mass estimates – non-variable emission biasing FWHM measurements.
- We're working on new, easy-to-implement ways to mitigate these biases.

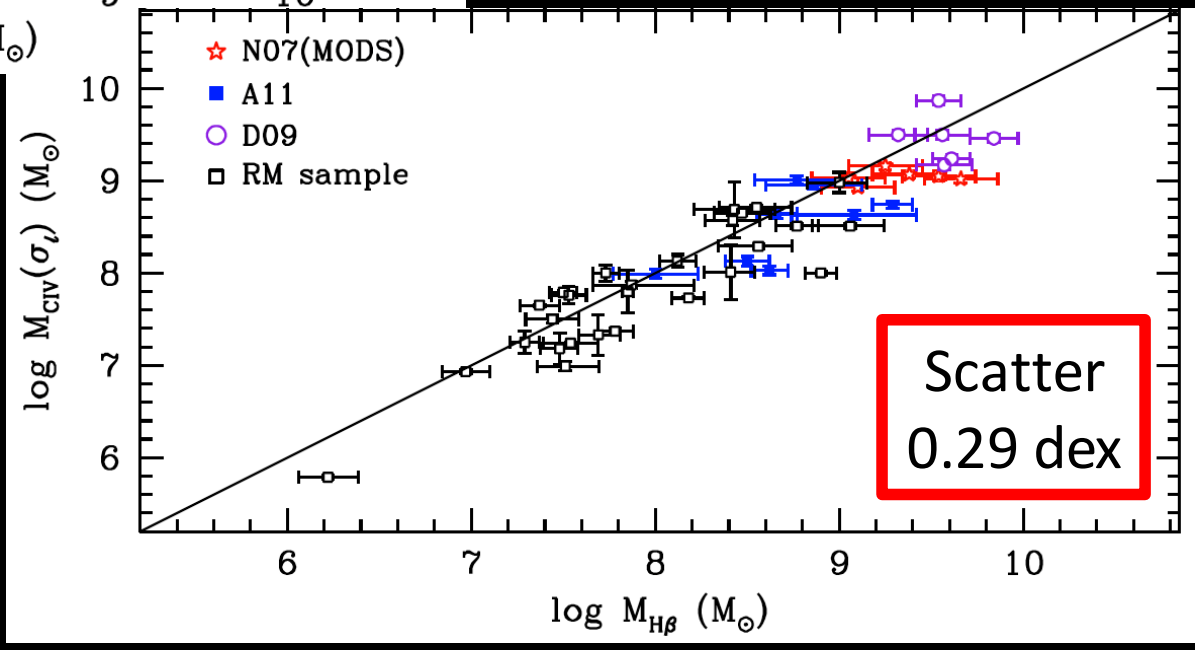
Stay Tuned!

Line Width Choice Affects Precision of CIV-based BH Masses



- For M_{CIV} (FWHM), the primary bias is due to the non-reverberating component(s).

