Probing AGN accretion history through X-ray variability

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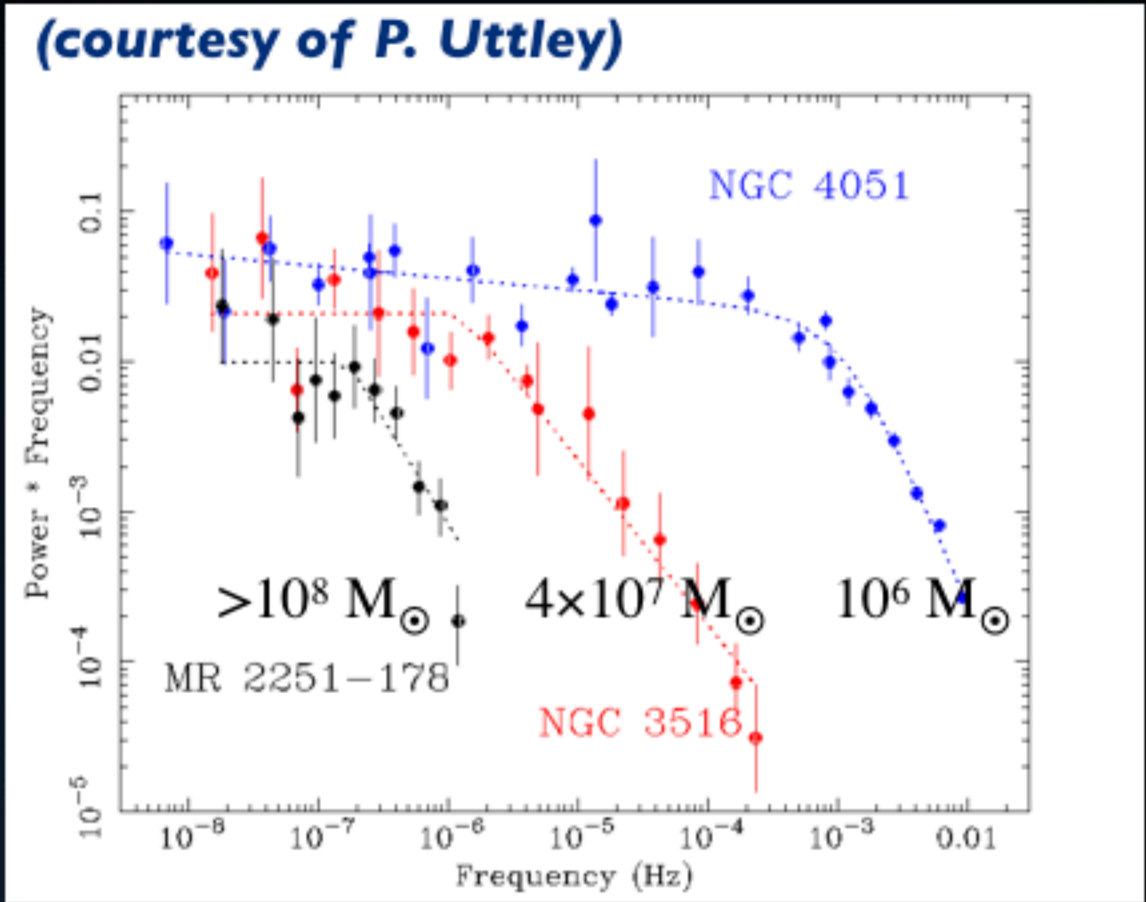
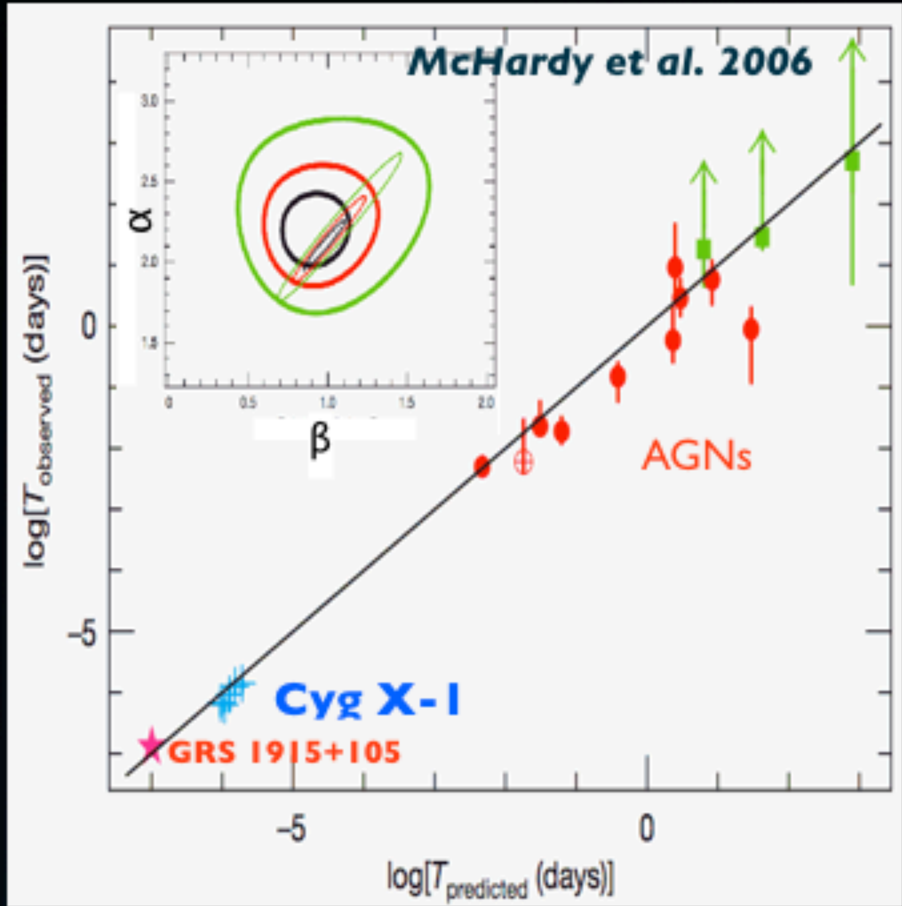
Variability properties of AGNs





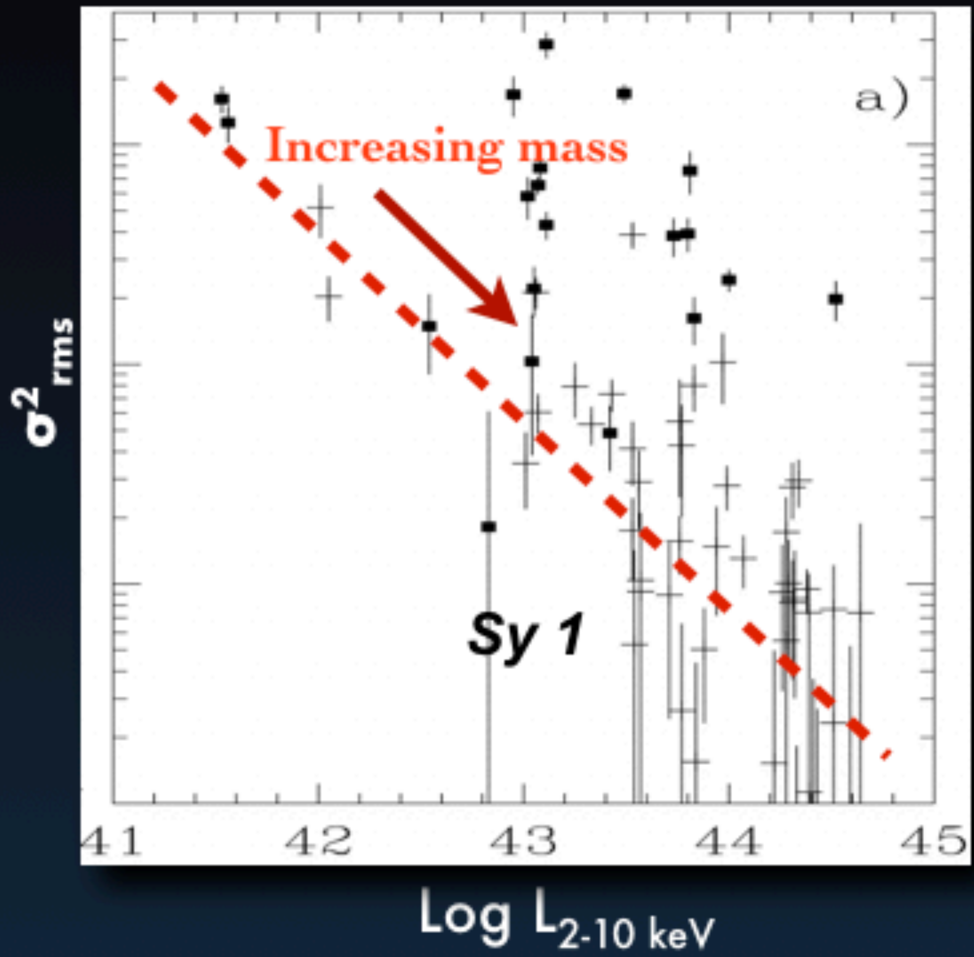
High frequency break seems to scale with BH mass and accretion rate

(Uttley & McHardy 2005, Markowitz & Uttley 2005, McHardy 2006)

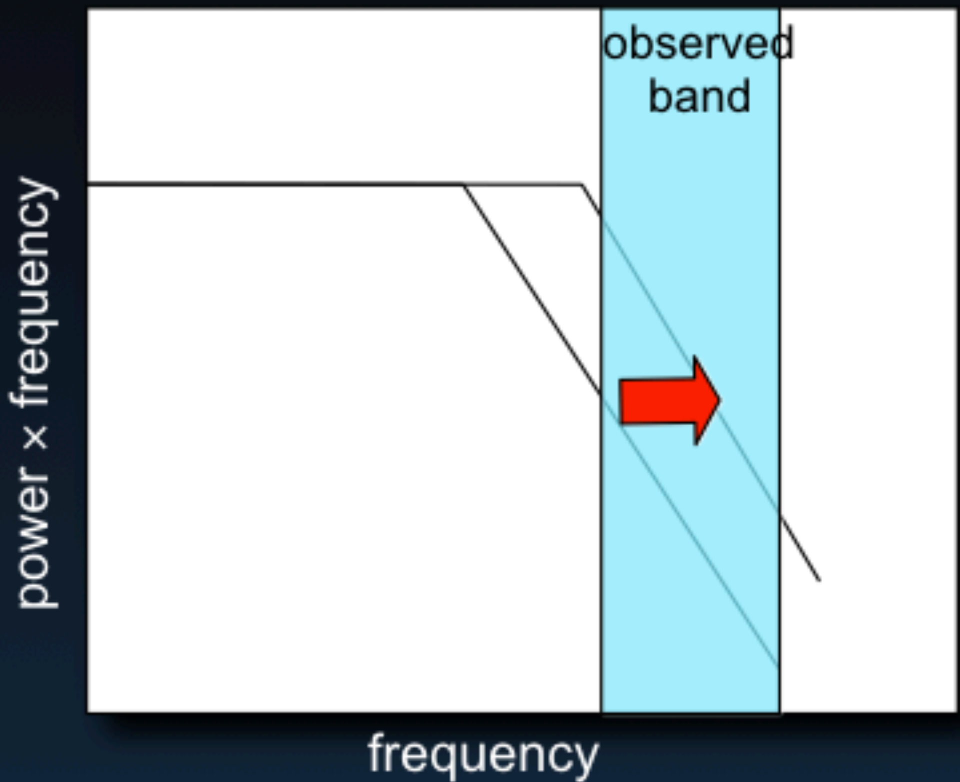
$$t_B \propto M_{BH}^{\alpha}/L_{bol}^{\beta}$$

Variability in poor statistics data

AGN variability is anti-correlated with L_X (Barr & Mushotzky 1986, Lawrence & Papadakis 1993, Nandra et al. 1997)



$$\sigma^2_{\rm NXV} = \frac{1}{N\overline{x}^2}\sum_{i=1}^{N}[(x_i - \overline{x})^2 - \sigma^2_{{\rm err},i}],$$



Can use 'excess-variance' to estimate mass (e.g. O'Neill et al., Gierlinski et al. 2007) **but** should take biases into account!

