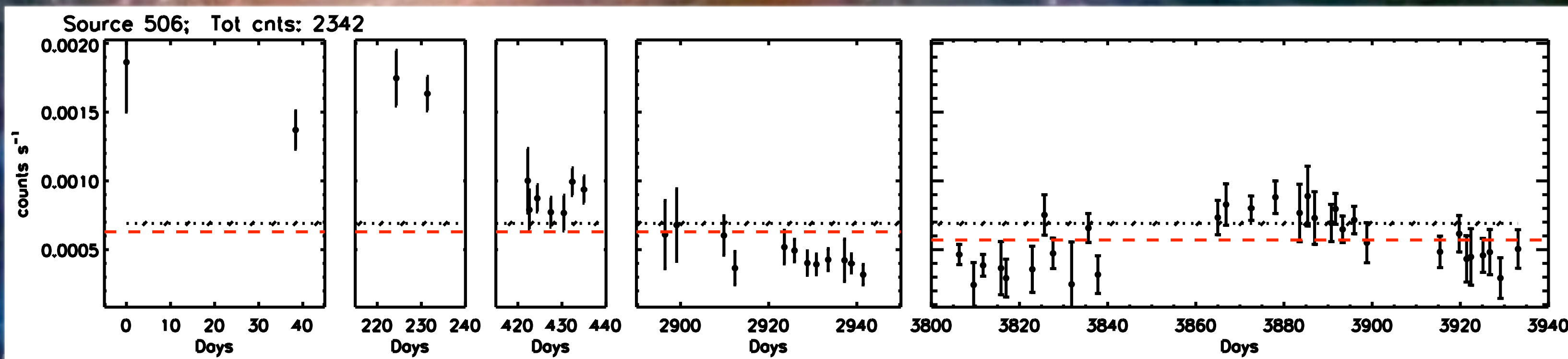
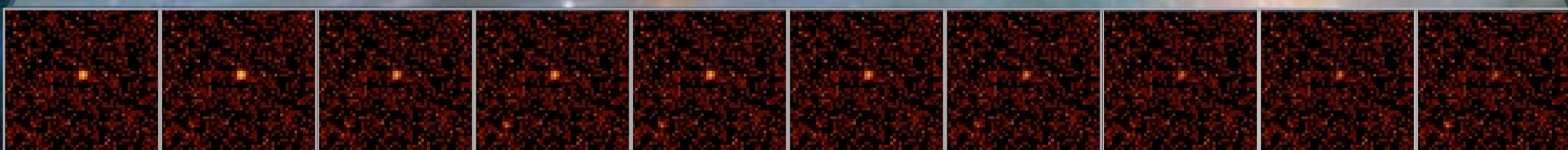
Recent results from X-ray variability of high z AGNs

Maurizio Paolillo, Viola Allevato, Iossif Papadakis, Ciro Pinto, Paolo Tozzi, Niel Brandt and the CDF collaboration

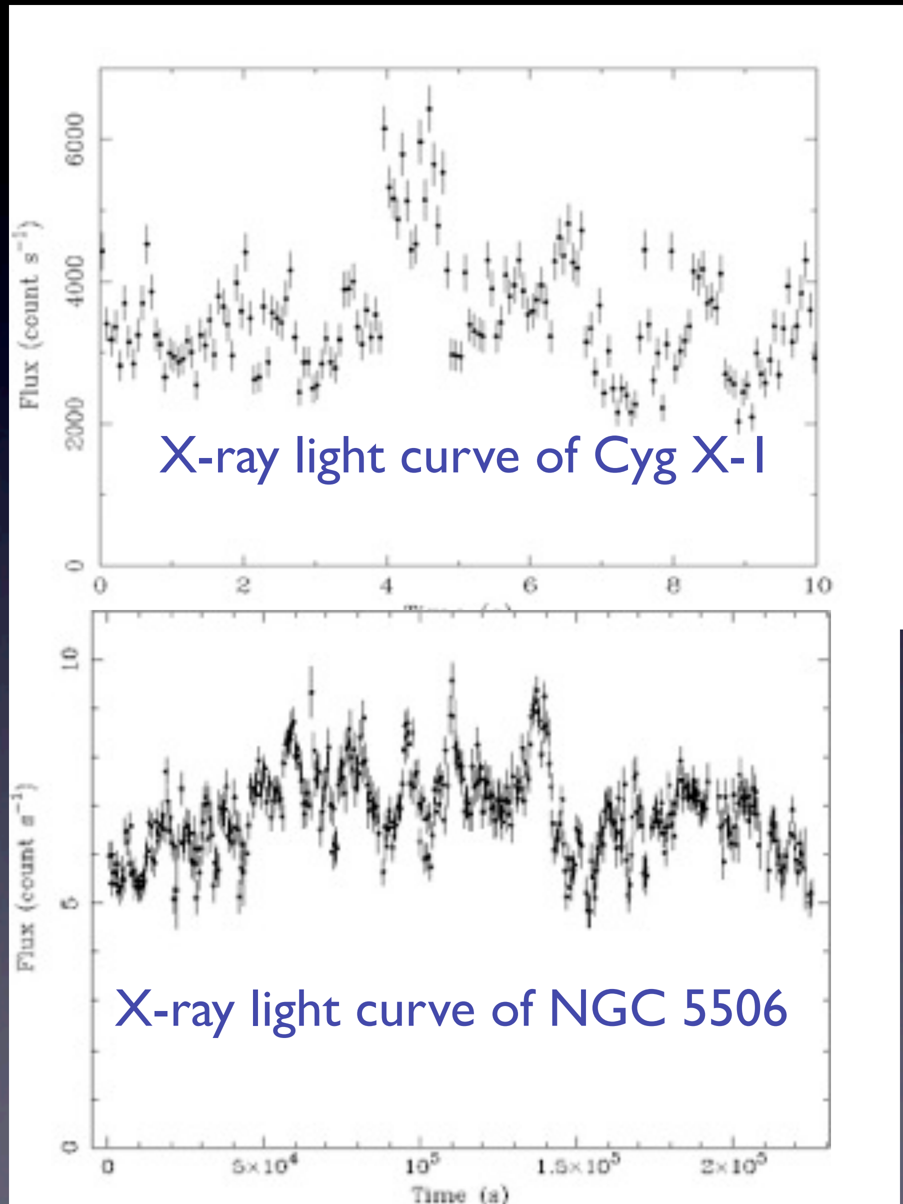




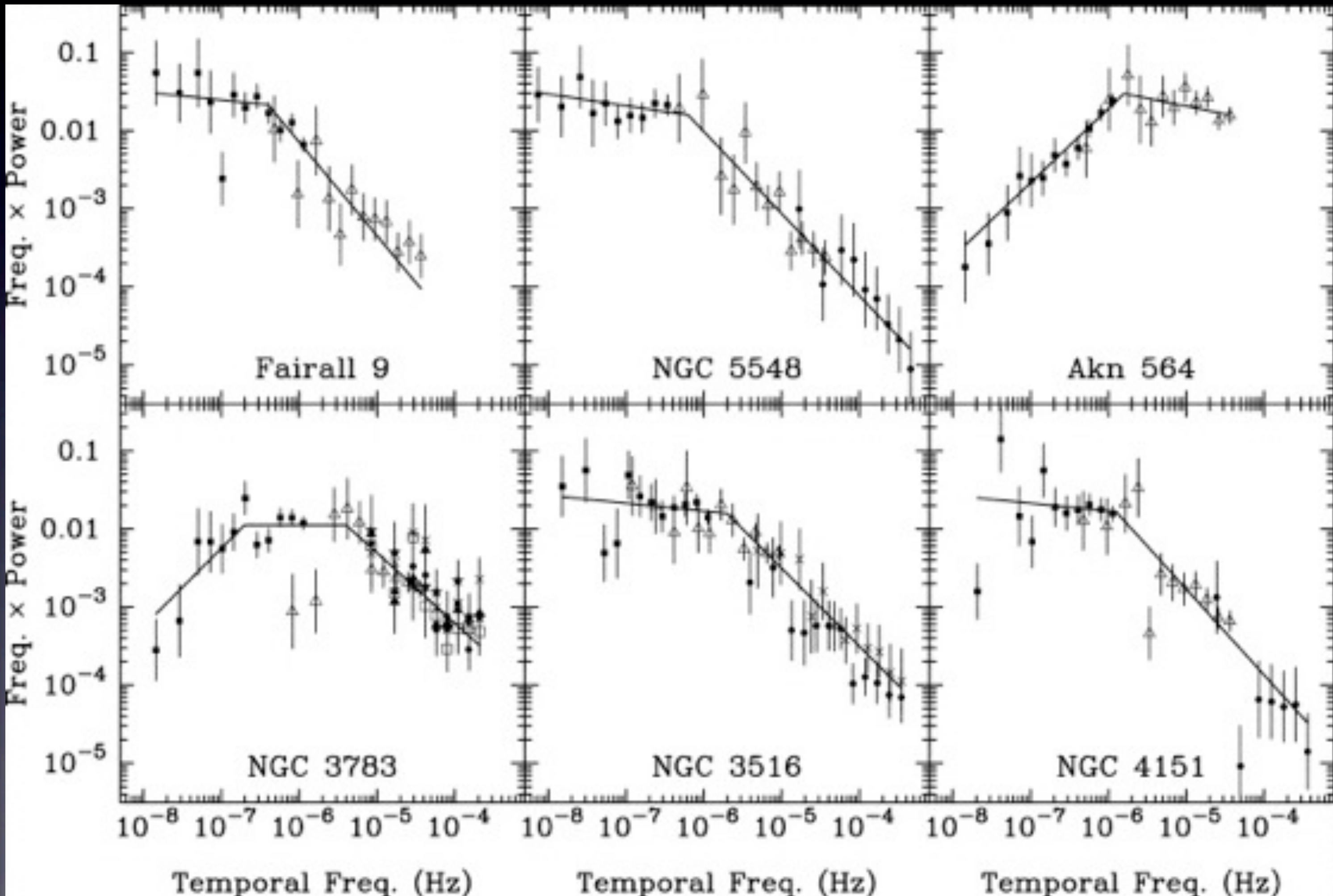
X-ray variability in accreting black hole systems

Most informations we have about AGN variability comes from nearby objects:

