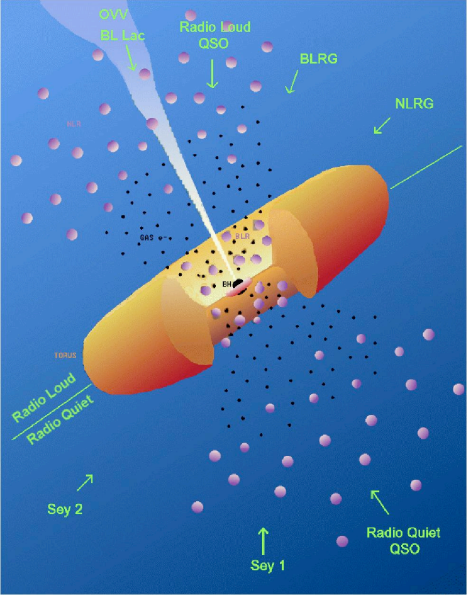
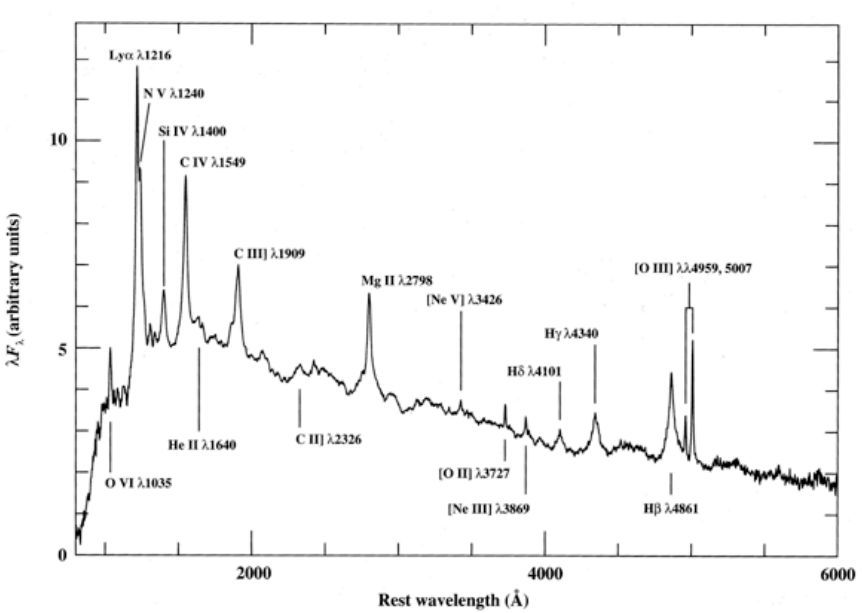
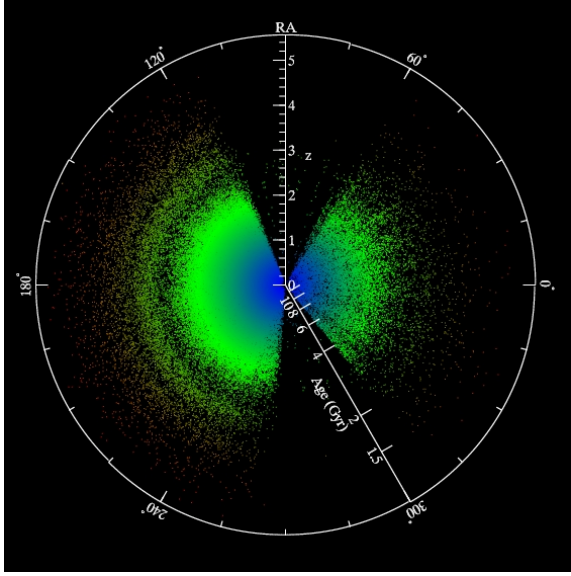






The Main Sequence of Quasars (or, the nature of Eigenvector 1)

Yue Shen

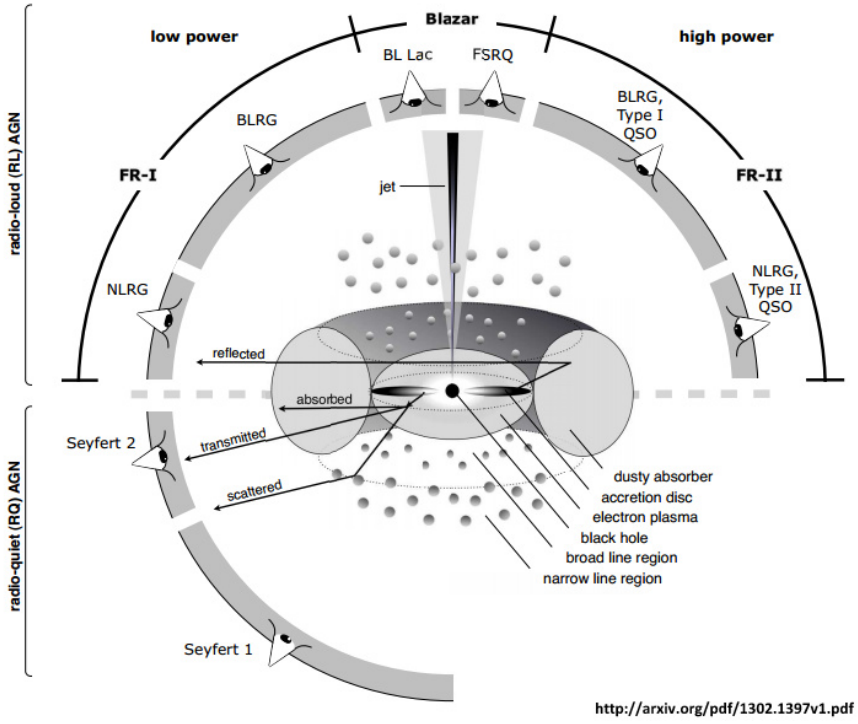
Hubble Fellow, Carnegie Observatories

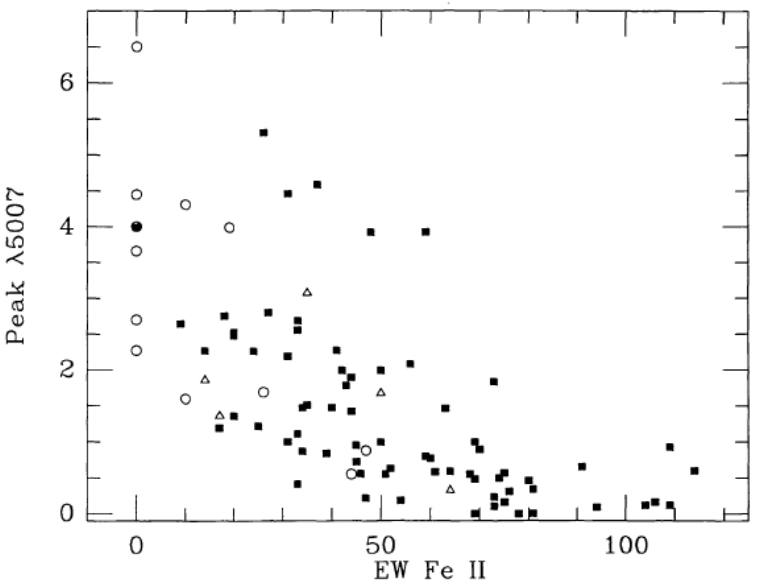
Based on the work of Shen & Ho (2014)

Outline

- Background: EV1 and orientation
- New observations of quasar properties (SDSS, WISE, etc)
- A simple unification for broad-line quasars
- Open questions

- Unification of Type 1 and Type 2 AGN



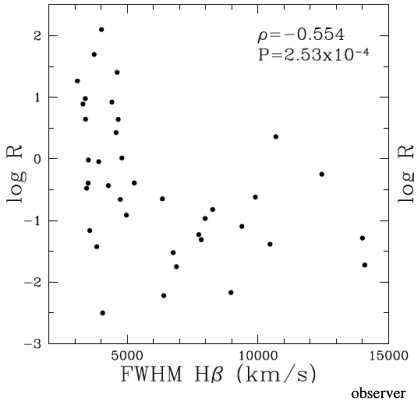


- Eigenvector 1 (EV1, Boroson & Green 1992): most of the variance in the optical spectra of (Type 1) quasars comes from an anti-correlation between FeII strength and narrow [OIII] strength

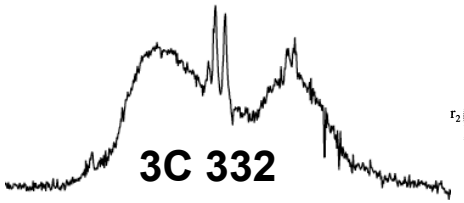
- Many other physical properties seem to correlate with EV1 (X-ray properties, CIV properties, narrow-line Seyfert 1s, BALQSOs, etc): Wang et al. 1996, Boller et al. 1996, Laor et al. 1997, Brandt et al. 2000, Sulentic et al. 2000, and many more

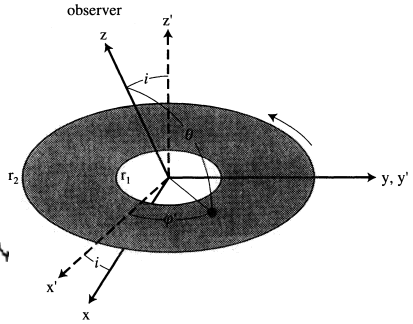
Evidence for a flattened BLR

- Radio jet orientation (Wills & Browne 1986, Runnoe et al.)