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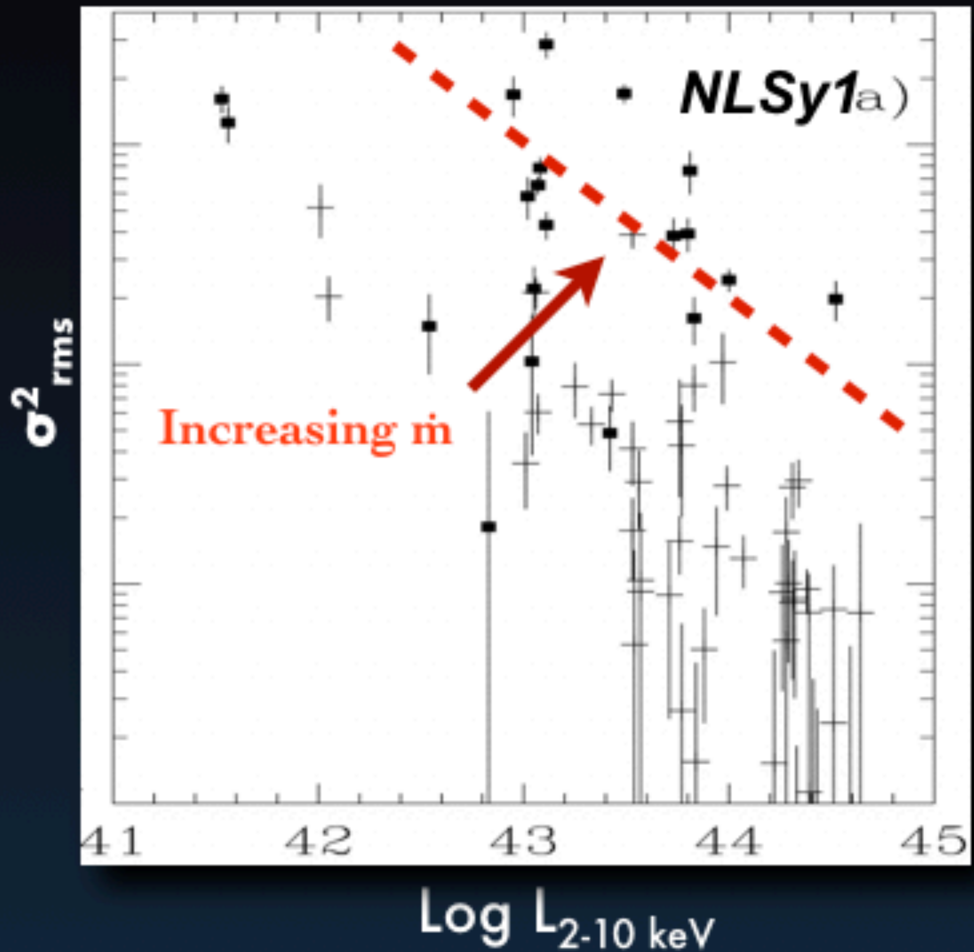

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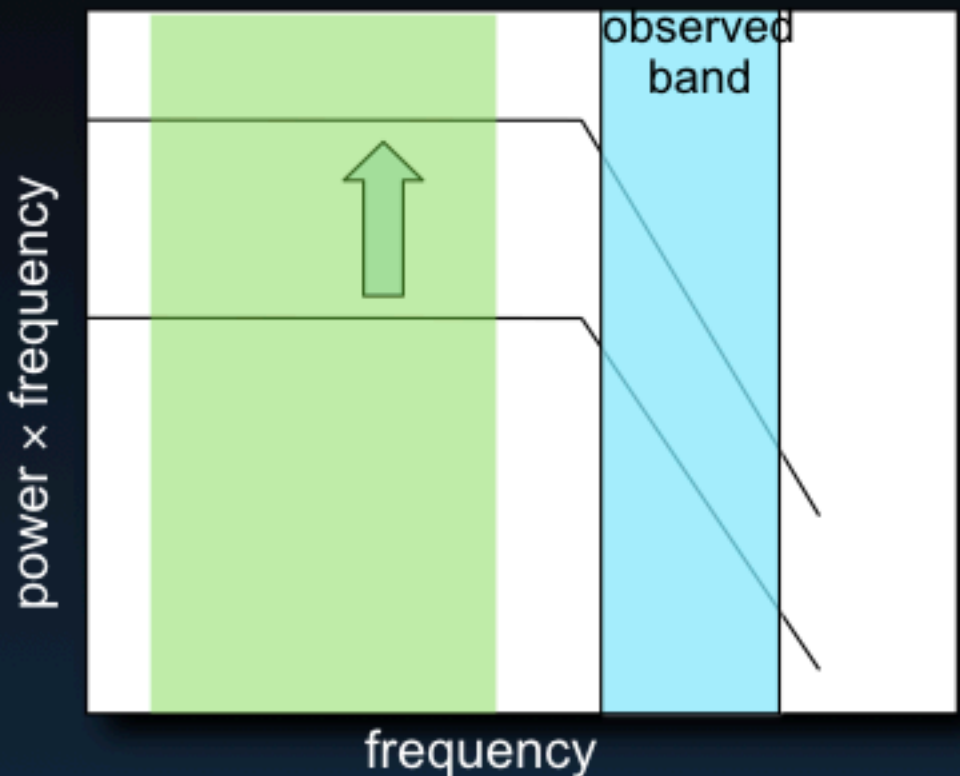


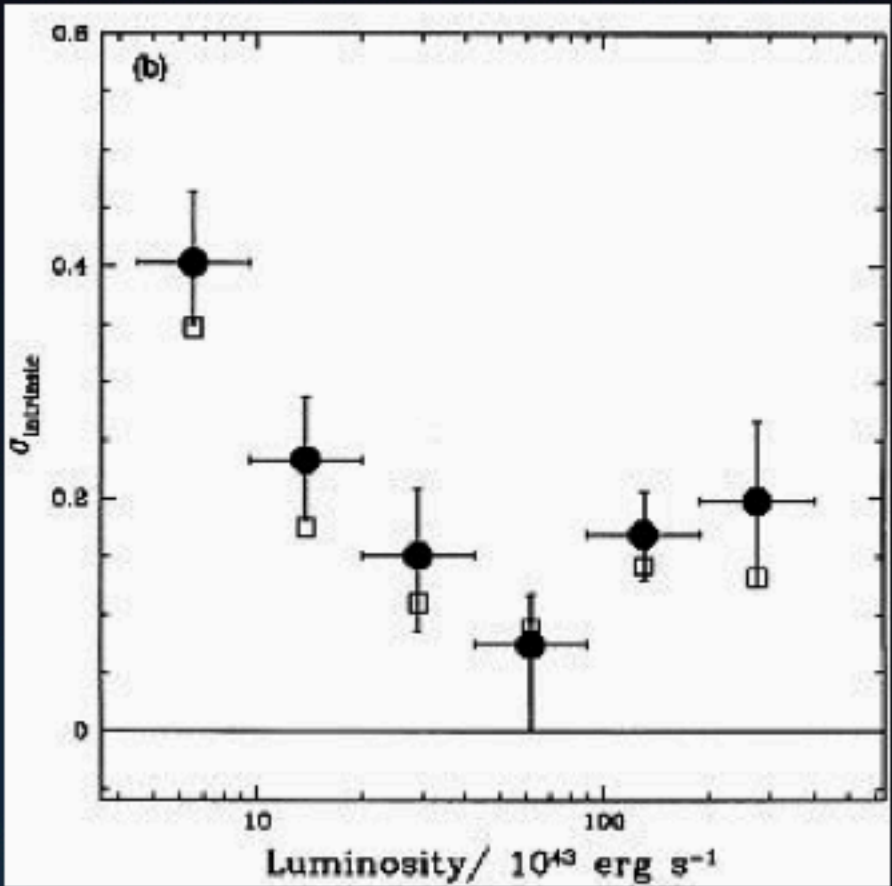
Does the normalization depend on accretion rate as well?

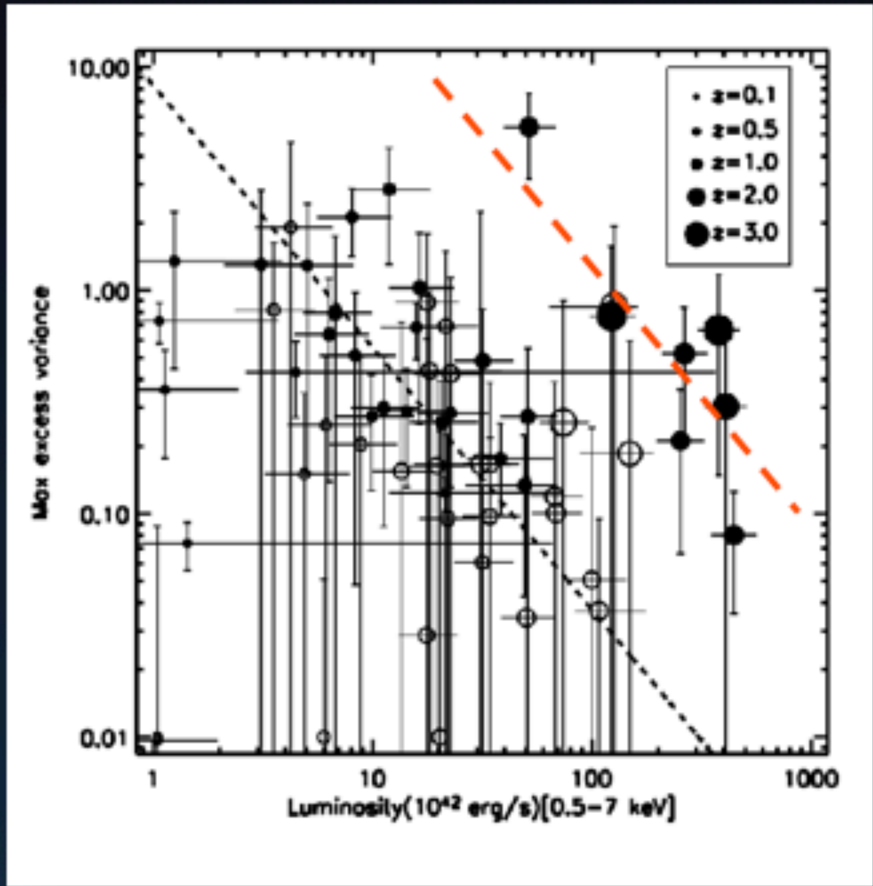
<u>Best sampled on long timescales!</u>

Increased variability at high z?

(Almaini et al. 2000; Paolillo et al. 2004)

The evolution of the L_X-var. relation could be produced by increase of the accretion rates or a decrease of the X-ray emitting region with look-back time.