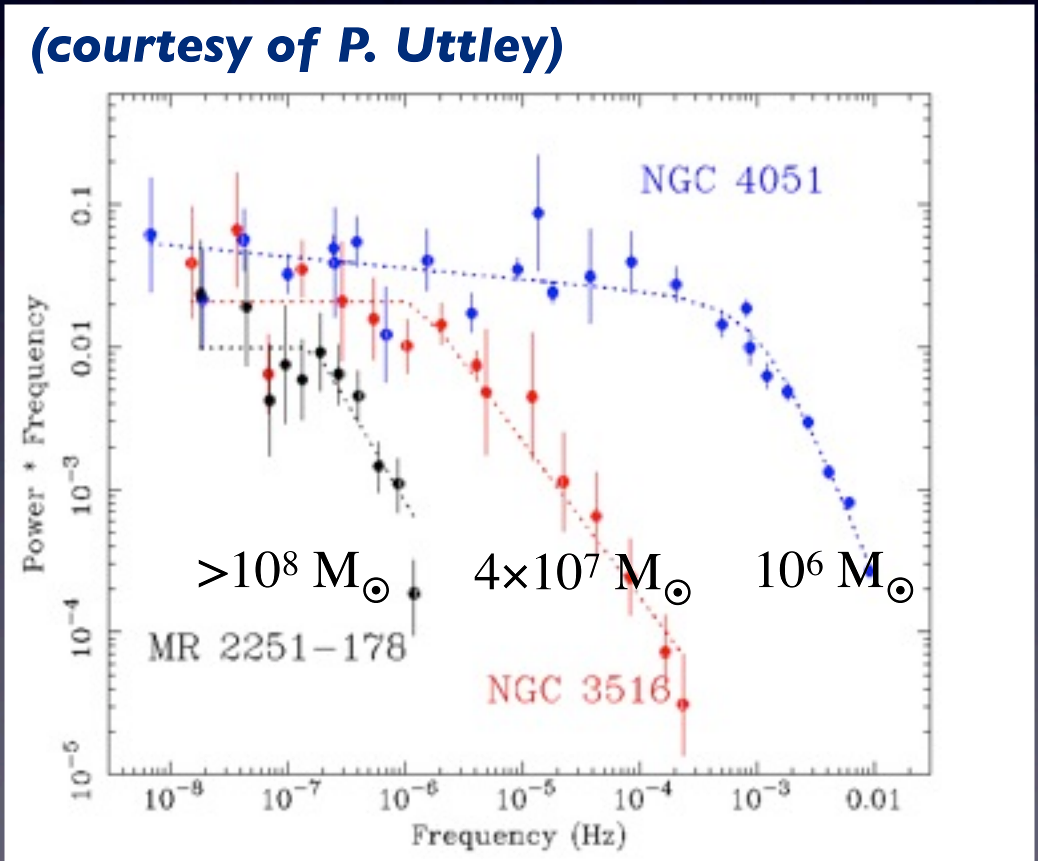
- Similarities between galactic BH and SMBH
- Similar temporal behavior, if rescaled by mass
- Power Density Spectrum dominated by red-noise

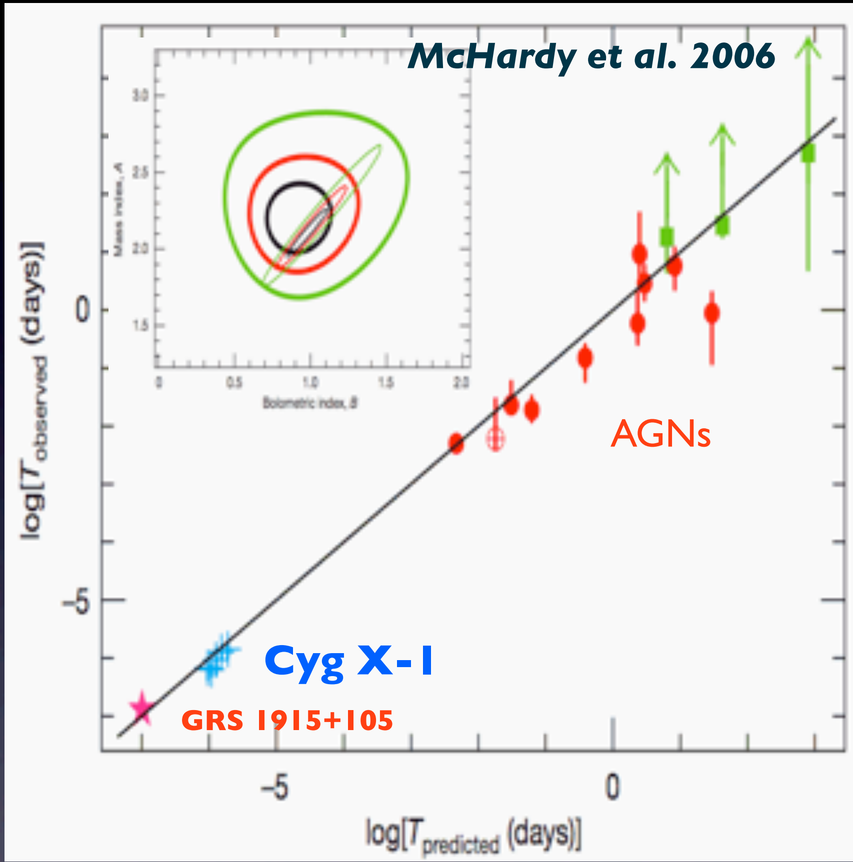


X-ray variability: Power Density Spectrum



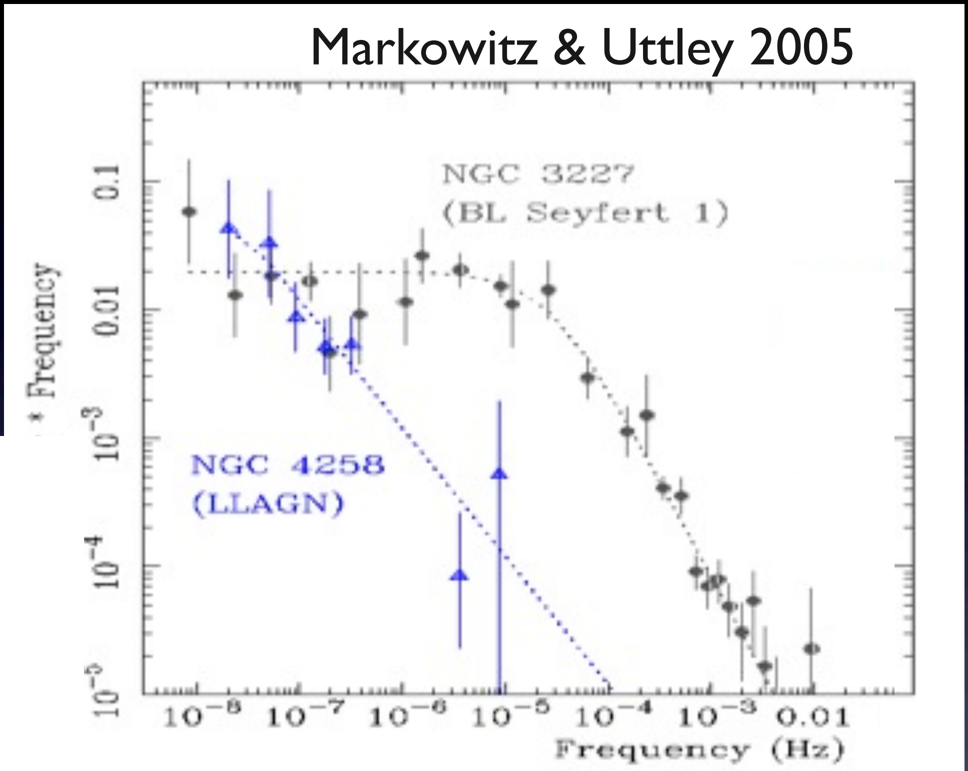
Characteristic time-scales scale with black hole mass and accretion rate



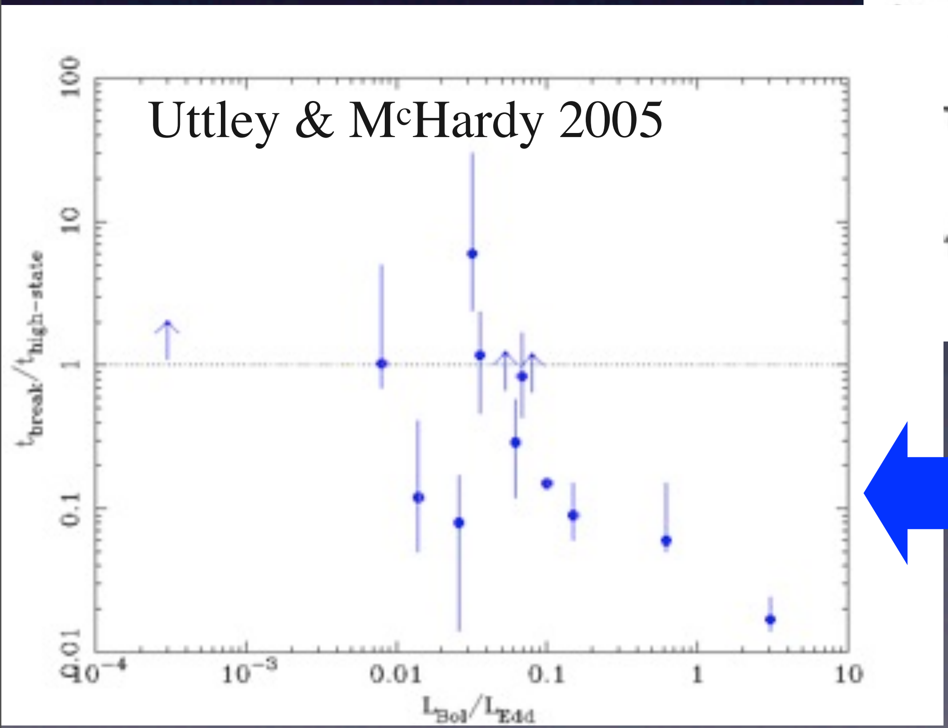


Characteristic time-scales scale inversely with accretion rate

For AGN with the same BH mass, PSD break time-scale appears to depend on luminosity



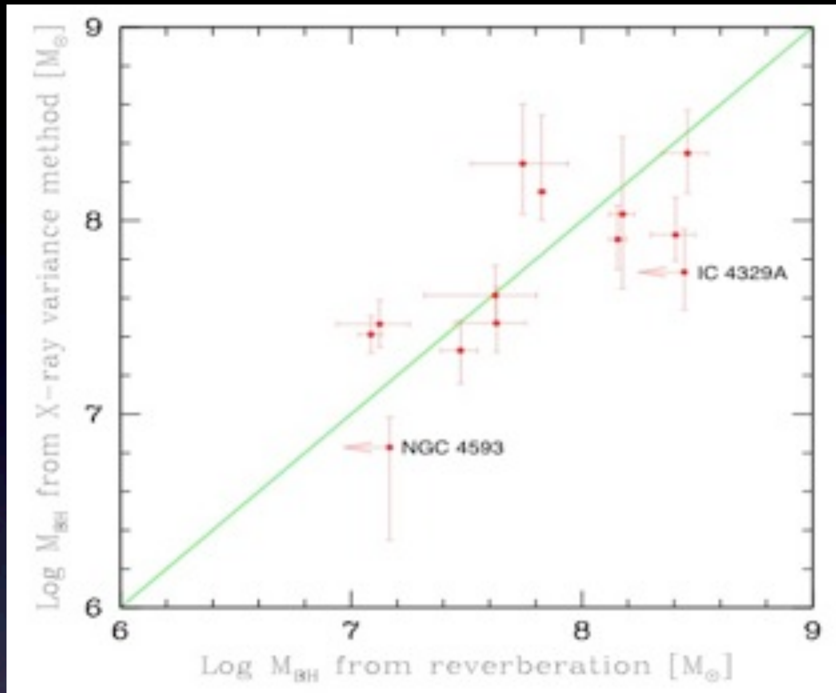
Time-scale normalised by BH mass scales inversely with L_{bol}/L_{Edd}

