A Catalogue of AGN In the XMM Archive (CAIXA)

Excess variances in AGN

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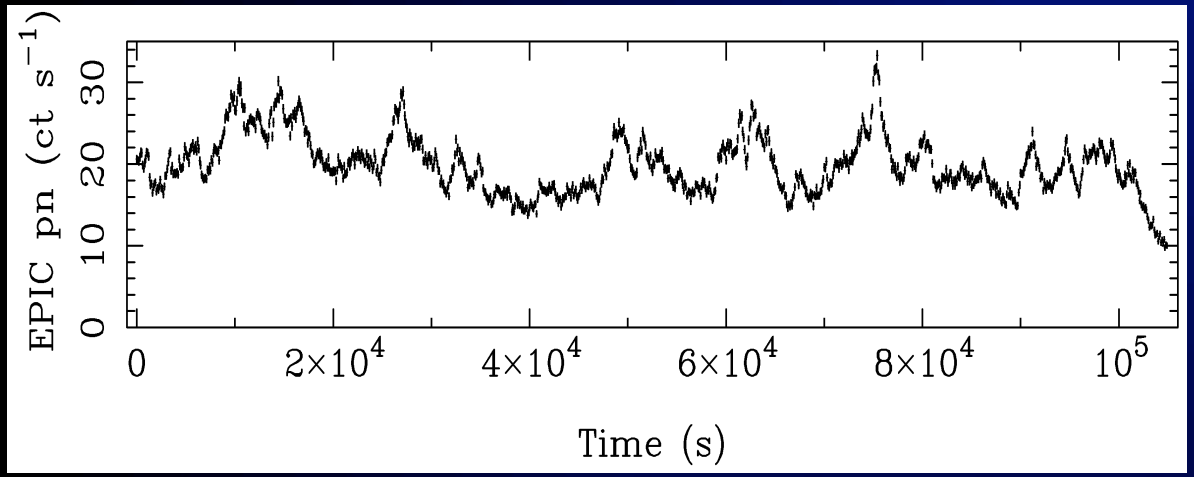
Are AGN variable in X-rays on days timescale?

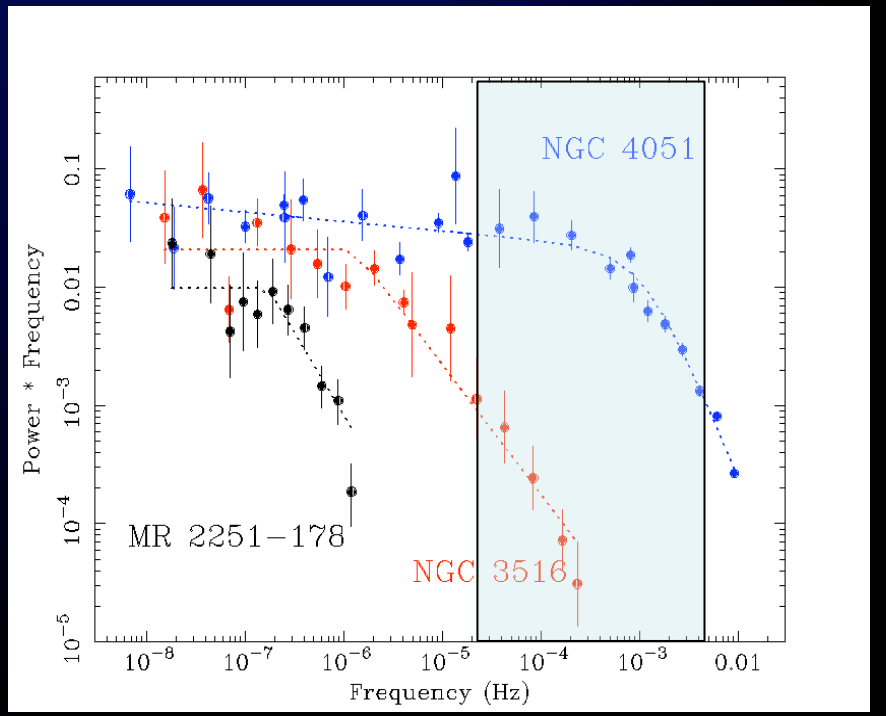
MRK 766: log(M_{BH})=6.25

Vaughan Fabian 03



Fourier transform: probably the most powerful variability analysis technique

➔ Power Spectral Density (PSD)



Uttley +05

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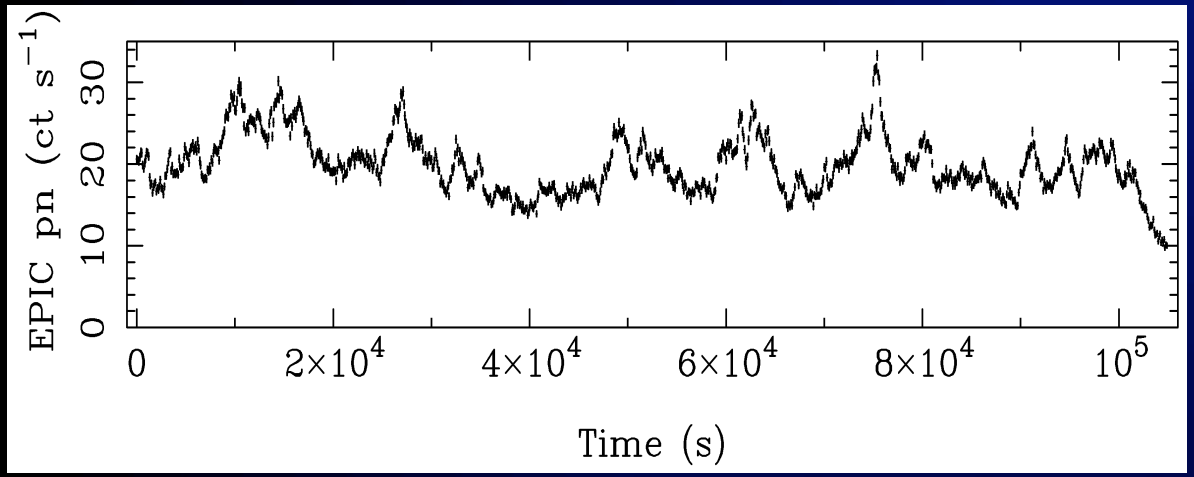
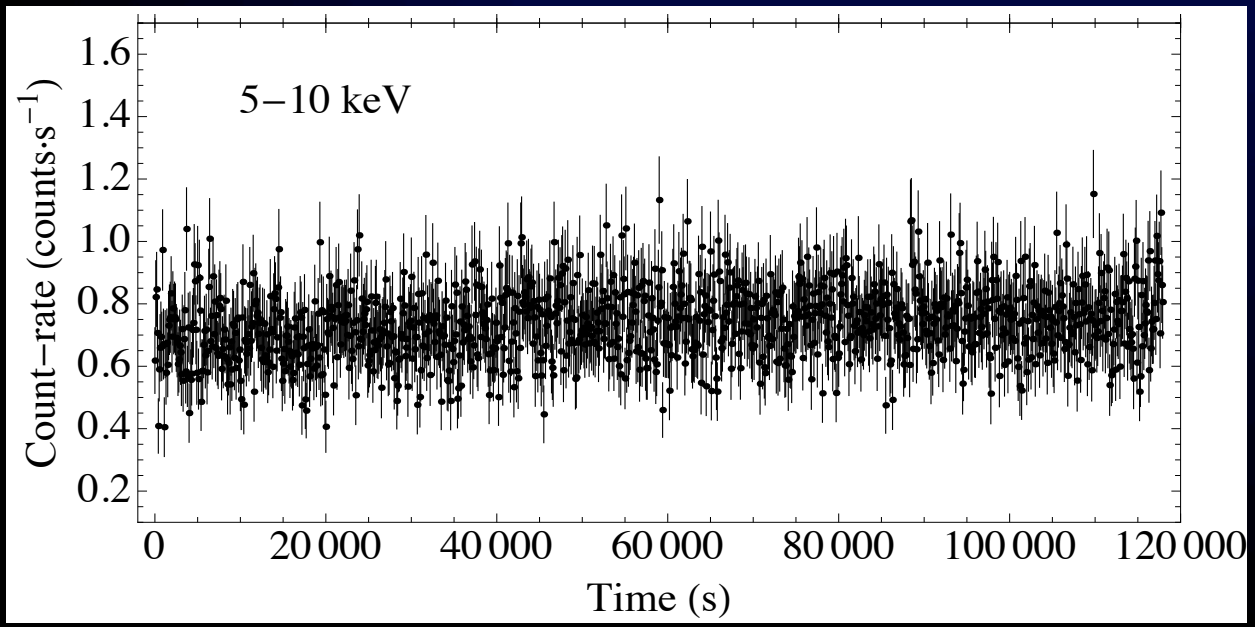


Fairall 9: log(M_{BH})=8.4

Emmanoulopoulos +11



PSD study in high mass AGN on days timescale:
➔ impossible!

1) Long monitoring
➔ only for few sources

2) Different technique
➔ excess variance

Are AGN variable in X-rays on days timescale?

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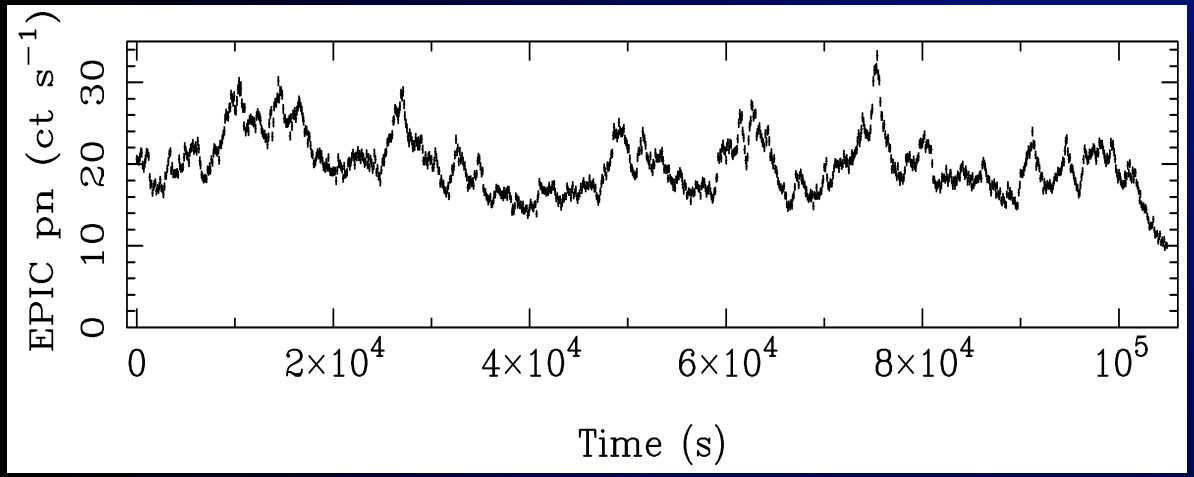

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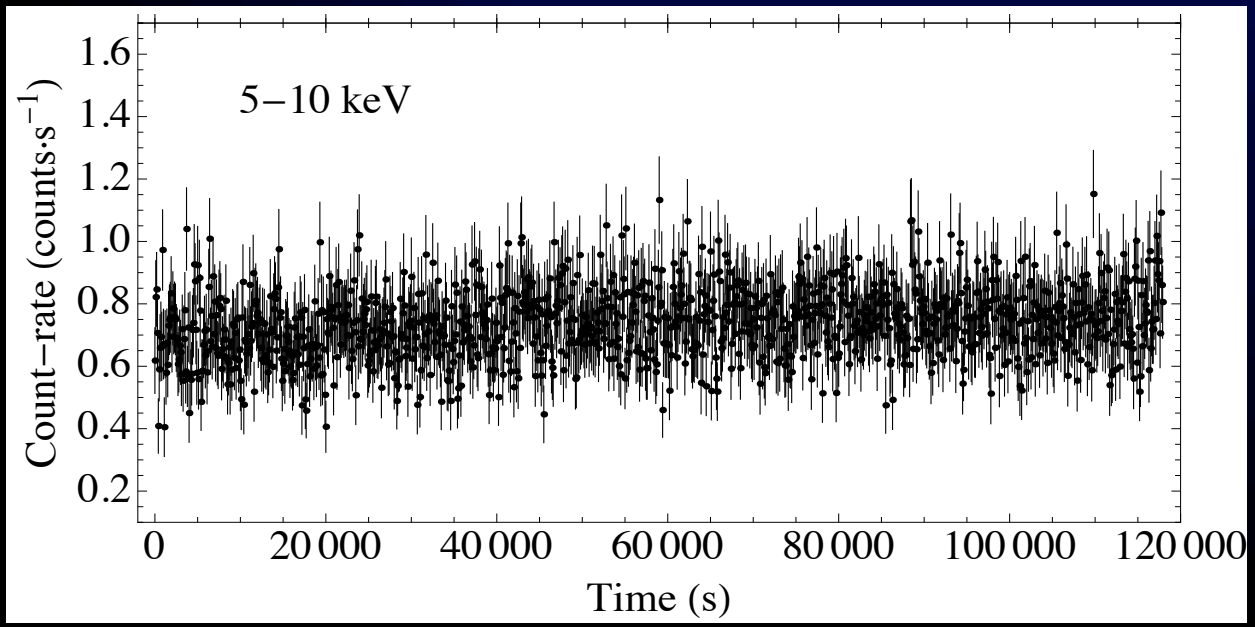


PSD study in high mass AGN on days timescale:
➔ impossible!

1) Long monitoring
➔ only for few sources

2) Different technique
➔ excess variance
➔ Not data demanding!