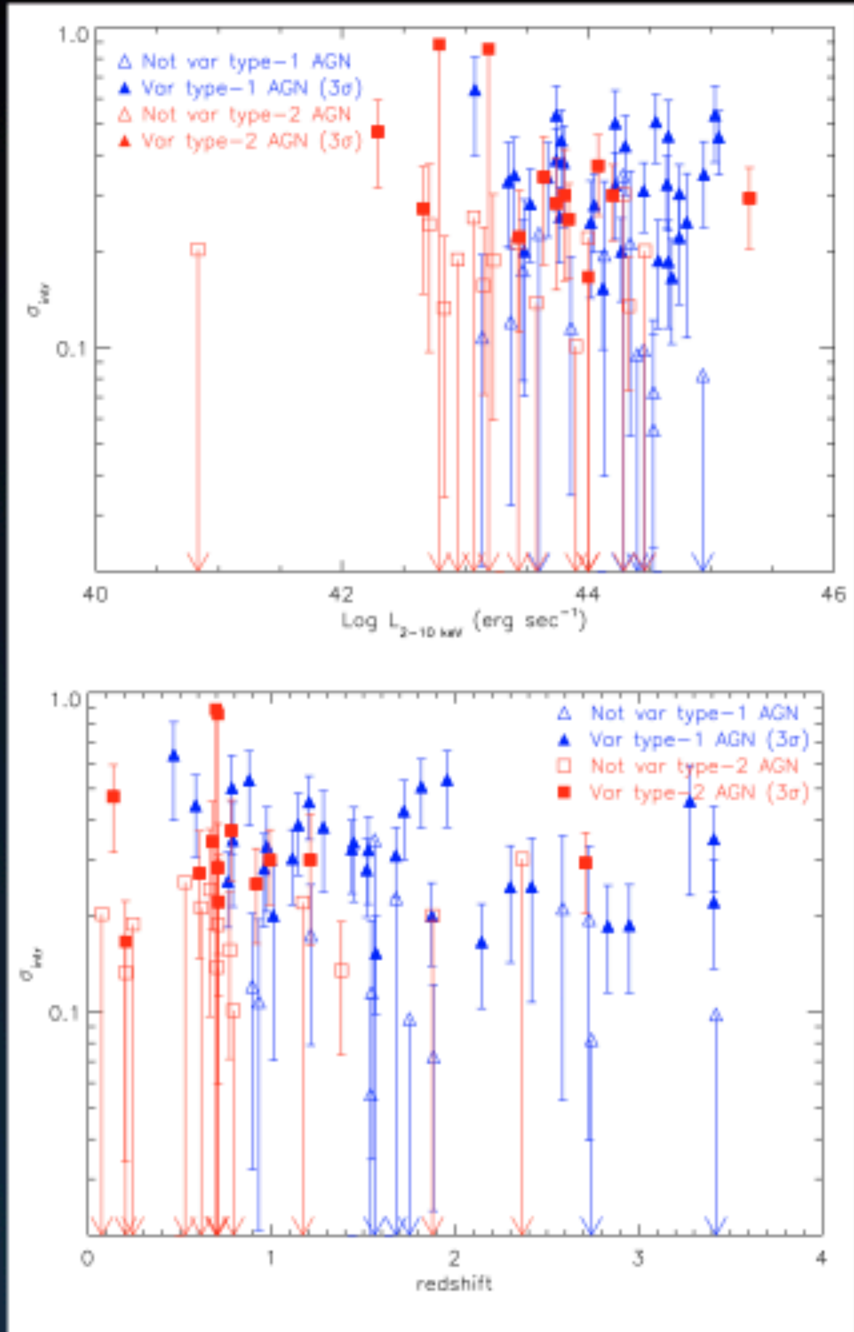




Null result for the XMM Lockmann Hole bright sample
(Mateos 2007)

- Variability on time scales from months to 2 years, of the 123 brightest objects detected with XMM-Newton in the Lockman Hole field.
- No dependence on redshift, X-ray luminosity or AGN type.

But....if complex dependence on redshift, luminosity and variability we need to <u>take all of them into account simultaneously</u>!



Increased variability in the Lockman Hole?

(Papadakis et al. 2008)

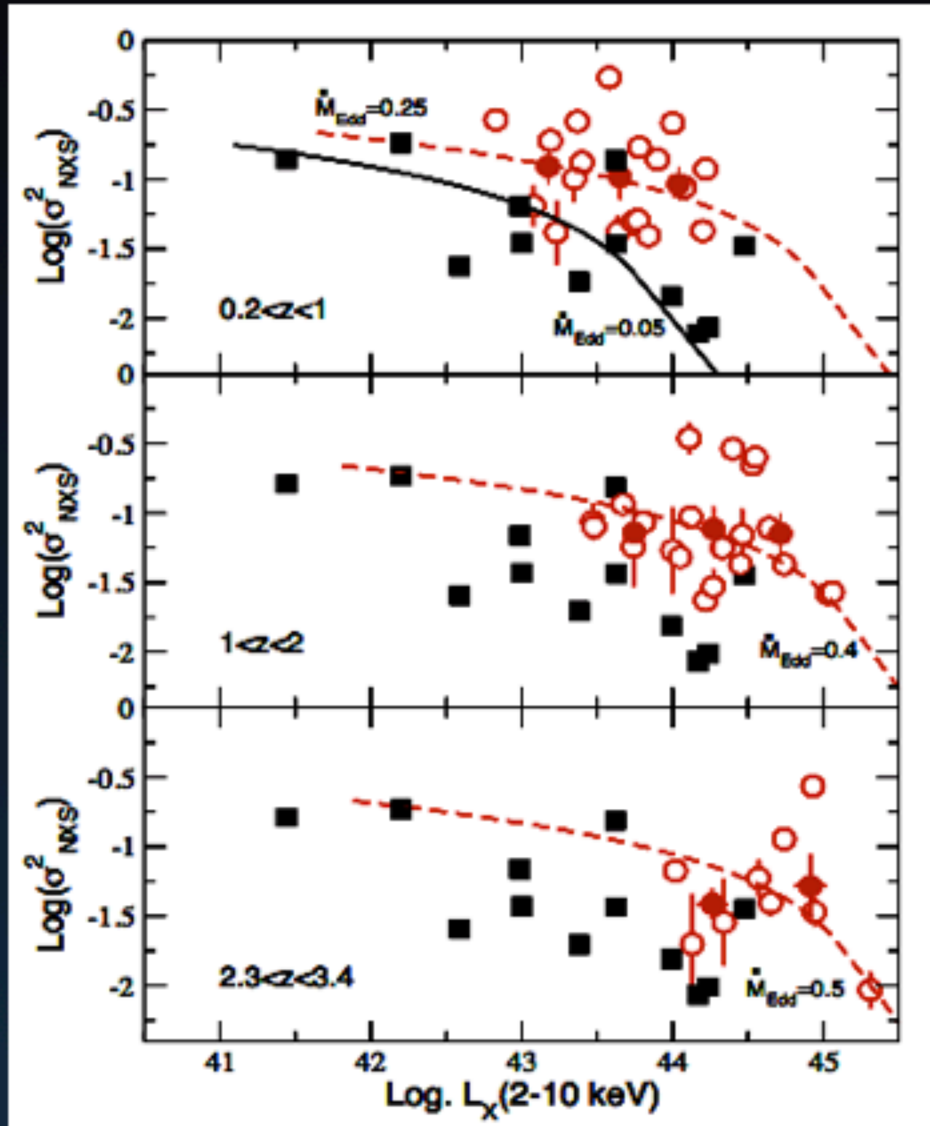
Fitting a more physically motivated model yields:

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

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

(N.B. assumes constant PSD amplitude)

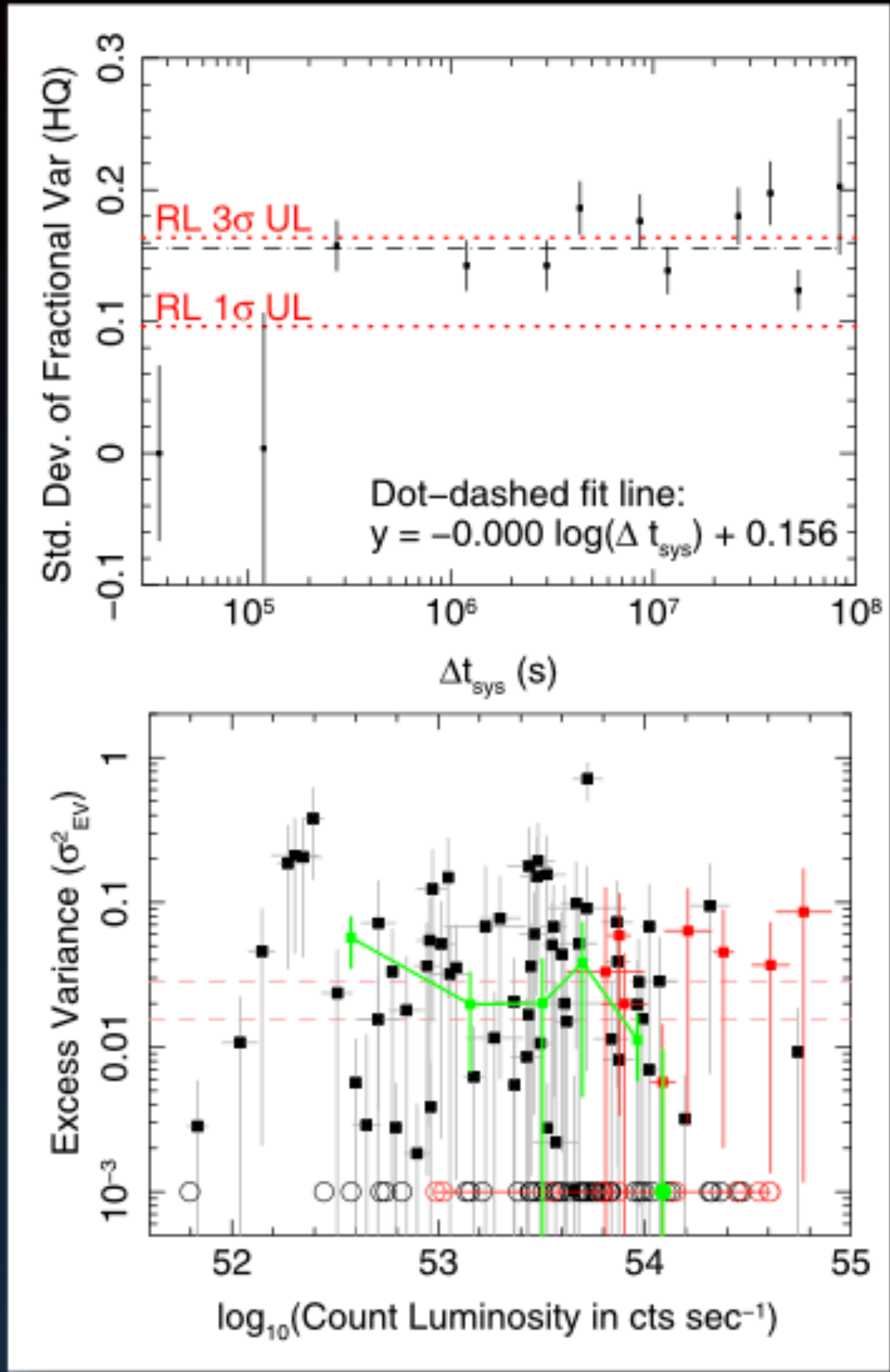
- Fitting the Lx-σ^2 anticorrelation requires higher accretion at high redshift.
- Variability-LX relation can be used in principle to probe both accretion rate and BH mass



Null result for the Chandra-SDSS sample:
(Gibson & Brandt 2012)

- 264 SDSS spectroscopic quasars in the Chandra archive ($z<5$) and with rest-frame timescales $<\Delta t_{sys} \approx 2000$ days,
- Significant ($>3\sigma$) variation in ≈30% of the quasars overall(≈70% for sources with >1000 counts per epoch).