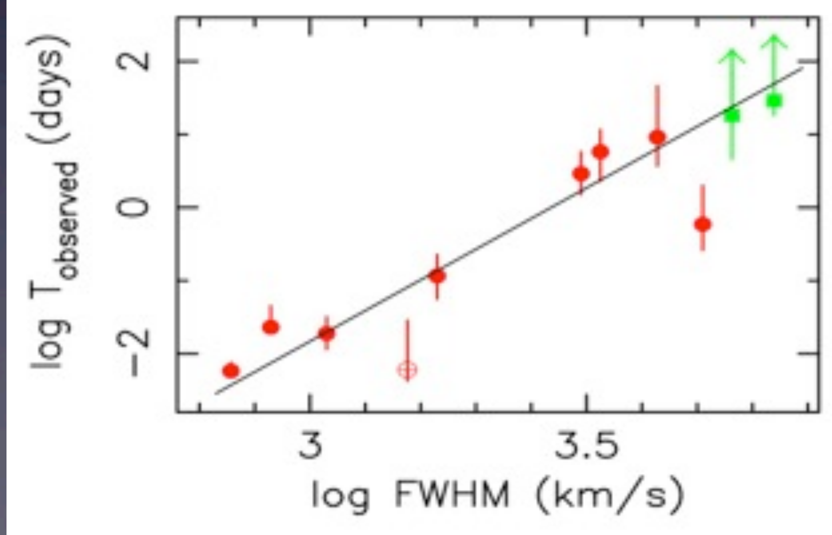


Mass estimates from X-ray variability

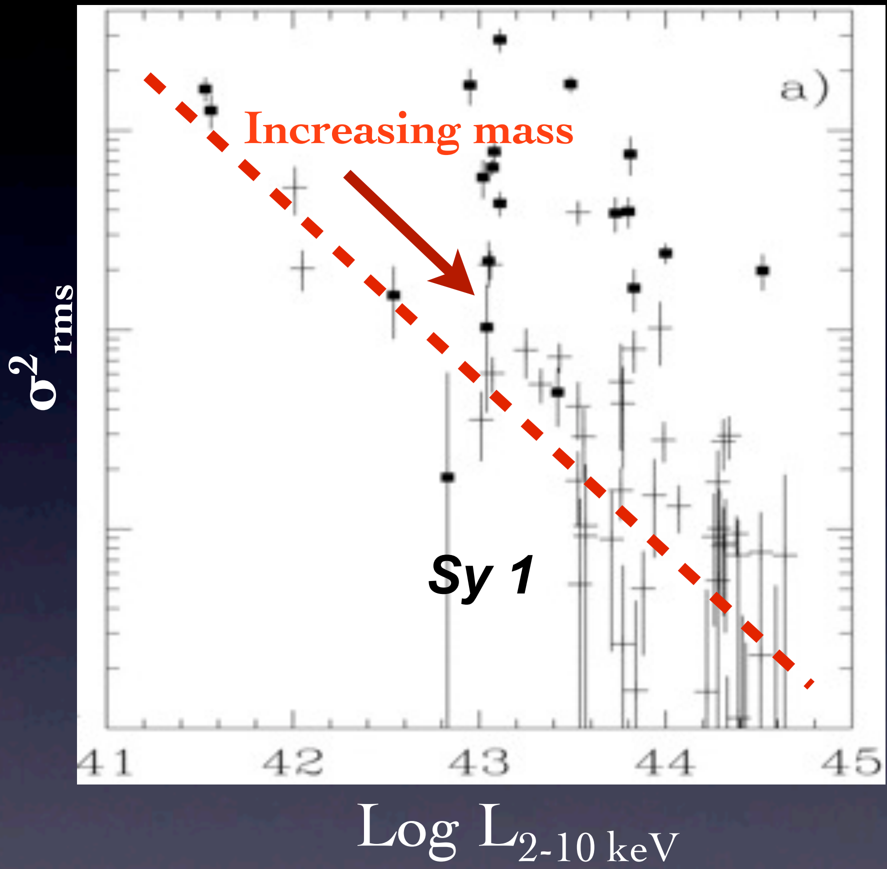
- High frequency break seems to scale with BH mass and accretion rate $t_B \propto M_{BH}^{\alpha}/L_{bol}^{\beta}$
- Mass can be estimated from amplitude of high frequency region of the PSD.
- So far comparison with independent mass estimates show a good agreement (McHardy et al. 2006, Nikolajuk et al. 2007)
- t_B also correlates with large scale properties of the AGNs: H_{β} FWHM

Promising method to measure mass and accretion rates in multi-epoch X-ray surveys.

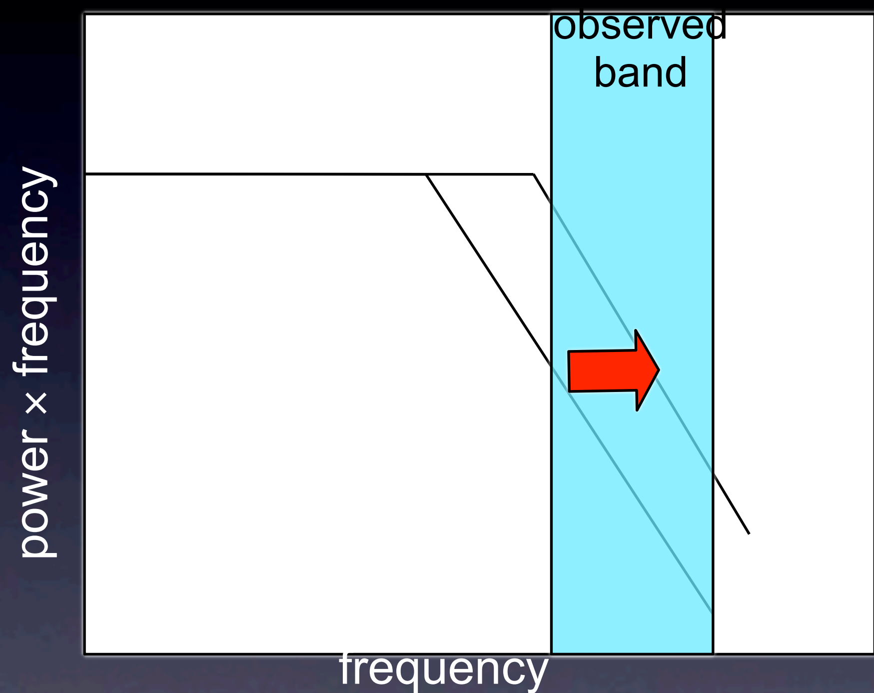




VARIABILITY IN POOR STATISTICS DATA

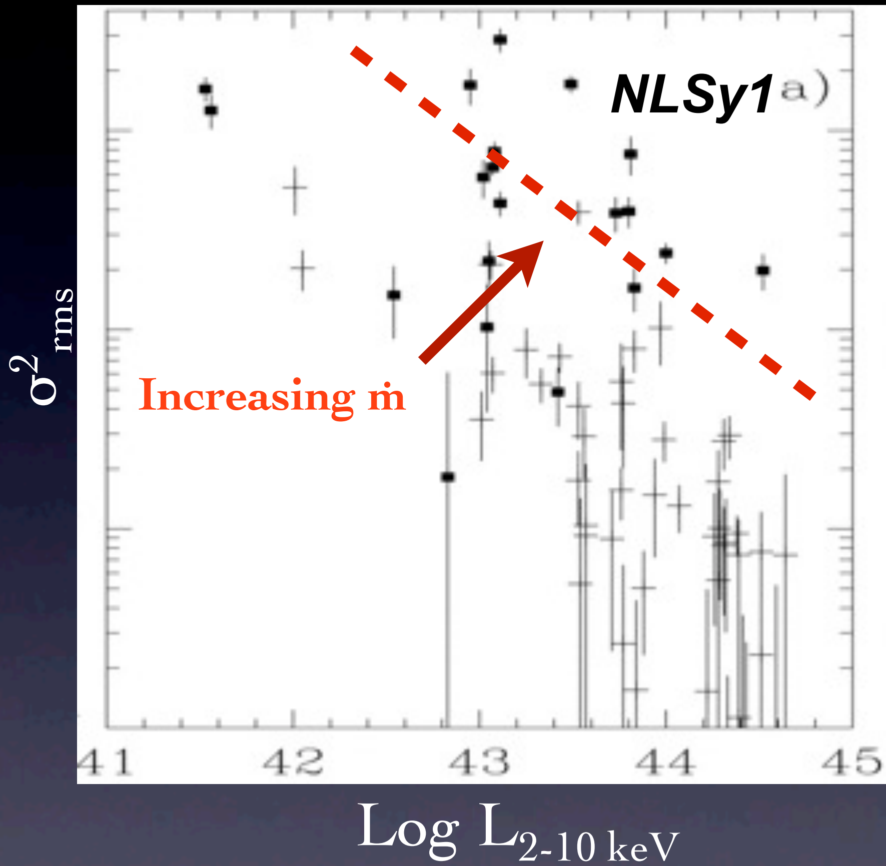


Black squares: NLS1, Crosses: BL Seyferts
(Turner et al. 1999)

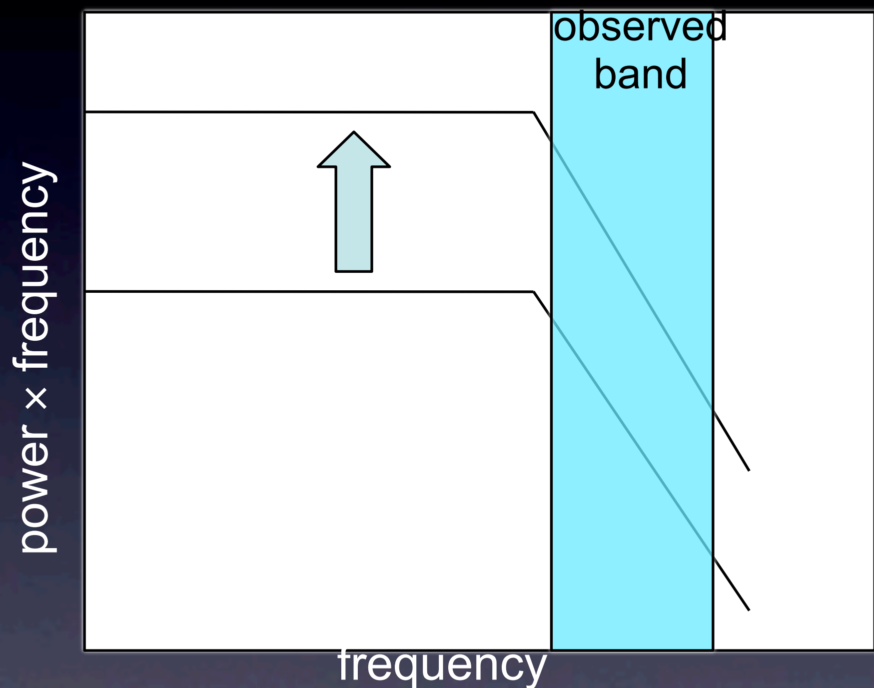


Can use 'excess-variance' to estimate mass [e.g. O'Neill et al., Gierlinski et al. 2007]
but should take accretion rate into account!