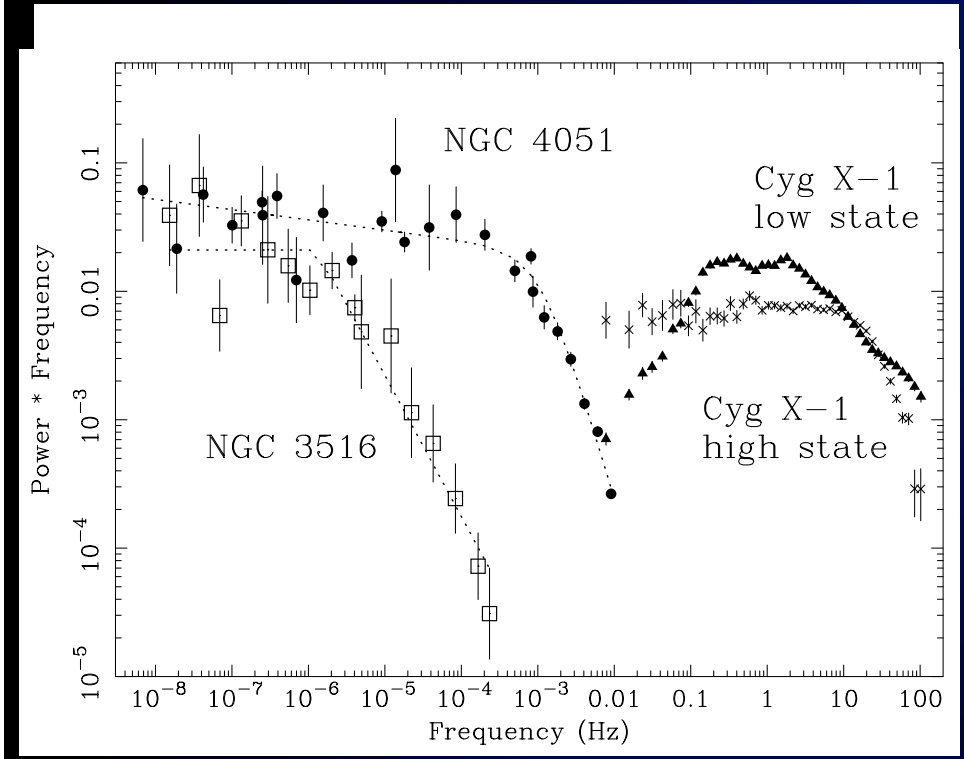
$$\sigma^2_{rms} = \frac{1}{N\mu^2}\sum_{i=1}^{N}[(X_i-\mu)^2-\sigma_i^2]$$

Xi = value in time bin i
N = number of time bins in interv.
μ = mean value in interv.
σ²i = Poissonian noise

Time bin = 250 s
Intervals = 10, 20, 40, 80 ks

2-10 keV band

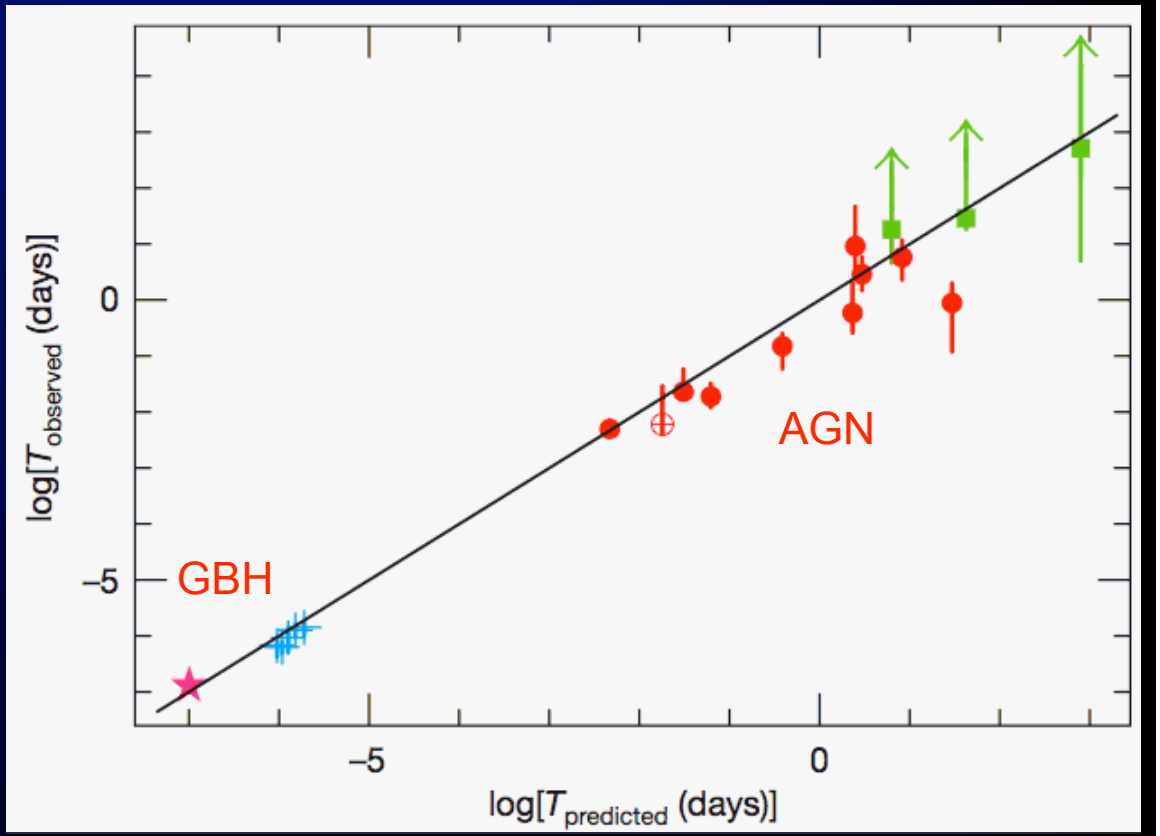
Scaling relations from PSD studies



Uttley +05

McHardy +04

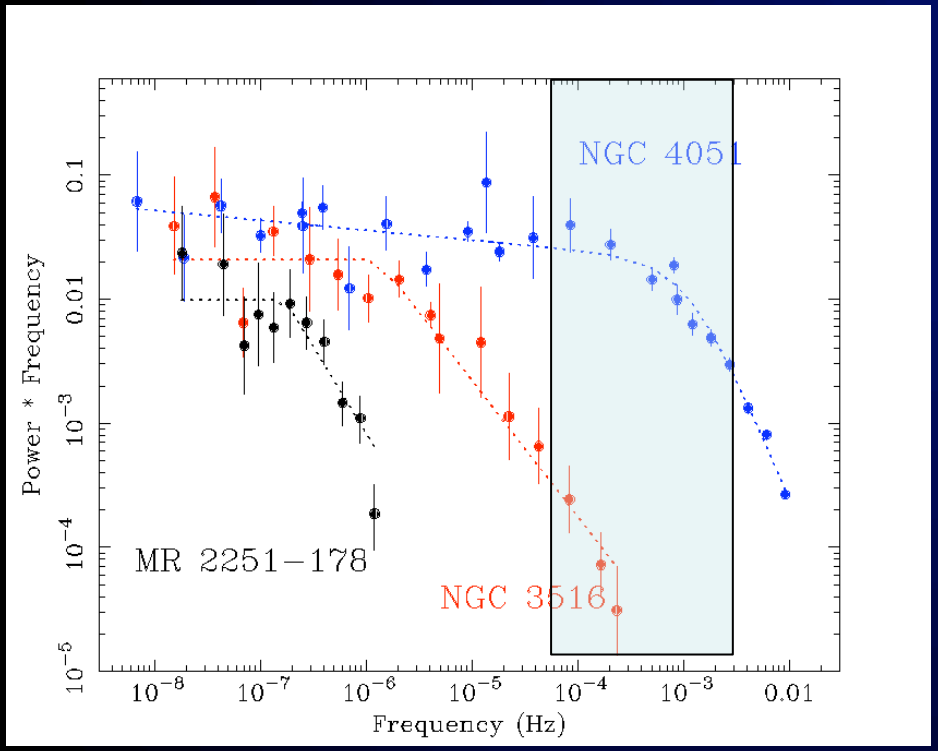
McHardy +06



The variability (v_b) scales in ALL accreting BH
➔ with M_{BH}
➔ AND accretion rate!

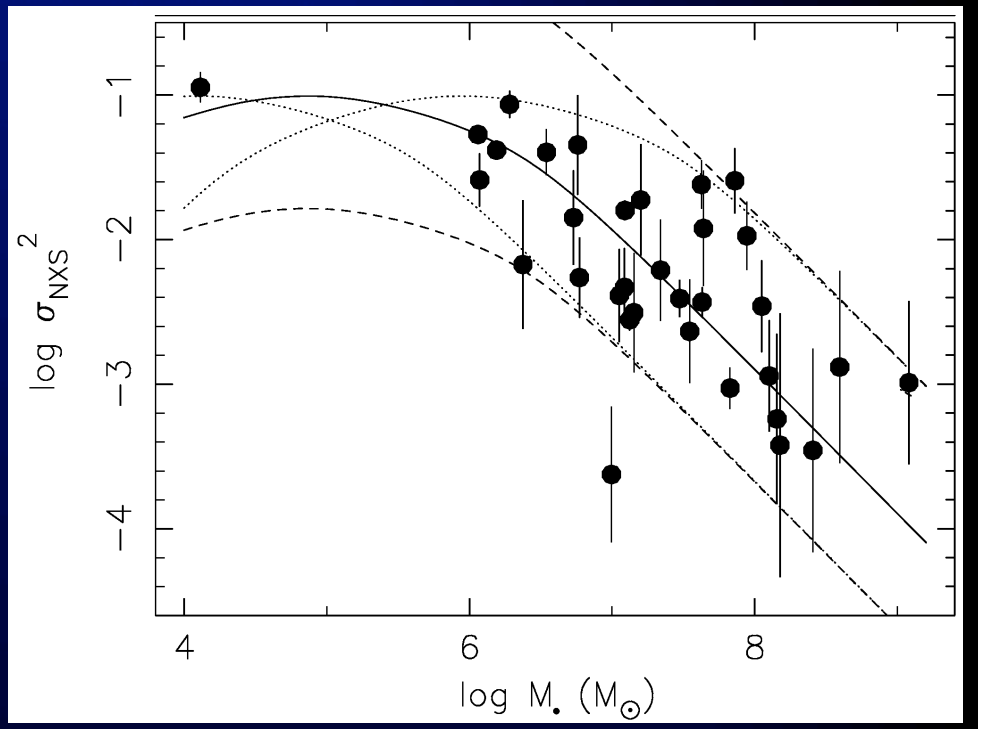
BUT: Tested in only in ~15 objects

Scaling relations from excess variance



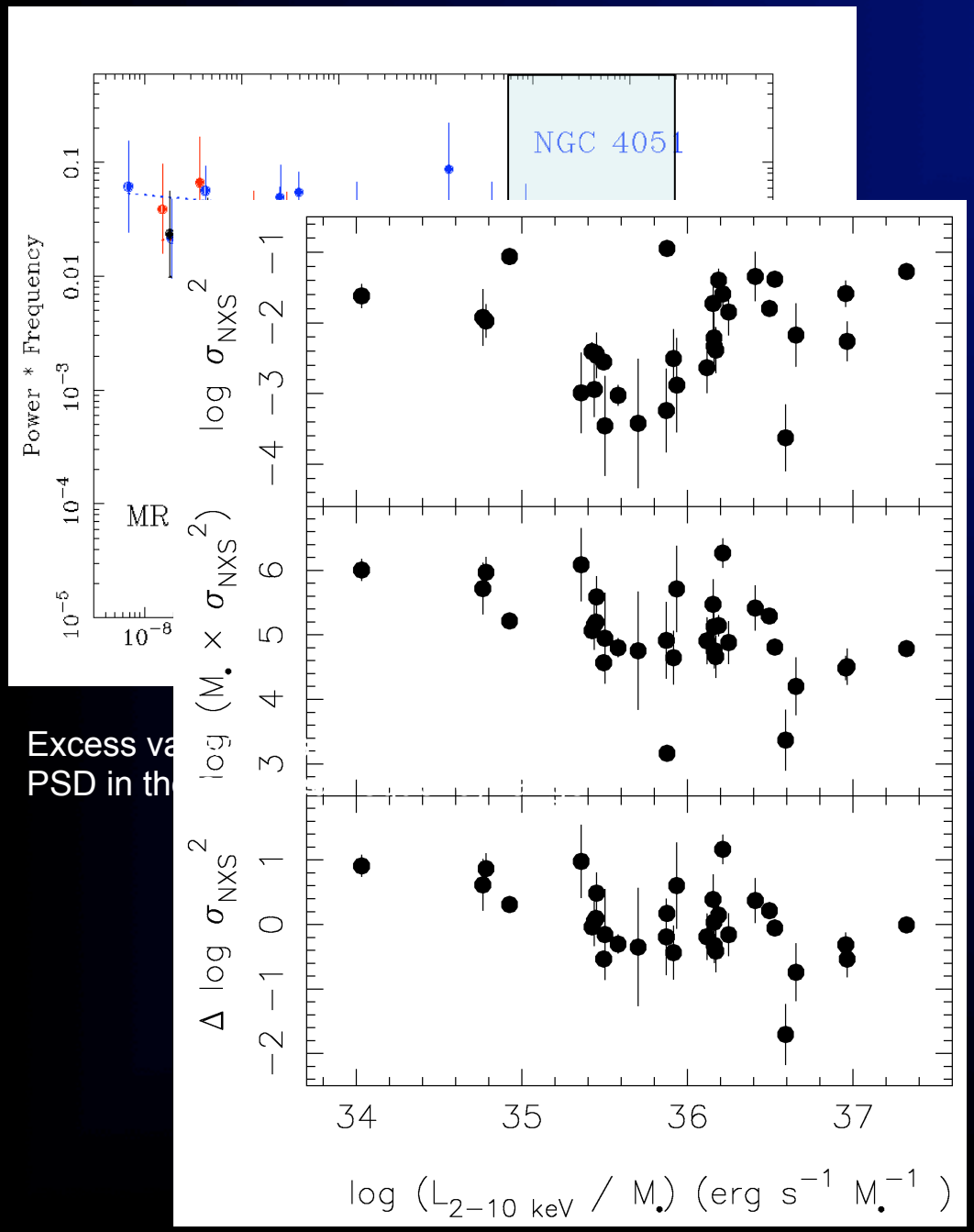
Excess variance is the integral of PSD in the sampled frequency range!