No evidence that quasars are more variable at higher redshifts ($z > 2$)

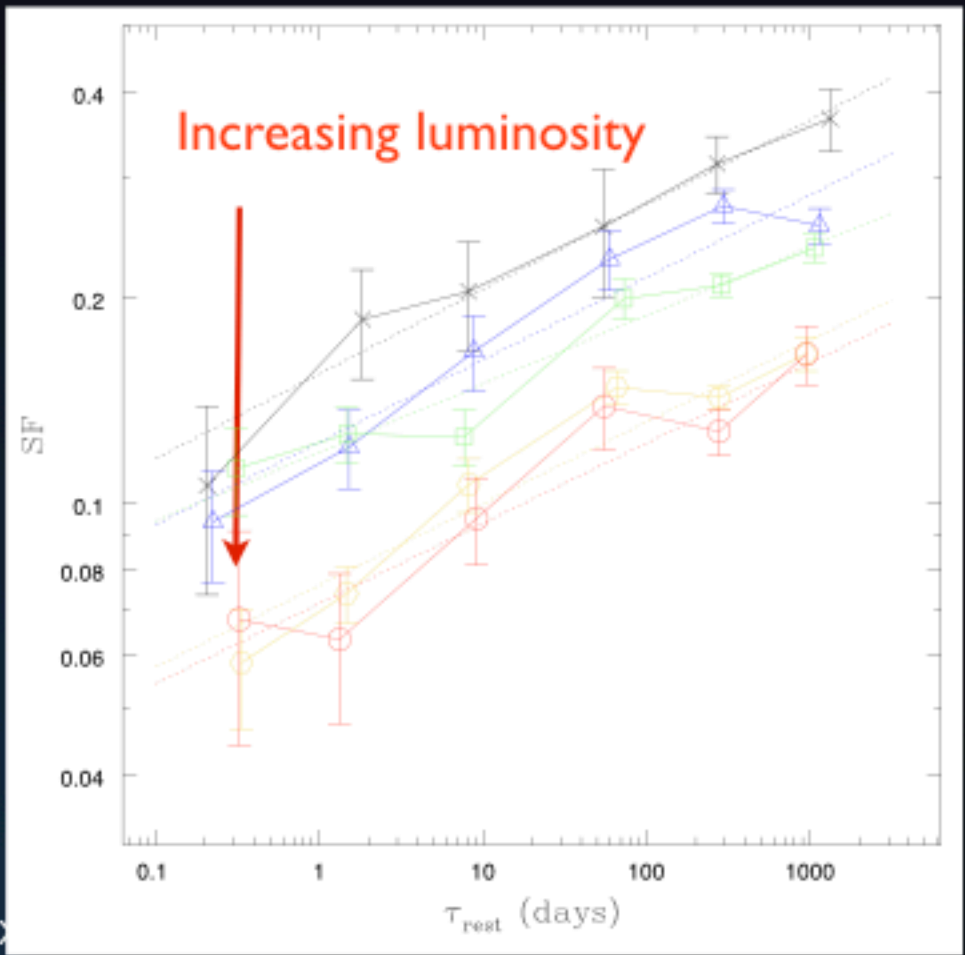


XMM and Swift serendipitous samples

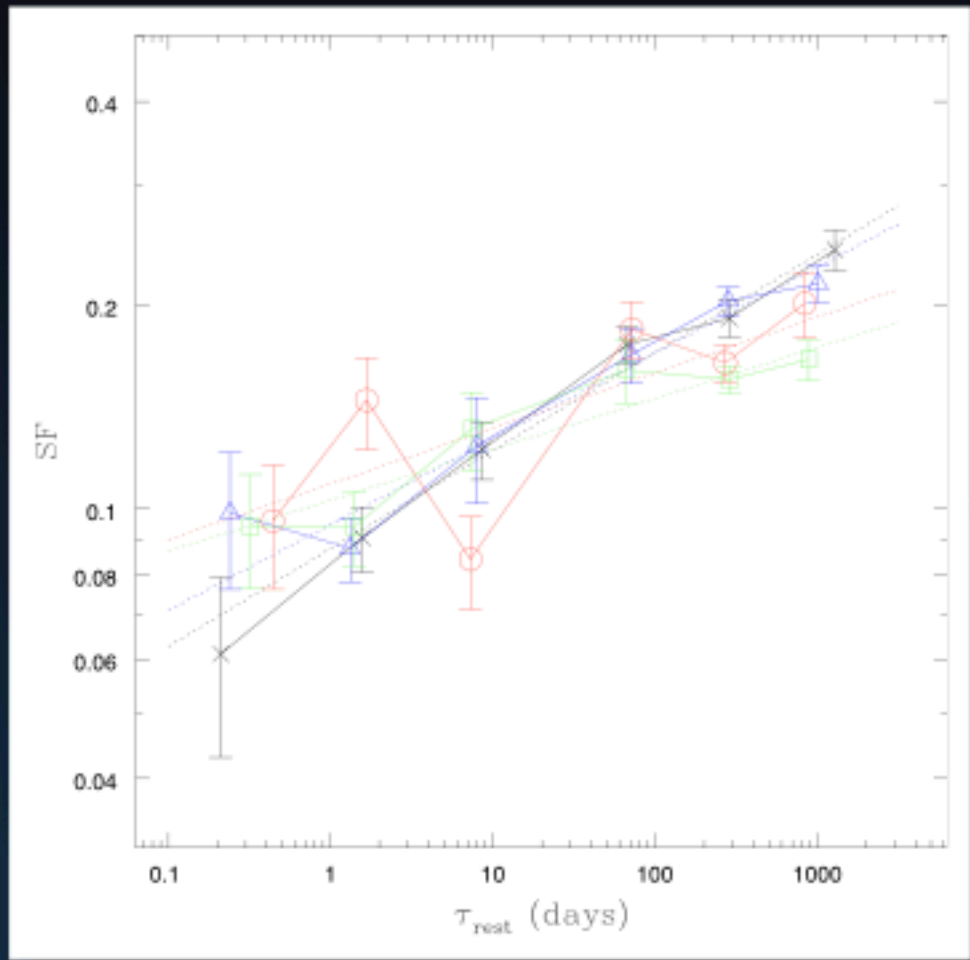
(Vagnetti, Turriziani & Trevese, 2011; Vagnetti et al. 2016)

- No evidence of a break in the SF

- Anti-correlation of the variability with X-ray luminosity



- No average increase of X-ray variability with redshift.

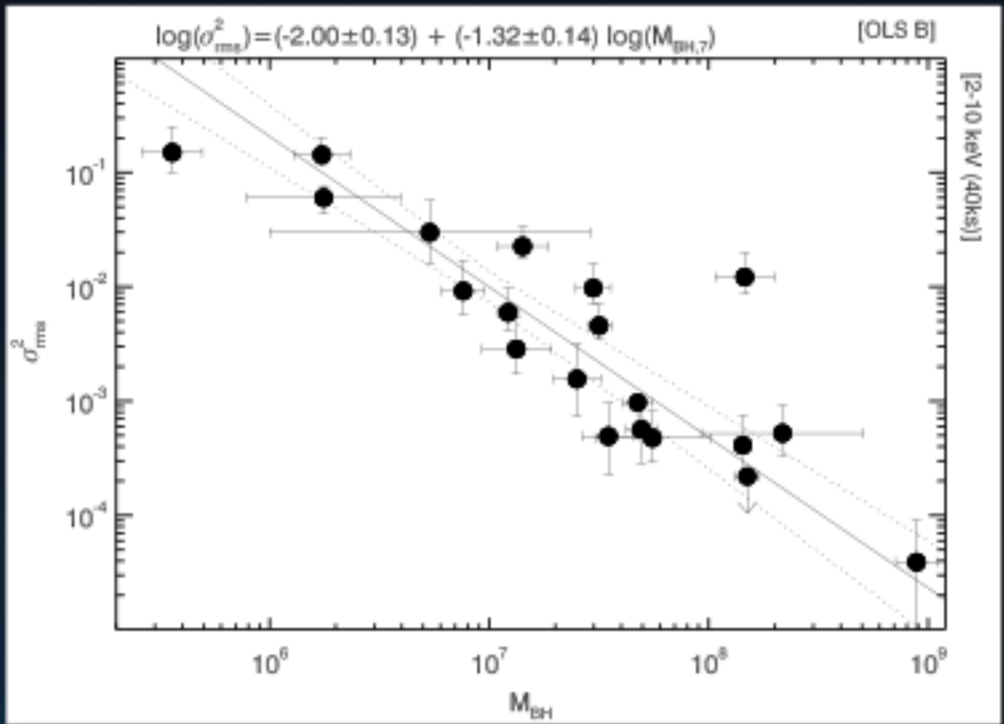


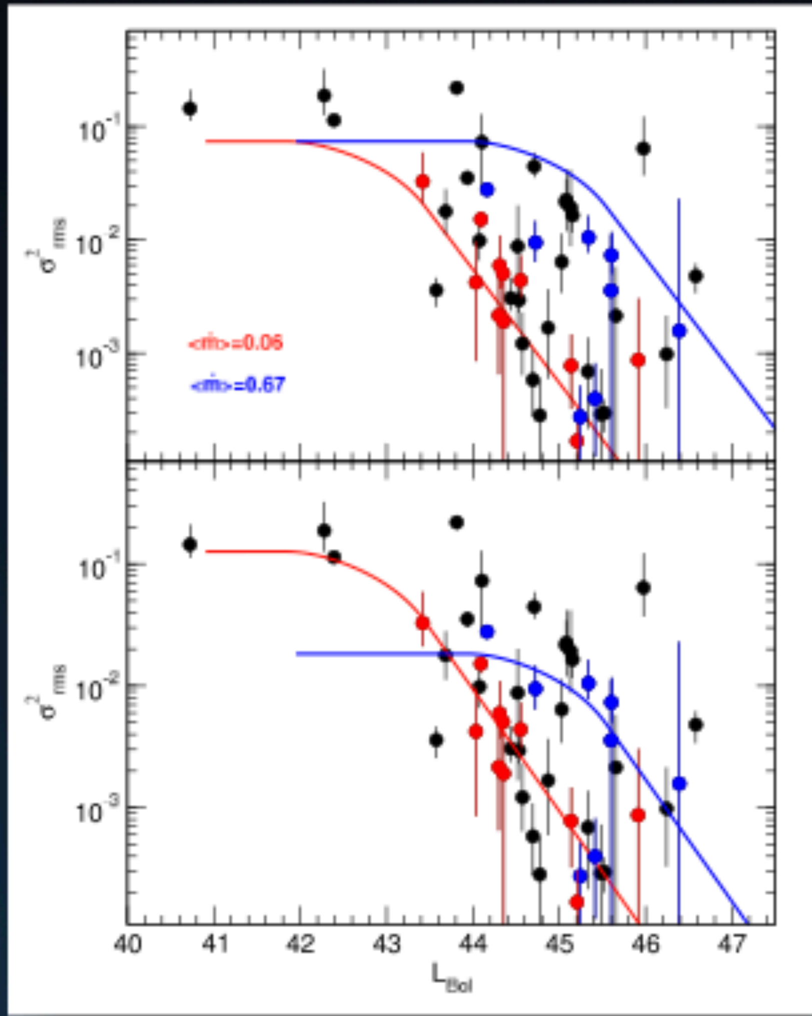
Constraining the relevant parameters: **the CAIXA sample**

(Ponti et al. 2011)

XMM-Newton sample of 161 radio quiet, X-ray un-obscured AGN studied on time scales less than a day. Mostly local (z<0.3) AGNs.

