THIN DISKS SLIM DISKS AND BLACK HOLE MASS MEASUREMENTS IN ACTIVE GALACTIC NUCLEI

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Various types of AGN accretion disks

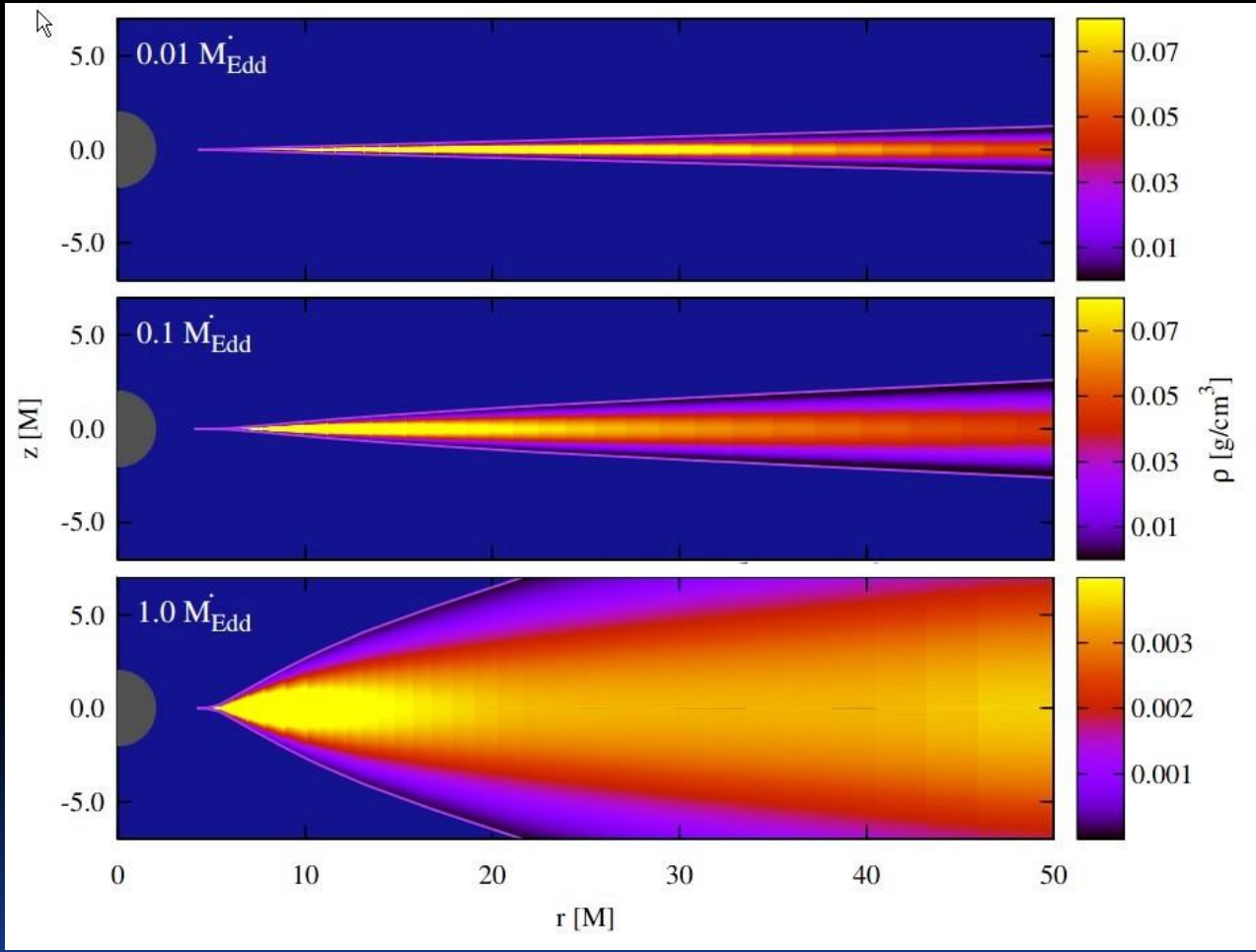
The VLT X-shooter project

Disk SED and BH spin

Line profiles and black hole mass measurements

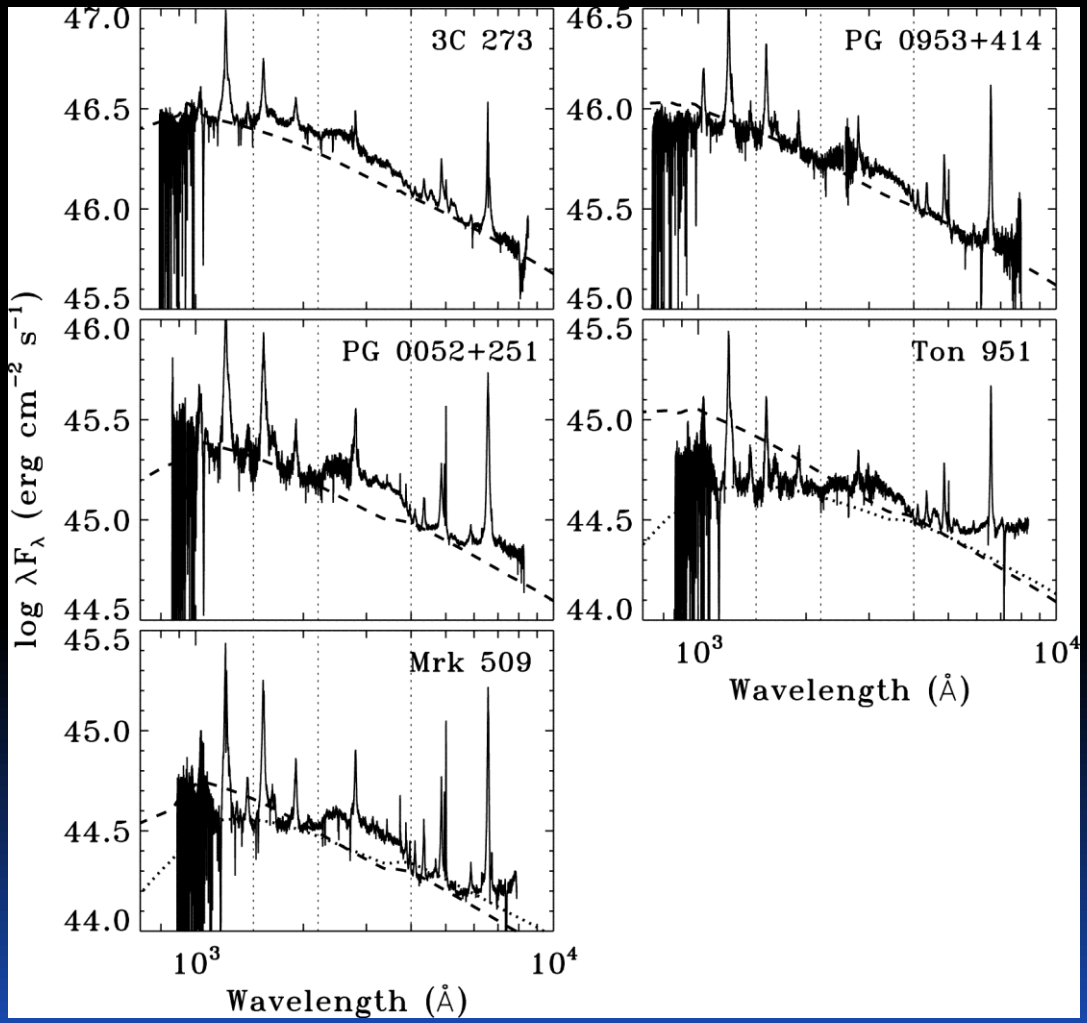
Collaborators:
Dan Capellupo, Paulina Lira, Benny Trakhtenbrot & Julià n Mejìa