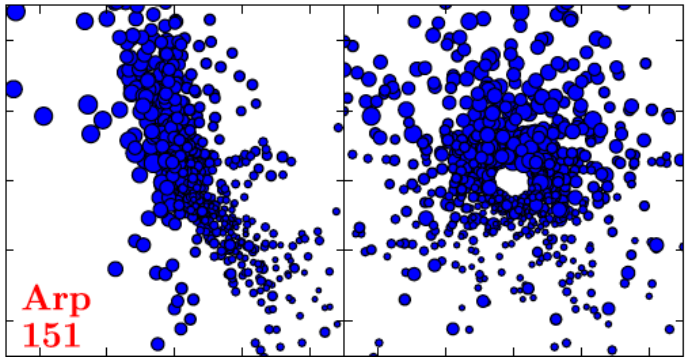


- Disk emitters (Chen, Eracleous, Halpern et al.)





- Dynamical evidence from reverberation mapping (Pancoast et al.)

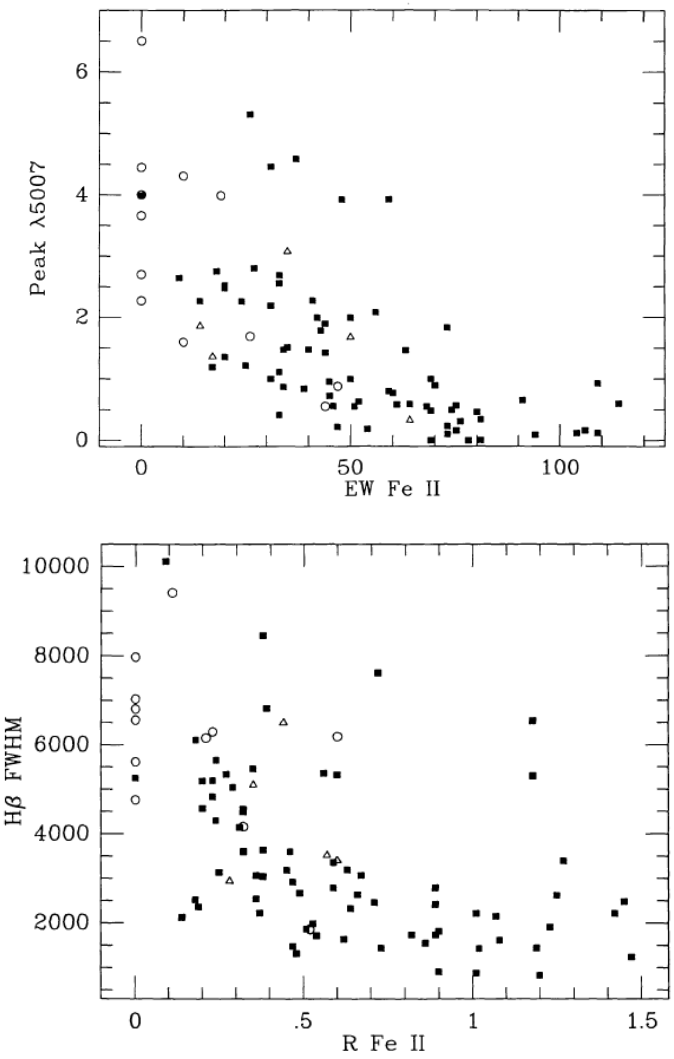


Motivation of our work

- What drives EV1?
  - Eddington ratio long suspected as the driver (Laor 2000, Boroson 2002), but a definitive proof is lacking

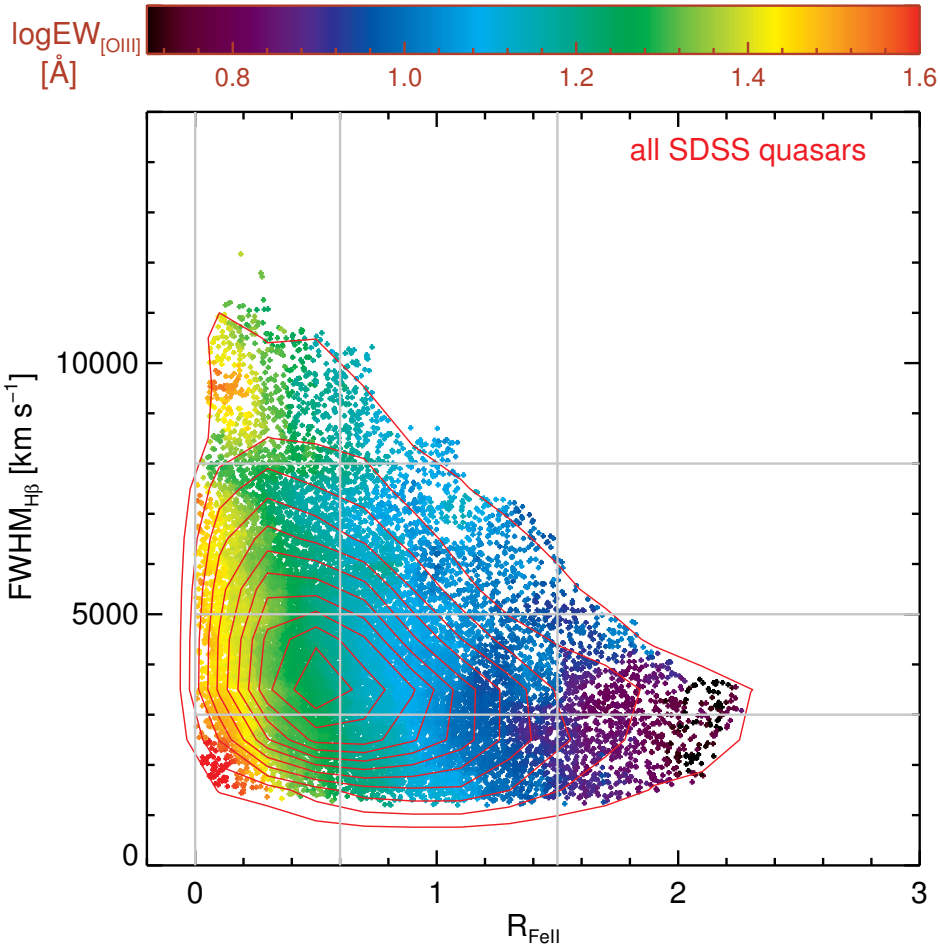
- How to integrate orientation into this picture?