Variability in poor statistics data

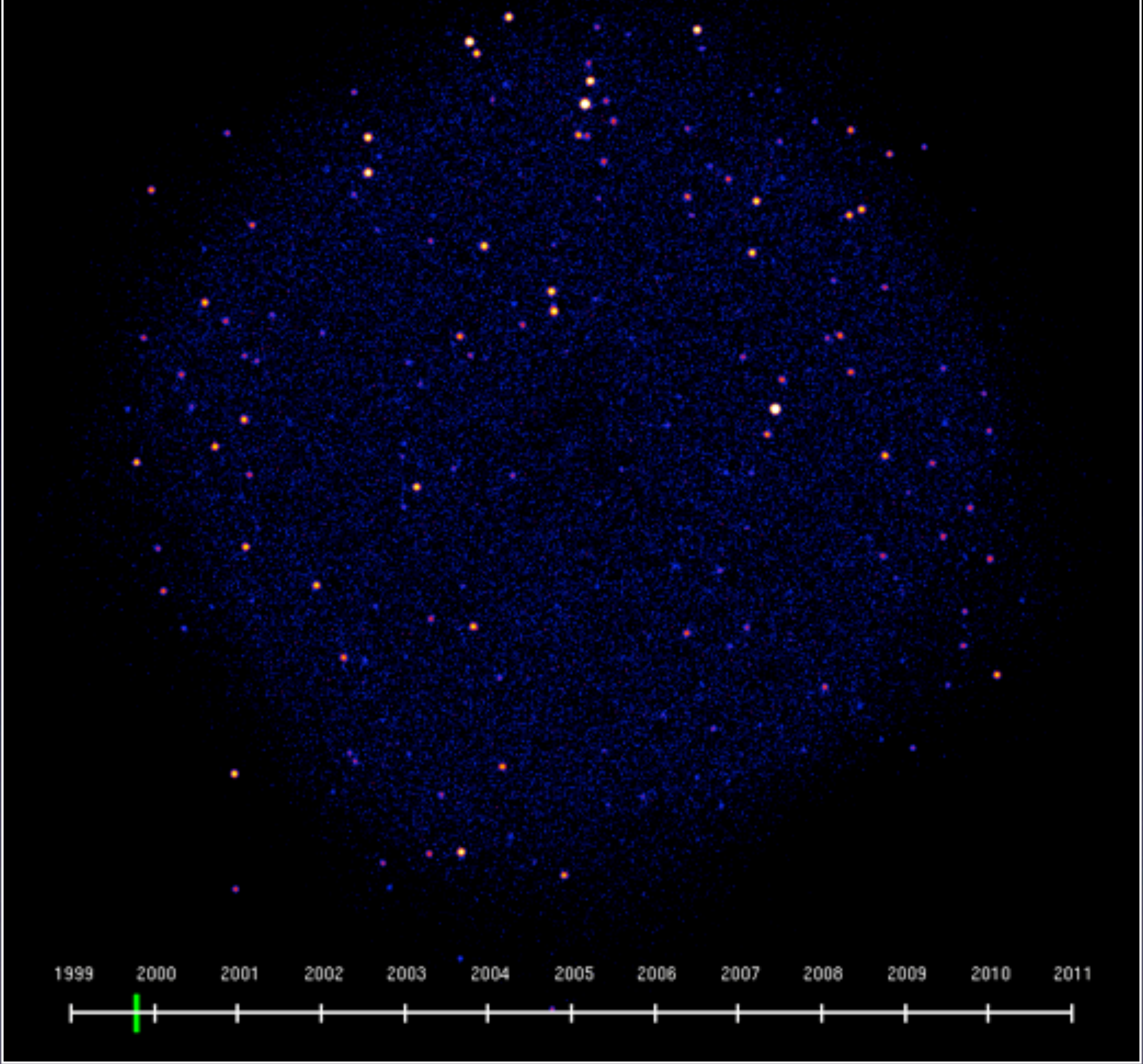


Black squares: NLS1, Crosses: BL Seyferts (Turner et al. 1999)



Can use ‘excess-variance’ to estimate mass [e.g. O’Neill et al., Gierlinski et al. 2007] **but** should take accretion rate into account!

10 years of CDFS X-ray monitoring

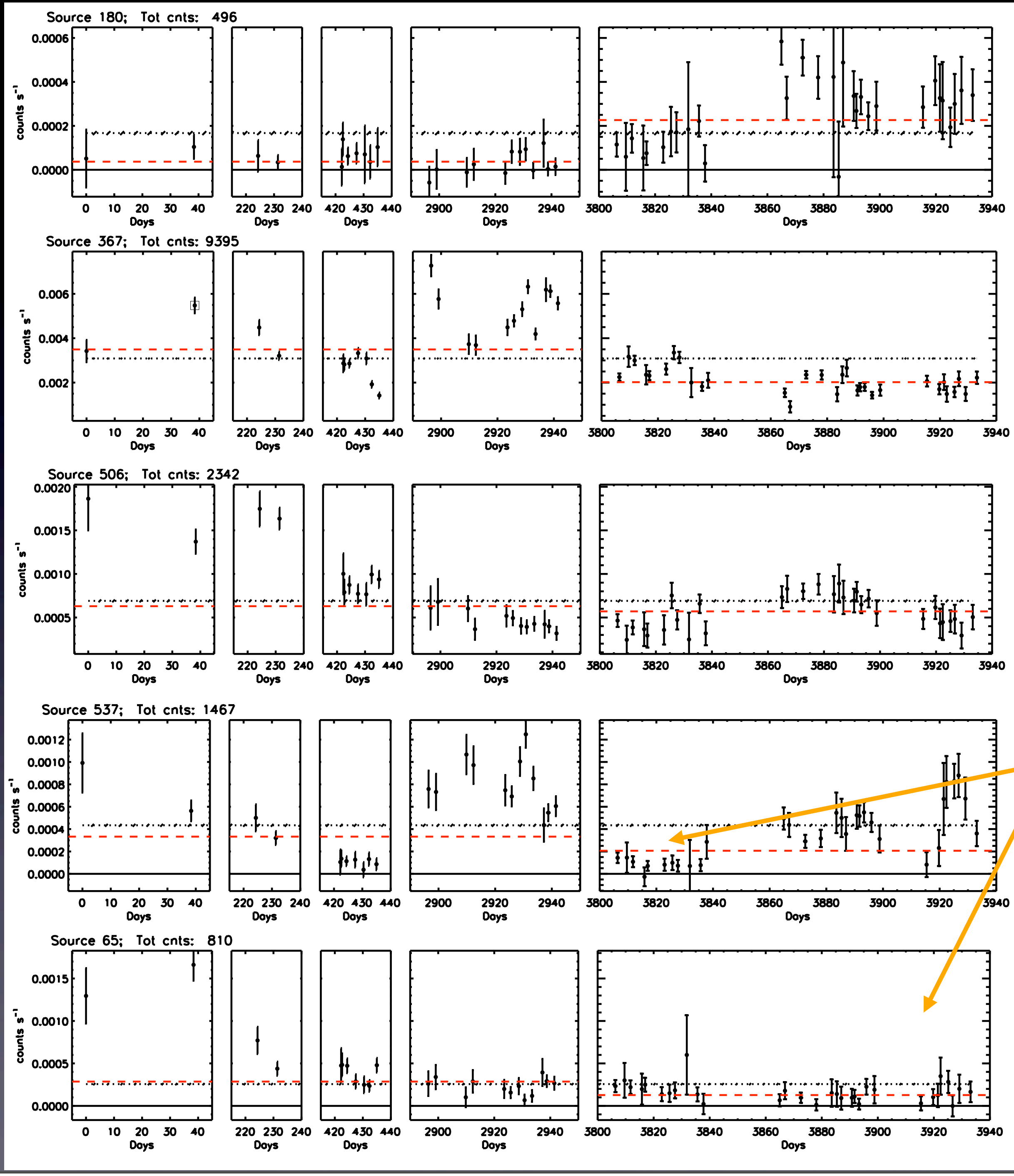


The 4 Ms CDFS dataset

Full movie at *http://people.na.infn.it/~paolillo/CDFS.html*)

flickering of faint sources is due to noise

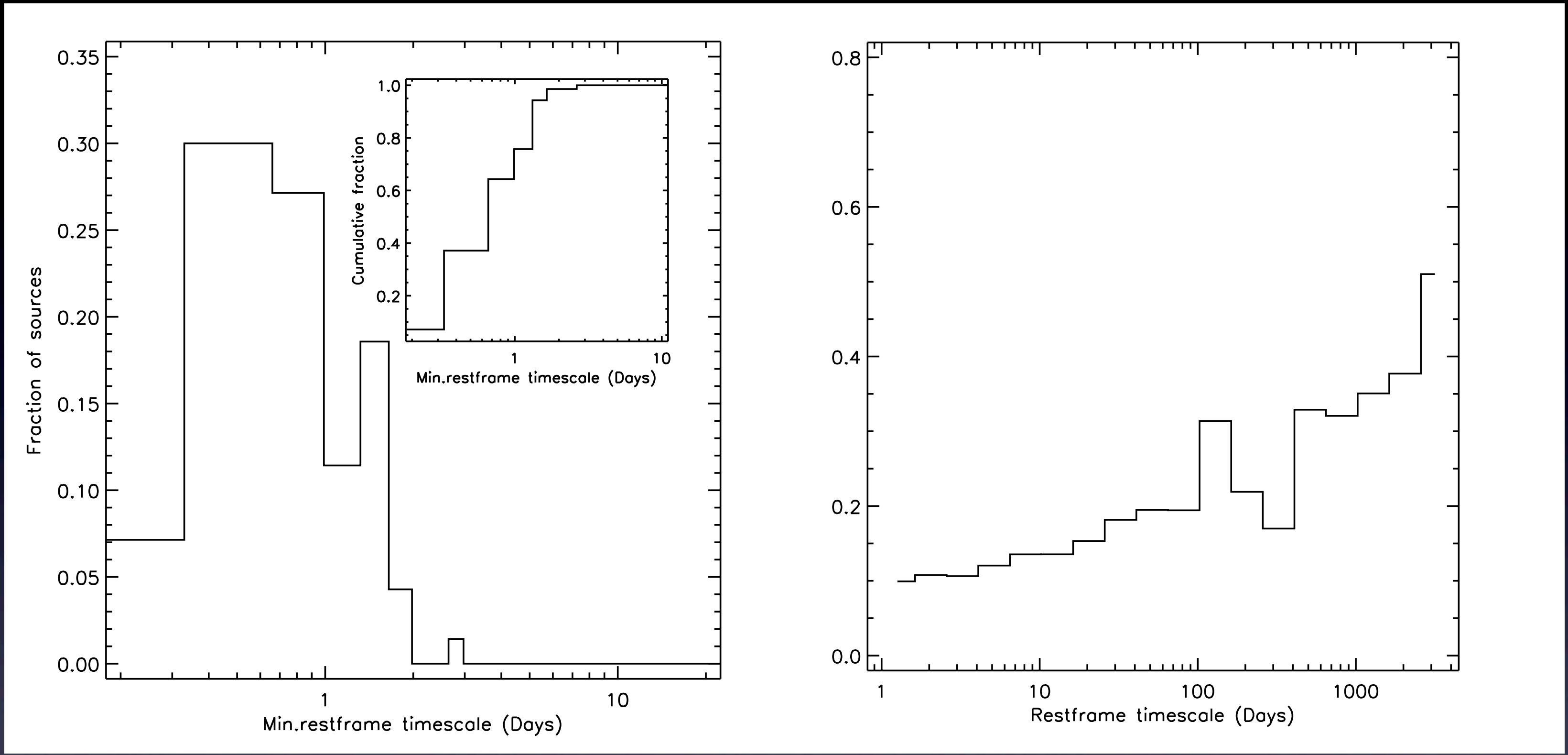
4Ms CDFS lightcurves (*Chandra data*)