Tight (~ 0.7 dex) correlation between σ^2 and M_{BH}, but <u>variable PSD amplitude</u>





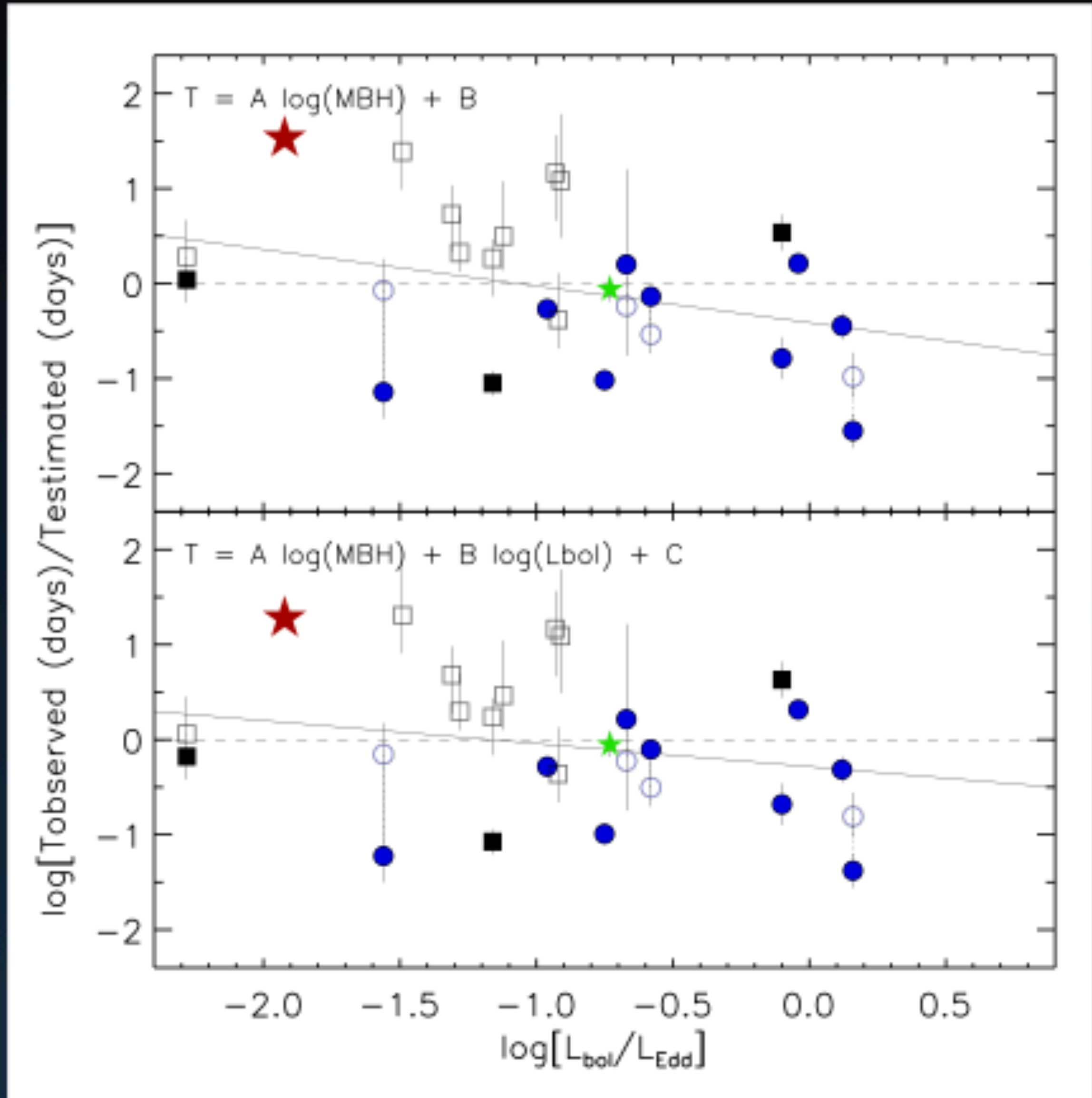
Accretion dependence challenged by XMM studies

Gonzales-Martin & Vaughan (2012) study 104 nearby AGN from XMM-Newton observations.

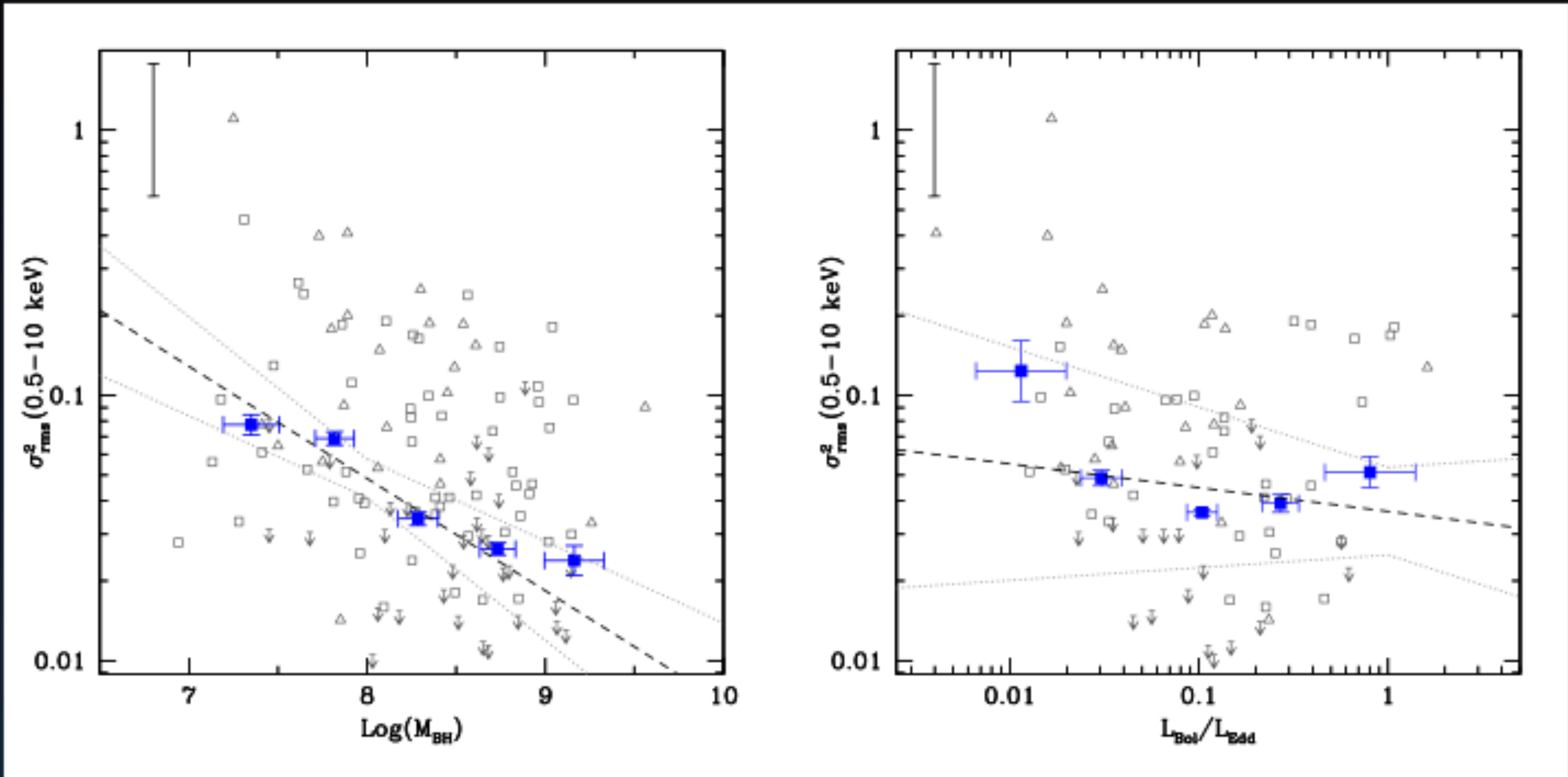
Possible scenarios:

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

Conclusion: Weak or no dependence on accretion rate.



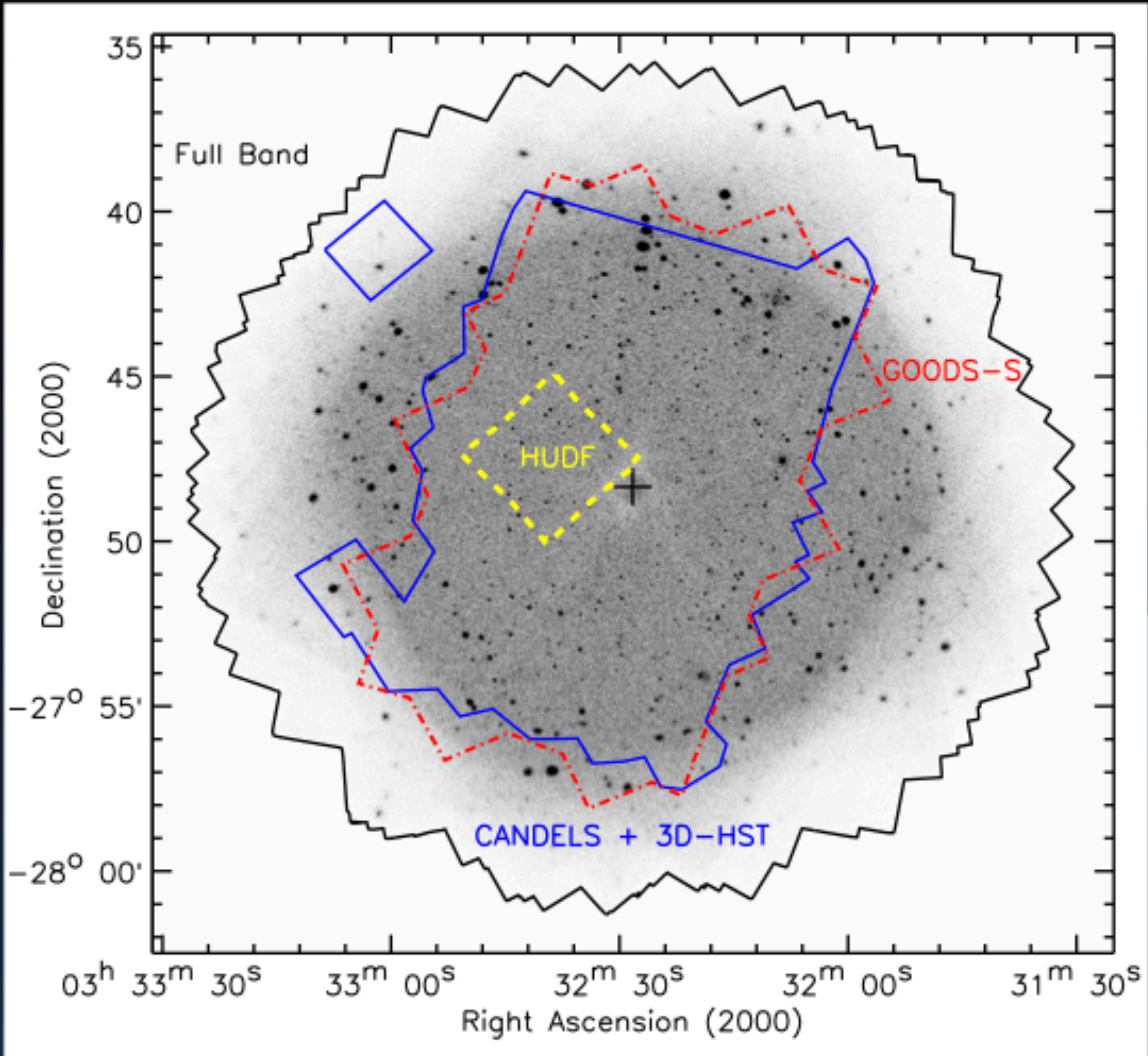
Constraining the relevant parameters: COSMOS field (*Lanzuisi et al. 2014*)

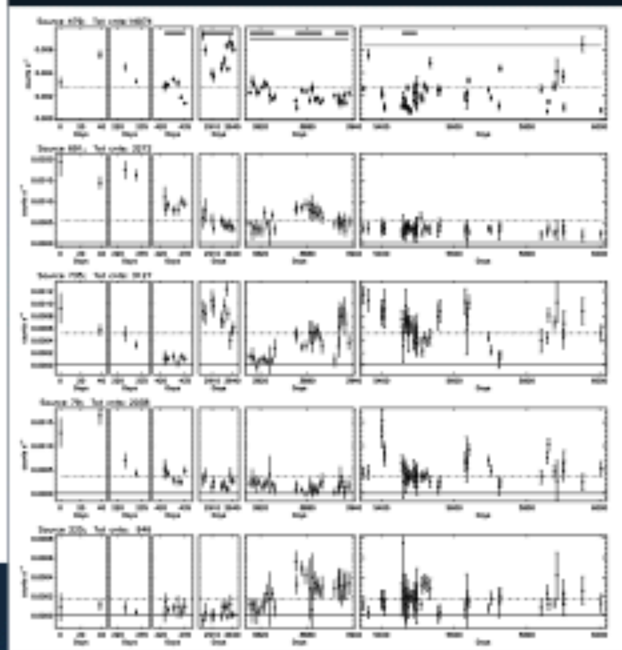


Dependence on mass, but no dependence on accretion!