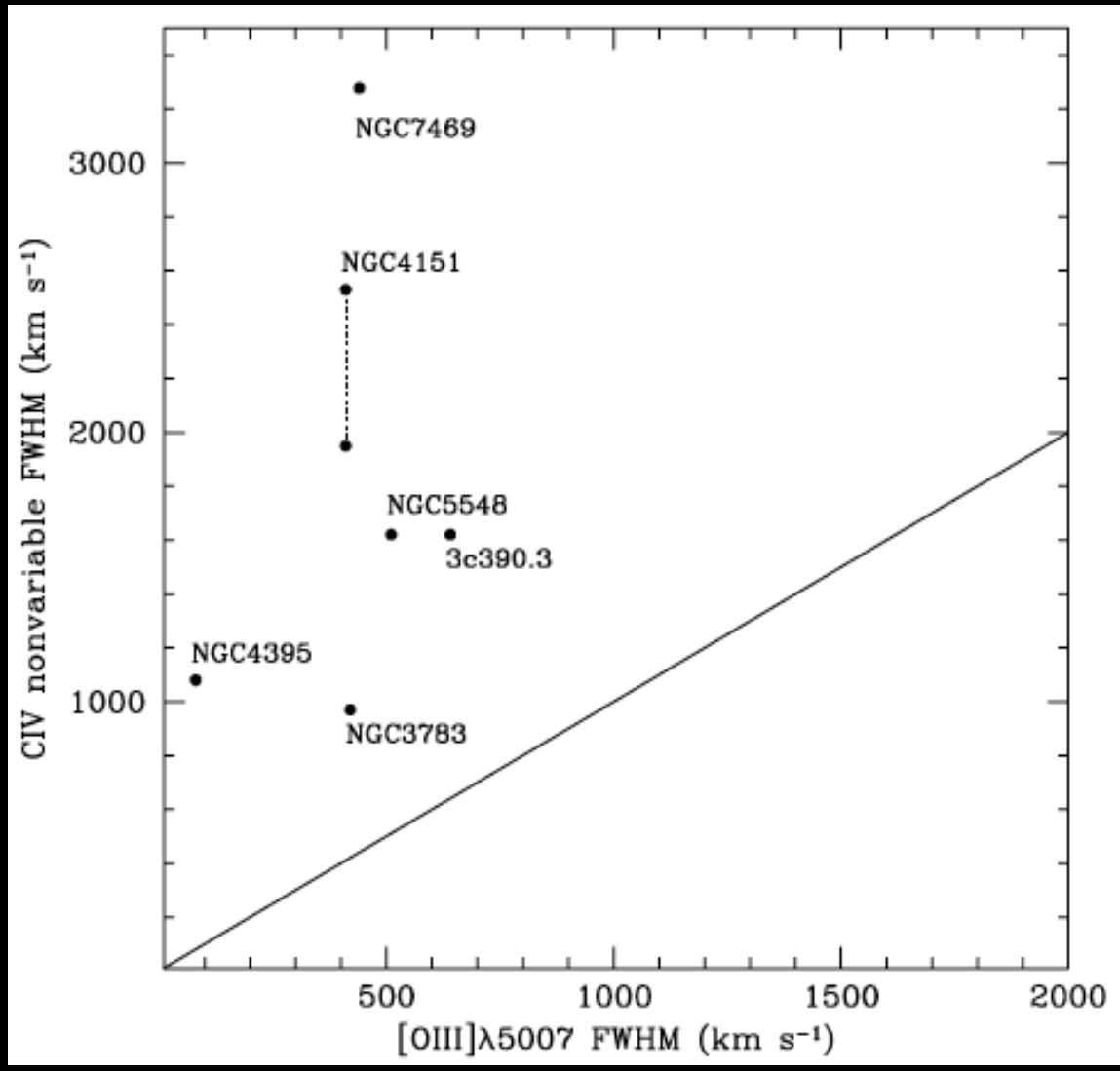
- $M_{CIV}(\sigma_{line})$ shows smaller scatter, but requires higher quality data.