O'Neill +05



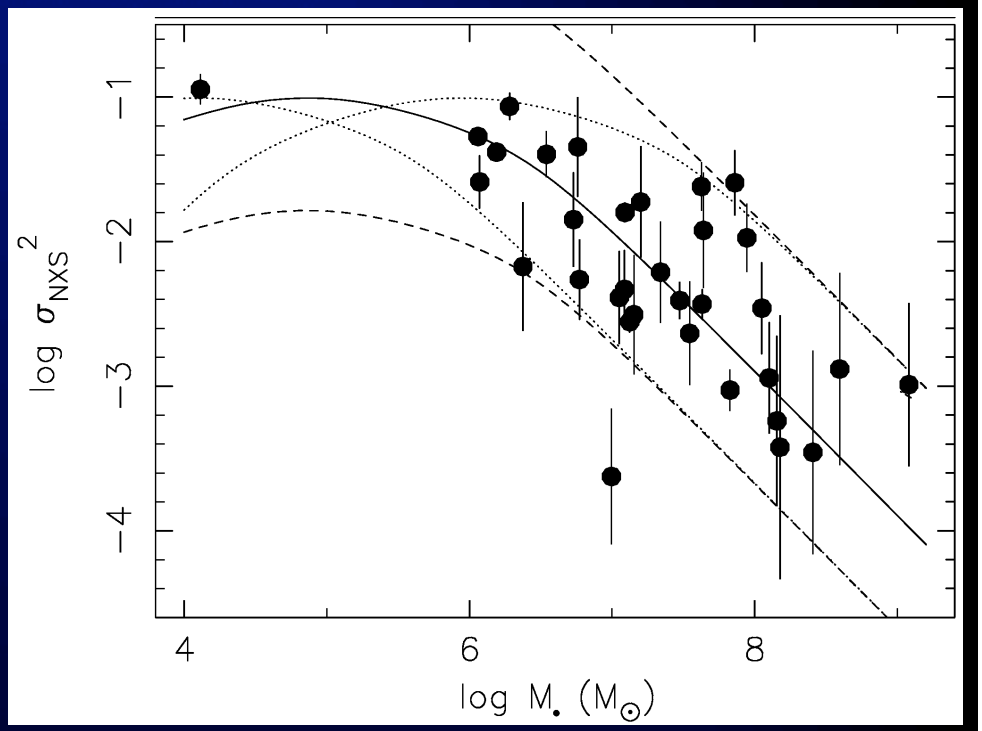
Excess variance depends on M_{BH}

Scaling relations from excess variance



Excess va
PSD in th

O'Neill +05



Excess variance depends on M_{BH}

Excess variance studies do not confirm the accretion rate dependence!

Open problems:
Does the variability depend on accretion rate?
On other parameters? (L, Γ, $FWHM_{H\beta}$, AGN type)

Test scaling relations on larger samples…

Testing scaling relations in large AGN samples

CAIXA:
(Catalogue of AGN In the XMM Archive)

All radio-quiet X-ray un-obscured AGN

pointed by XMM for >10ks

➔ 161 AGN (260 XMM observations)
> 3 times the AGN of O'Neill et al. (2005)

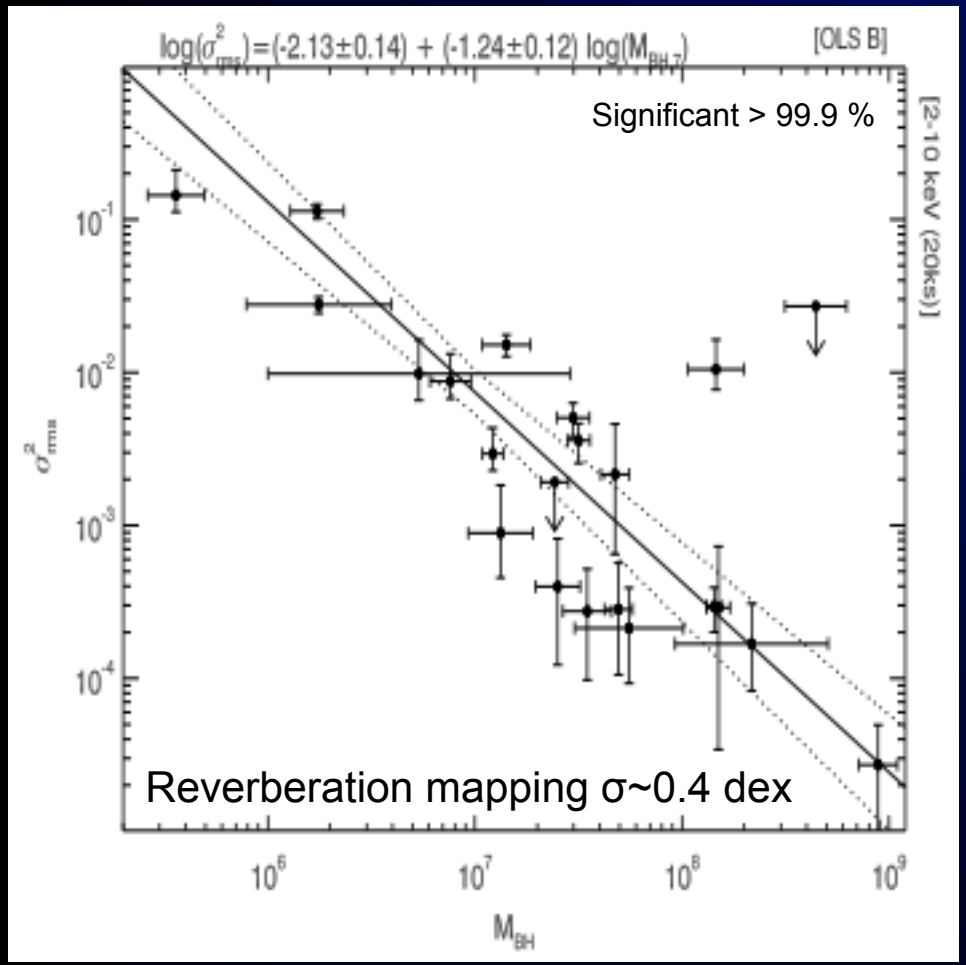
BH mass for 125 AGN
$FWHM_{H\beta}$ for 158 AGN
L_{Bol} from: Woo Urry 2002; Vasudevan et al. 2007; Marconi et al. 2009

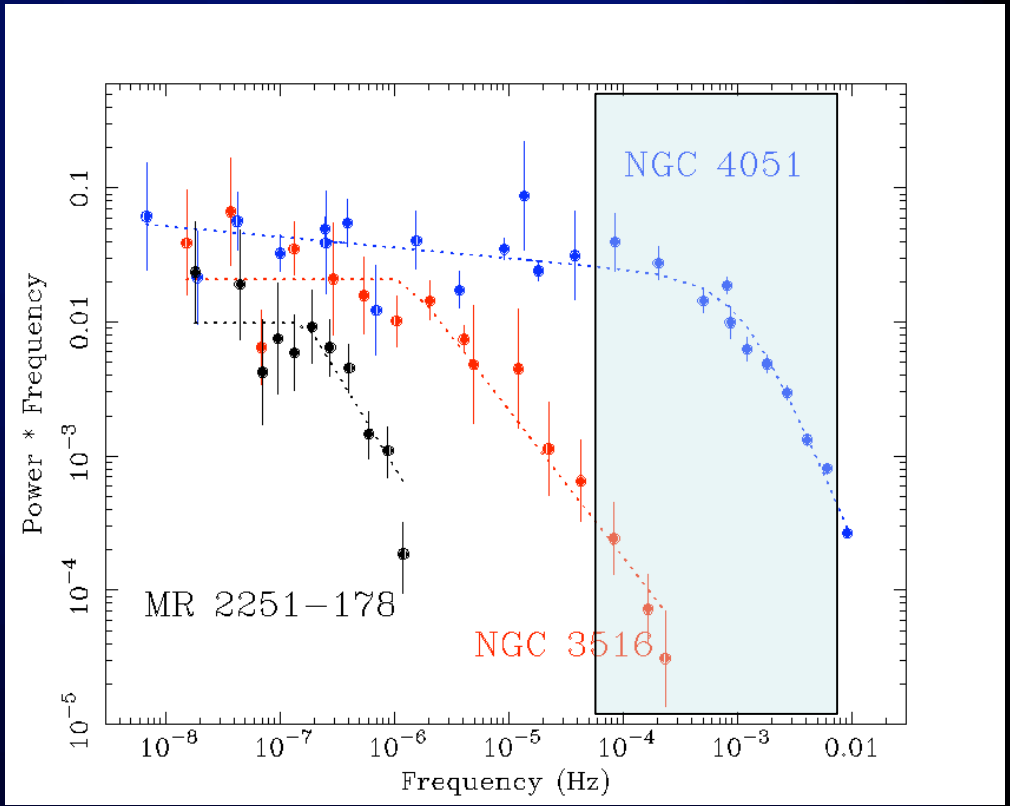
Reverberation:

All AGN with BH mass from reverberation

➔ 32 sources (29 of which are in CAIXA)