Thin and slim accretion disks



Sadowski 2011

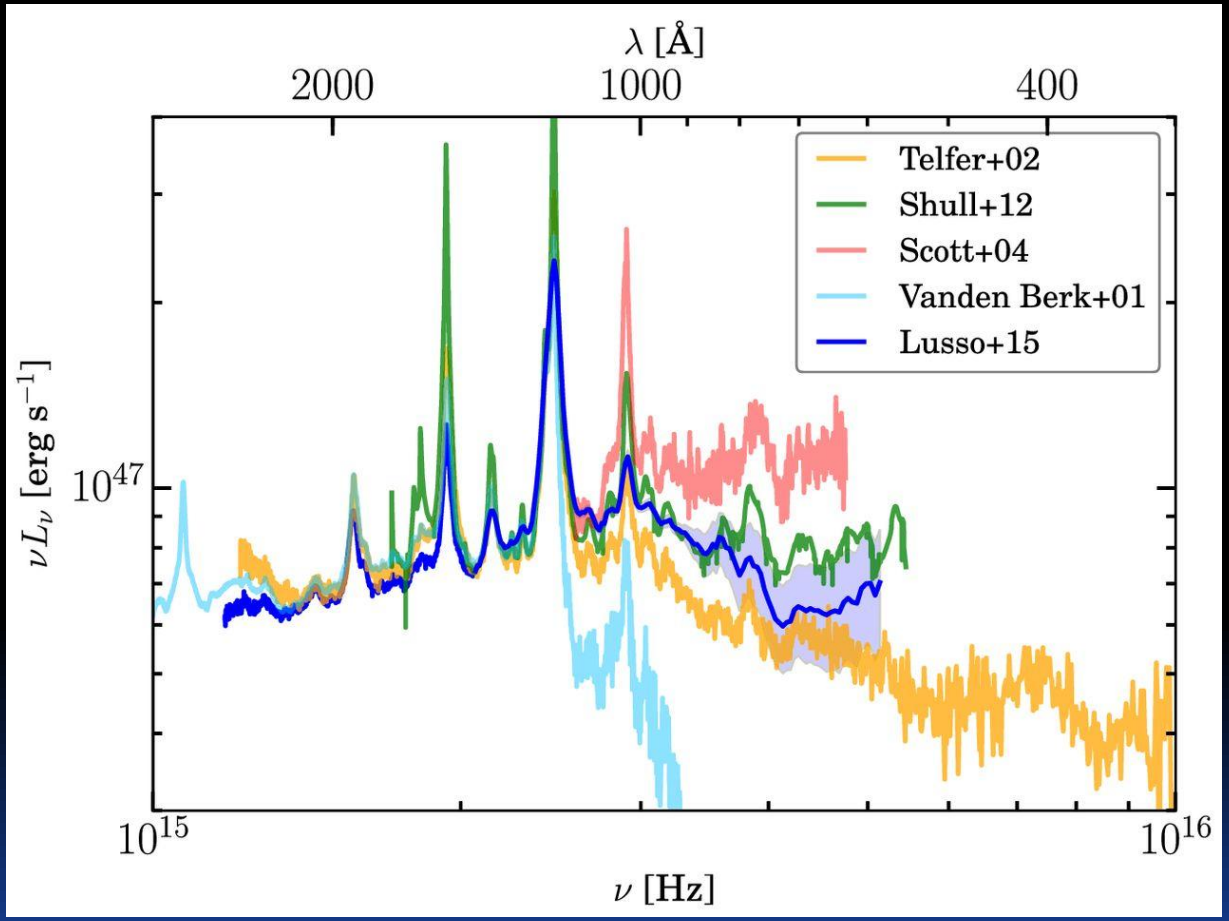
Evidence for thin accretion disks in AGNs



Davis et al. 2007

More comparison with observations – the UV spectrum

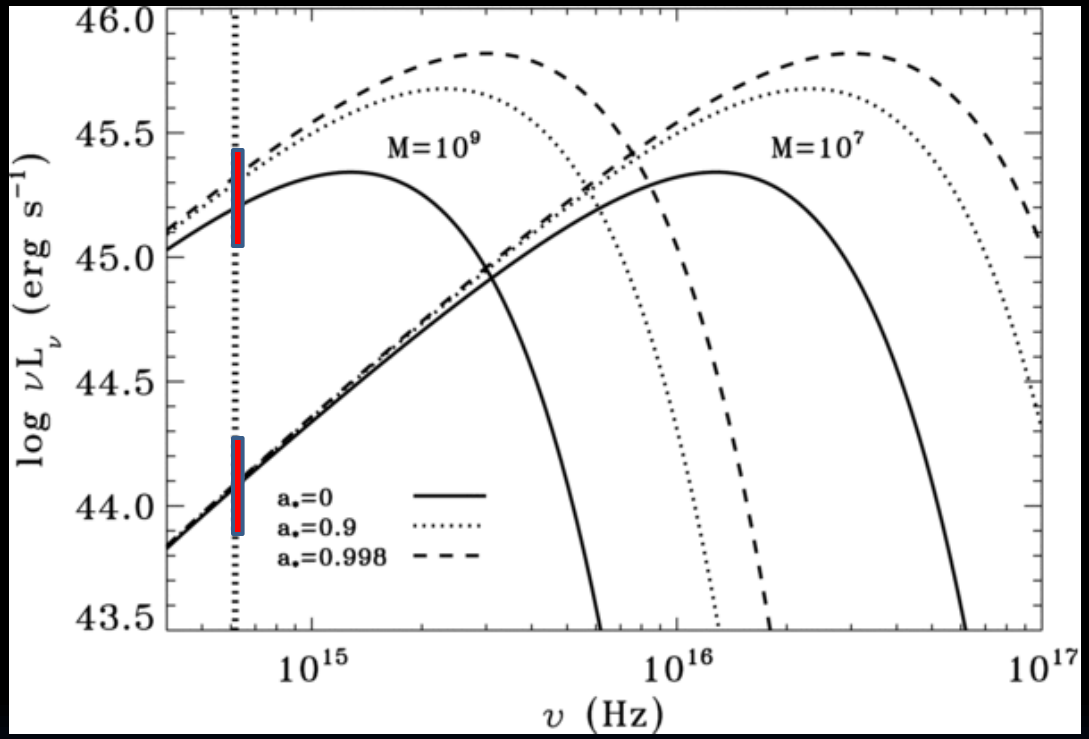
Advance in recent years:
1. Mass measurements
2. Accretion rate measurements
3. Better instrumentation



E. Lusso et al. MNRAS 2015;449:4204-4220

Measuring accretion rates

Collin 2002
Davis & Laor 2011



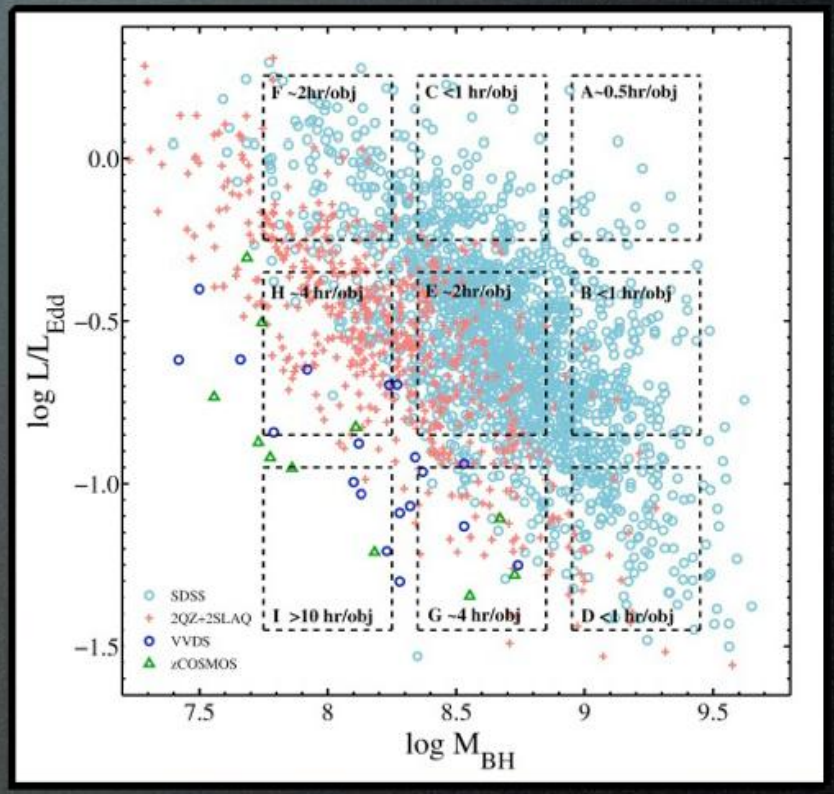
$$4\pi D_L^2 F_\nu = f(\theta)[M_8 \dot{M}_\odot]^{2/3} \left[\frac{\lambda}{5100\text{Å}}\right]^{-1/3}$$

$$f(\theta) = \frac{f_0 F_\nu}{F_\nu(\,face-on)} = f_0 \frac{\cos\theta(1+b(\nu)\cos\theta)}{1+b(\nu)}$$