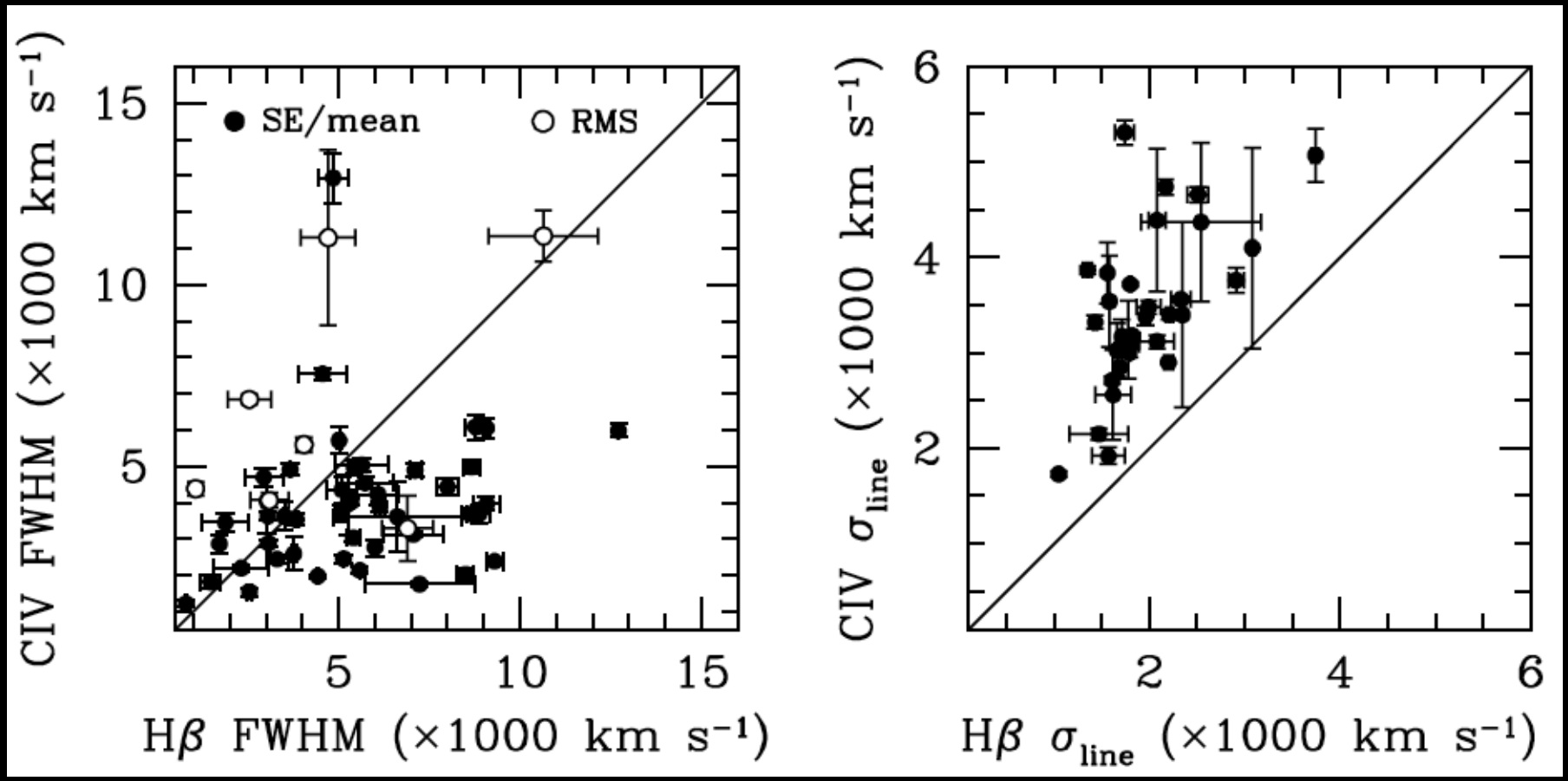
(Denney et al. 2013, ApJ, 775, 60)

CIV Non-variable Component is NOT [OIII]-like NLR emission

- After subtracting the rms profile, we measure the residual profile width of the non-variable component.
- They are all MUCH broader than the [OIII] 5007 width in all objects