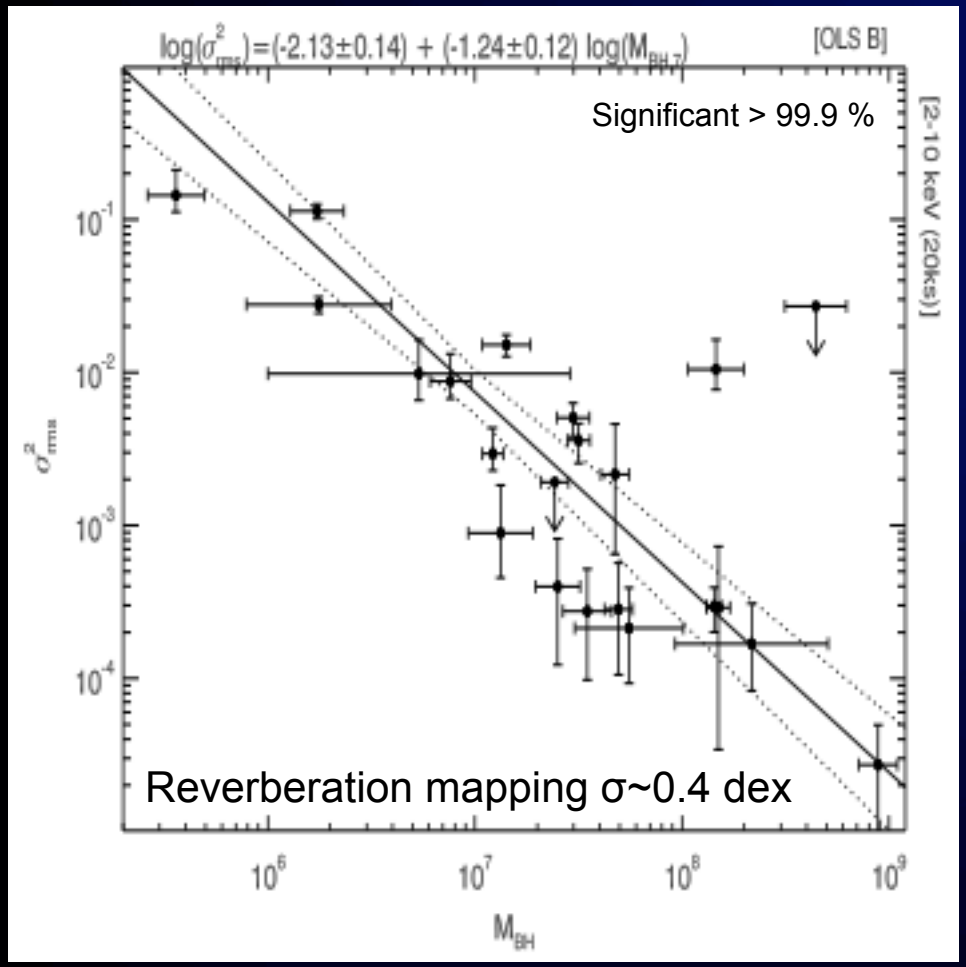
Variability vs. M_{BH}

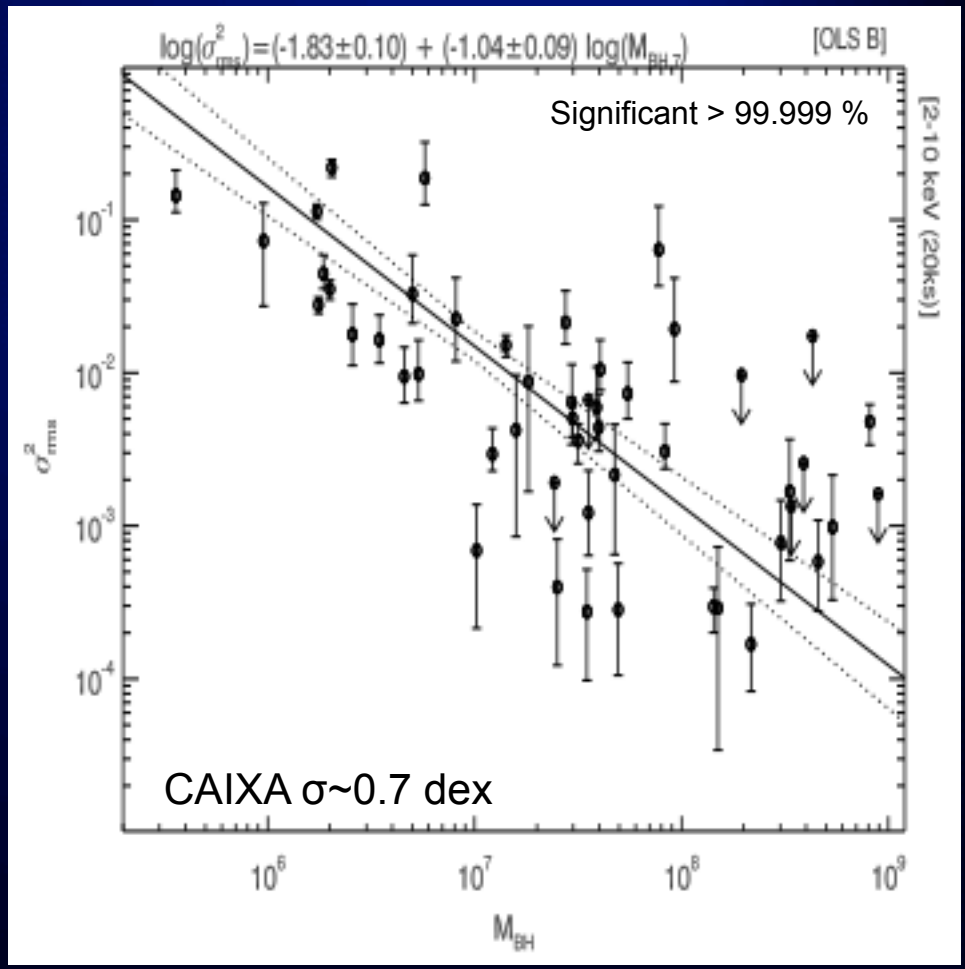




Variability extremely well correlated with M_{BH}
Slope ~ -1 ➔ universal PSD scaling with M_{BH}
(scatter ~ factor 2-3)

Variability vs. M_{BH}

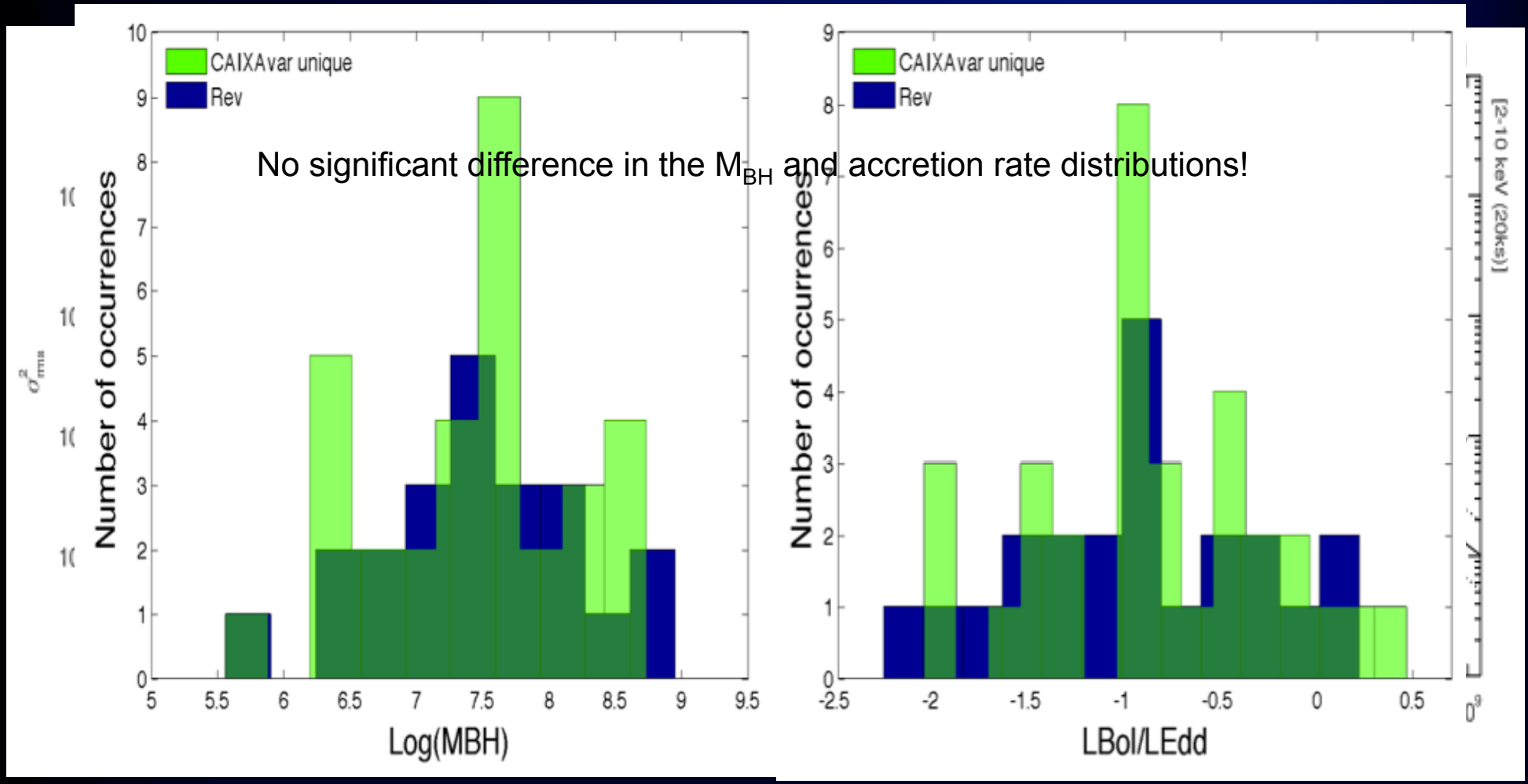




Which is the origin of the larger scatter in the CAIXA sample?

1) The scatter is due to the larger uncertainties associated with non-reverberation BH mass estimates
2) The variability depends on a second parameter + CAIXA spans a larger range of this parameter

Variability vs. M_{BH}



No significant difference in the M_{BH} and accretion rate distributions!

Which is the origin of the larger scatter in the CAIXA sample?

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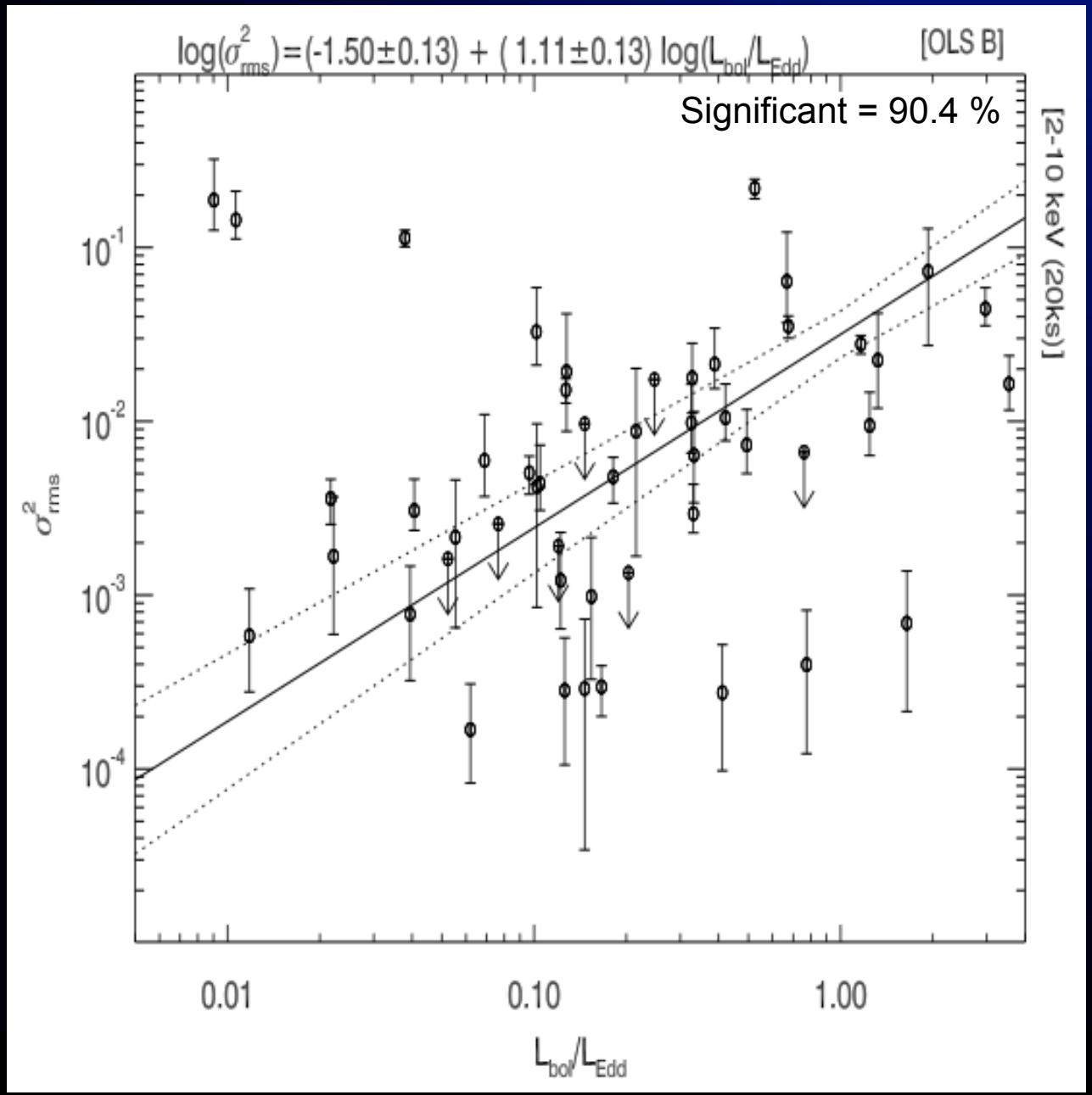
➔ X-ray variability: tool to measure of M_{BH}

➔ More accurate than single spectra estimates

Variability vs. accretion rate



1) Not very significant

2) Large scatter

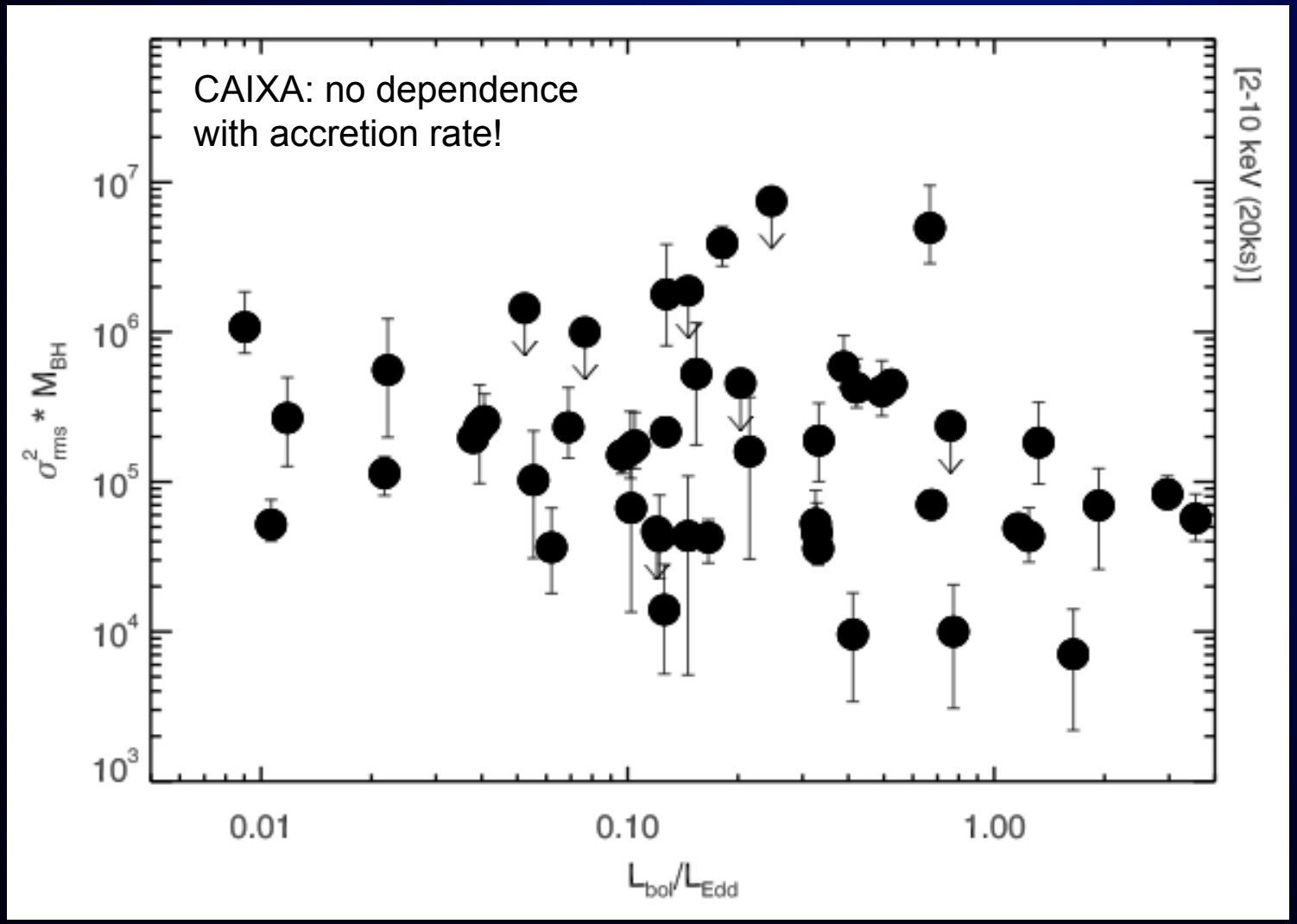
3) Correlation driven by M_{BH} dependence?