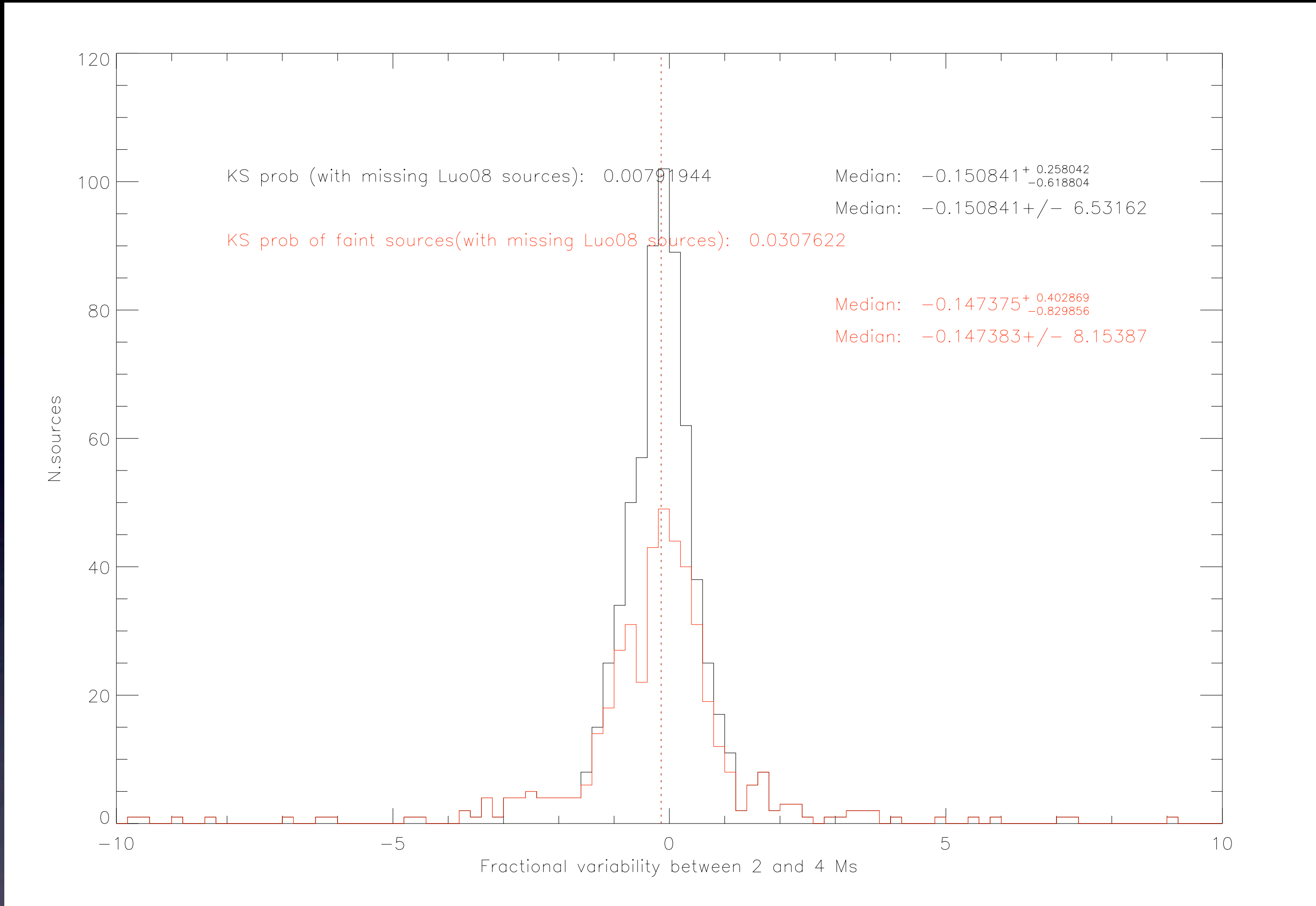
Faint AGN detection does depend on variability: some are undetected within observing campaigns of just a few days!

in 4Ms CDFS all missing 2Ms AGNs show evidence of variability, bringing them below the detection threshold.

10 years of CDFS monitoring

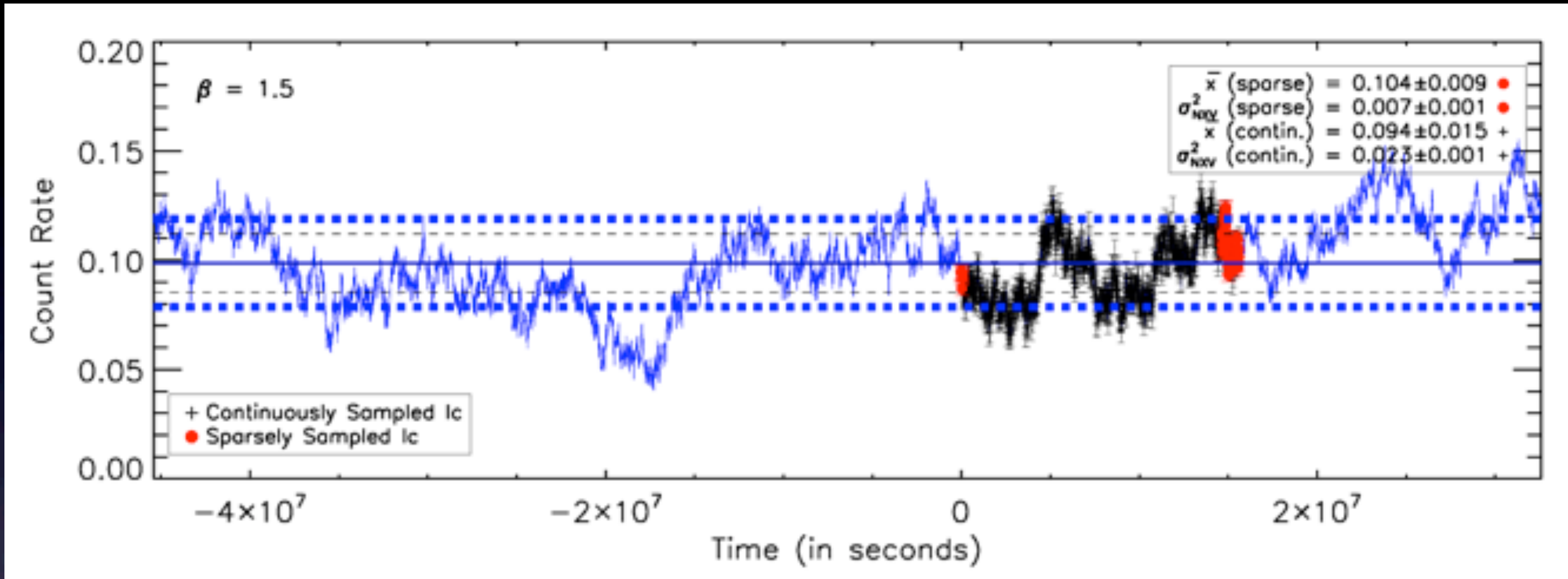


- The majority of AGNs possess significant (Δf/f>10%) intrinsic variability (>90% accounting for sensitivity limits)
- We detect variability over timescales ranging from days to 10 years
- The CDFS lightcurves are dominated by long-term variability.
- 95% of the sources possess short term variability on < 2 days.



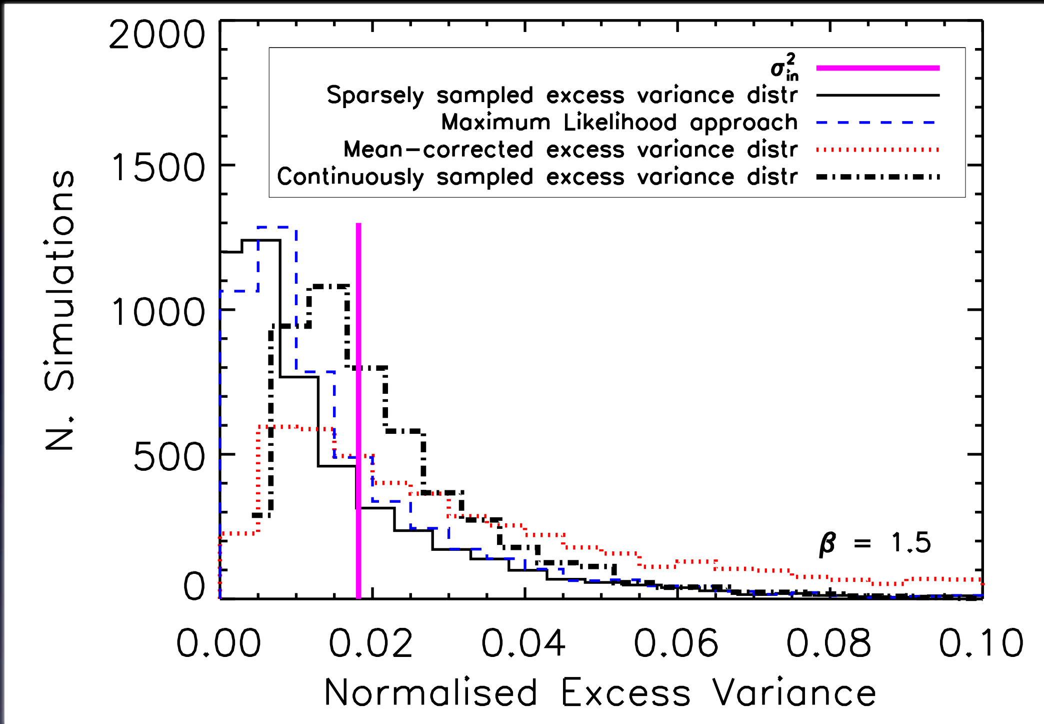
- Variability from one Ms to the next in Chandra data can reach factors of a few!
- In 4Ms Chandra CDFS missing 2Ms AGNs show evidence of variability, bringing them below the detection thresholds.

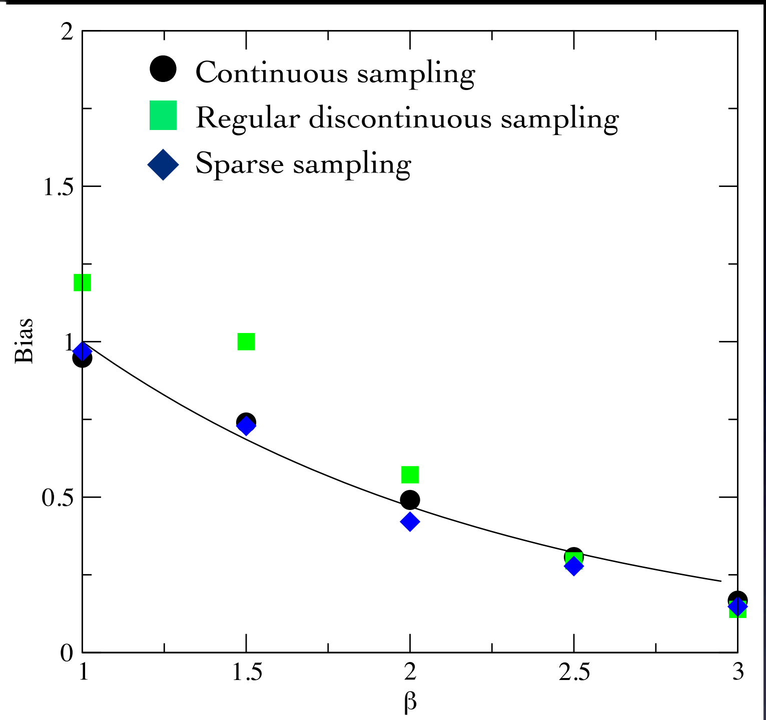
Variability estimates: biasing
(Allevato et al. 2012)



- We developed a simulation code based on the Timmer & Koenig (1995) algorithm, accounting for different background and sampling (Allevato et al. 2012).
- Simulated red-noise lightcurves with baseline as XMM-CDFS observations obtained in 2002/03.