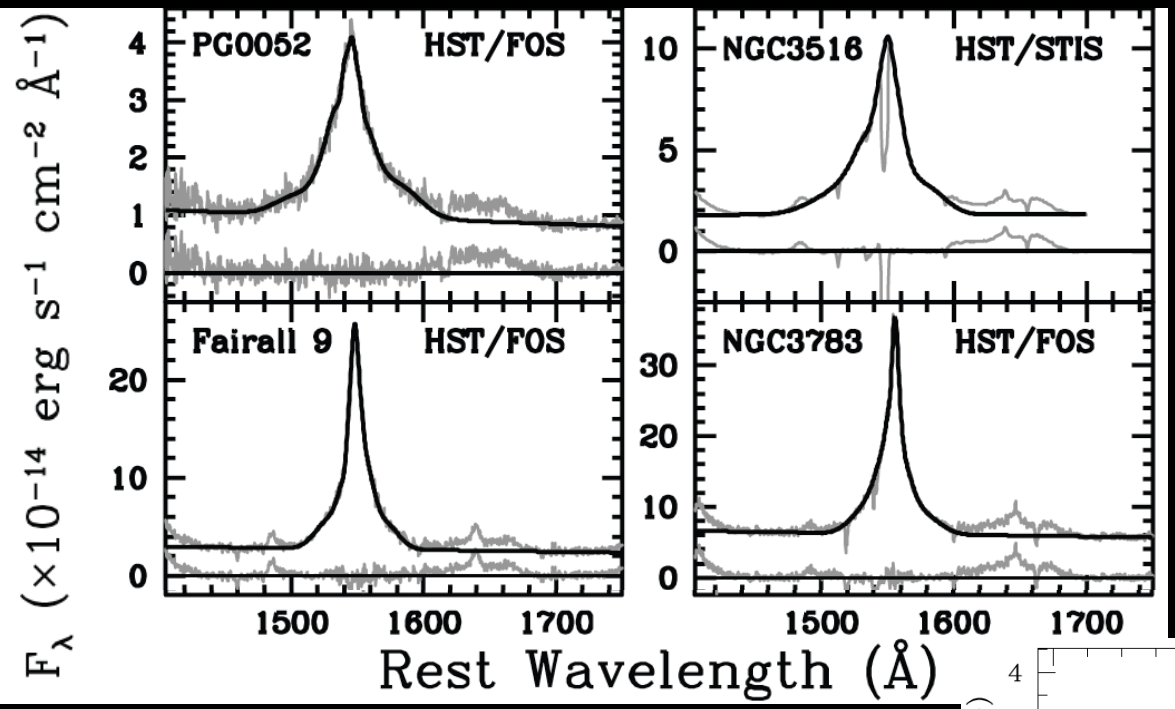
What Line Width Meets Virial Expectations?



(Denney et al. 2013, ApJ, 775, 60)

- CIV FWHM does NOT follow virial expectations, but CIV line dispersion does.