Variability ~ M_{BH}^{-1}

➔ Variability * M_{BH}

Get rid of M_{BH} dependence

VariabilityM_{BH} vs. accretion rate*



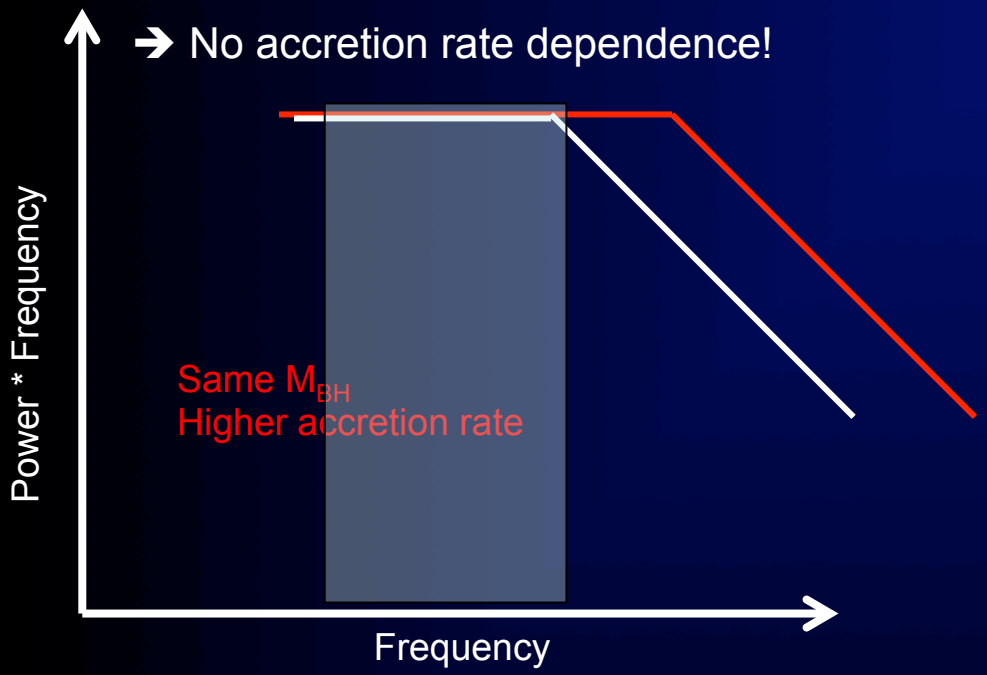
We confirm the result of O'Neill et al. (2005)
No dependence with accretion rate is observed

BUT: how can be that PSD and excess variance give different results?

VariabilityM_{BH} vs. accretion rate*

CASE 1:
Small BH mass
Break at high frequency

➔ No accretion rate dependence!



No dependence with
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McHardy et al. 2006

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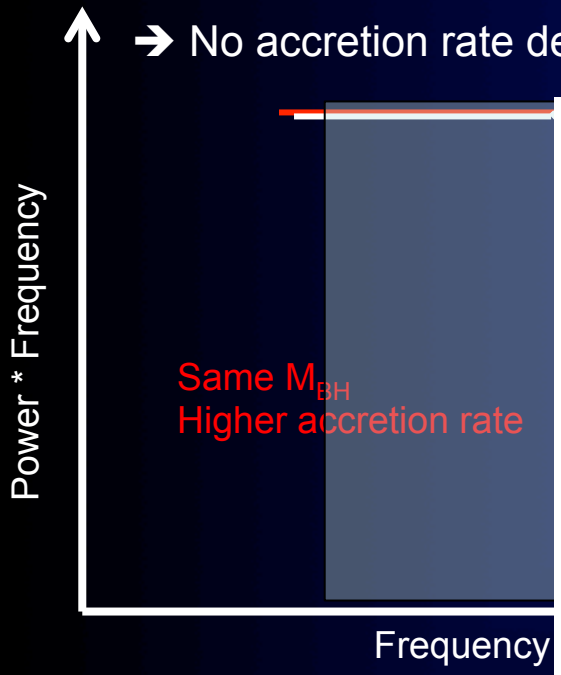

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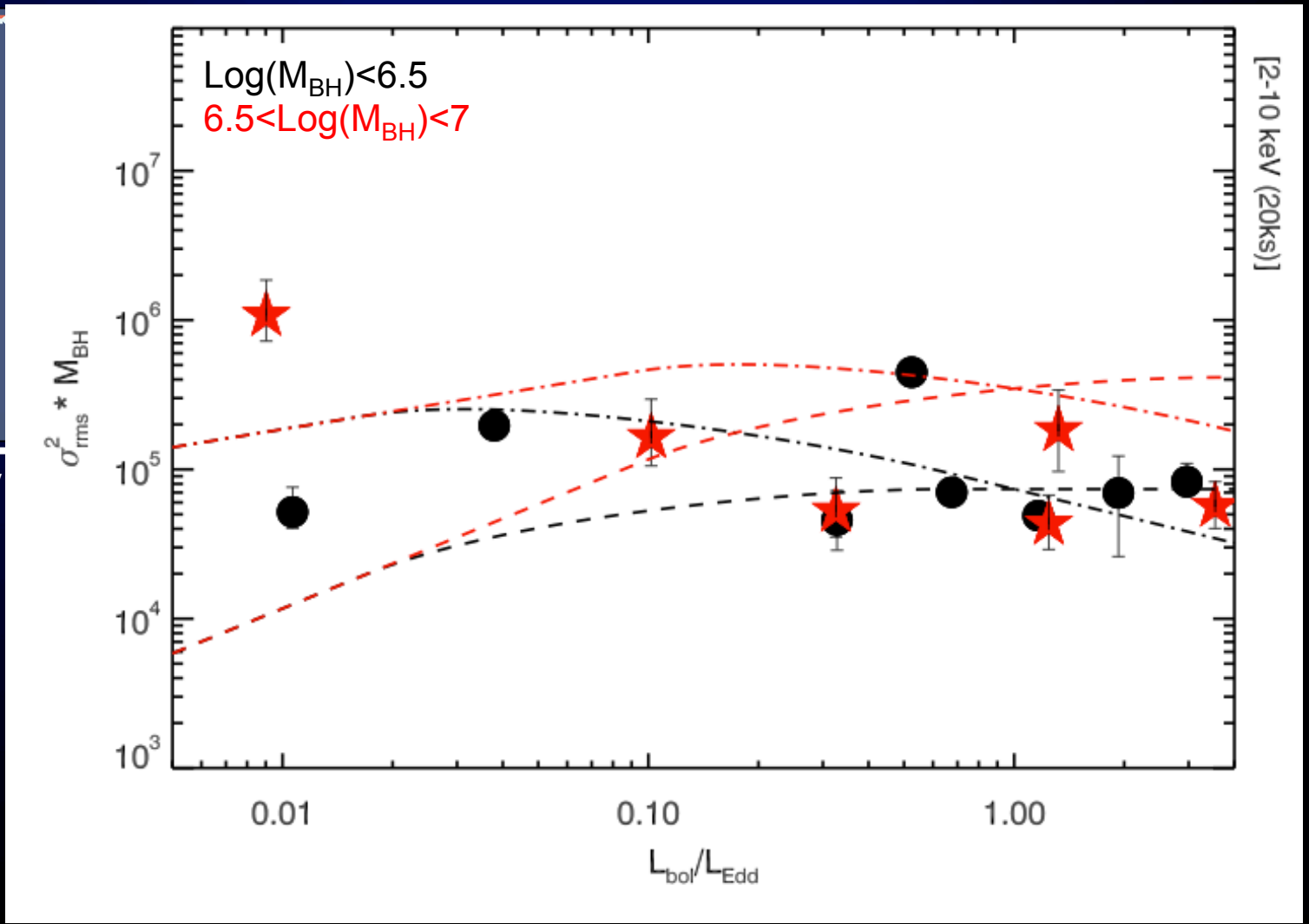
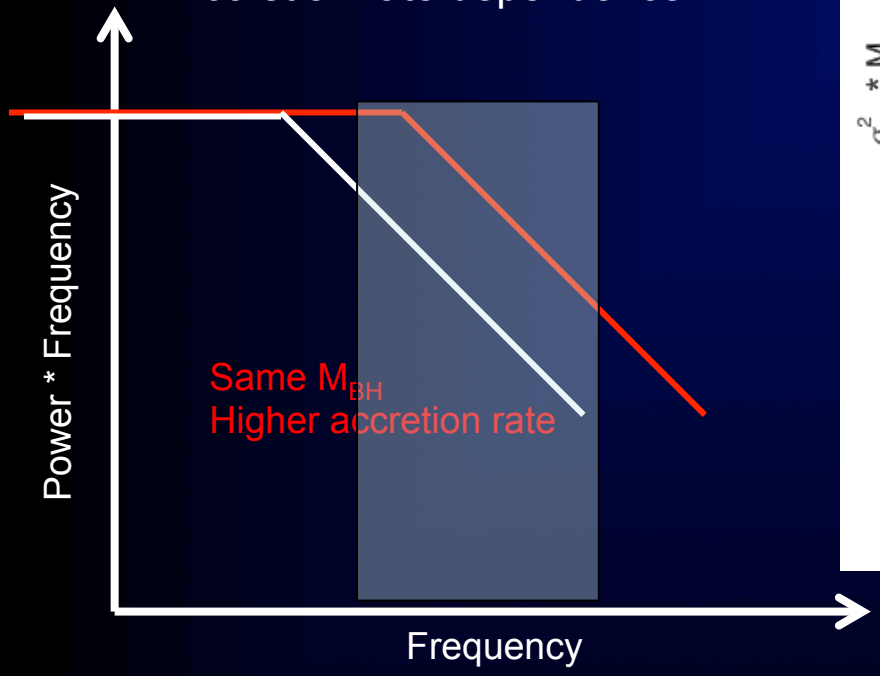


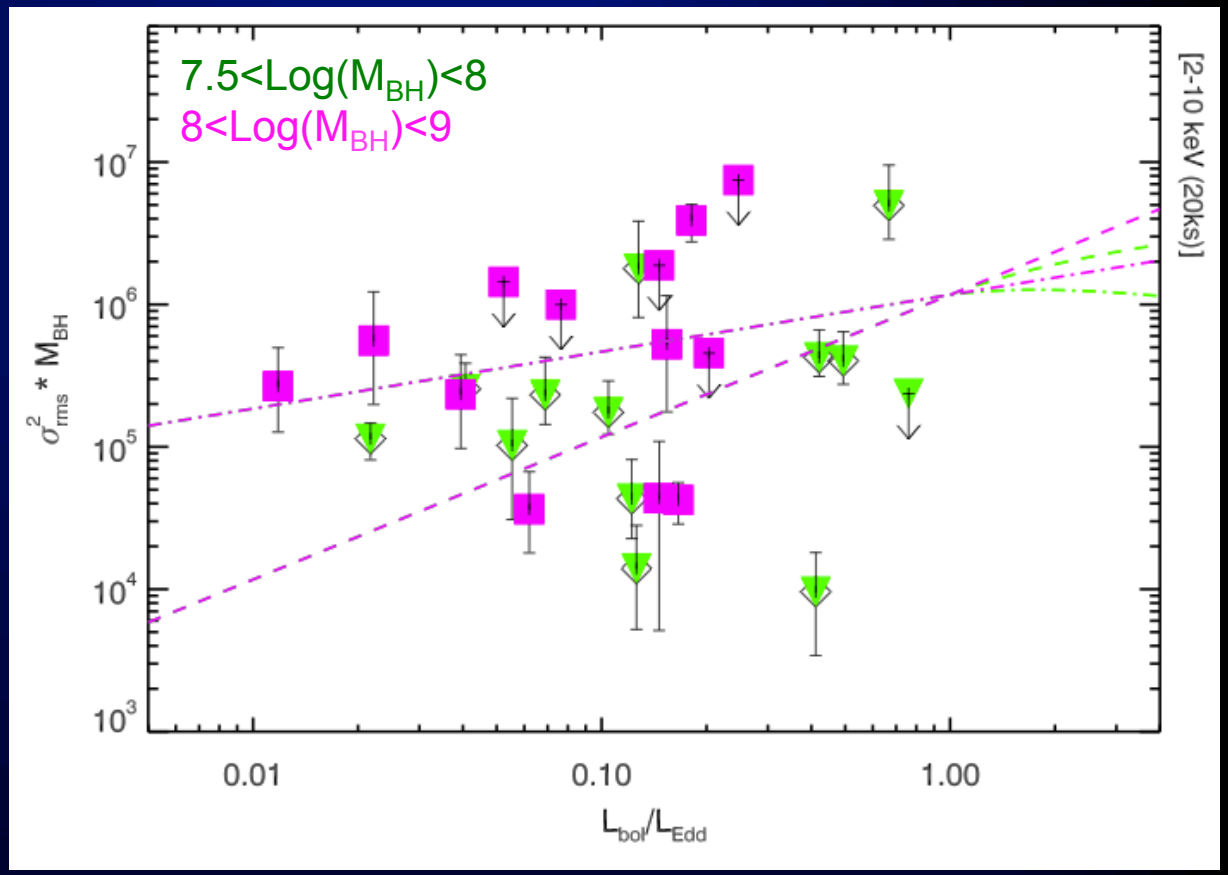
McHardy et al. 2006

Variability*M_{BH} vs. accretion rate

CASE 2:
High BH mass
Break at low frequency

➔ Accretion rate dependence!