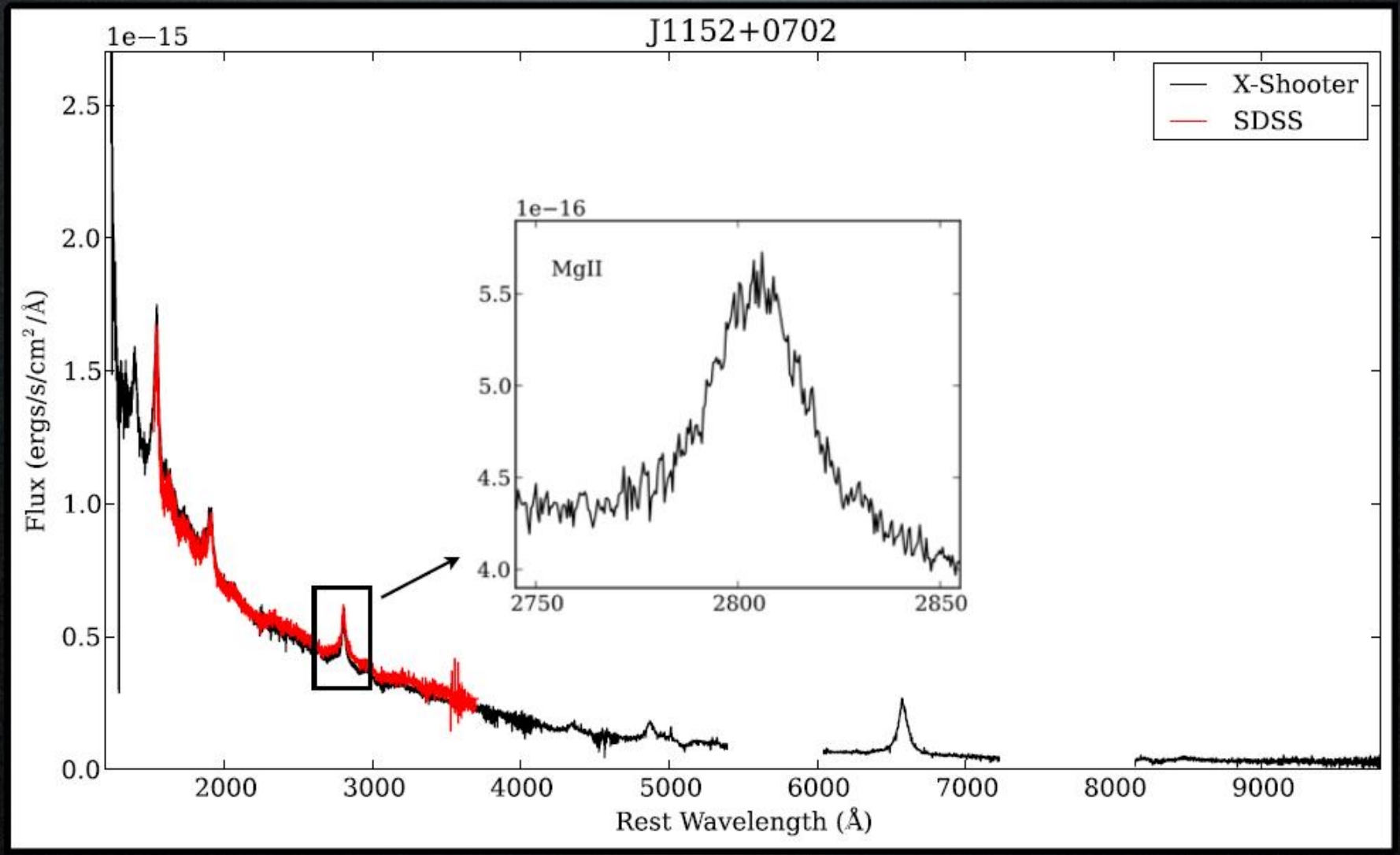
The z=1.55 Xshooter sample

(taken from Dan Capellupo recent talk)

- Three main science goals:
  1. Origin of the AGN SED
  2. BELR Physics
     - Dependence of BEL line profile/widths/ intensity on M_{BH} and L/L_{edd}
  3. Comparison of M_{BH} Estimates (Hβ, Hα, MgII, CIV)