Data Quality Affects CIV-based BH Masses

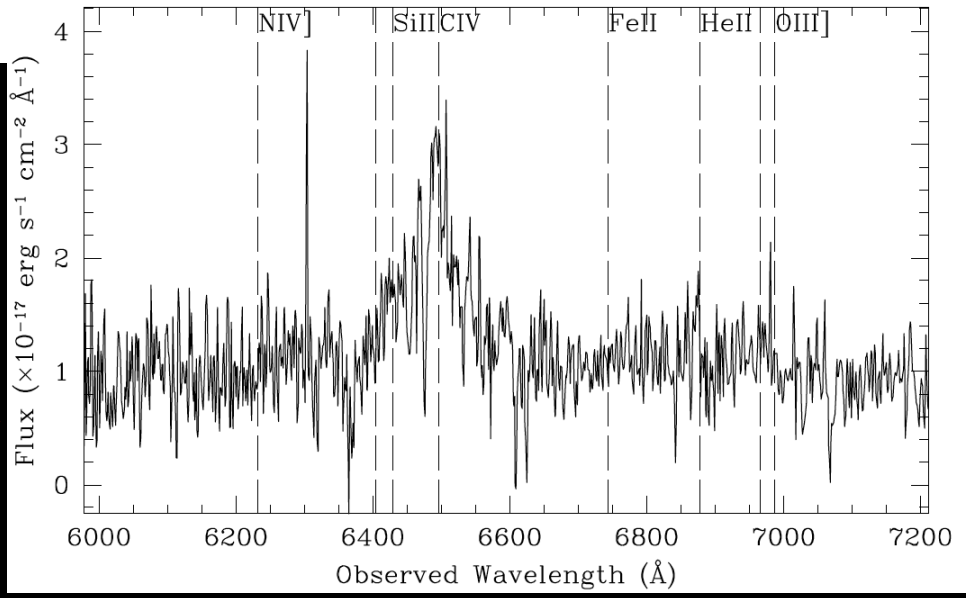


- Calibration data looks like this

- S/N >~ 20-50

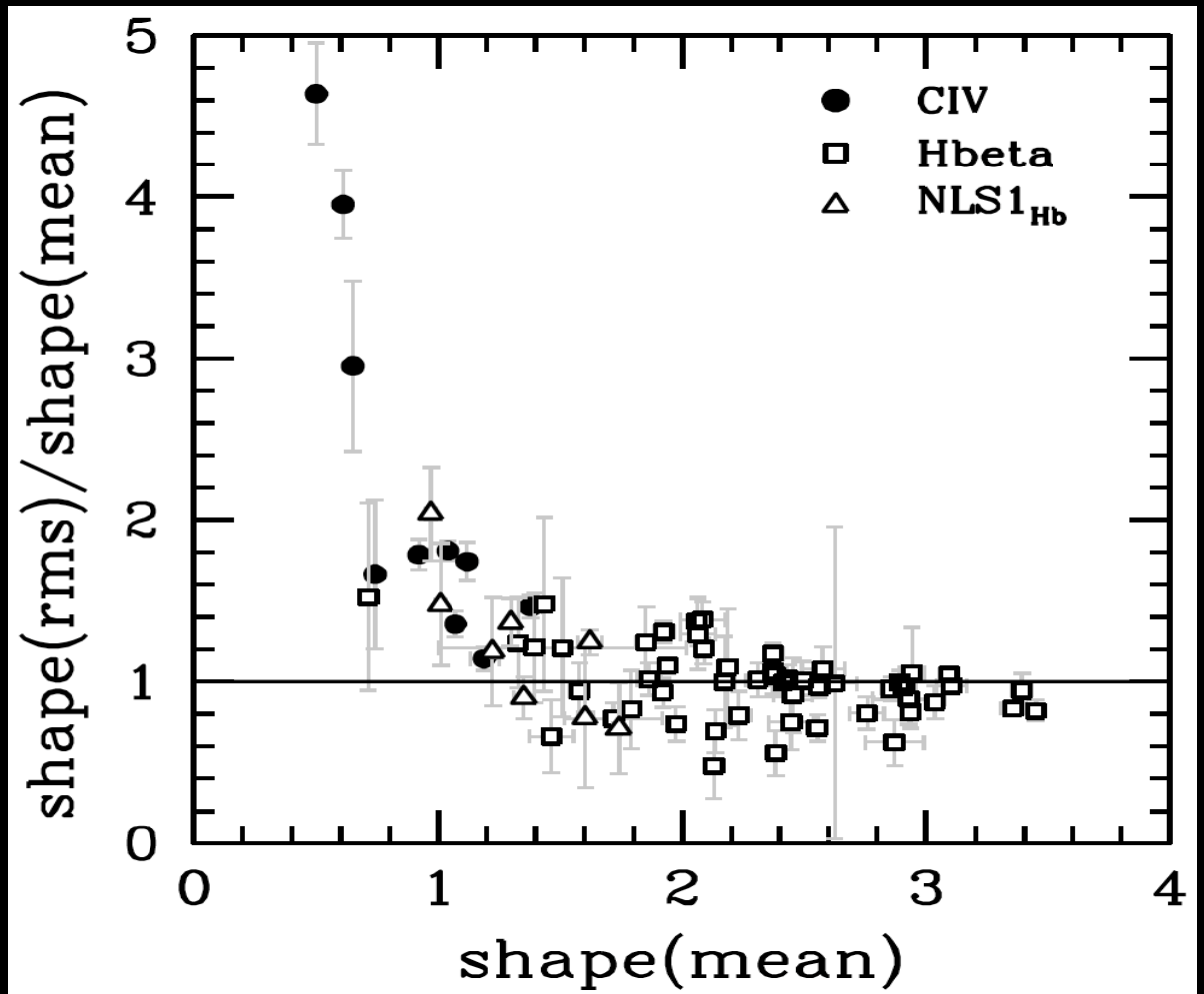
(Denney et al. 2013, ApJ, 775, 60;
see also Park et al. 2013, ApJ, 770, 87)

- Typical survey data
- S/N <~ 5



Does the SE Profile Trace the Variable?

- Again characterize CIV and Hβ profiles by their "shape" = (FWHM/σ_{line}):



The Hβ SE profile **IS** a good proxy for the rms profile

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.