20 years ago



87 PG quasars from BG92

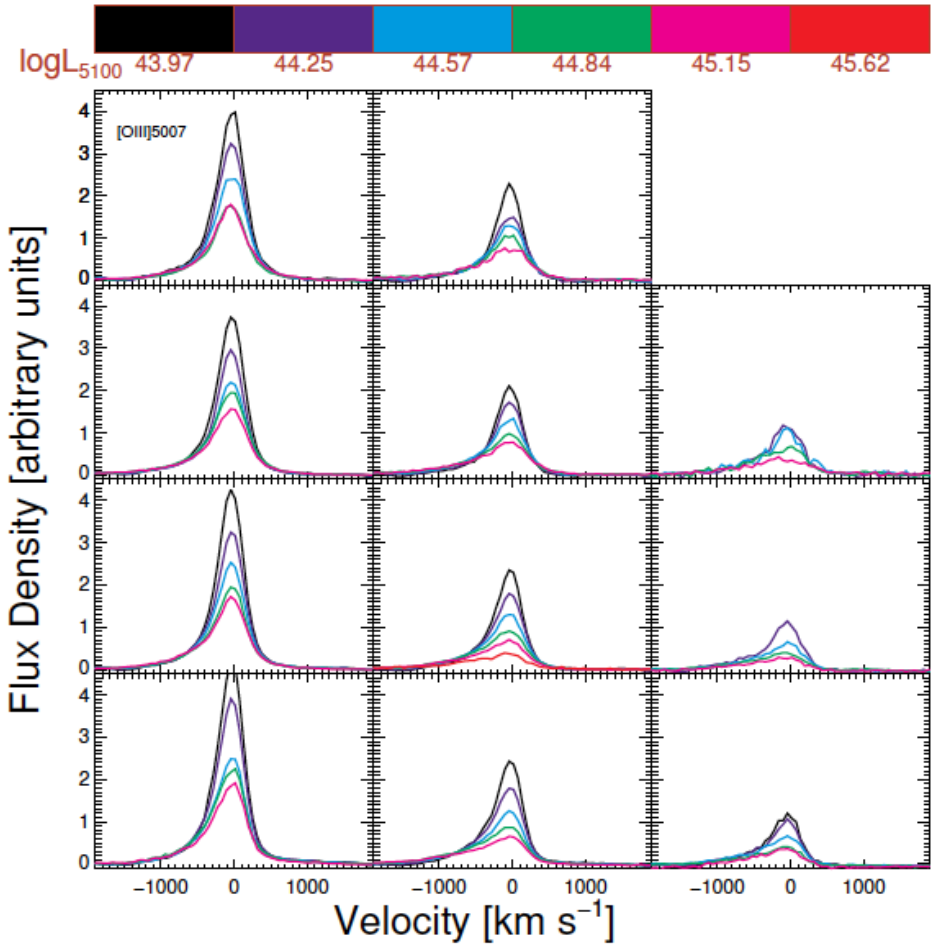
Now

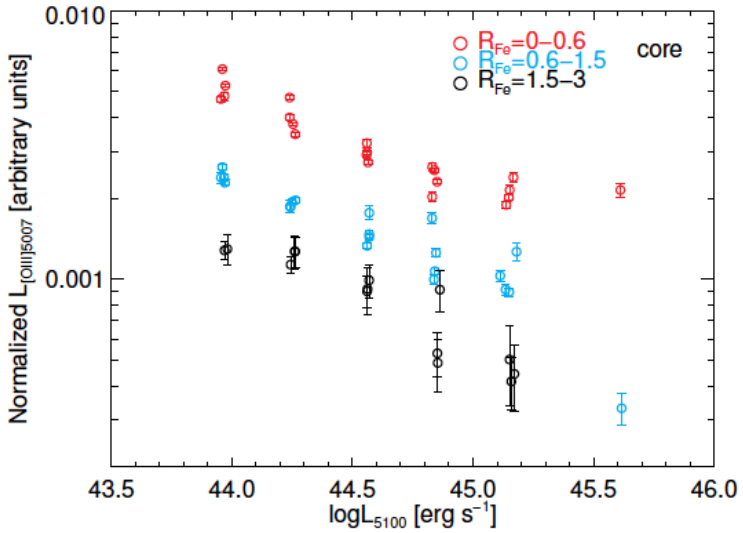


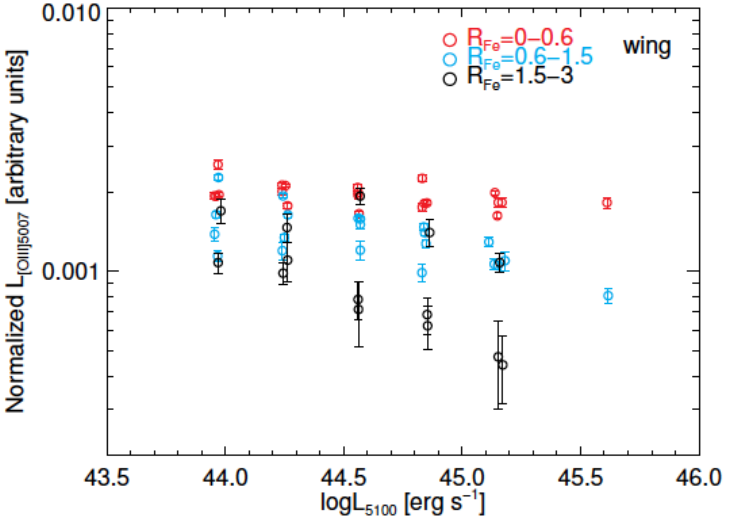
>20,000 quasars from SDSS DR7 (Shen & Ho 2014)

This 2D FWHM (Hbeta) versus Rfe EV1 plane is also known as the 4DE1 plane used by Sulentic and collaborators

A closer look at [OIII]