Variability estimates: biasing
(Allevato et al. 2012)

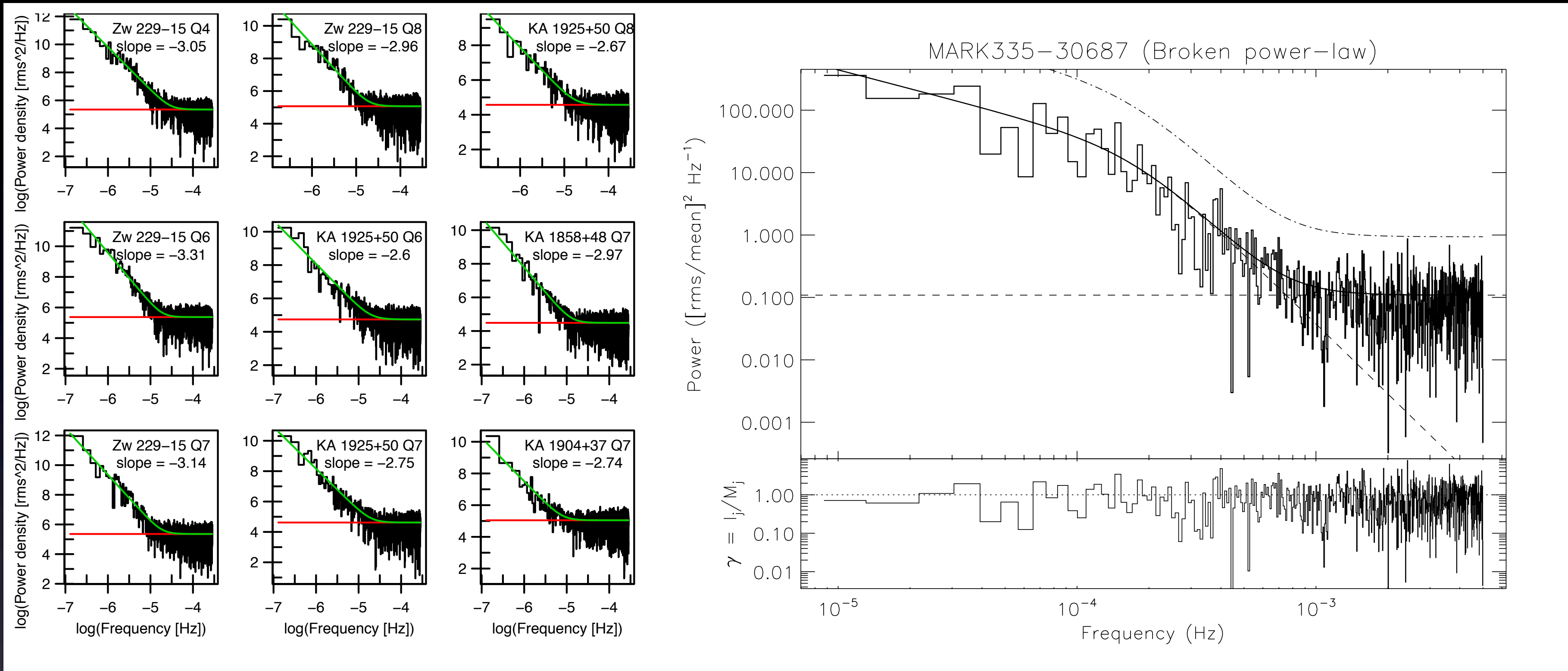




- Sparse and irregular sampling results in biased estimates and large uncertainties, but even continuous observations are actually inaccurate estimates of the intrinsic variance
- Individual lightcurves are useless
- The good news are that the average quantities (repeated observations or large samples) are well behaved

Evidence of steep PSD slopes

(Mushotzky, R.F., et al. 2011. ApJL, 15, 6) Gonzales-Martin & Vaughan (2012)



- Effect of sparse sampling may produce underestimates of the intrinsic variance by a factor of ≤2 for PDS with slopes shallower than -2, but up to one order of magnitude for steeper PDS .
- Recent Kepler and XMM results show that this could be the case for some AGNs (and for some radio loud objects).

Probing mass and accretion rate

$$\nu_{bf} = 0.029\eta\dot{m}_{Edd}(M_{BH}/10M_{\odot})$$

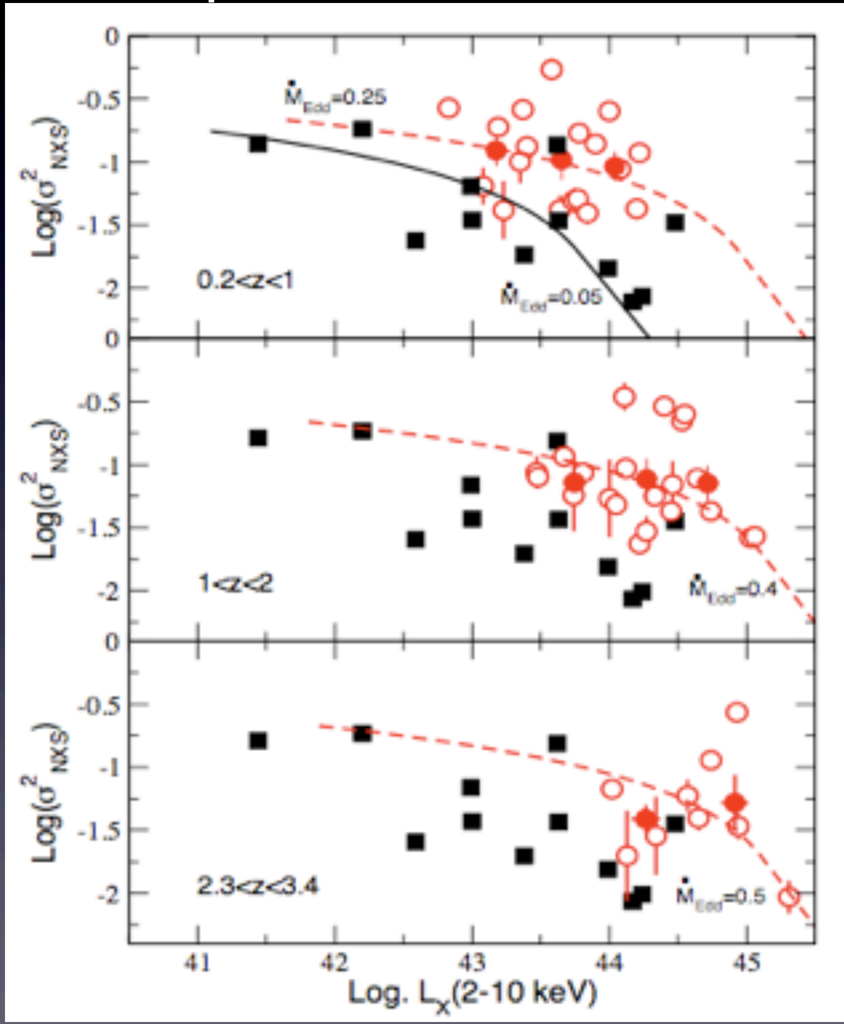
$$L_{bol} = 1.3\eta\dot{m}_{Edd}10^{39}(M_{BH}/M_{\odot})\ \mathrm{erg/s}$$

Variability-LX relation can be used in principle to probe both accretion rate and BH mass

However we need high-quality, well sampled data

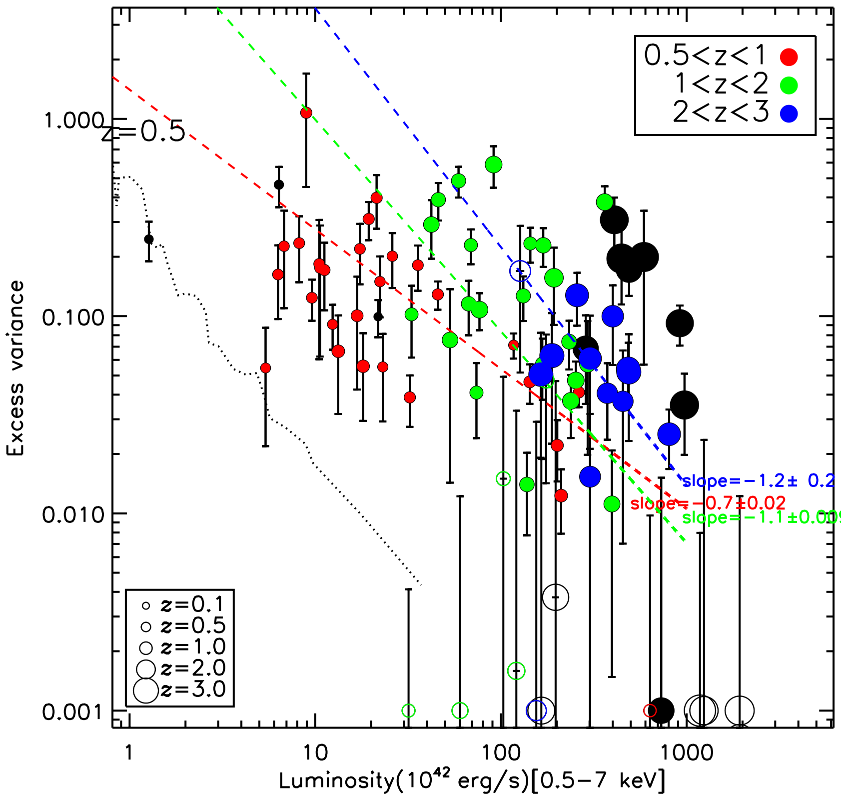
(also redshift change the effective sampled timescales and energy bands)