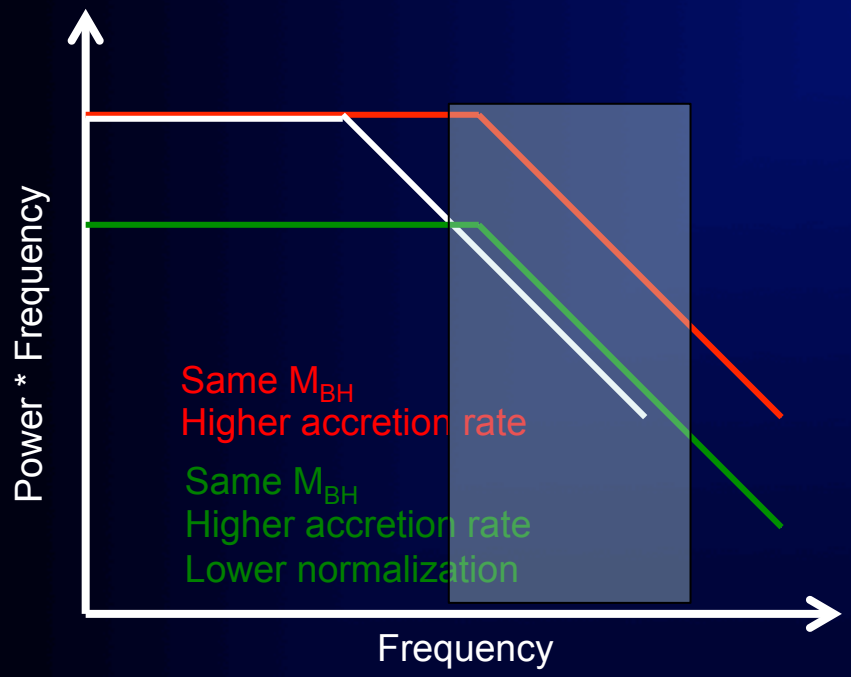
As expected the more massive AGN show a trend of higher variability with accretion rate

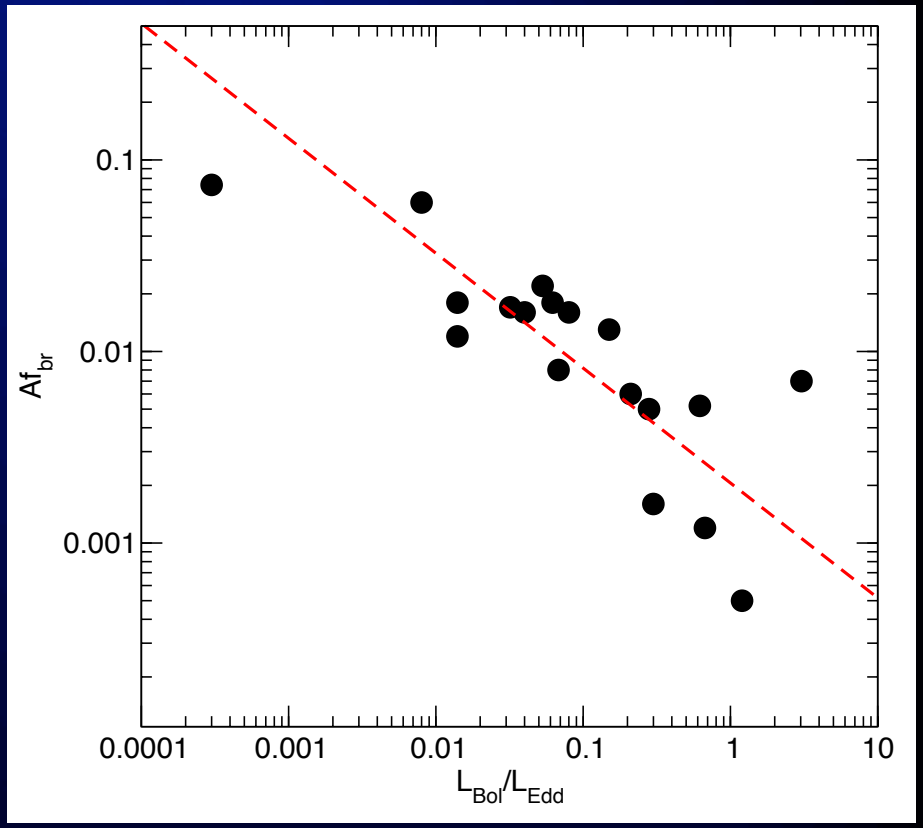
The large scatter probably is due to uncertainty on L_{bol} and M_{BH}

Dependence weaker than expected… how can that be?

McHardy et al. 2006

PSD norm vs. accretion rate?





Preliminary

Similar behavior observed in BHB **Gierlinski +08**

First evidence of Mdot vs. PSD norm correlation

PSD high frequency tail more fundamental than break

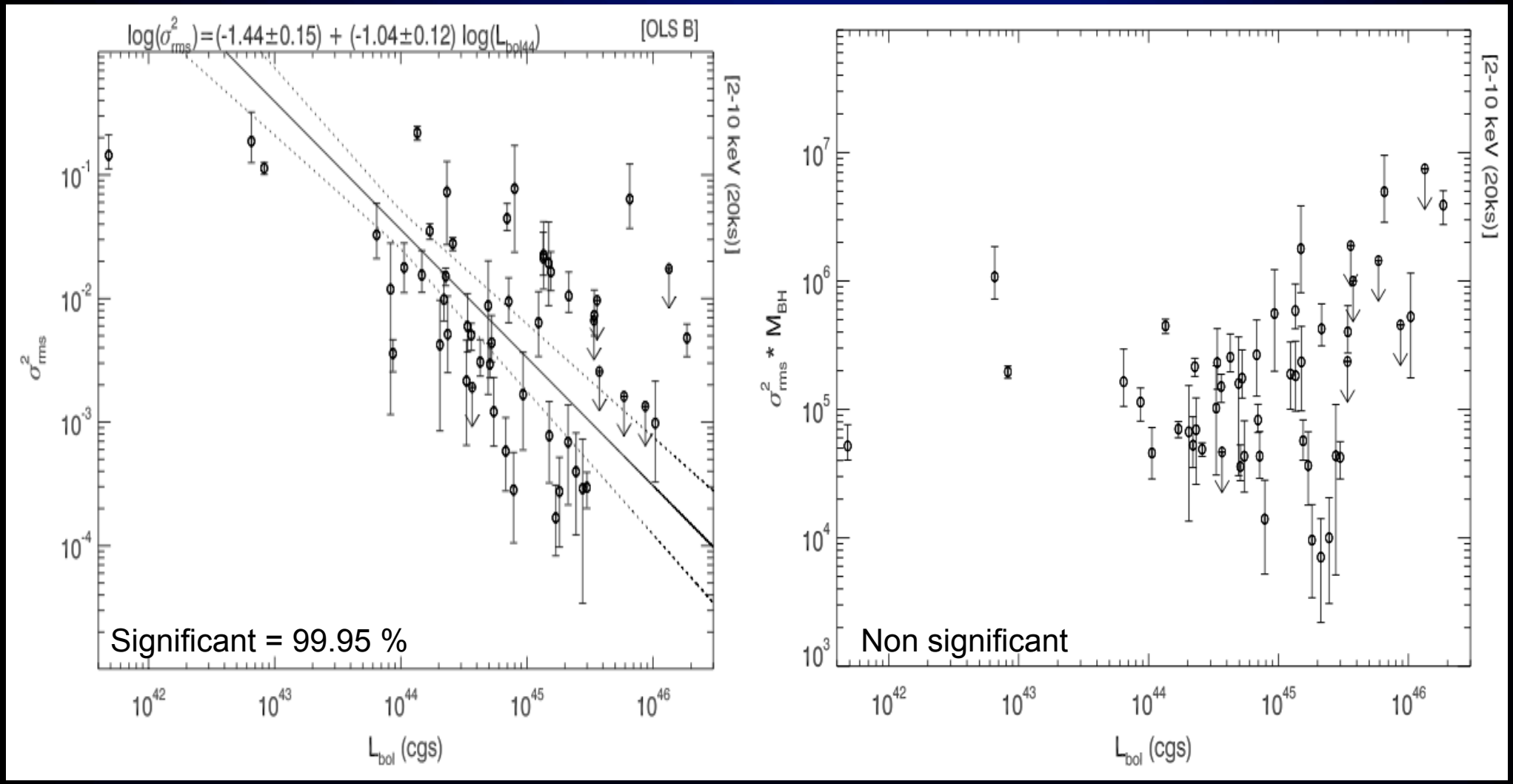
Excess variance DO NOT observe accretion rate dependence because:

1) Different expected relation with M_{BH}

2) Variation in PSD normalization

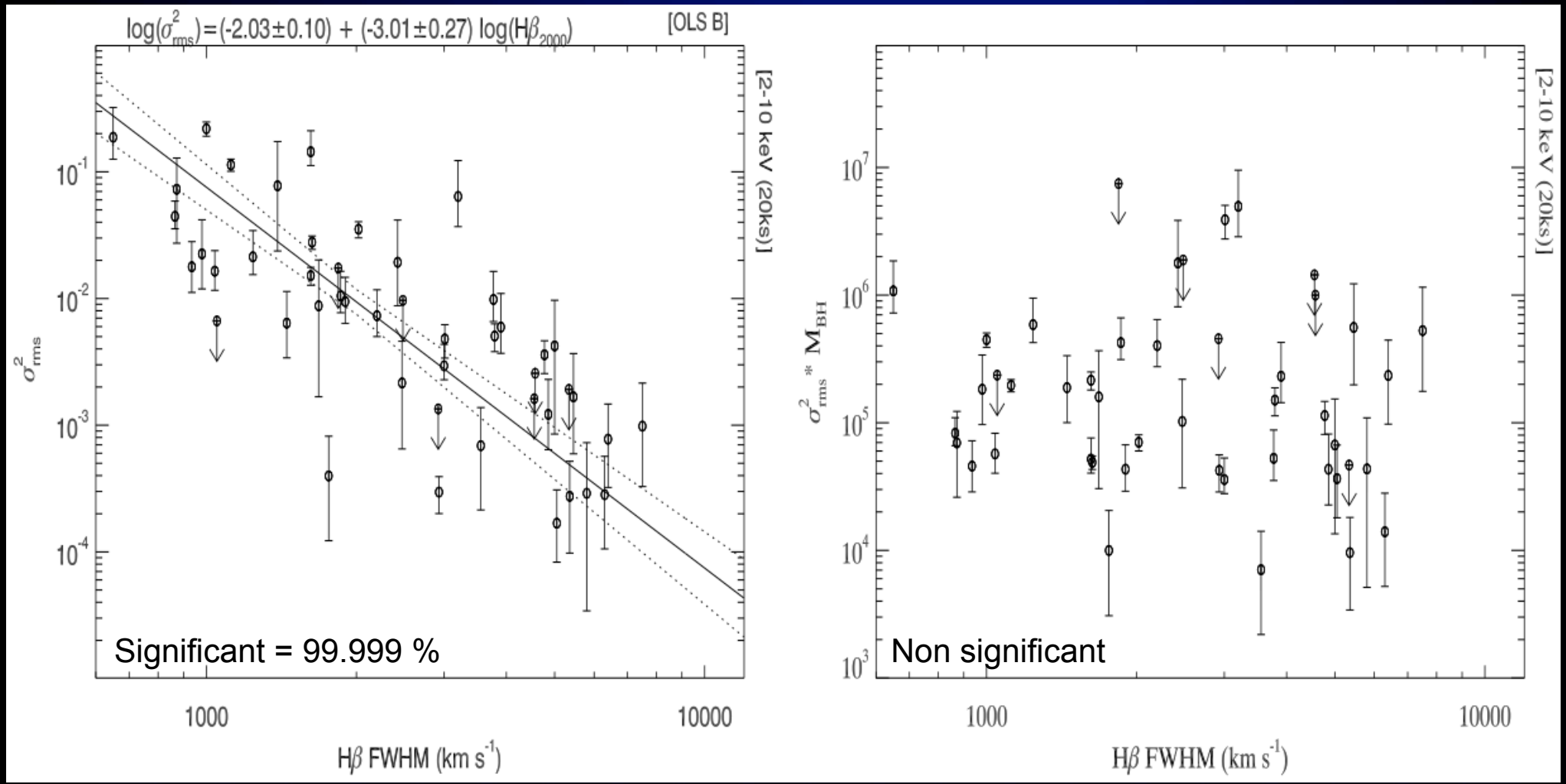
3) Large scatter in L_{bol} and M_{BH}

Variability vs. Luminosity



The variability vs. luminosity relation is a byproduct of the variability vs. M_{BH} relation