7Ms CDFS dataset

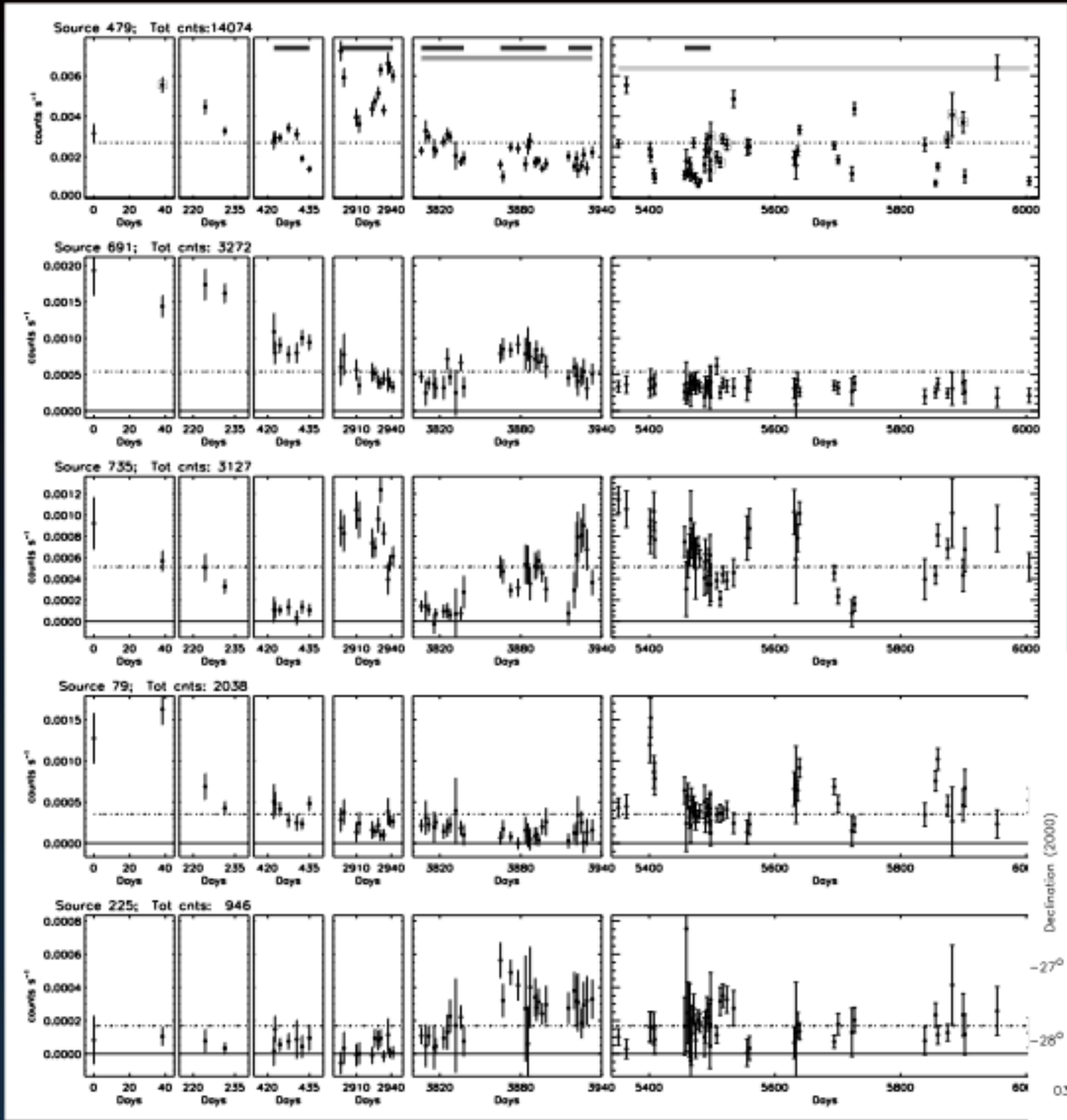
(Luo et al. 2016)

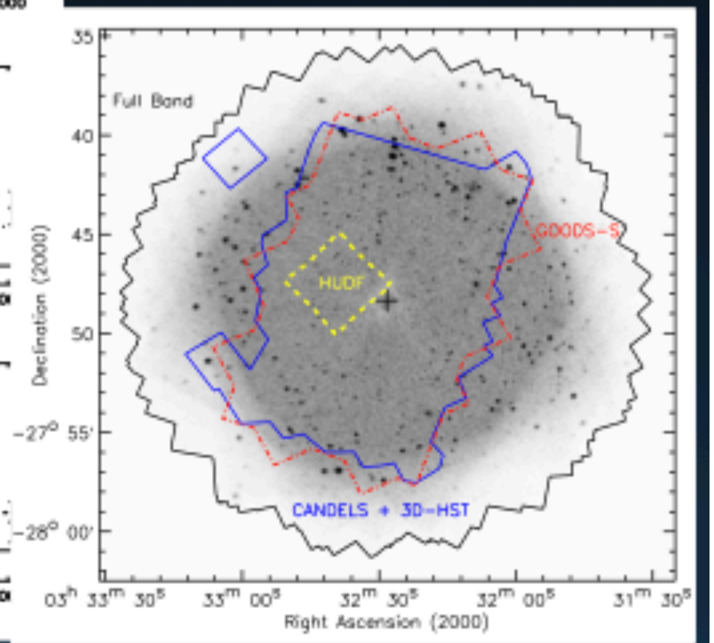




7Ms CDFS lightcurves

(Paolillo et al. 2017, submitted)

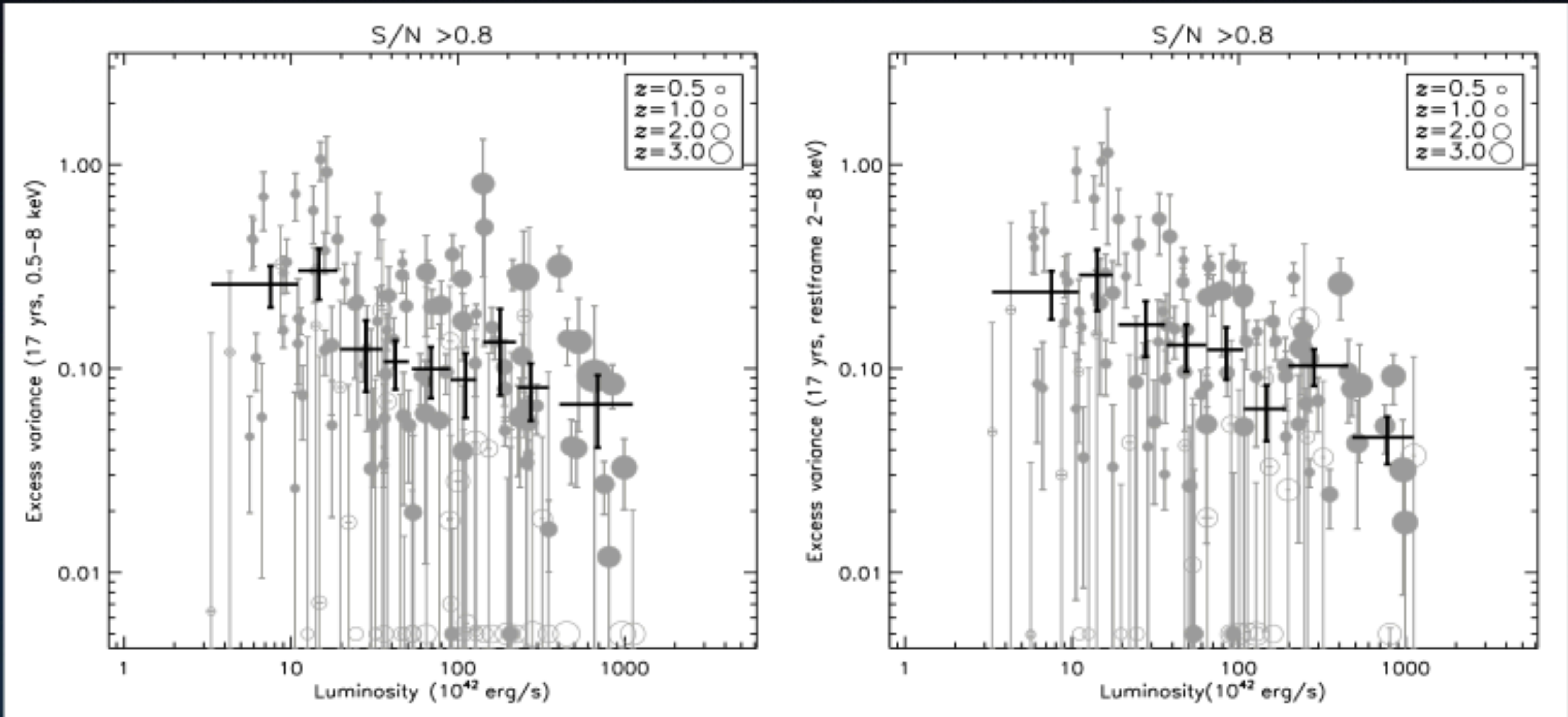




Lx-variability correlation

High-z AGN do follow the L_X-variability relation but ….

AGNs at different redshift sample different timescales, so need to correct or model this effect!