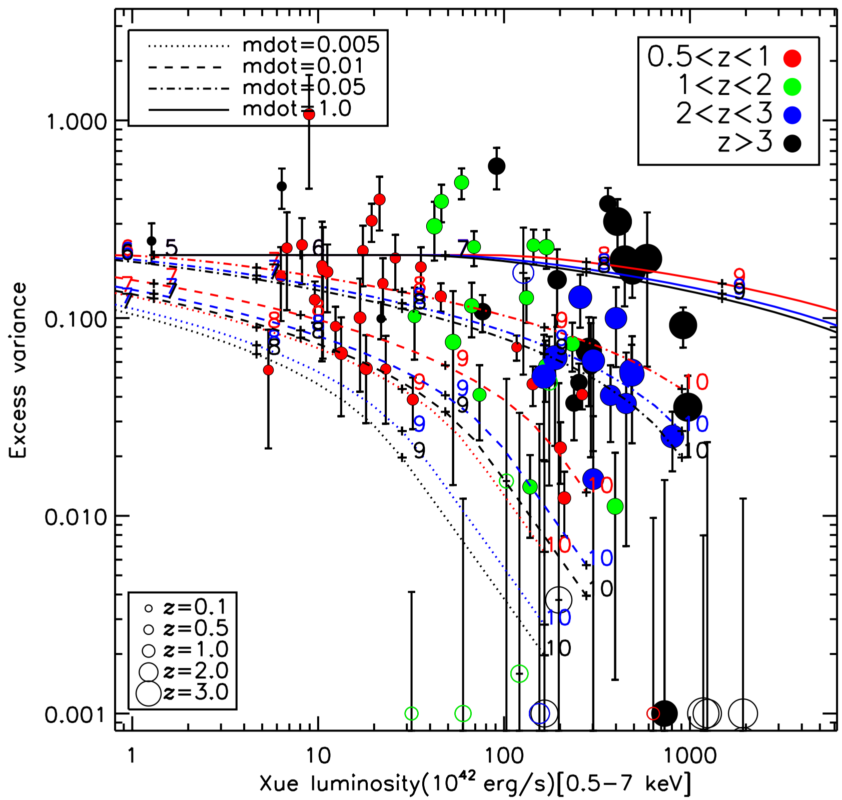
Papadakis et al. 2008



Variability evolution with redshift

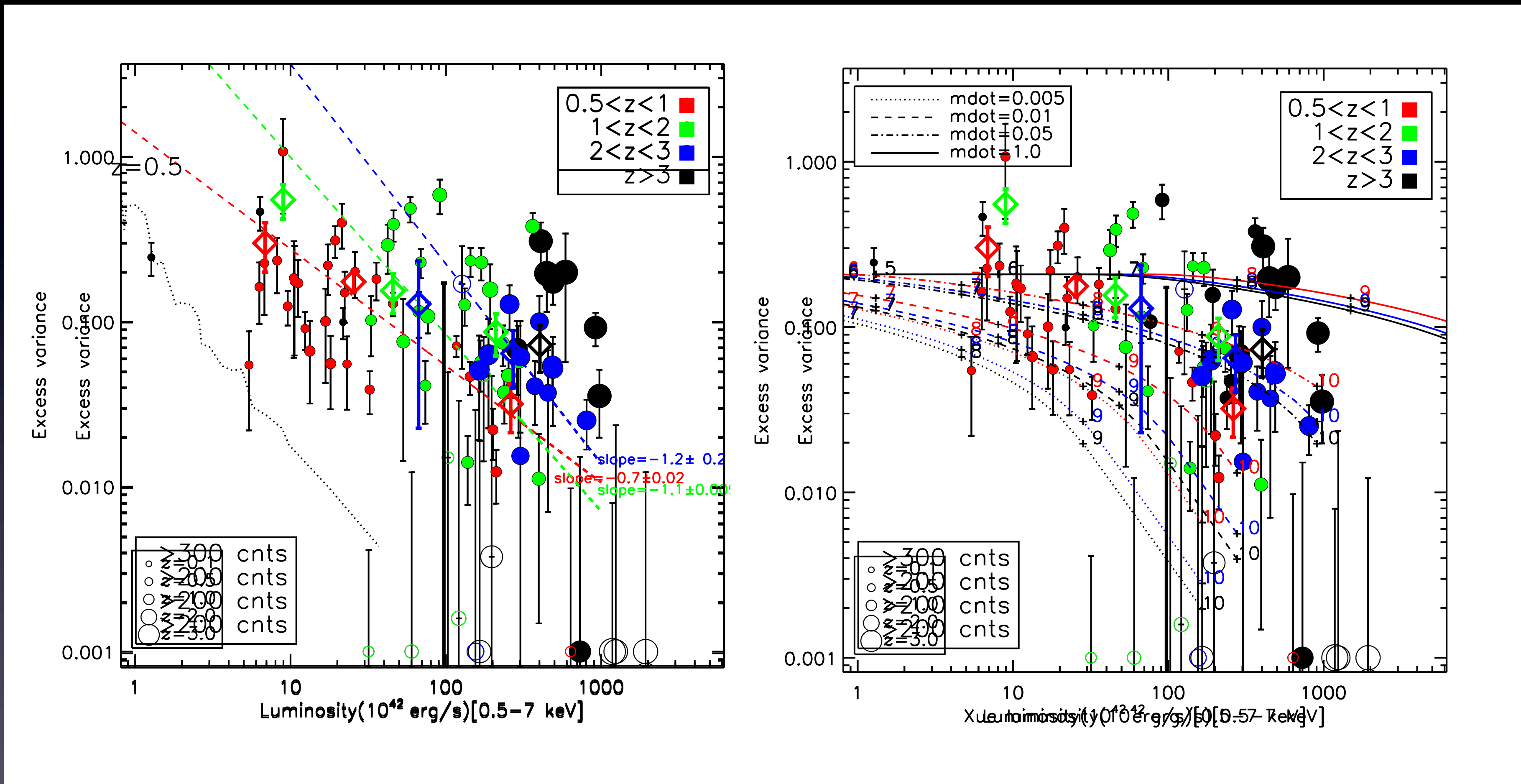
Did BH accreted more in the past?





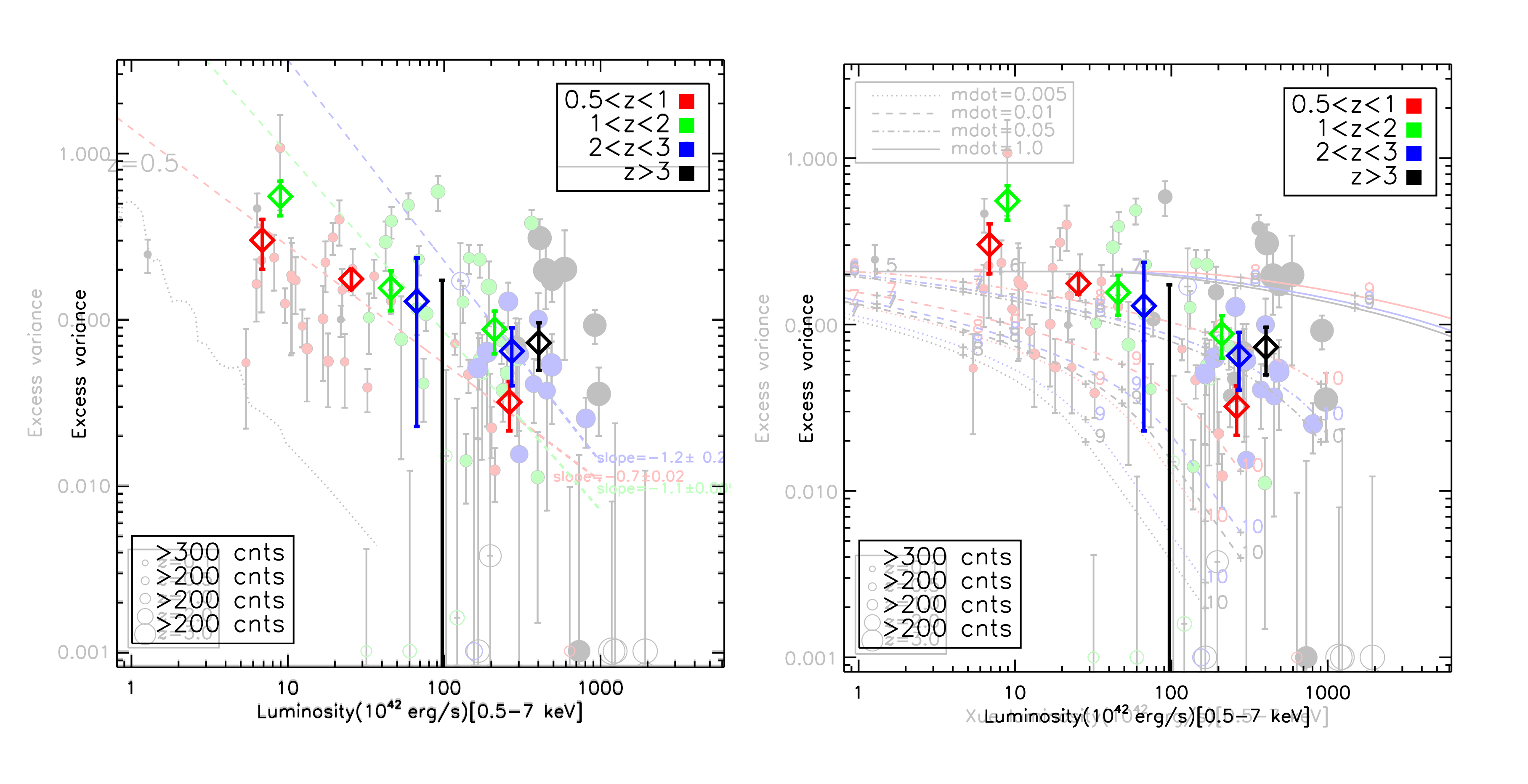
Variability evolution with redshift

Did BH accreted more in the past?



Variability evolution with redshift

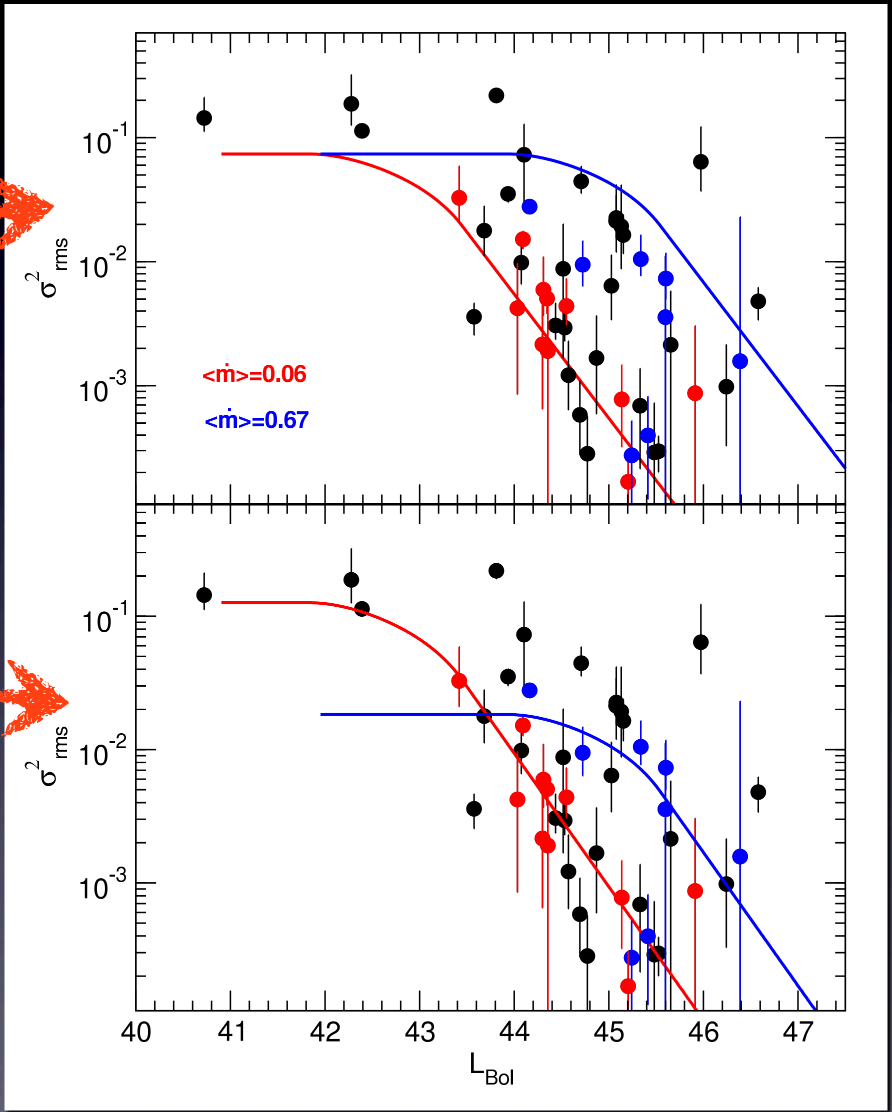
Did BH accreted more in the past?