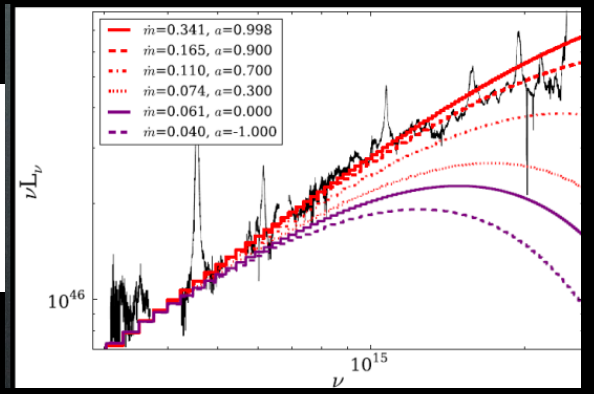


Example Spectrum

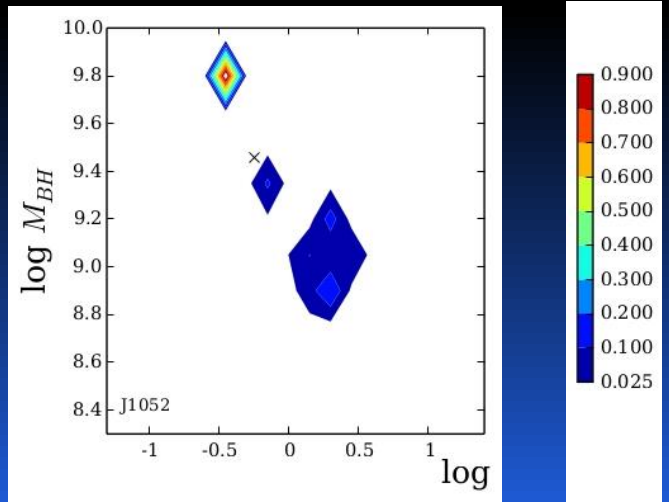


Measuring black hole spin
Bayesian analysis

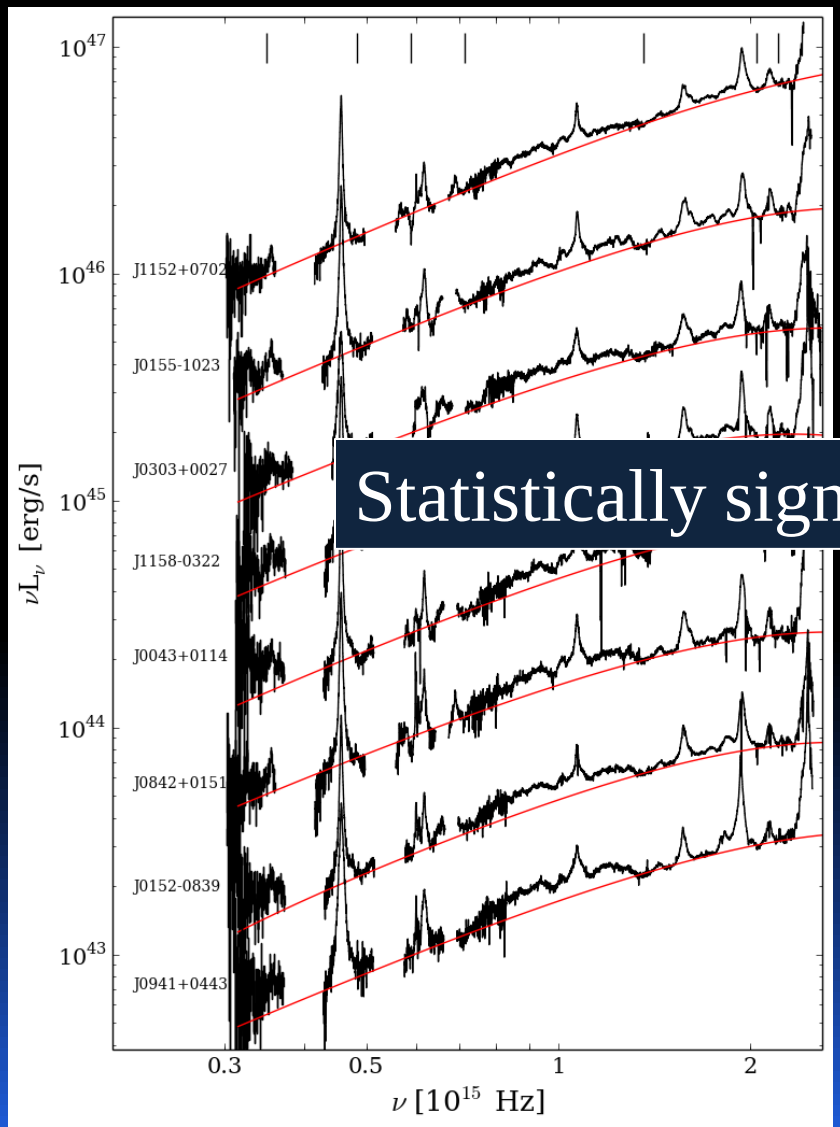
$$4\pi D_L^2 F_\nu = f(\theta)[M_8 \dot{M}_\odot]^{2/3} \left[\frac{\lambda}{5100\text{Å}}\right]^{-1/3}$$

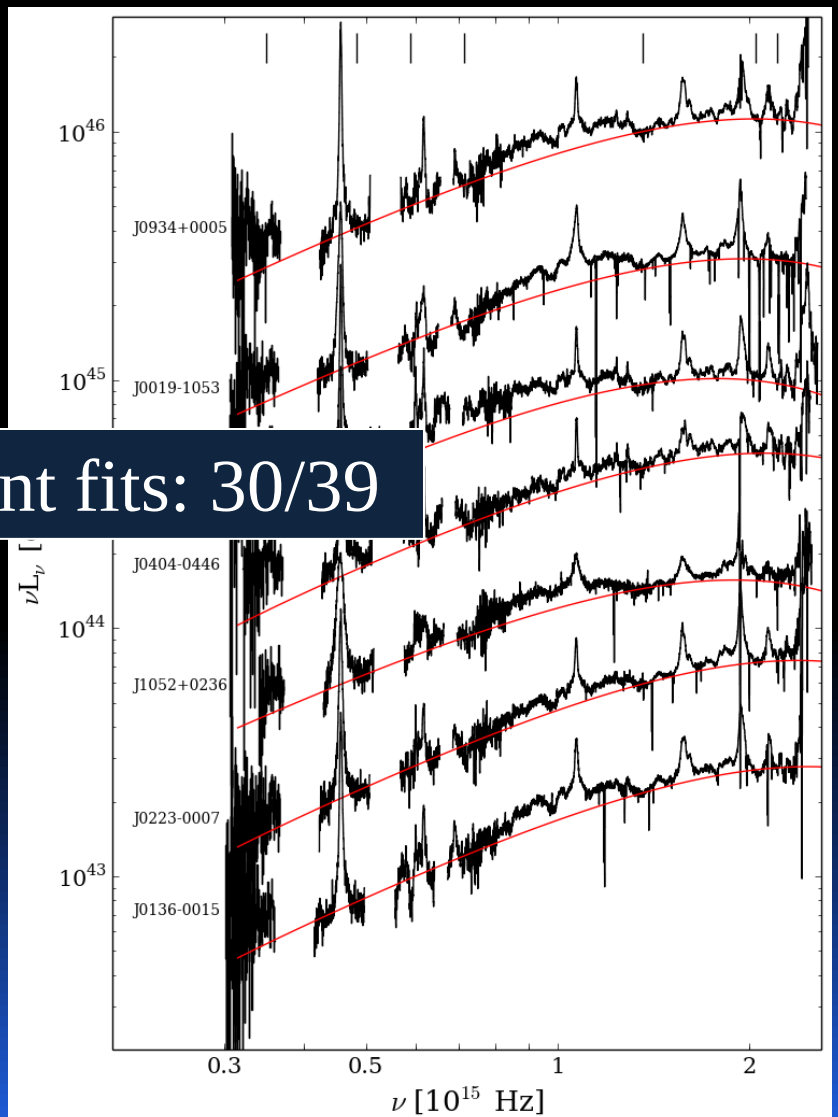


$$\text{posterior pbb} = \underbrace{\exp(-\chi^2/2)}_{\text{likelihood pbb}} \times \underbrace{\exp(-(M_{BH}^{obs} - M_{BH}^{model})^2/2\sigma_M^2) \times \exp(-(\dot{M}^{obs} - \dot{M}^{model})^2/2\sigma_{\dot{M}}^2)}_{\text{prior pbb}}$$



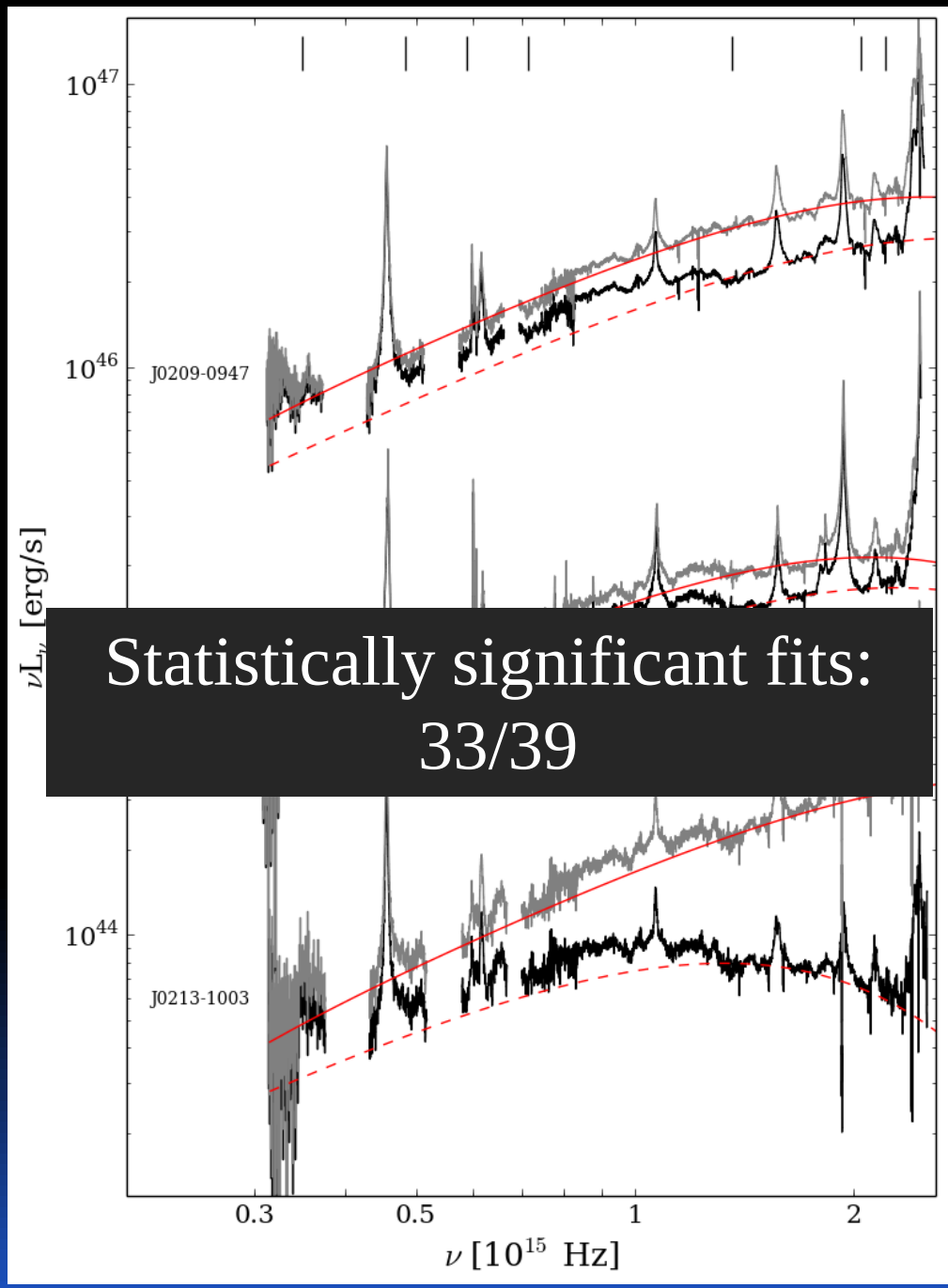
Fitting accretion disk models
Capellupo et al 2015