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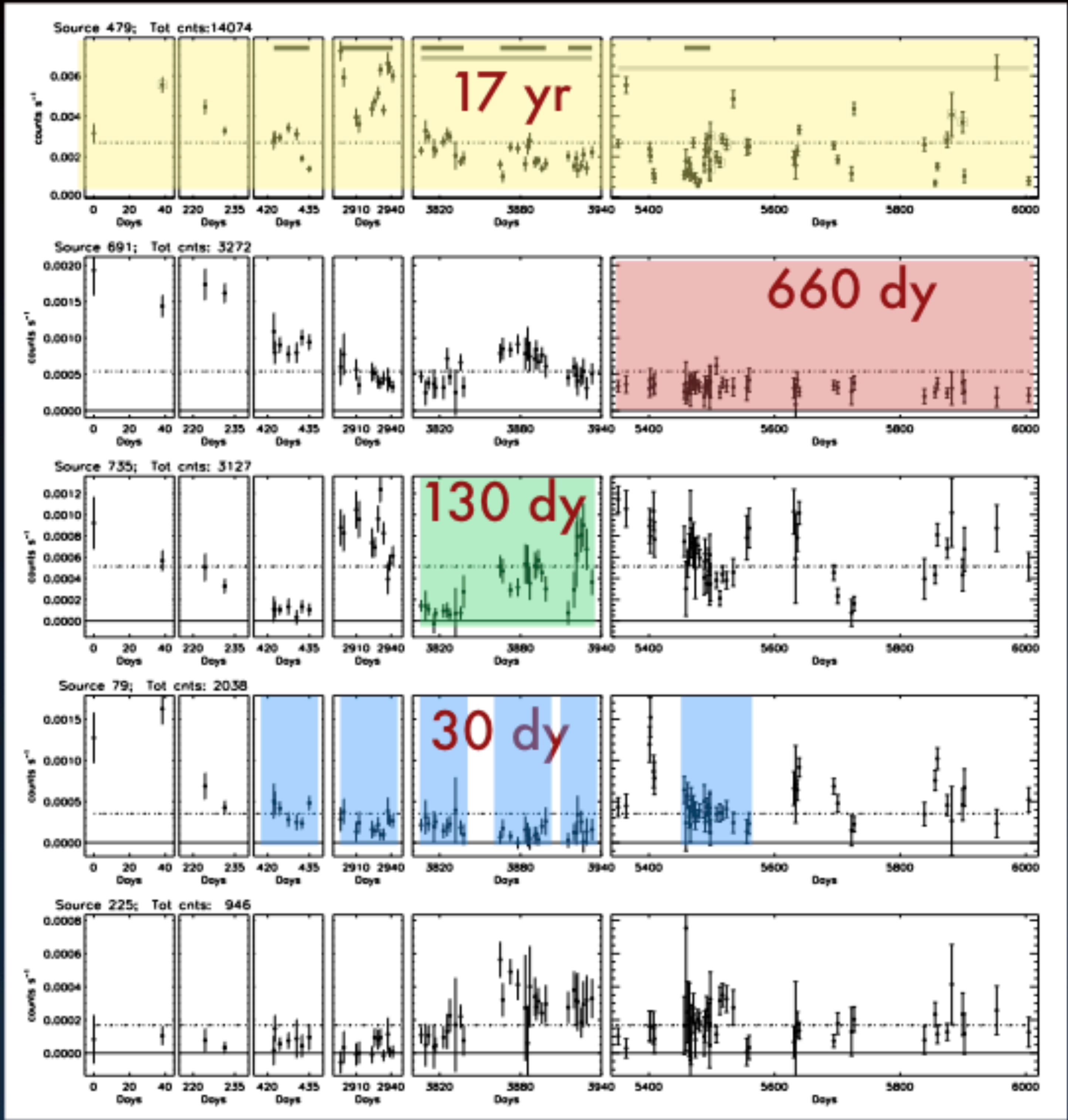
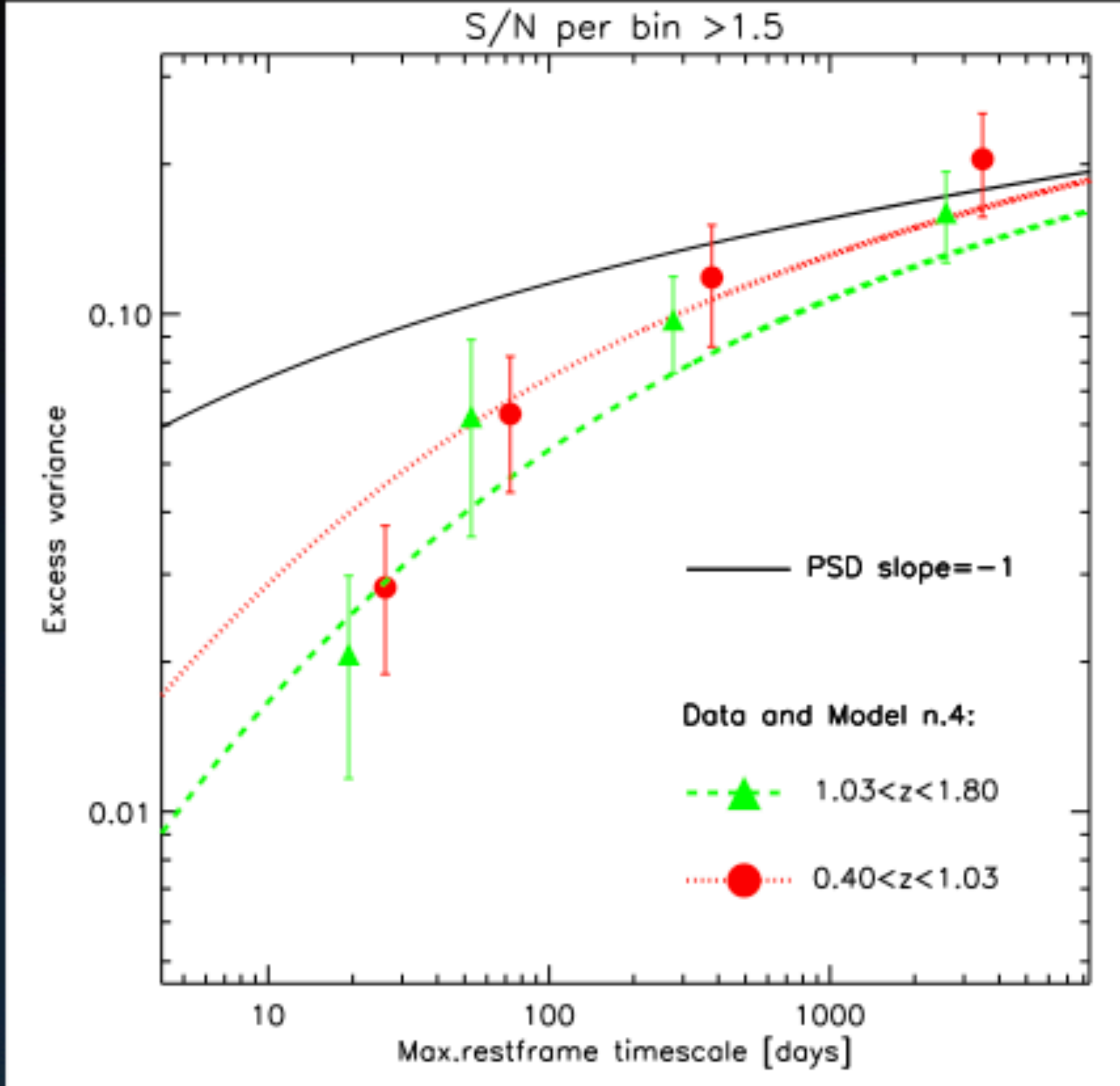


- The 7Ms data allow to sample AGN variability on different timescales, from a few days up to 17 yrs.
- A proxy to a proper PSD analysis

What PSD for high-z AGNs?

- A single flat ($\sigma_{NXV}=\nu^{-1}$) power-law PSD only fits long timescales
- Steeper PSD slopes ($\sigma_{NXV}=\nu^{-1.5}$) provide poor fits to some timescales
- A bending power-law seems the best fit for high-z AGNs, reproducing both the high frequency cutoff and the redshift dependence:

$$\mathrm{PSD}(\nu) = A\nu^{-1}\left(1+\frac{\nu}{\nu_b}\right)^{-1}$$

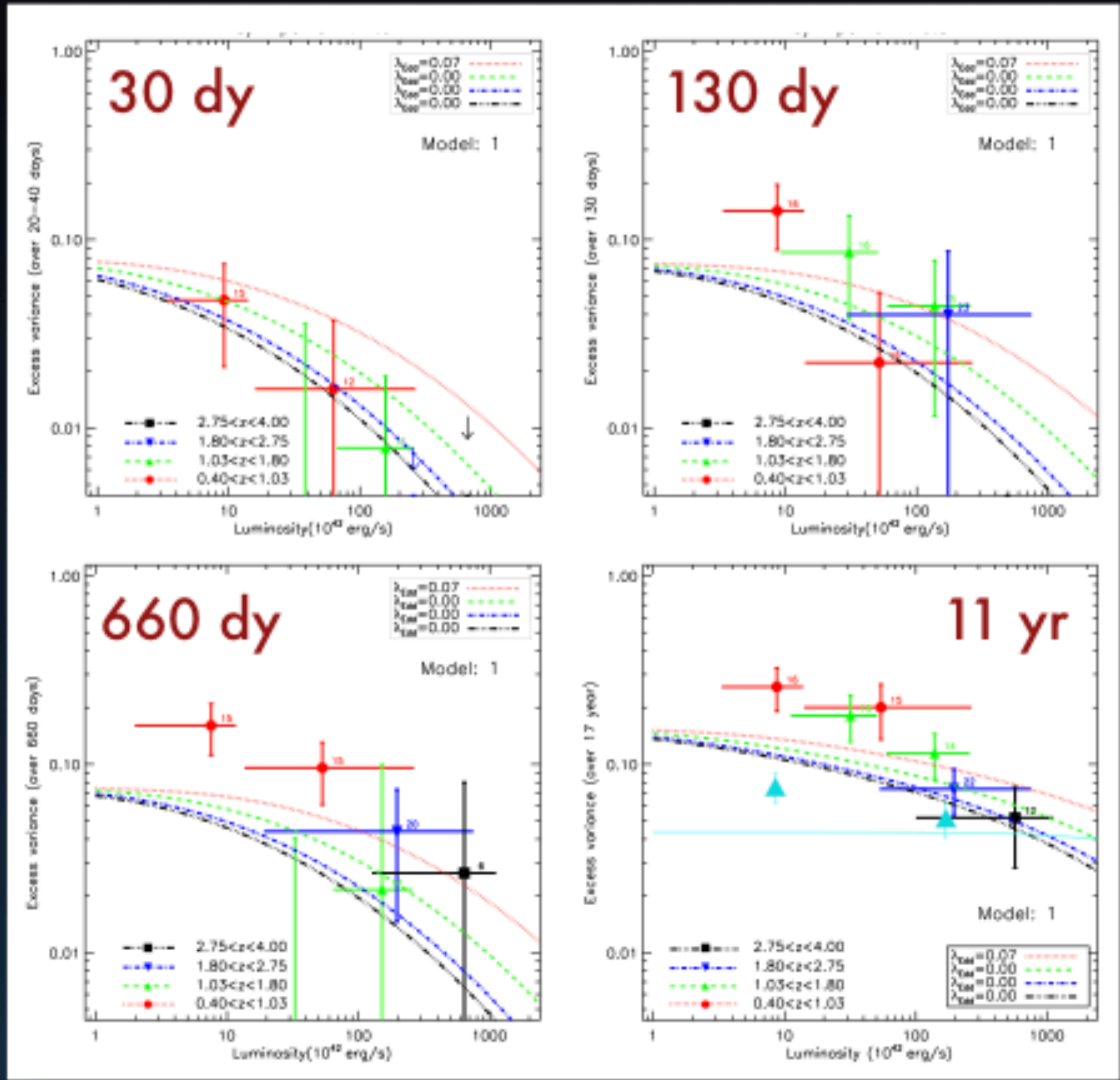


Constraining the model: fit results

Model 1:

- bending frequency depends only on BH mass as $\nu_b \propto M^{-1}$ (Gonzales-Martin & Vaughan, 2012)
- fixed PSD normalization (Papadakis et al. 2004, 2008)