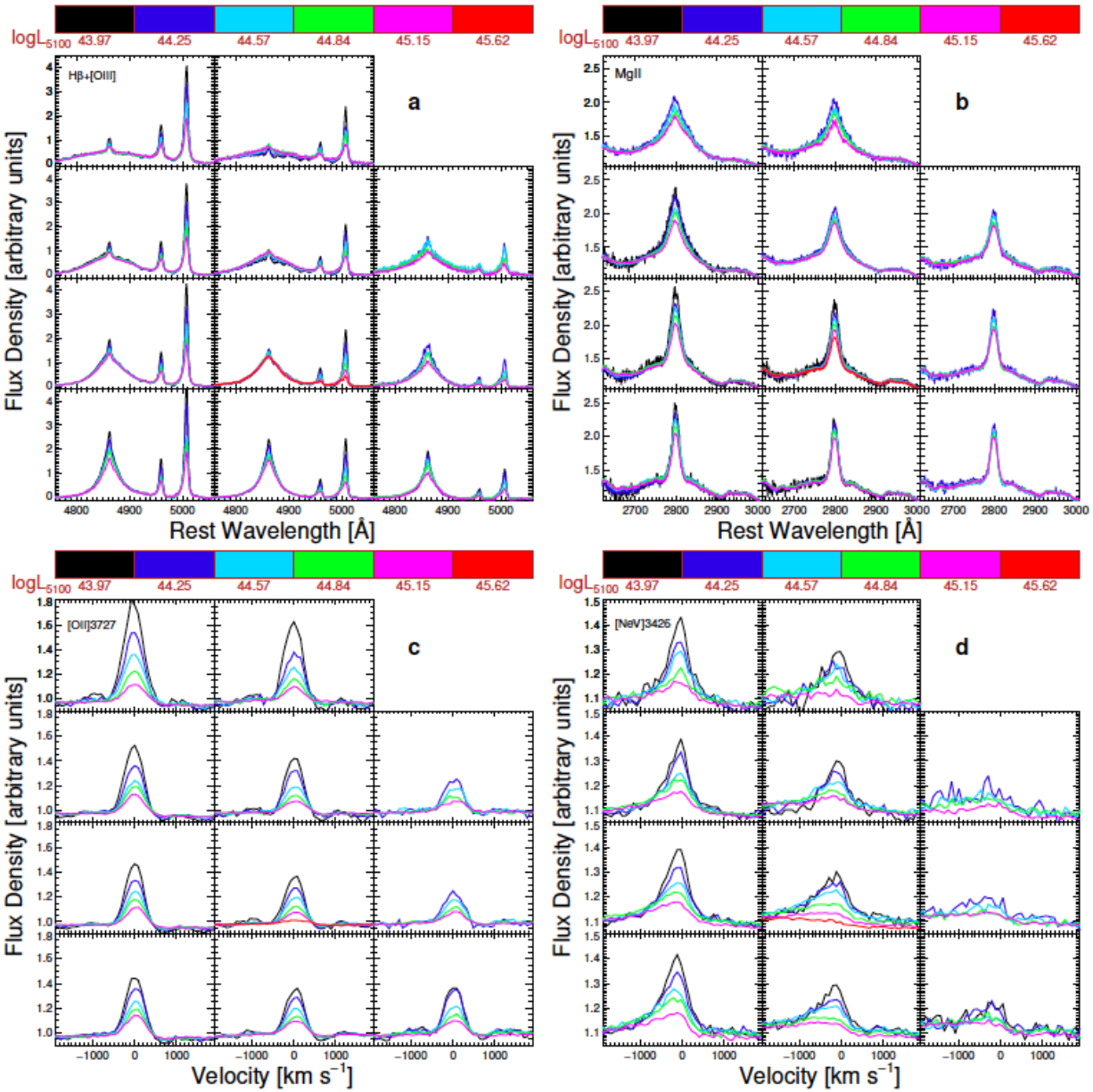




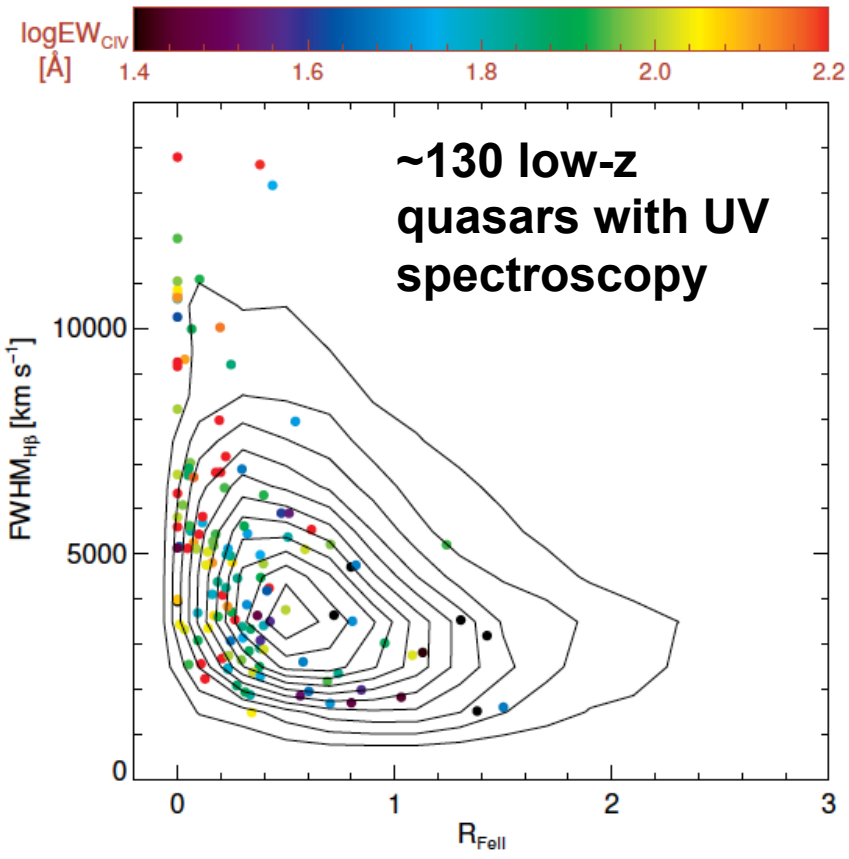


EV1 + Baldwin effect for [OIII] (e.g., Stern et al. 2013, Zhang et al. 2013)