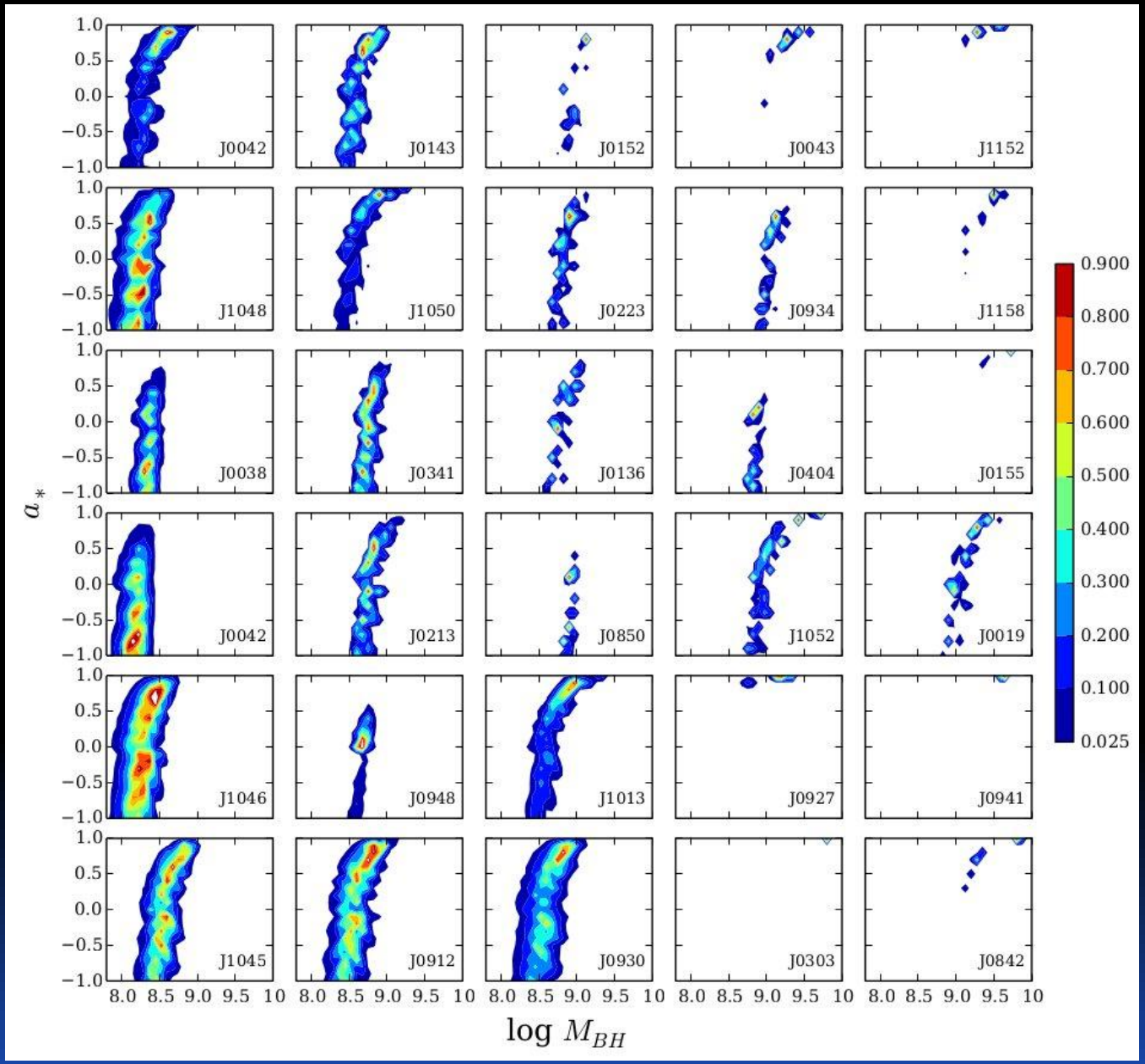
Statistically significant fits: 30/39

Intrinsic reddening



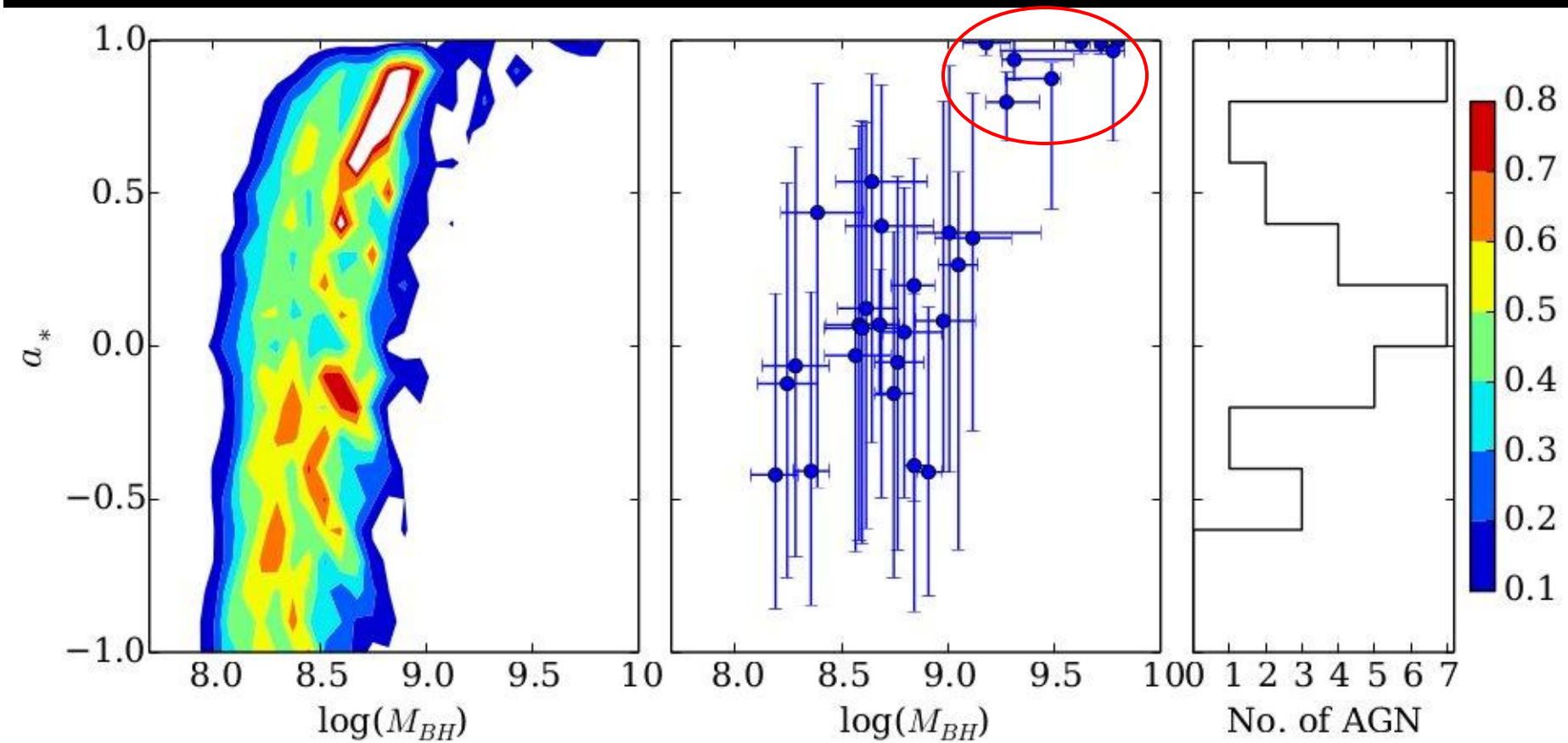
Statistically significant fits: 33/39

L/L_{Edd}= 0.01 – 0.4

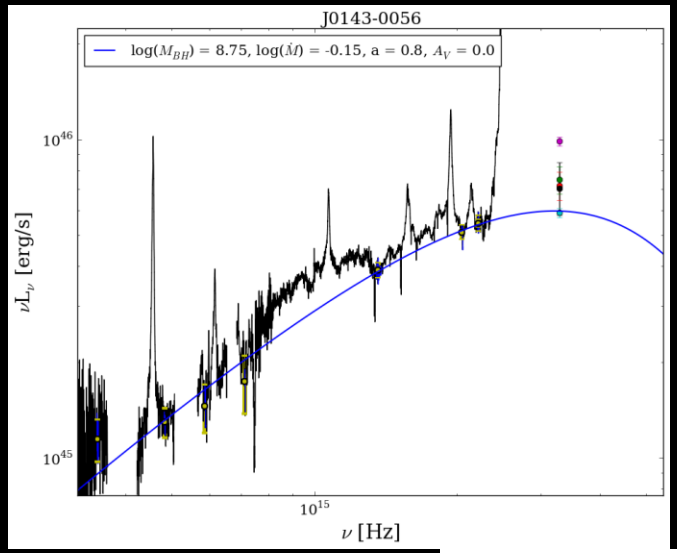


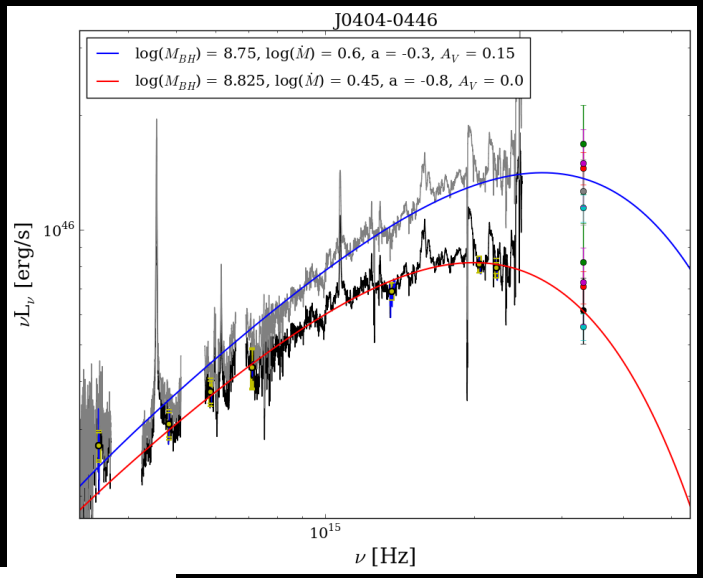
Log M=8.1-9.6

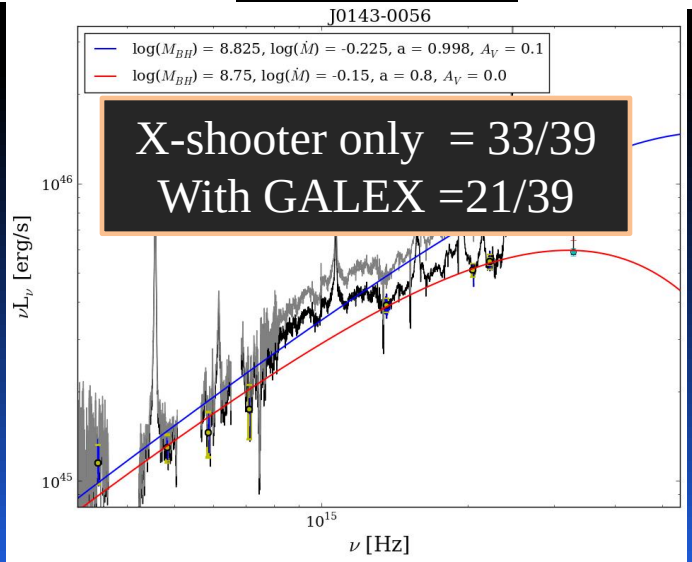