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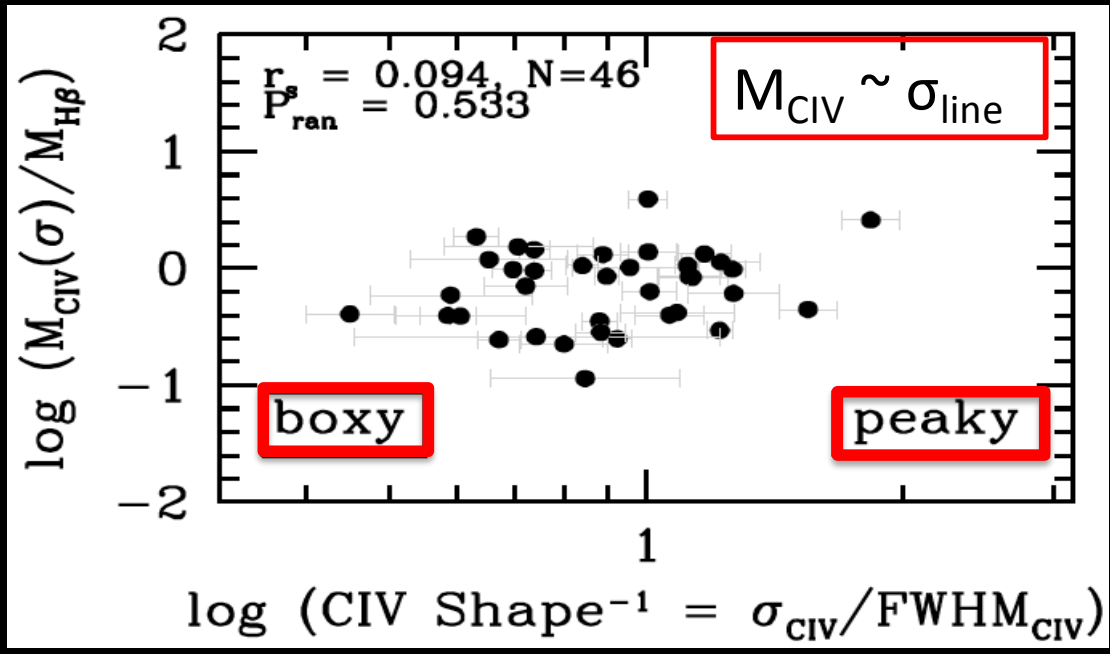
But the CIV profile is **NOT**

Denney 2012, ApJ, 759, 44

Is Characterizing the Line with the Line Dispersion the Answer?

Pros:

- Seem to be less intrinsic bias in the velocities:
  - SE mass calibration consistent with virial
  - All lines in individual source consistent with virial.
  - Less susceptible to non-variable components in line core (NLR in Hbeta – Denney et al. 2009, and component of unknown origin in CIV)