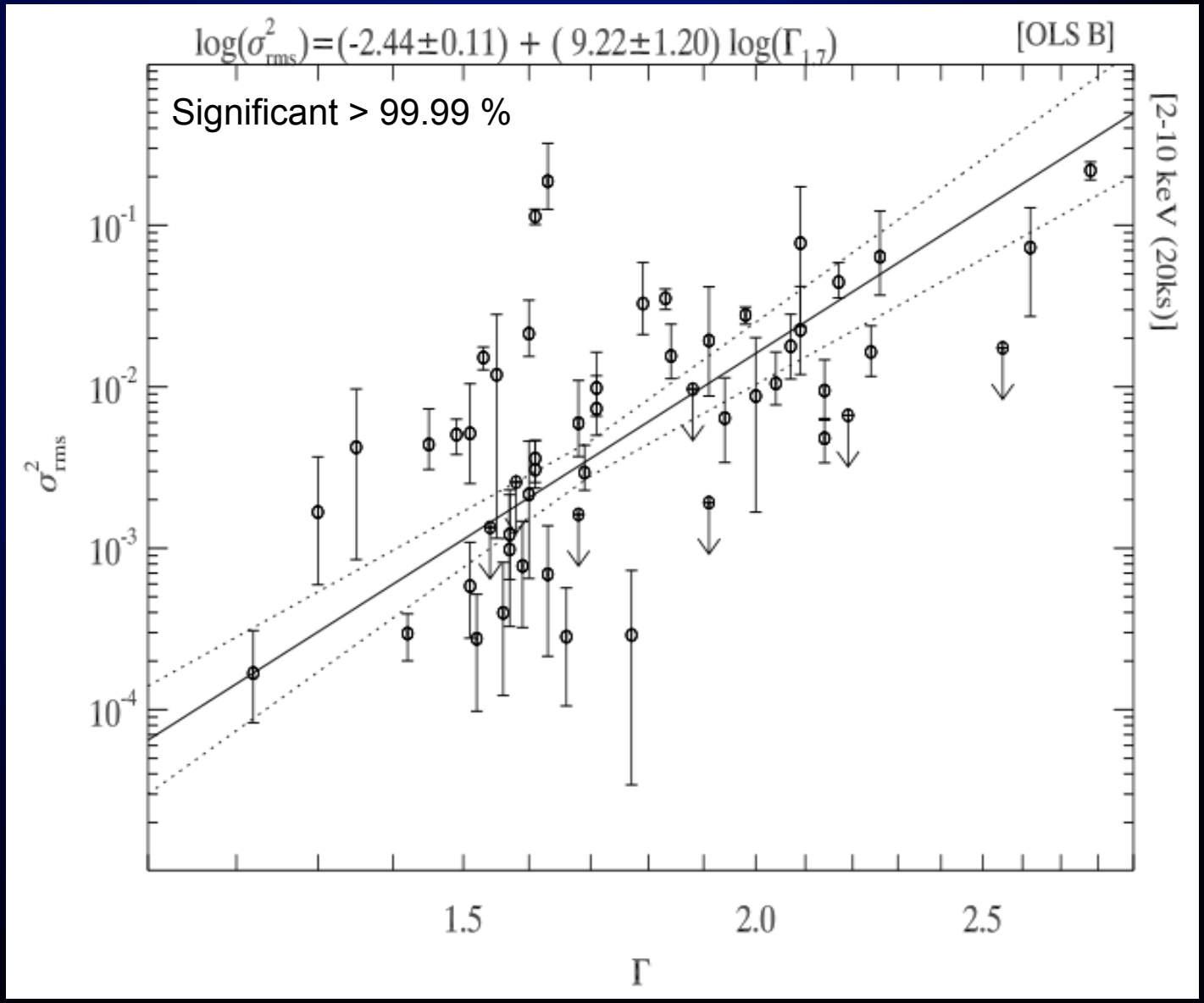
Variability vs. FWHM$_{H\beta}$



The variability vs. FWHM$_{H\beta}$ relation is a byproduct of the variability vs. M_{BH} relation

Variability vs. spectral index

Variability-Γ correlation already observed but never so significant!



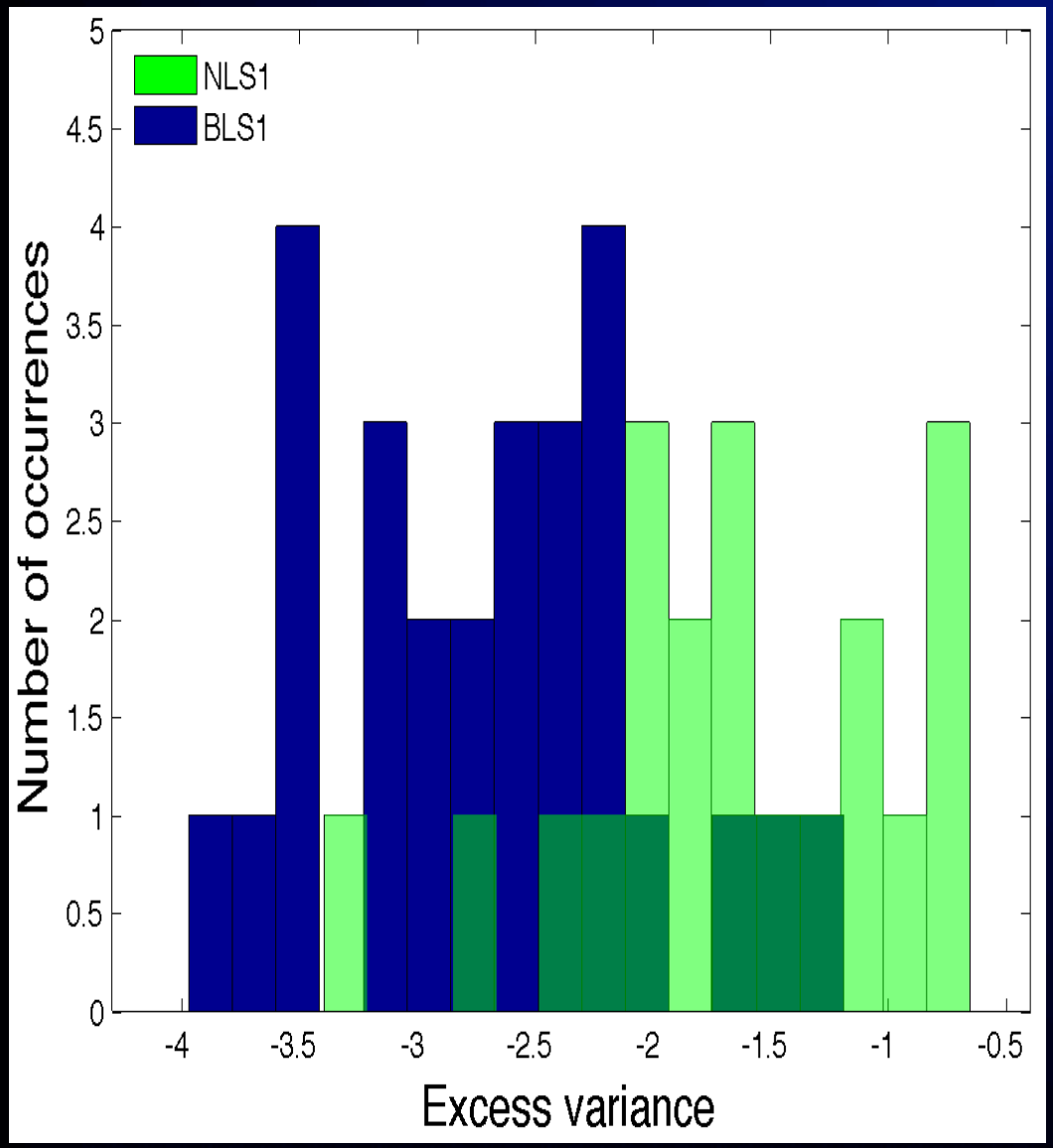
In CAIXA:

Γ vs. M_{BH} not significant

Γ correlated with Mdot?
(possible but $\Gamma \sim \dot{M}^{0.1}$)

Shemmer+06; Saez+08; Sobolewska+09; Wu+08

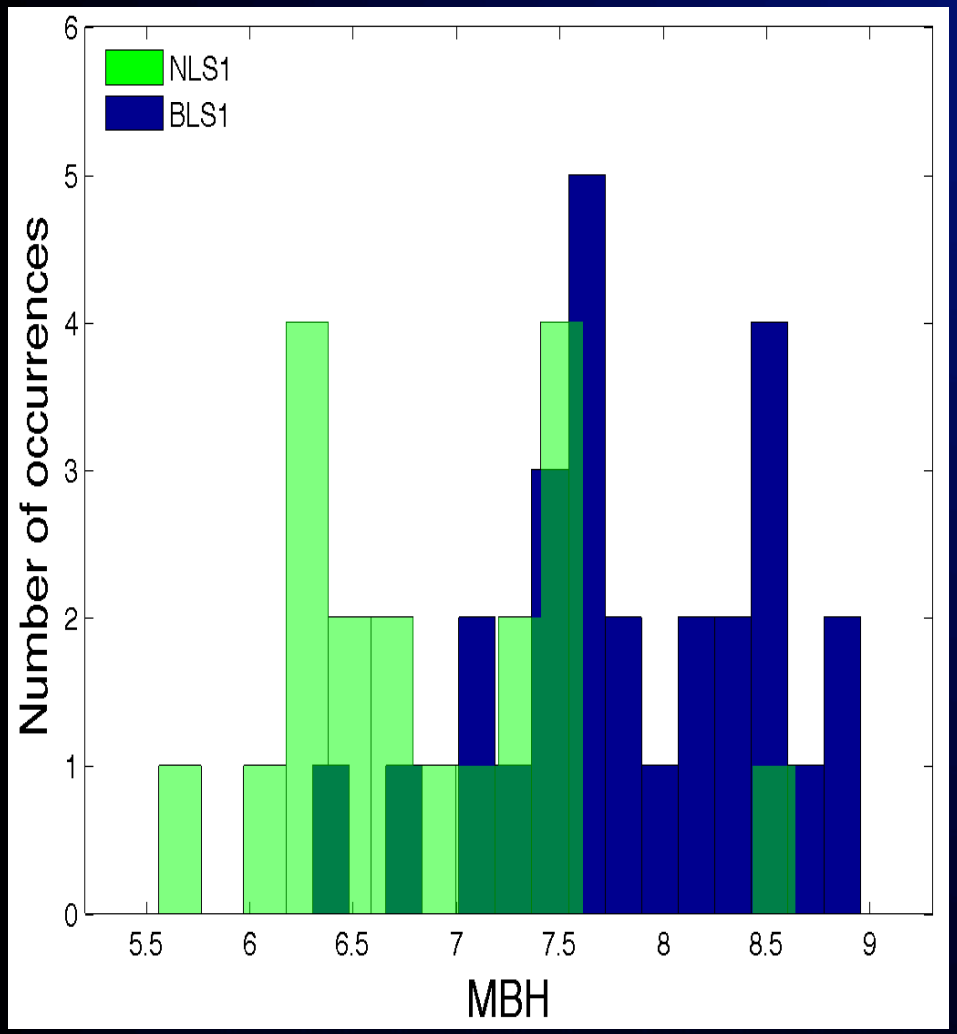
Are NLS1 more variable?

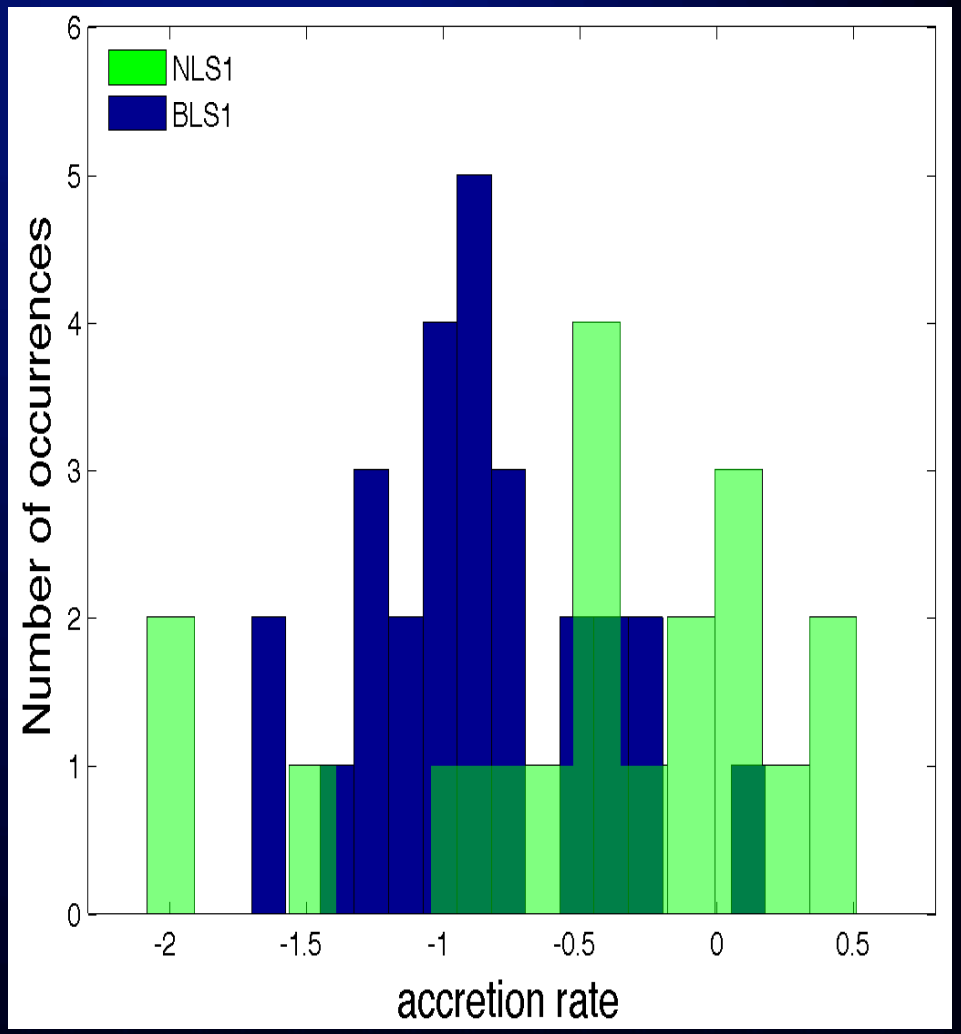


NLS1 are more variable than broad line AGN

Why?