Population properties
Spin up spin down or selection effects?



Adding GALEX data







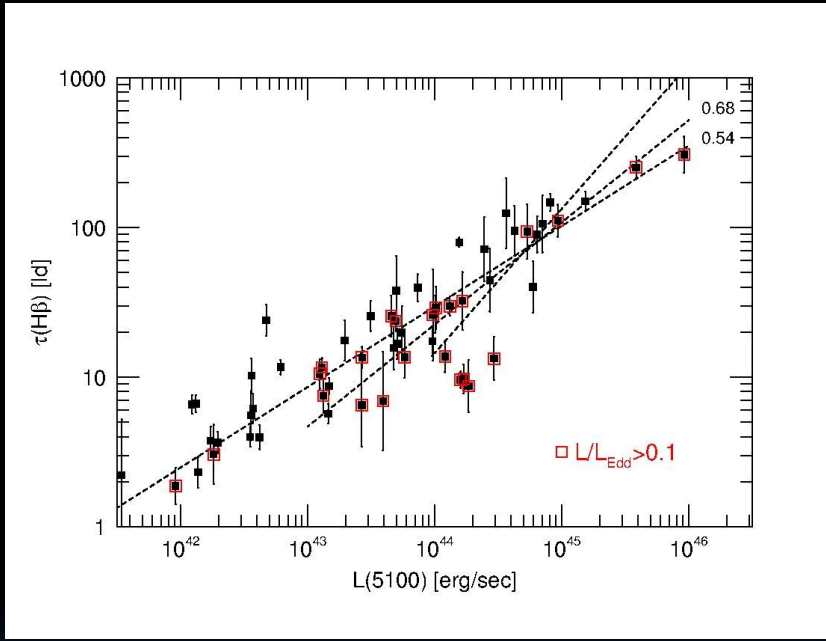
Emission line profiles (Julièn Mejìa et al):

Reverberation mapping

BLR size and BH mass estimates

Du et al 2015

Collaborators:
JM Wang, Hagai Netzer, Shai Kaspi, Pu Du, Hu Chen, Luis Ho, JM Bai