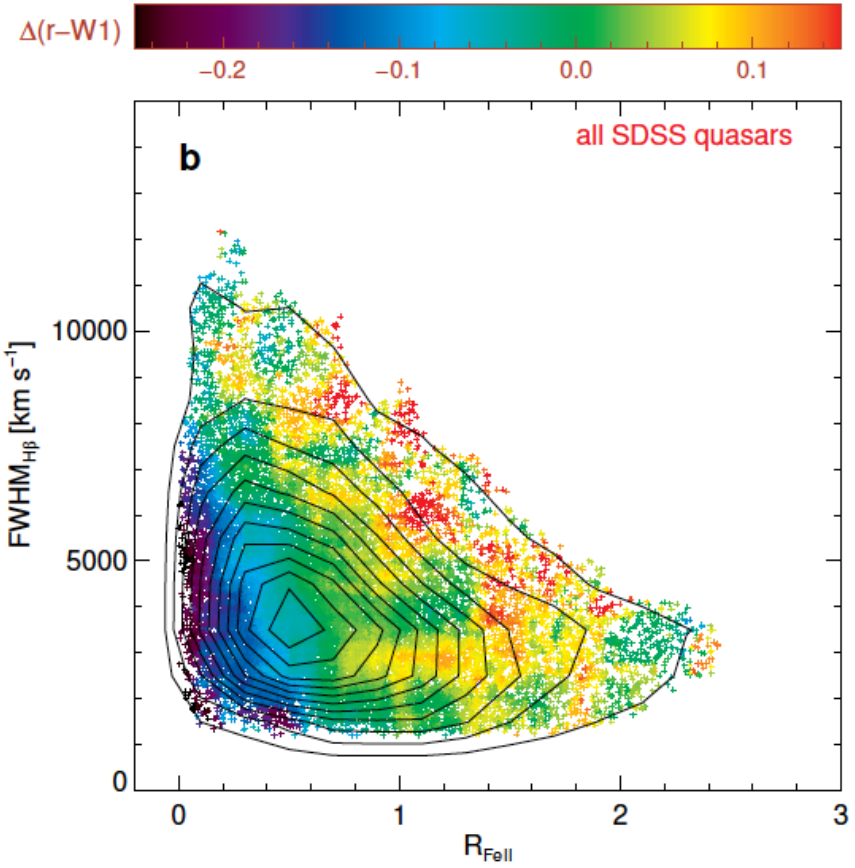
Other properties along EV1

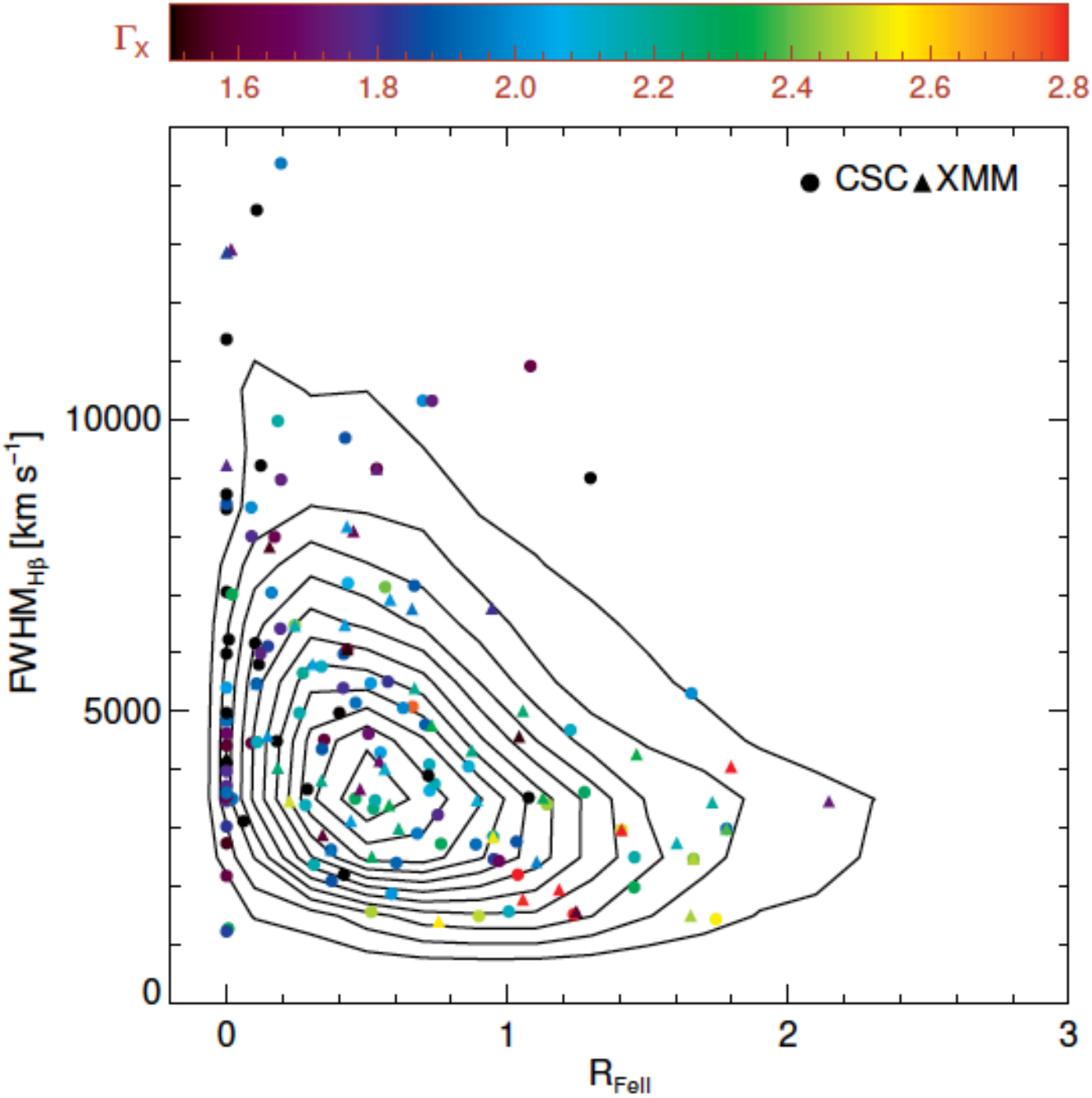


CIV properties along EV1

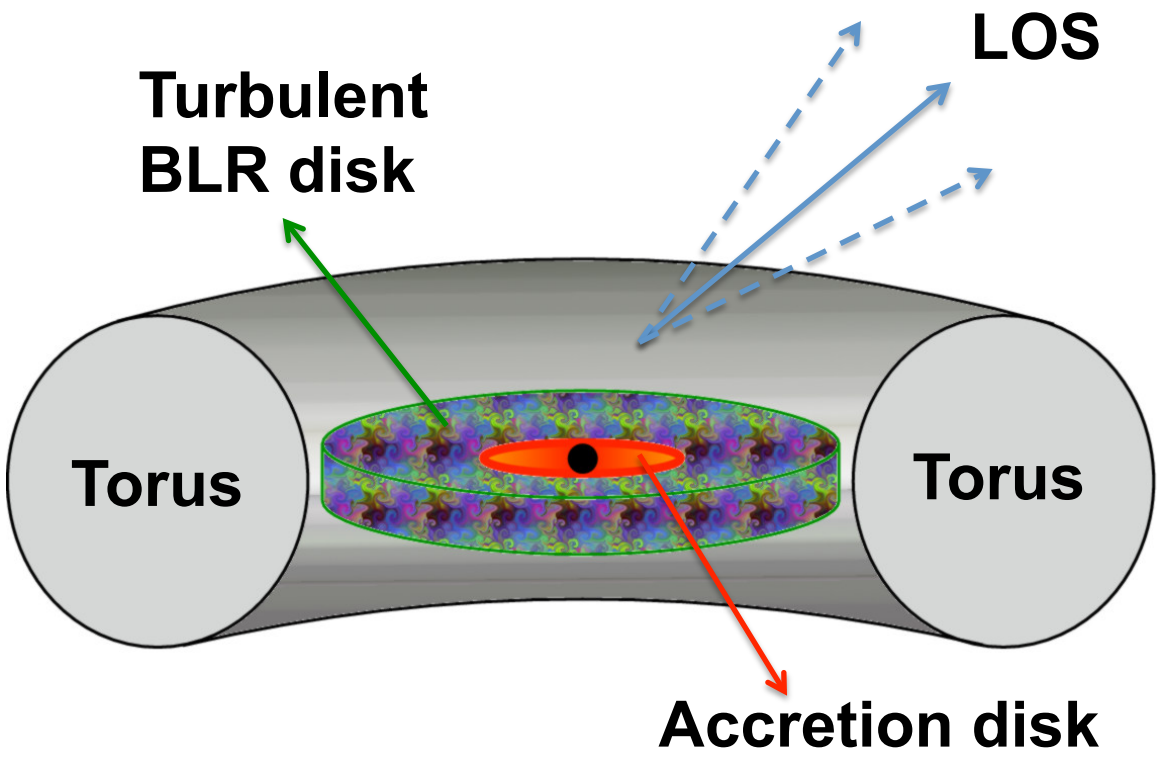


Torus emission along EV1

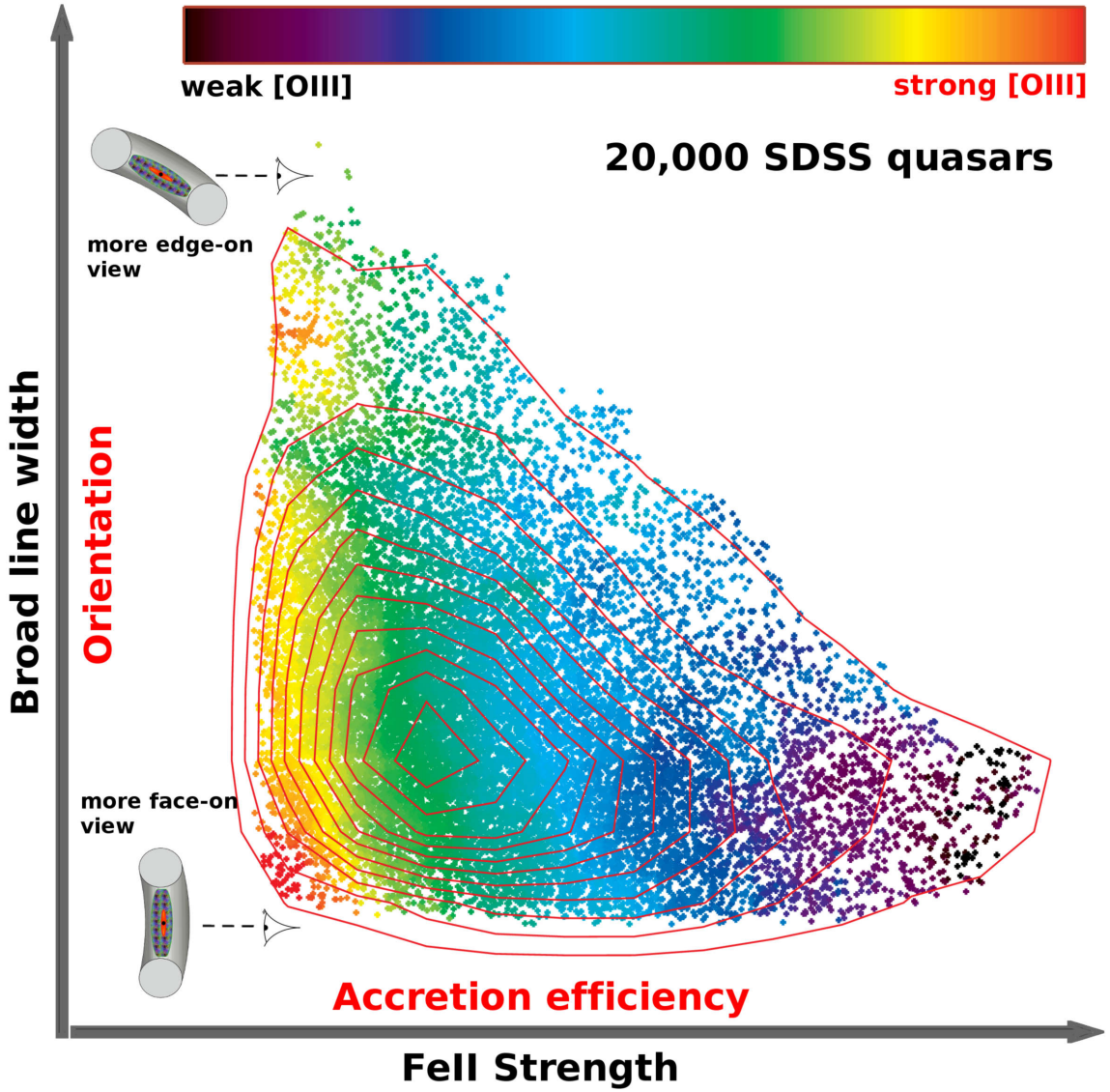



Γ_X
1.6
1.8
2.0
2.2
2.4
2.6
2.8
CSC▲XMM
FWHM$_{H\beta}$ [km s^{-1}]
10000
5000
0
0
1
2
3
R_{FeII}