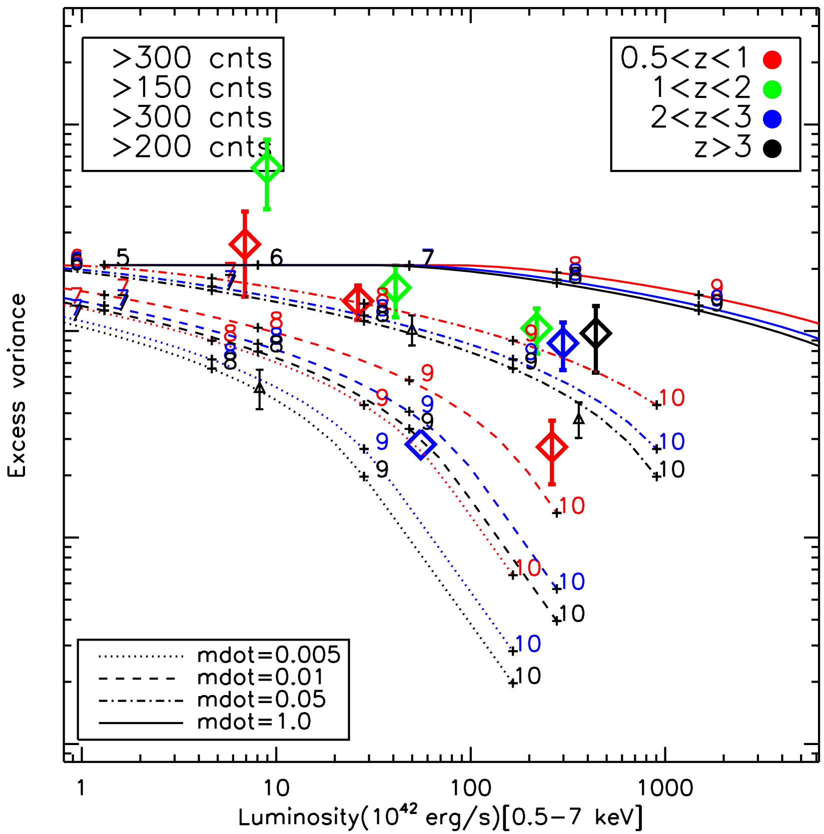
Modeling the variability

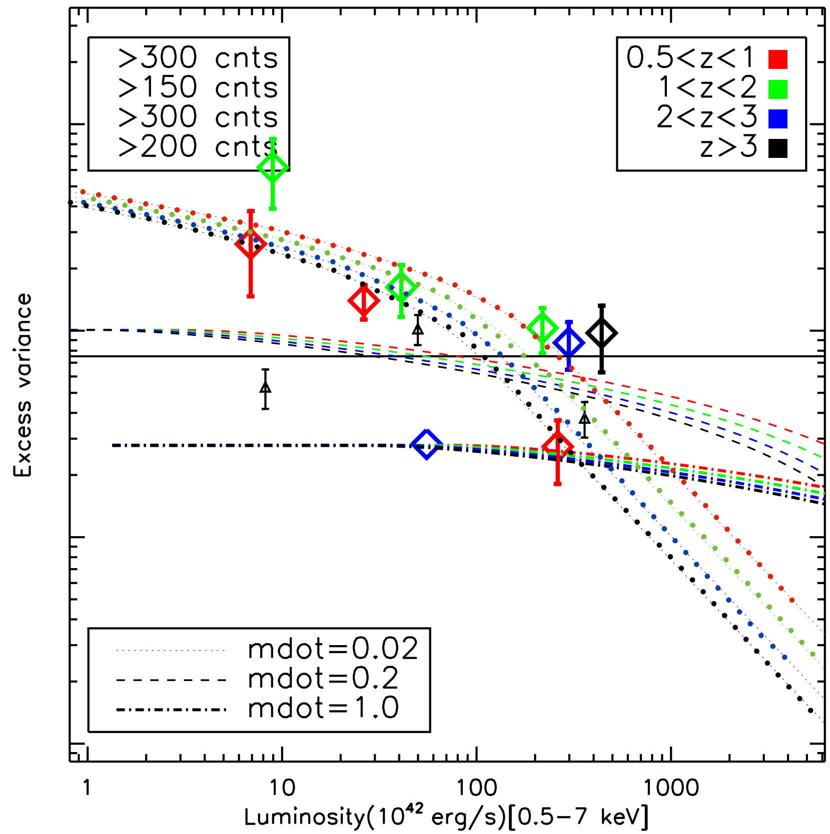
Ponti et al. 2011 show that the assumption of a fixed PSD amplitude (Papadakis et al. 2004, 2008) does not yield satifactory fits to the CAIXA sample.

They adopt a variable amplitude which counter-balance the accretion rate dependence of the PSD break.



Which model for CDFS sources?





Papadakis et al. (2008)

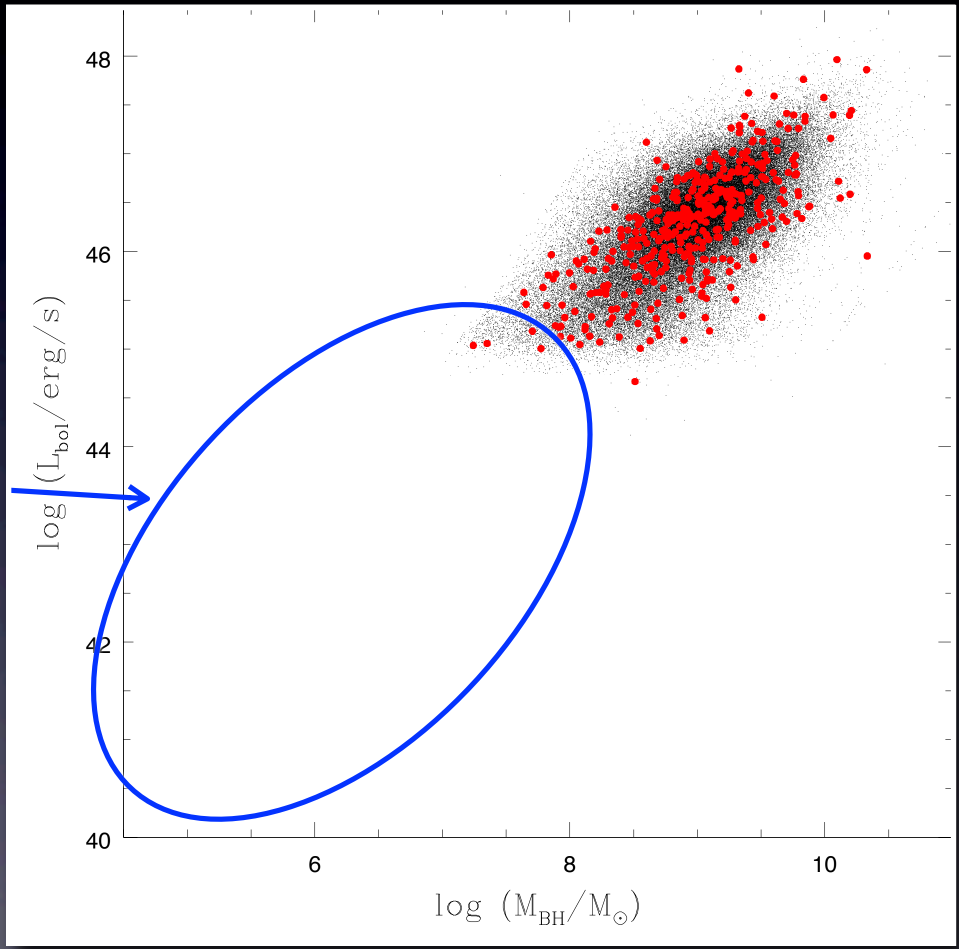
Ponti et al. (2011)

Extension to serendipitous surveys

[courtesy of F.Vagnetti]

The nearby AGN sample may not be representative of the bulk of the AGN population:

- the figure shows the distribution of M_{BH} and L_{bol} for the XMM-Newton Serendipitous Source Catalog (red circles, Vagnetti, Turriziani, Trevese 2011) derived from the catalogue by Shen et al (2011) (black dots)
- the relation by McHardy et al (2006) is based on **a** few AGNs with low masses and luminosities: it is uncertain that it can be applied to normal quasars of high M_{BH} and L_{bol}



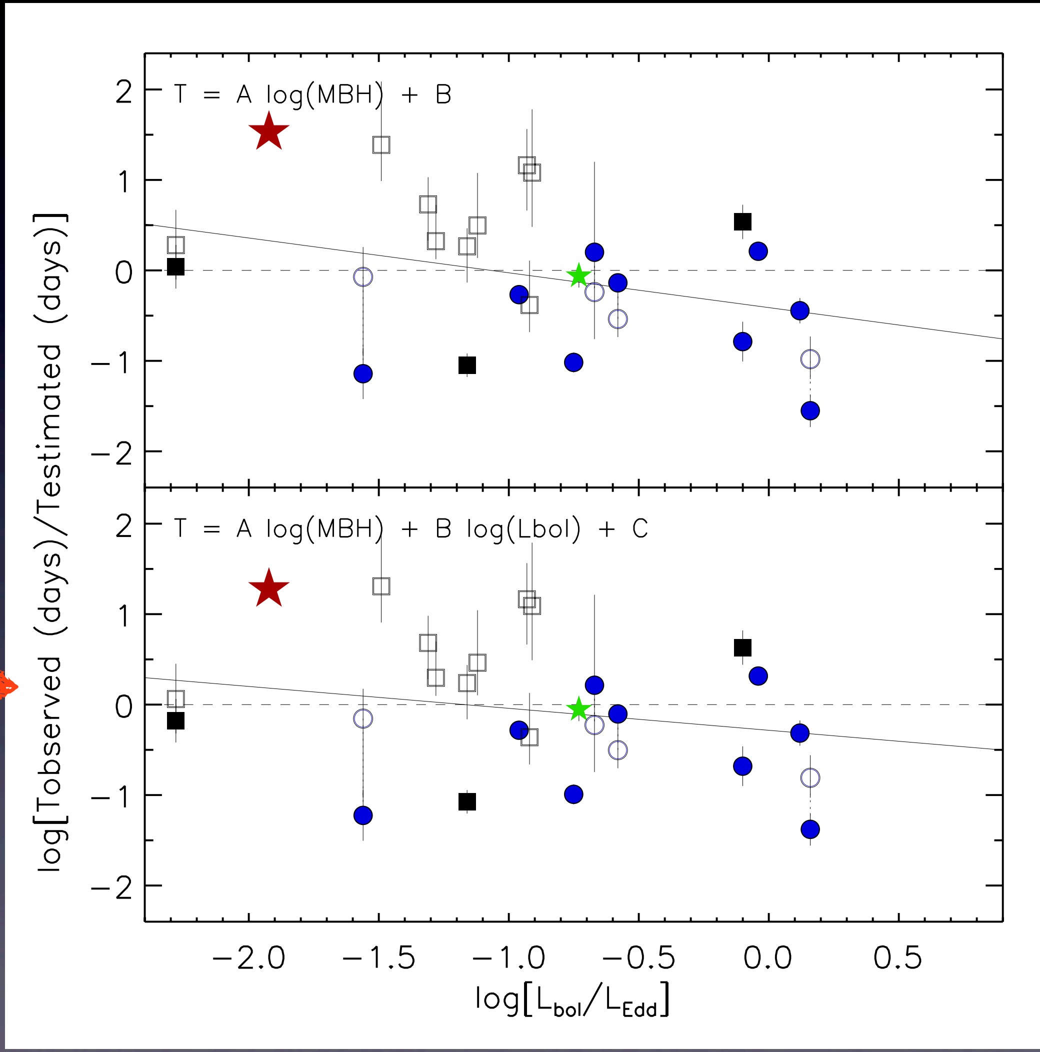
(Vagnetti, Turriziani, Trevese 2011)

Further uncertainties....

Gonzales-Martin & Vaughan (2012) study 104 nearby AGN from XMM-Newton observations. They test different scenarios:

- Break timescale depends only on BH mass
- Break timescale depends only on BH mass and accretion rate.

The coefficient B is consistent with zero, i.e. weak or no dependence on accretion rate.



Conclusions

- 10 years of Chandra monitoring confirm most results found in the 1 Ms dataset.
- Must account for variability to get a complete catalog on these long timescales.
- Variability may allow to trace BH mass and accretion rats. However:
  - we need to account for observational bias to match observations to models, i.e. simulations or analytical recipes .
  - the PSD behavior is still unclear even for nearby AGNs.
- Complete homogeneous datasets are needed to compare nearby and distant AGN samples.

If you cannot read the conclusions, it means you're tired and is time for BEER!

Conclusions

- 10 years of Chandra monitoring confirm most results found in the 1 Ms dataset.
- Must account for variability to get a complete catalog on these long timescales.
- Variability may allow to trace BH mass and accretion rats. However:
  - we need to account for observational bias to match observations to models, i.e. simulations or analytical recipes .
  - the PSD behavior is still unclear even for nearby AGNs.
- Complete homogeneous datasets are needed to compare nearby and distant AGN samples.