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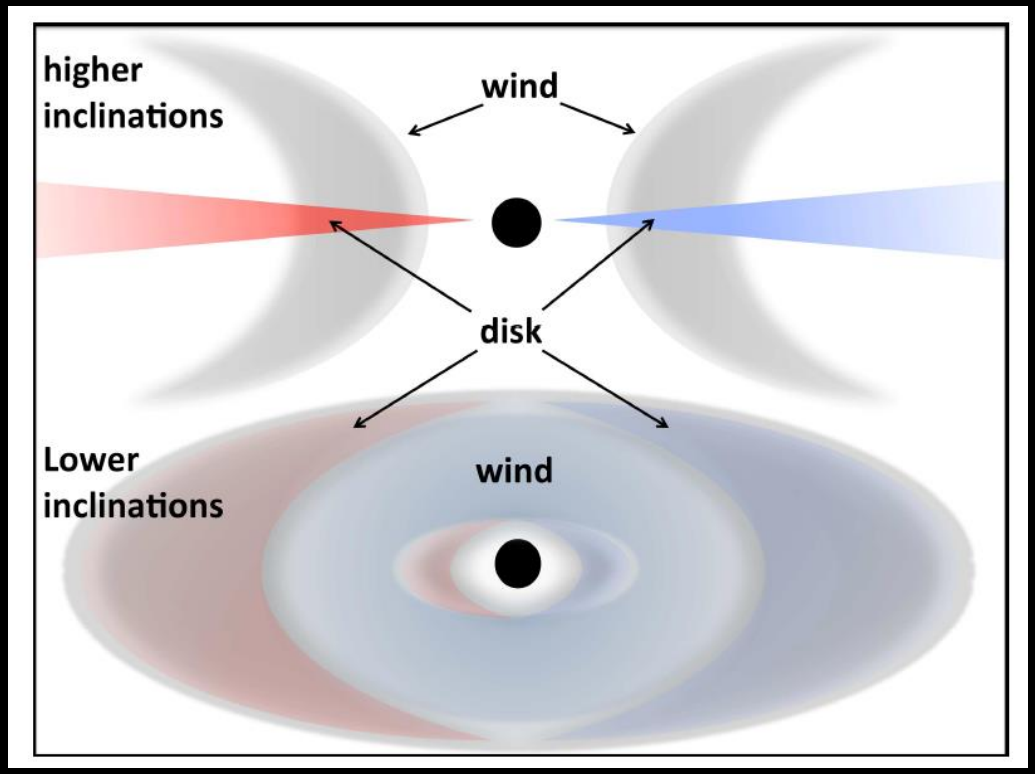
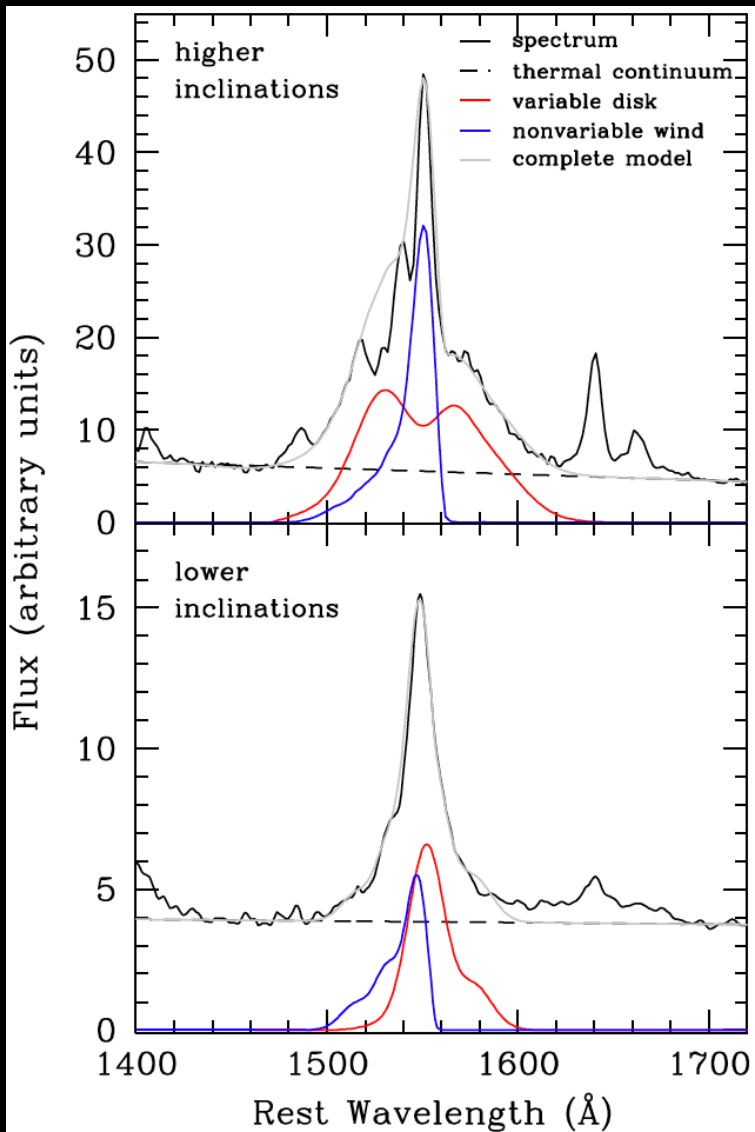
Cons:

- More sensitive to data quality (i.e., S/N, see Denney et al. 2009, 2013)
- More sensitive to prescriptional differences (see Park et al. 2013; Denney et al. 2013)
- More sensitive to blending and HOW you deal with it (see Denney et al. 2009)