Dissecting the $FWHM_{Hb}$ – R(Fe) plane

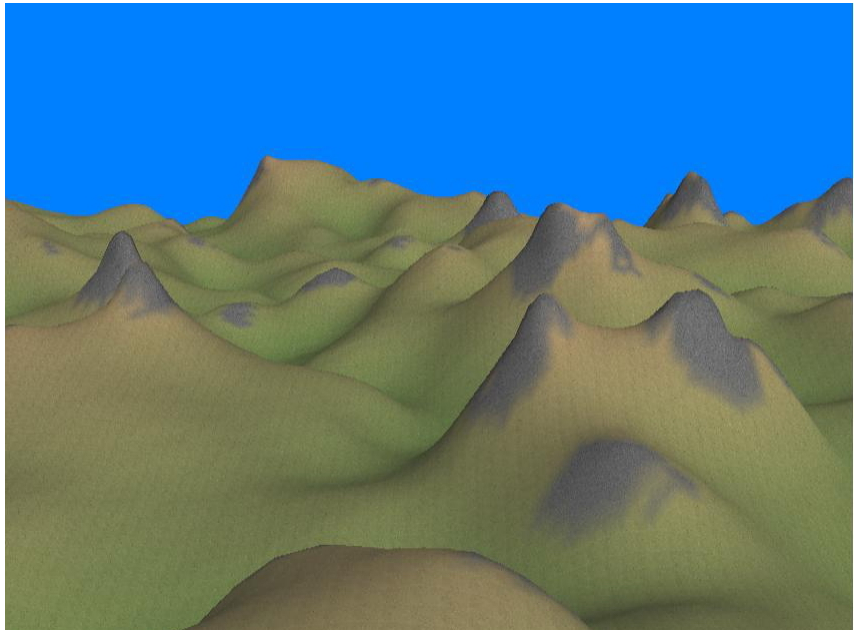


Dissecting the $FWHM_{Hb}$ – R(Fe) plane

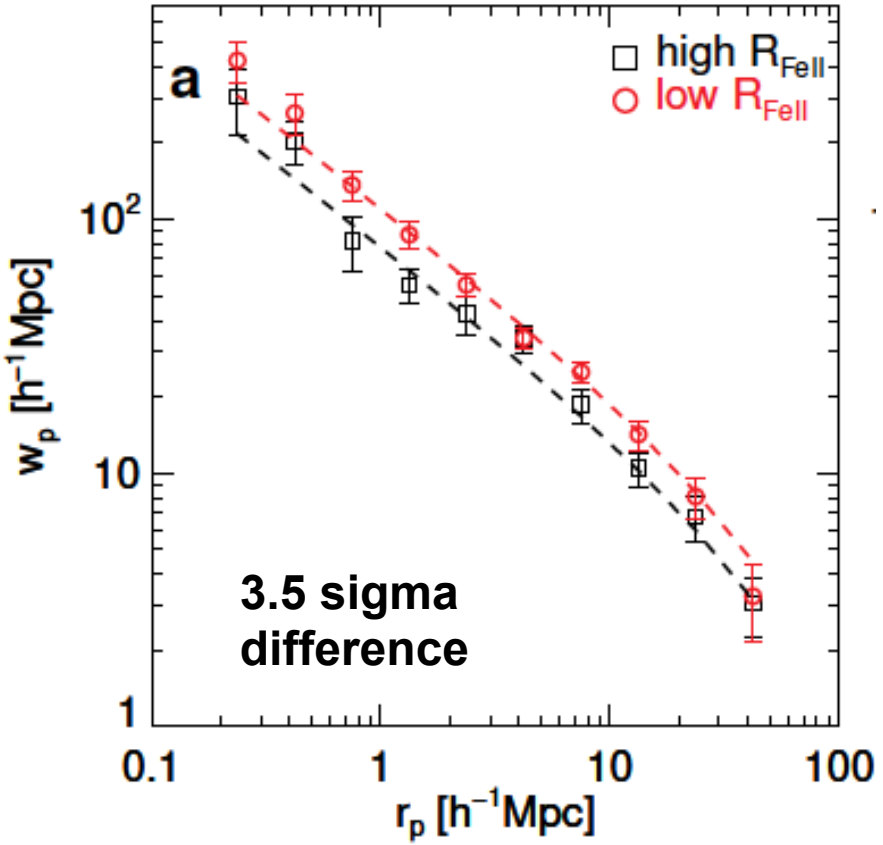


FeII strength (Rfe) correlates with Eddington ratio

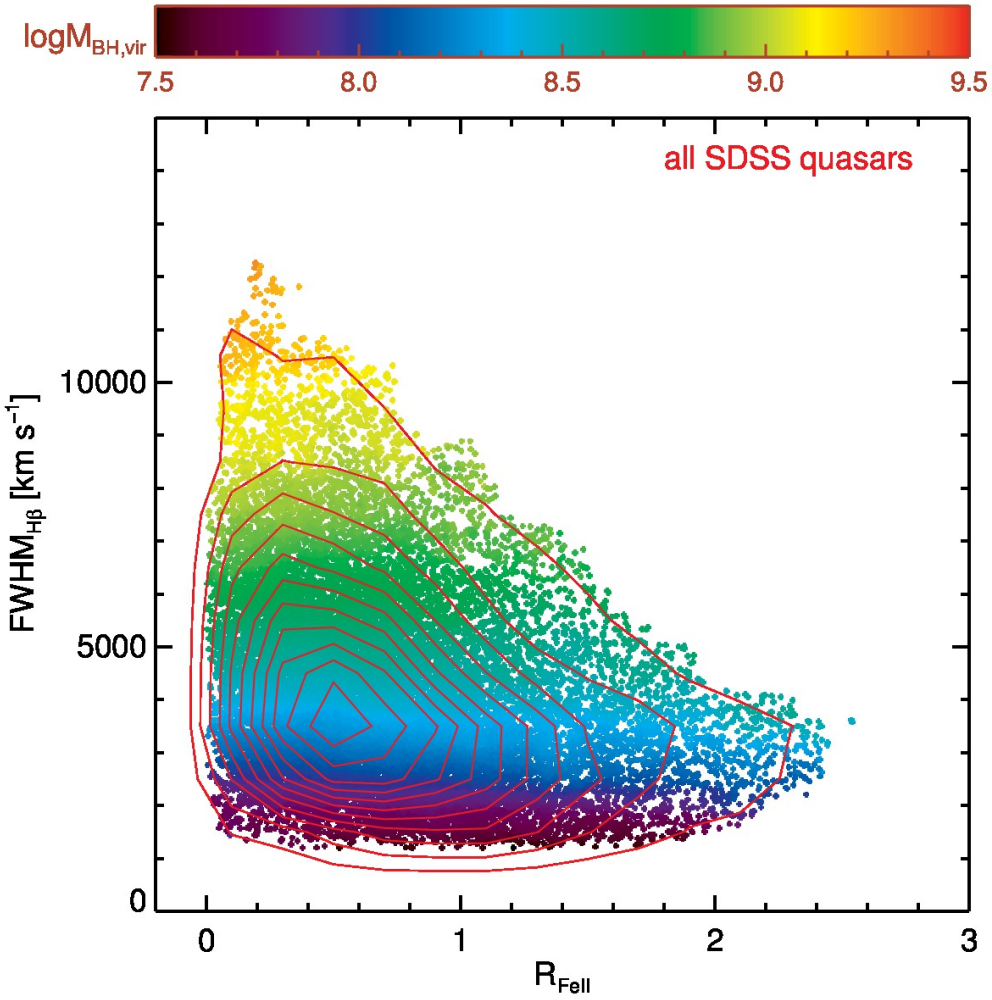
- Test using quasar clustering (SDSS quasars roughly have the same luminosity)