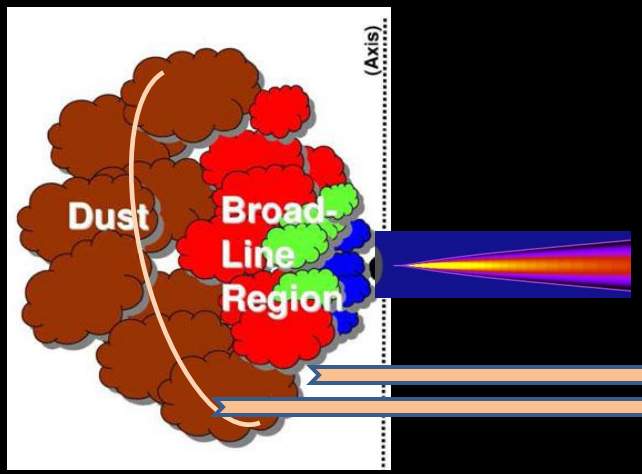


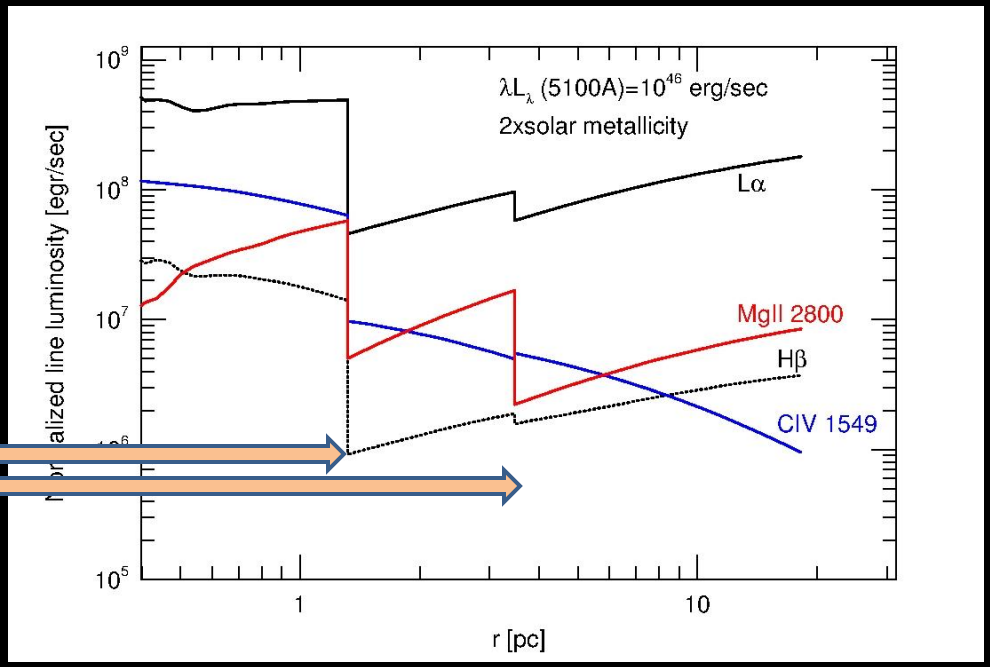
What lines are the most reliable BH mass indicators?

$$R_{BLR} = \alpha L^{\beta} \qquad (\beta = 0.6 \pm 0.1)$$

$$M_{BH} = f \frac{R_{BLR}(line) FHHM(line)^2}{G}$$

BLR size: Emissivity weighted radius

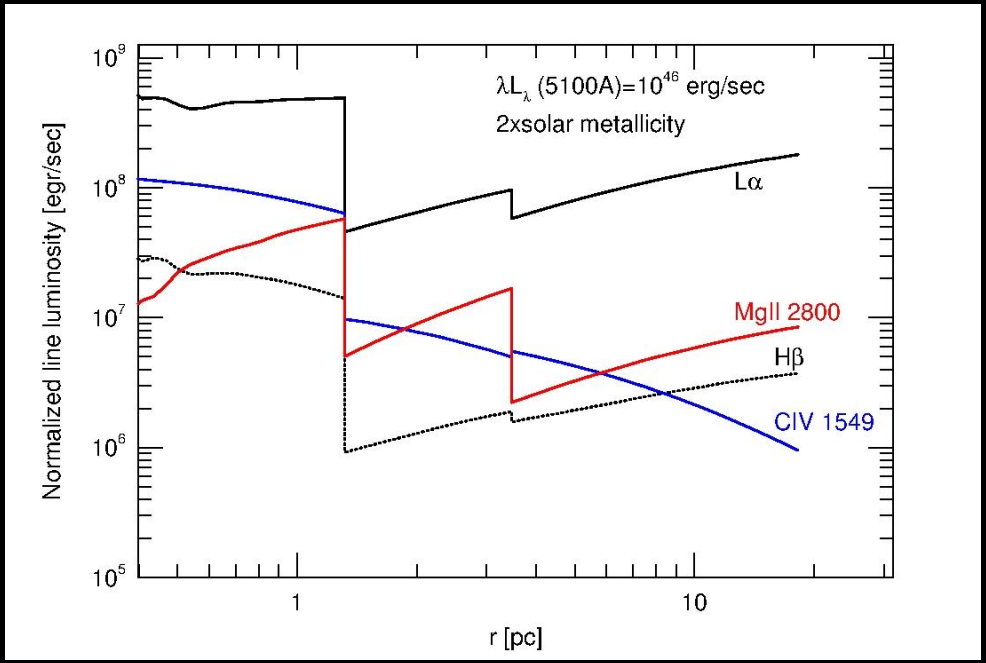




The "Virial Product"
R_{BLR} (line)xFWHM(line)^2
is the same for all lines

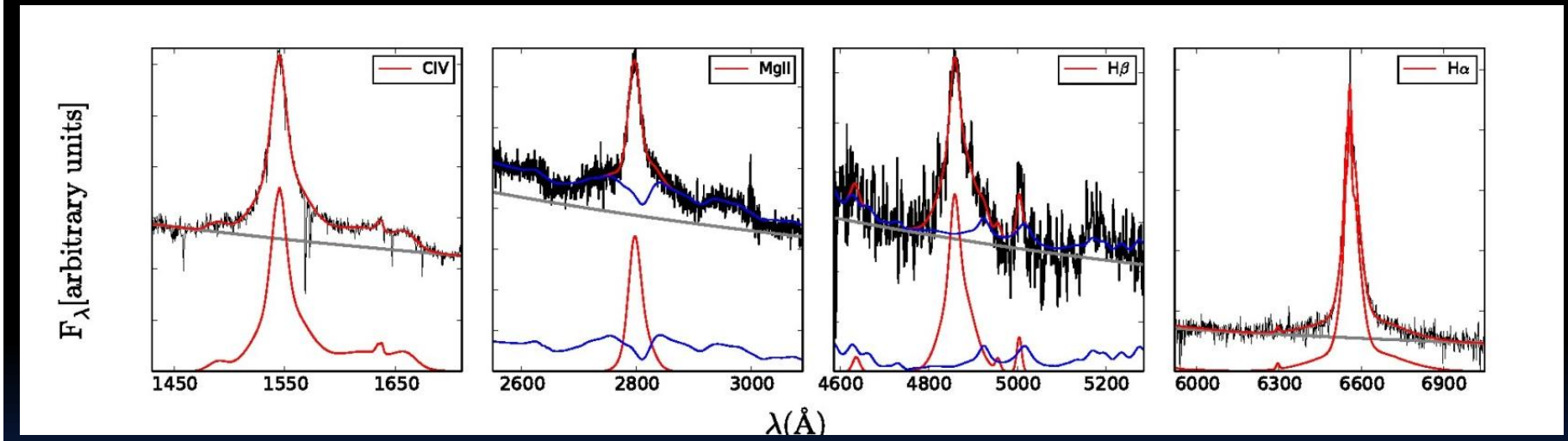
$R_{BLR}(H\beta)=3.6\ R_{BLR}(CIV\ 1549)$ => $FWHM(CIV1549)=1.9\ FWHM(H\beta)$
$R_{BLR}(H\beta)=0.3R_{torus}$(graphite grains)