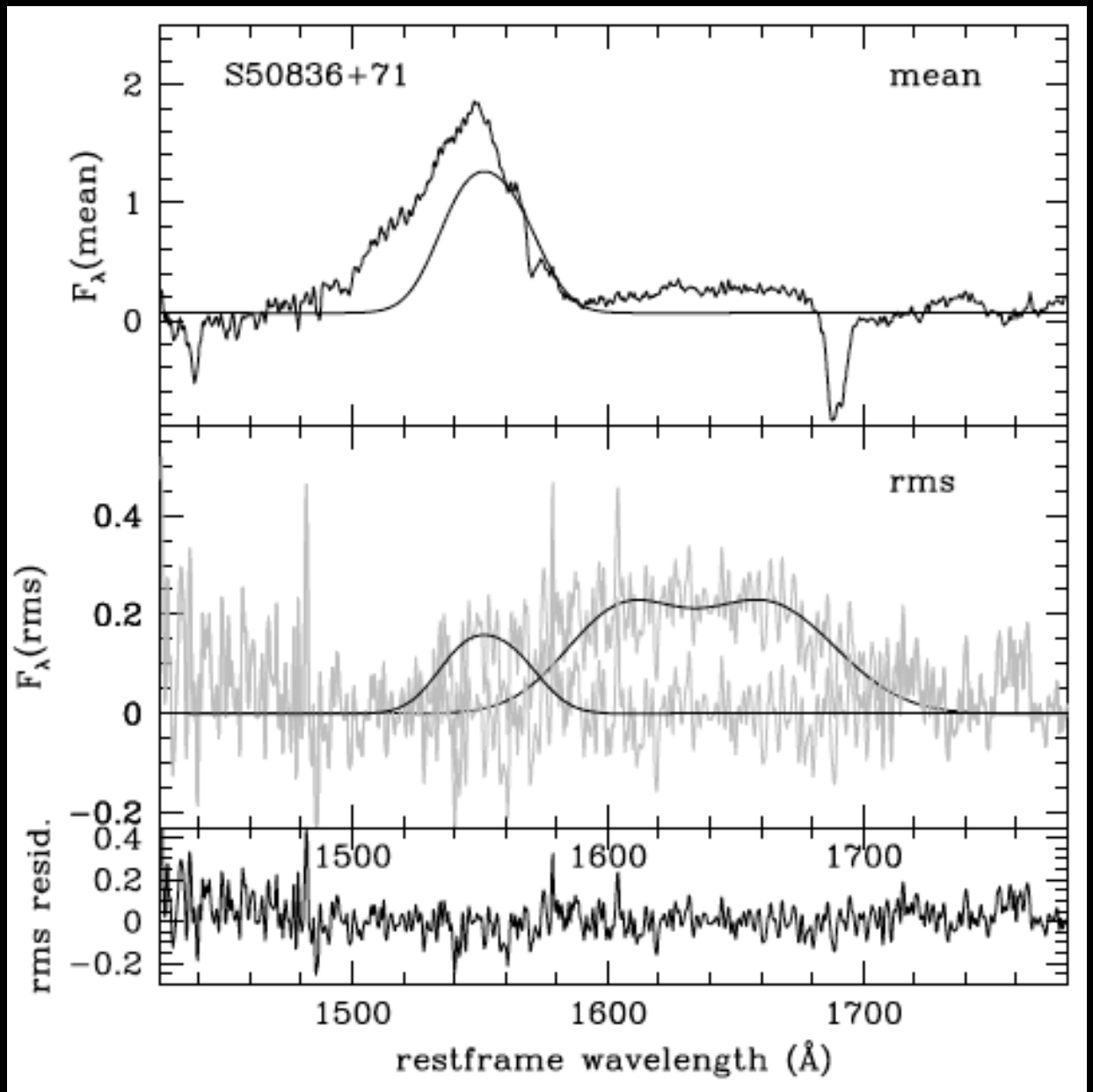
What do the observed CIV Line Profiles Look Like?





The differences we see in these two objects reflect the differences we would *expect* to see from our simple model!

The “boxiest” RM result



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