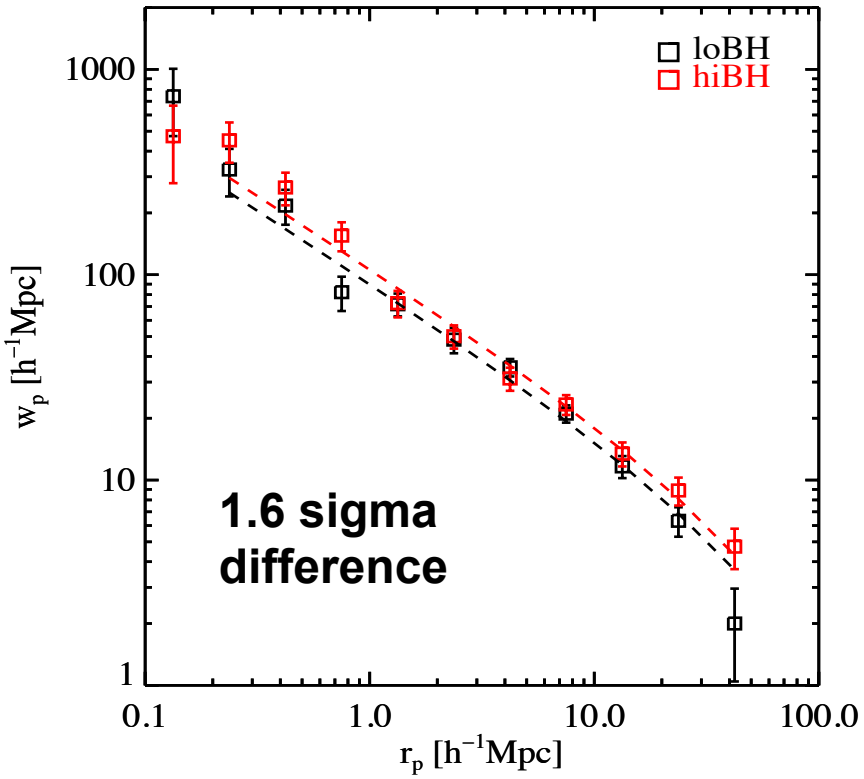


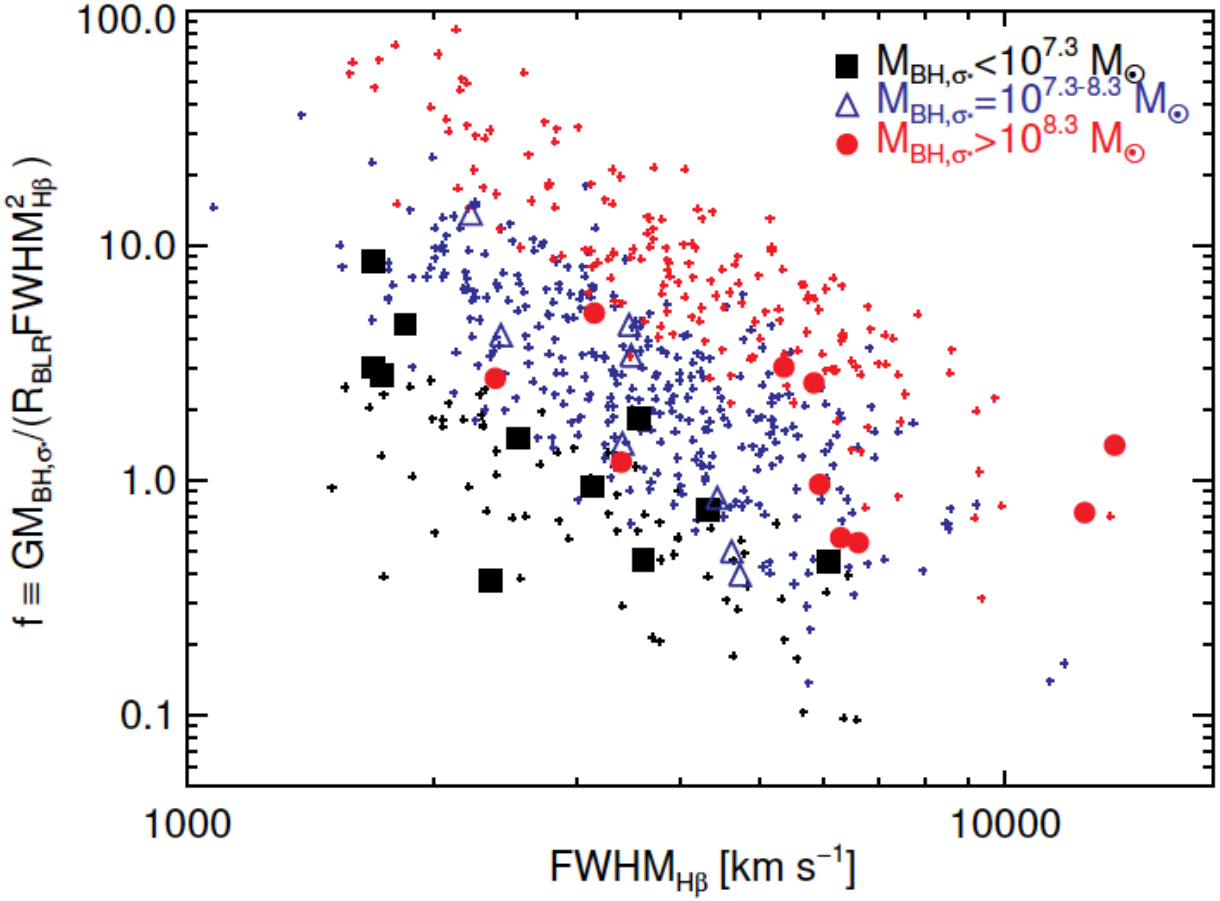
Peaks in a Gaussian random density field