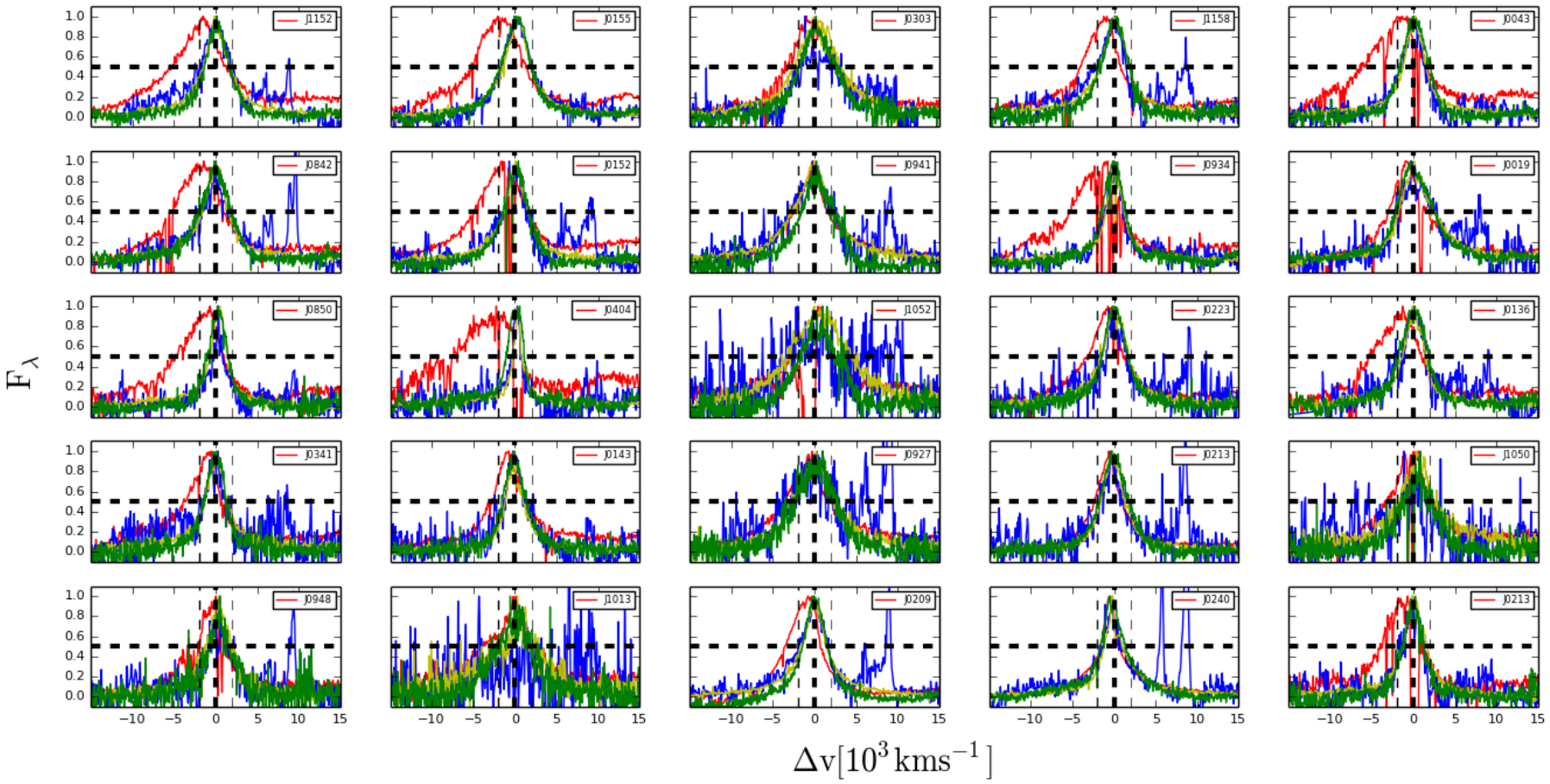
BLR size:
Emissivity weighted radius

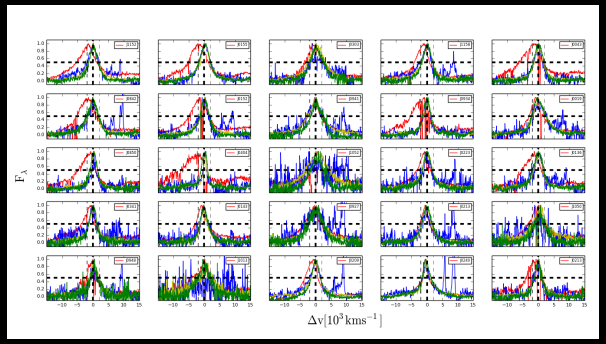


In this model
R(CIV)=0.5R(H β)
R(MgII)=2.0R(H β)

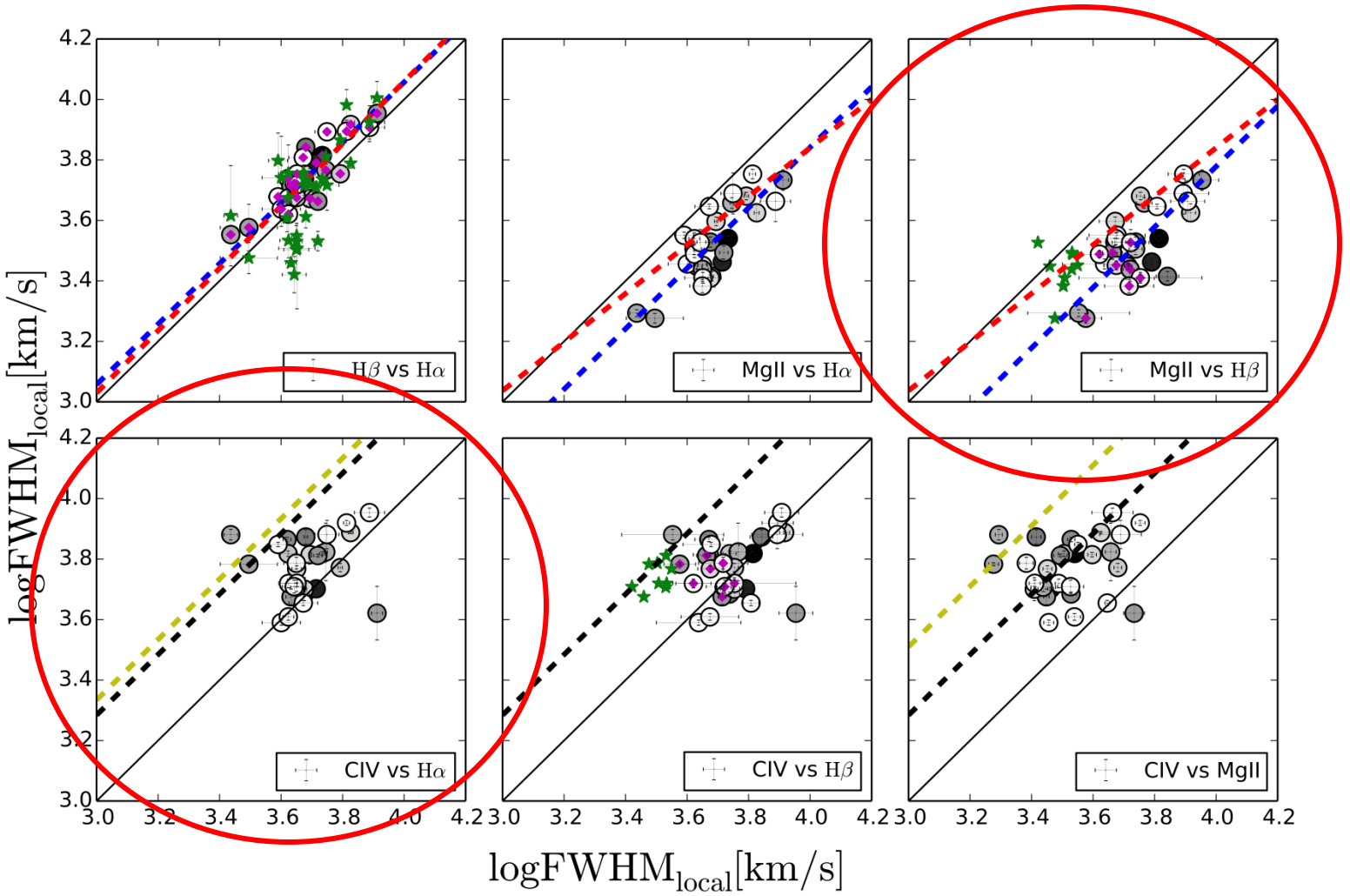
Local (powerlaw) and global (disk) SED




J1152
J0155
J0303
J1158
J0043
J0842
J0152
J0941
J0934
J0019
J0850
J0404
J1052
J0223
J0136
J0341
J0143
J0927
J0213
J1050
J0948
J1013
J0209
J0240
J0213
F_λ
$\Delta v[10^3\,\mathrm{kms}^{-1}]$



- FWHM(Hα)=FWHM(Hβ)
- FWHM(MgII 2798)=0.63 FWHM(Hβ) =>
  - R(MgII 2798)=2.5R(Hβ) (what about FeII?)
- FWHM(CIV 1549)<1.9 FWHM(Hβ) and line is blue-shifted
  - Contradiction with the virial assumption and with the RM measured size
  - Mass correction factors based on CIII]/CIV improve the situation


Hβ vs Hα
MgII vs Hα
MgII vs Hβ
CIV vs Hα
CIV vs Hβ
CIV vs MgII
logFWHM_local[km/s]
logFWHM_local[km/s]
3.0
3.2
3.4
3.6
3.8
4.0
4.2

Conclusions:

- High quality spectra of z=1.55 AGNs selected by their mass and accretion rate show that:
  - 77% of the sources are fitted well with thin disk SEDs
  - Additional 10% consistent with thin disk SEDs after correcting for intrinsic reddening and/or disk winds.
  - BH spin can be measured, reliably, in most of the sources
- All three lines, Hα, Hβ and MgII 2798 can be used to obtain reliable M(BH) but CIV1549 is not (although correction factors can be used)
- Based on FWHM(MgII 2798), the emission region of this line is close to the inner torus wall.