Are NLS1 more variable?

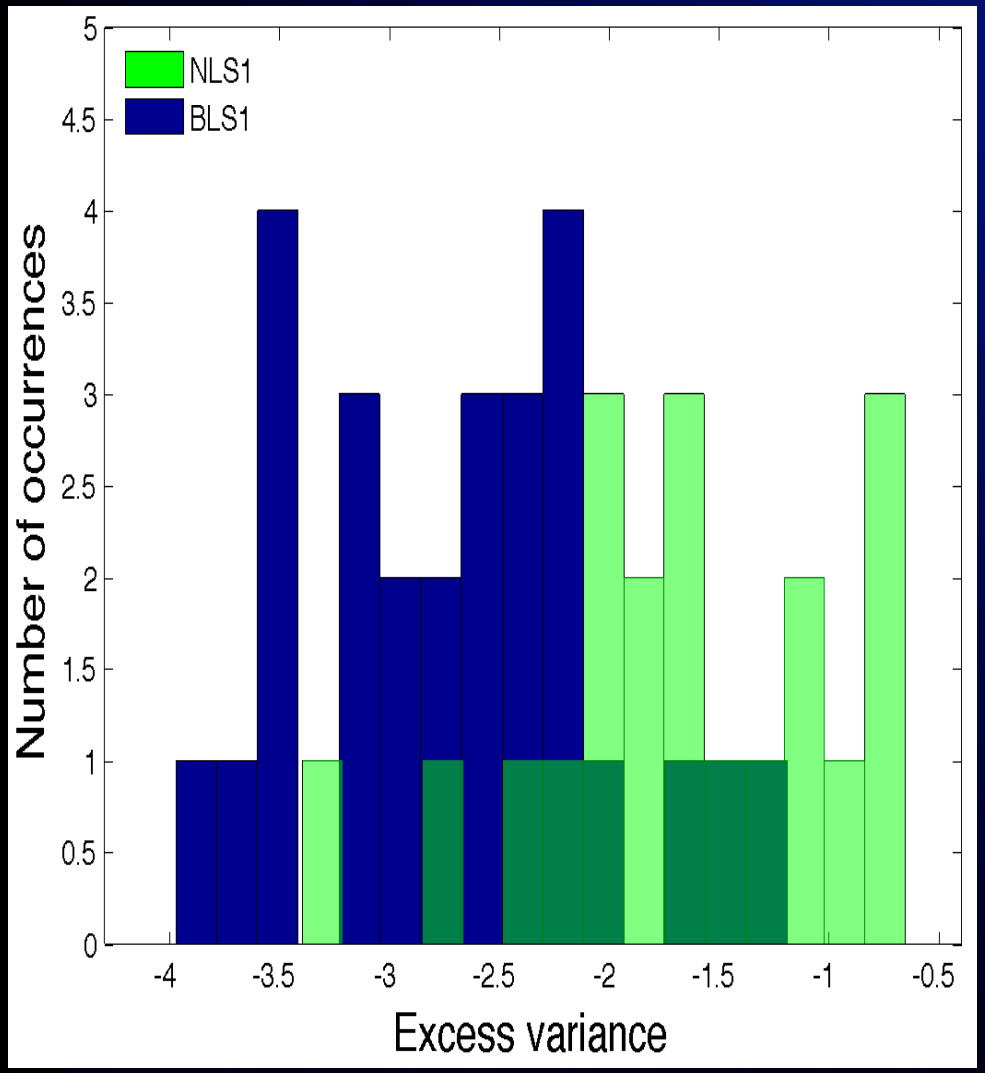


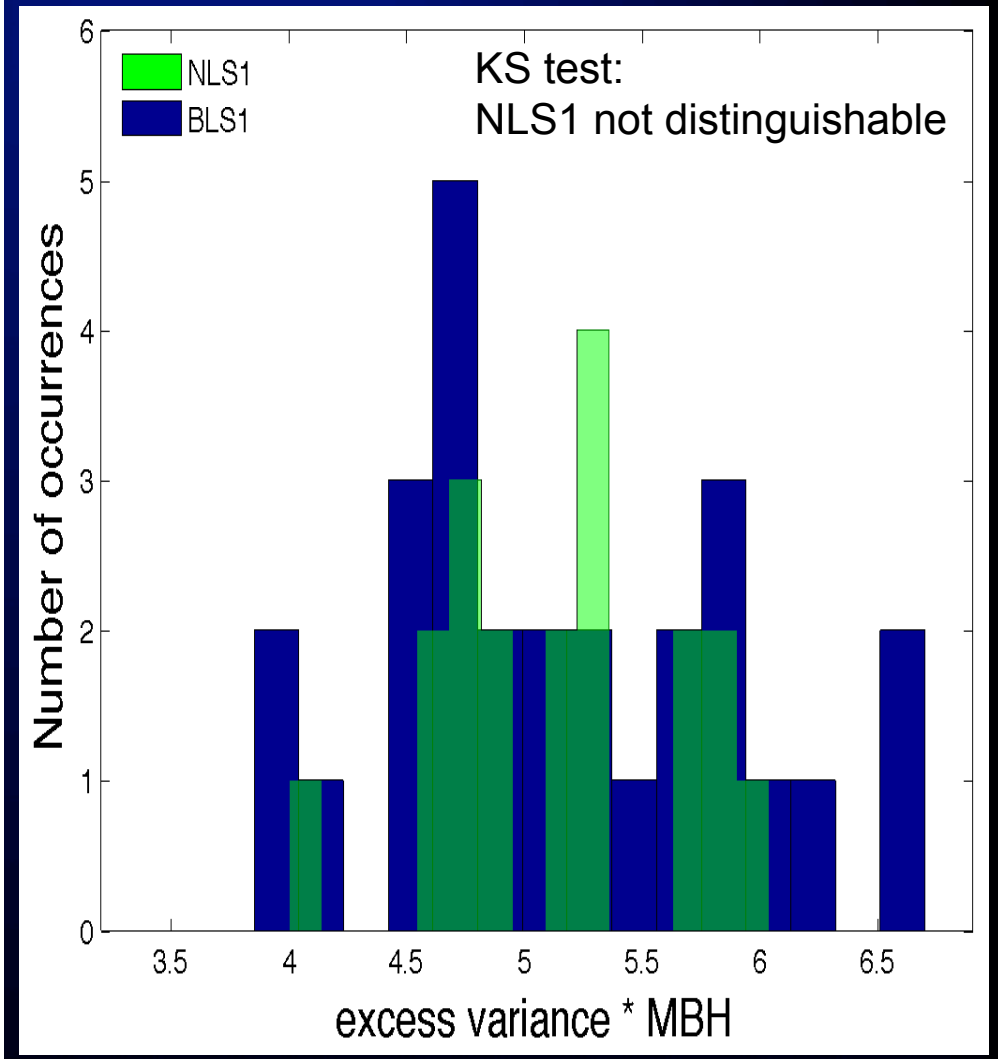


NLS1 are more variable than broad line AGN
Why?

NLS1 ➔ smaller M_{BH}
➔ higher accretion rate

Are NLS1 more variable?

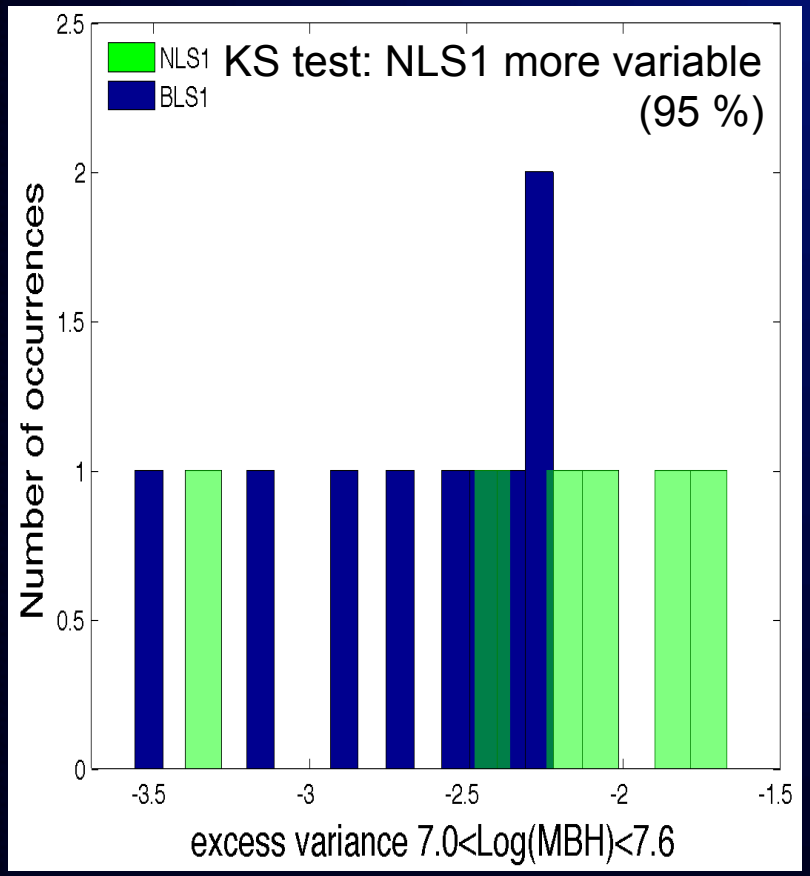


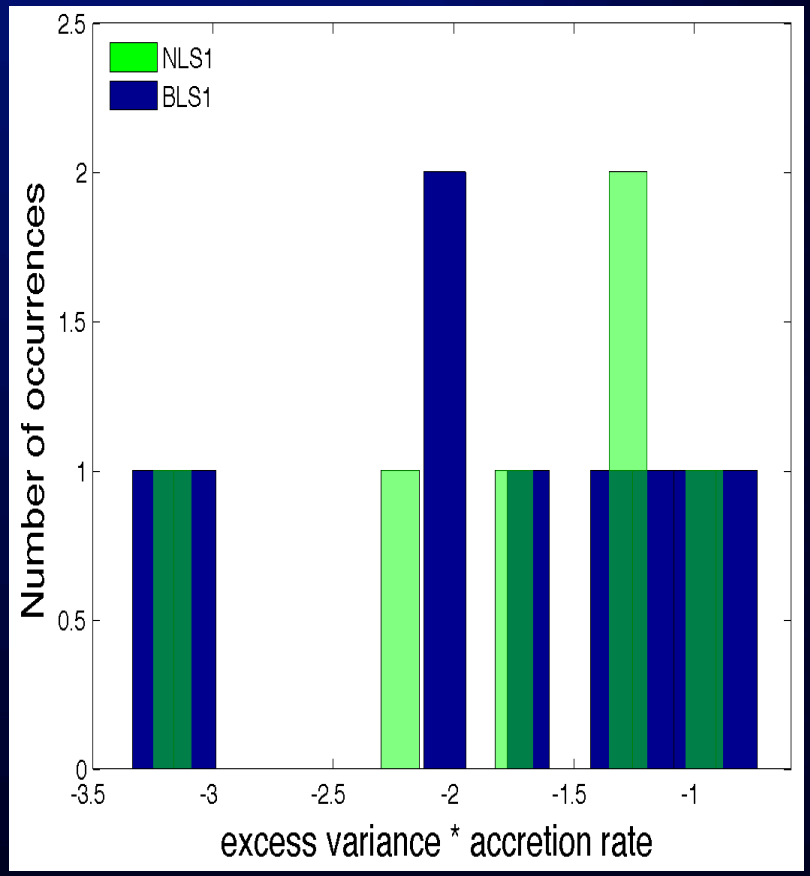


NLS1 are more variable than broad line AGN
Why?

NLS1 higher variability mainly due to smaller M_{BH}

Are NLS1 more variable?





NLS1 suggest scaling with accretion rate

Conclusions:

1) Excess variance is an accurate tool to measure M_{BH} ➔ scatter < factor 2-3
   (more accurate than the ones based on single epoch spectra…)

2) The expected excess variance vs. accretion rate relation is complex (depends on M_{BH})
   + large scatter in the relation is introduced by uncertainties on L_{Bol} and M_{BH}
   + indications for a PSD normalization vs. accretion rate anti-correlation
   Thus O'Neill et al. (2005) missed the accretion rate dependence (McHardy et al. 2006)

3) Excess variance vs. luminosity relations is a byproduct of variability vs. M_{BH} relation
4) Same for excess variance vs. $FWHM_{H\beta}$ relations

5) Excess variance well correlated with 2-10 keV spectral index (>99.99 %)
   This is not a byproduct of M_{BH} dependence

6) NLS1 more variable than BL AGN simply because of smaller M_{BH} and higher accretion rate