Orientation induces FWHM dispersion





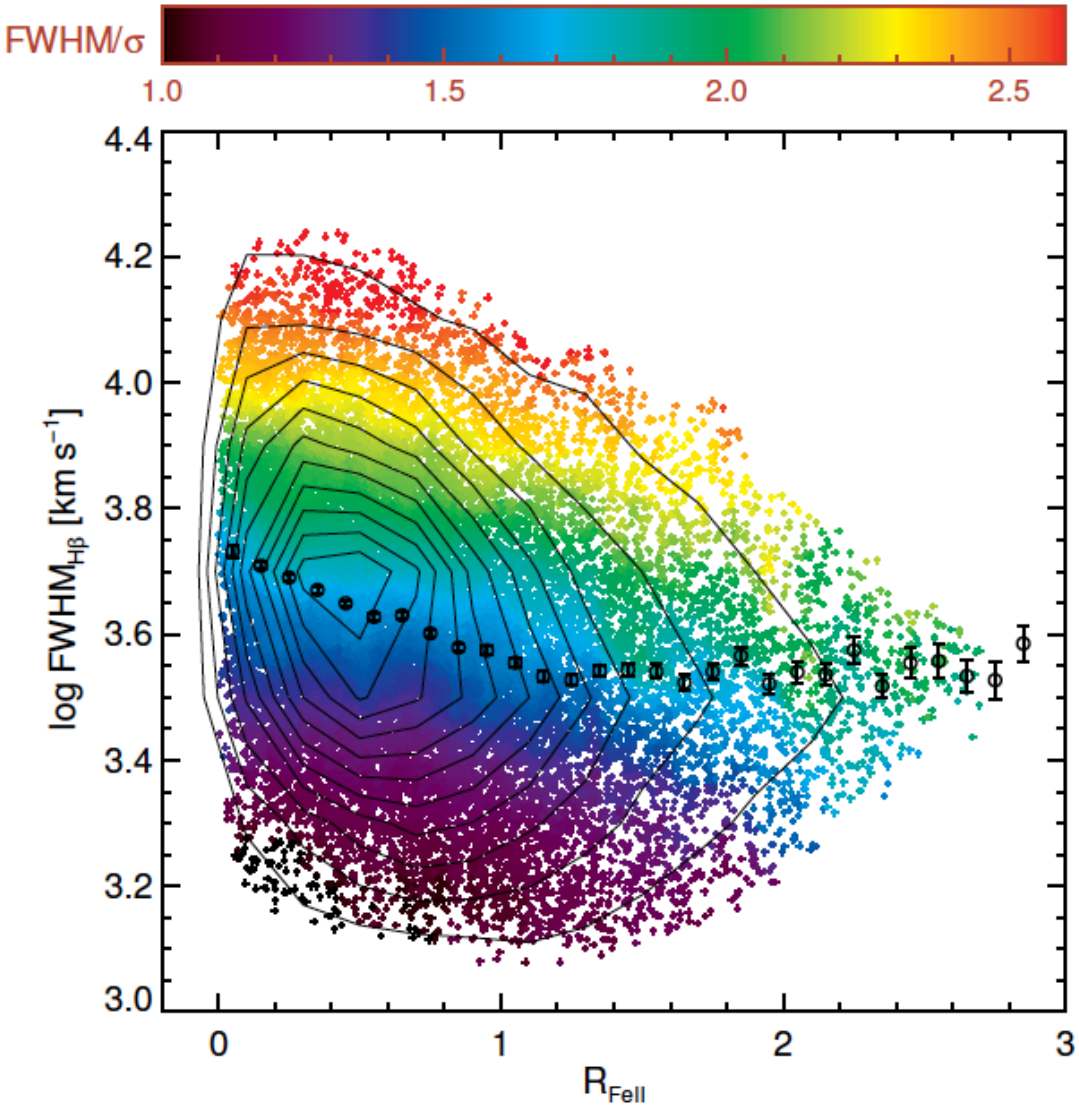


Large symbols: the local RM AGN sample

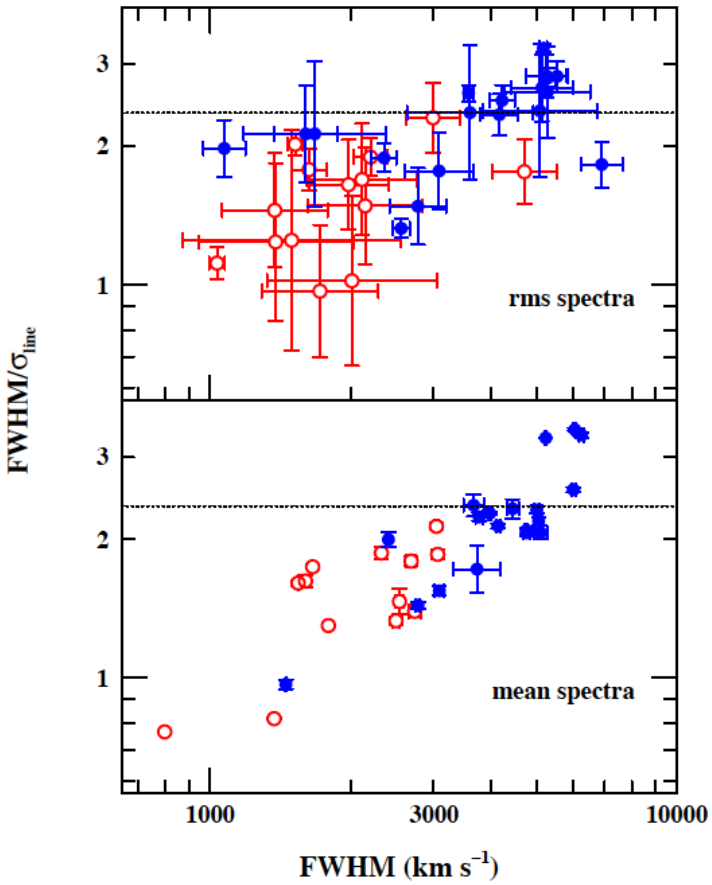
Small symbols: low-z SDSS AGN from Shen et al. (2008)

Independent BH mass estimates from the M-sigma relation

$$f \equiv GM_{\rm BH}/(R_{\rm BLR}{\rm FWHM}^2_{{\rm H}\beta})$$



Broad line shape as an indicator for orientation (Brotherton 1996, Collin et al. 2006).



Peterson (2011)

A simple unification scheme for quasar phenomenology

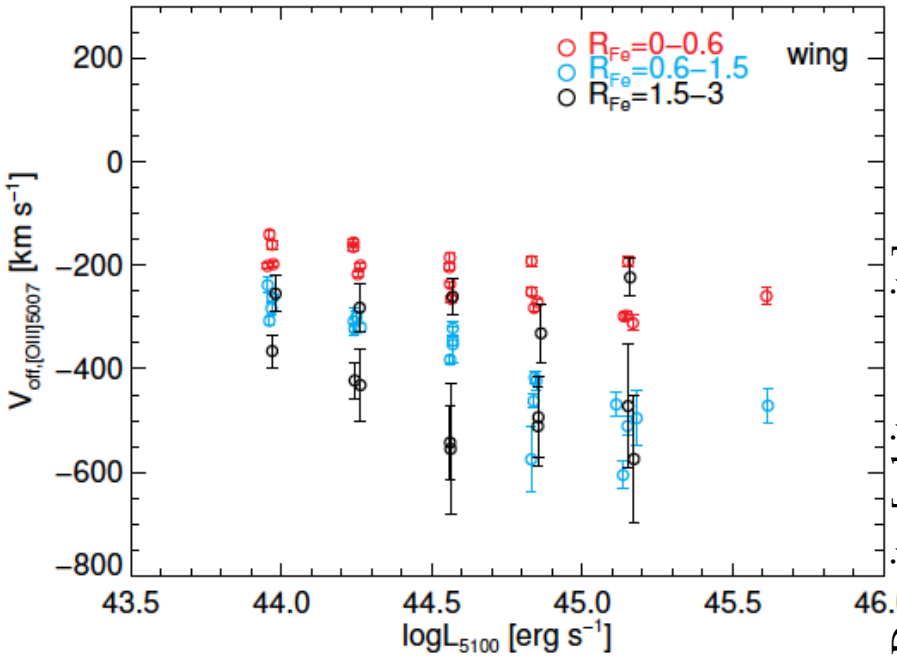
- EV1 is an Eddington ratio sequence, where most quasar properties correlate with optical FeII strength
- Dispersion in FWHM_Hbeta at fixed Rfe largely due to orientation --- a flattened BLR geometry in the general quasar population

Implications: virial BH mass estimates based on FWHM_Hbeta should be treated with caution; a shallower dependence of virial BH mass (with a slope <2) on FWHM expected (Wang et al. 2009, Feng et al. 2014)

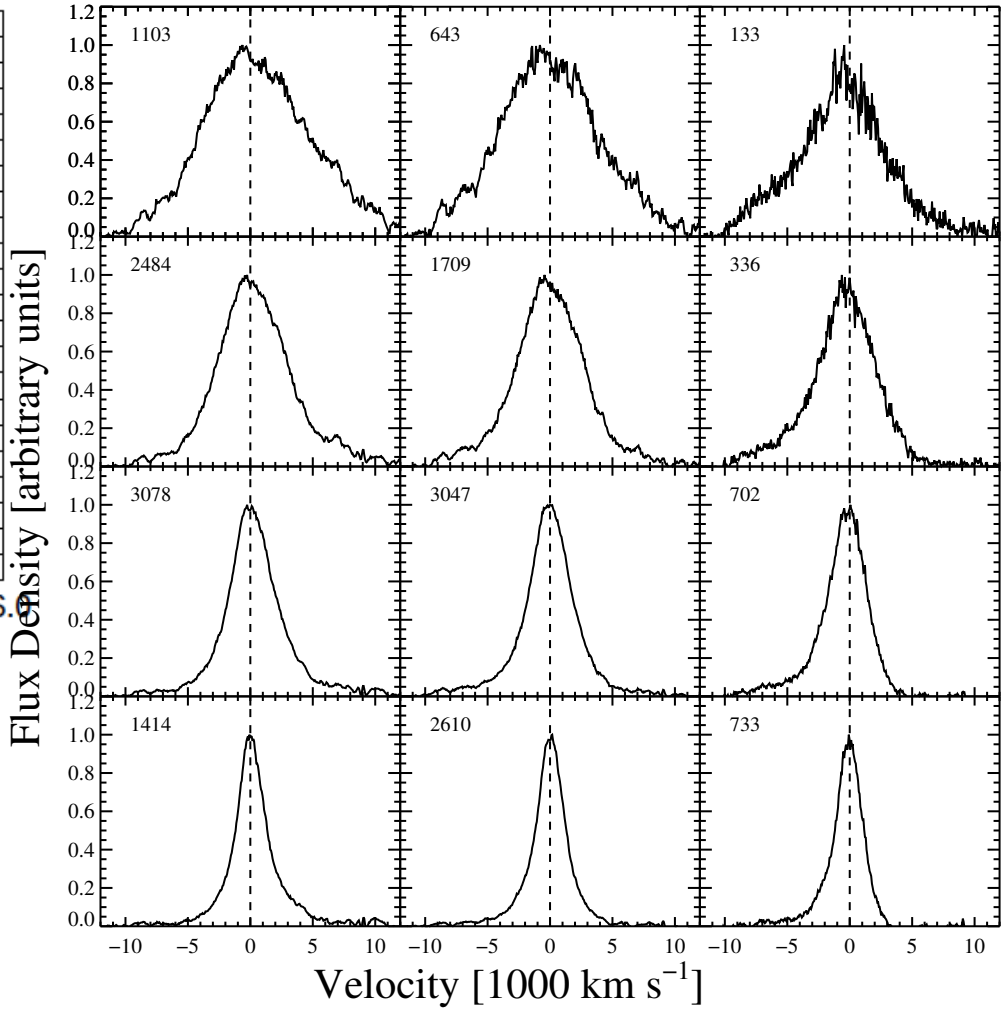
Open questions

- How Eddington ratio changes emission line strengths (in particular FeII), torus emission, and X-ray properties?
  - SED regulates photoionization
  - Changes in accretion flow structure?
- Outflows?
- Nature of the Baldwin effect?
- Fainter AGNs (smaller BHs) will follow similar EV1 trends, but may have offsets in their physical properties

Evidence for outflows?



Narrow [OIII] line blue wing



Broad Hbeta profile in the EV1 plane