Model is rejected at >99% c.l. for any λ_{Edd}>0.03

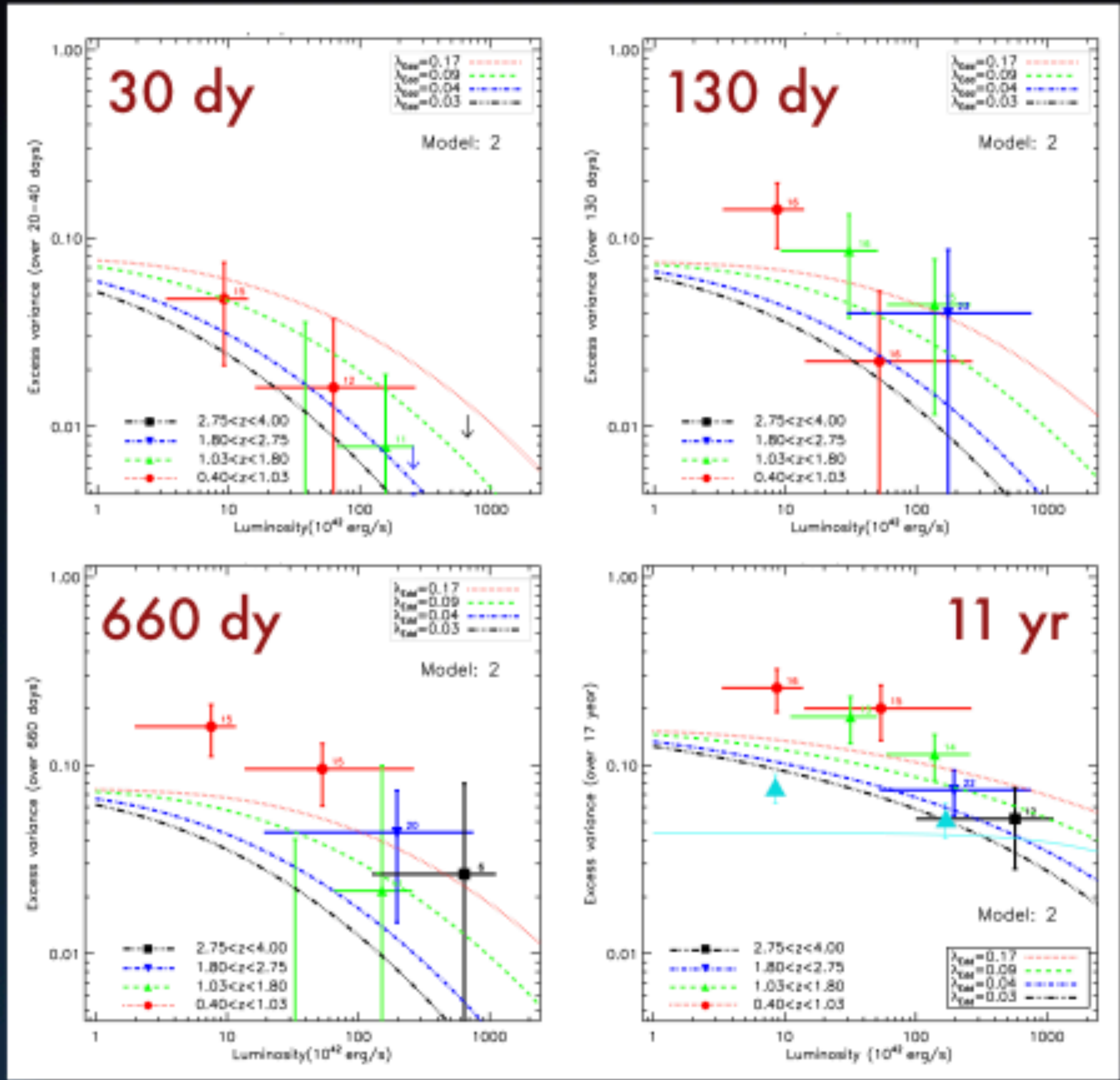


Constraining the model: fit results

Model 2:

- bending frequency depends on BH mass and acc.rate through $\nu_b \propto L/M^2$ (McHardy et al. 2006)
- fixed PSD normalization (Papadakis et al. 2004, 2008)

Model is acceptable at ~1% c.l.

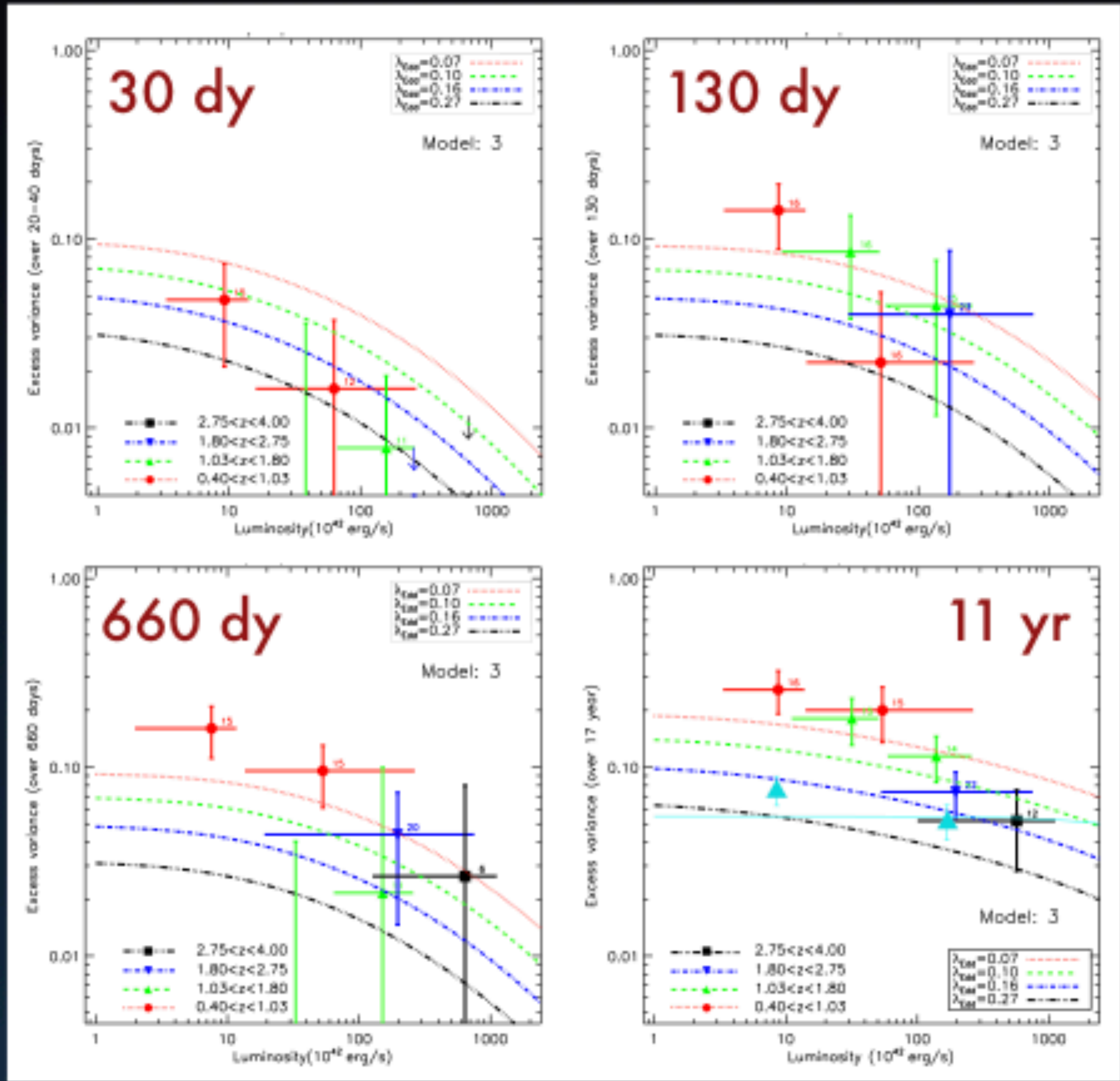


Constraining the model: fit results

<u>Model 3:</u>

- bending frequency depends only on BH mass as $\nu_b \propto M^{-1}$ (Gonzales-Martin & Vaughan, 2012)
- PSD normalization depends on λ_{Edd} (Ponti et al. 2011)

Model is rejected at >99% c.l.

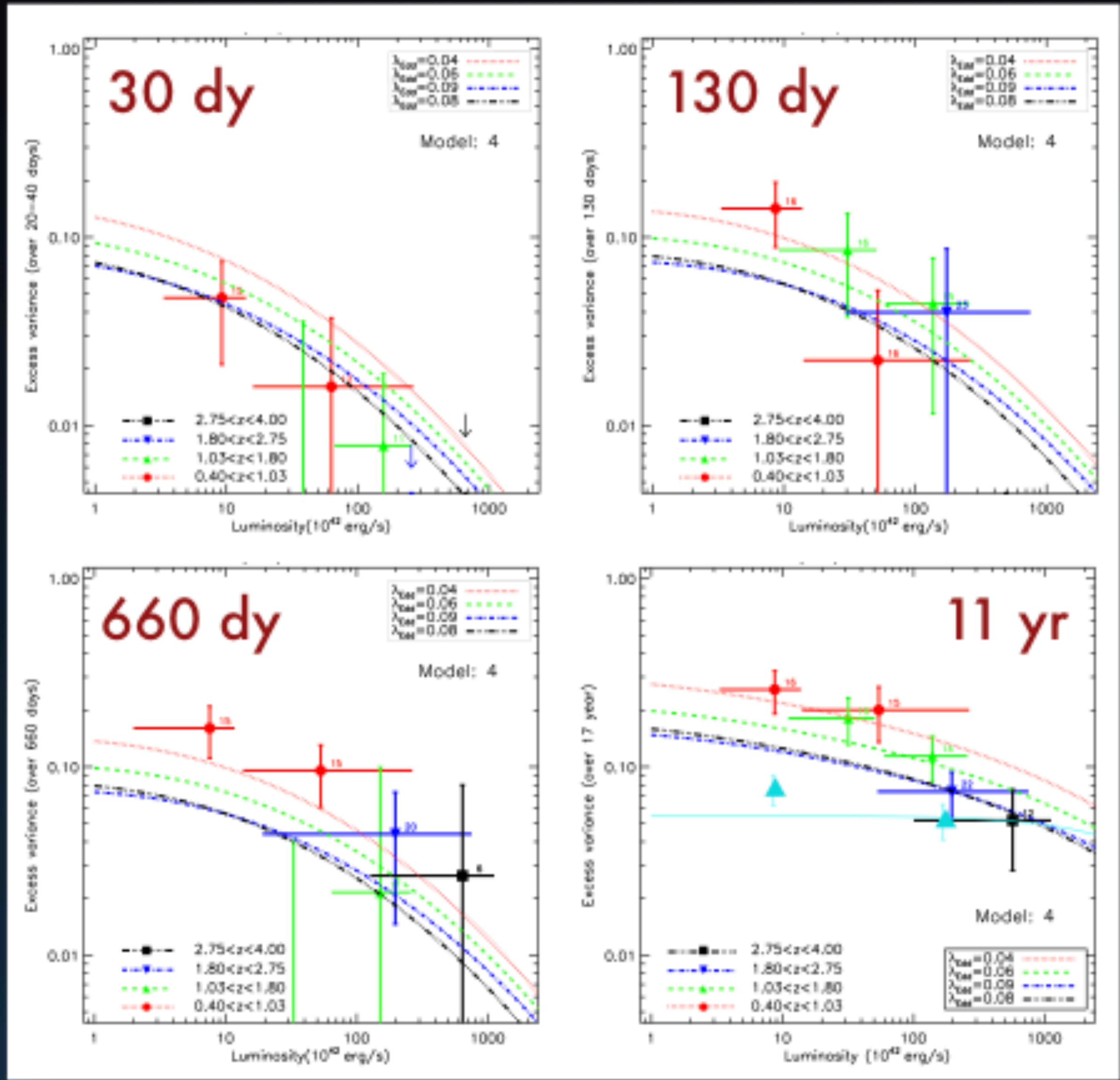


Constraining the model: fit results

Model 4:

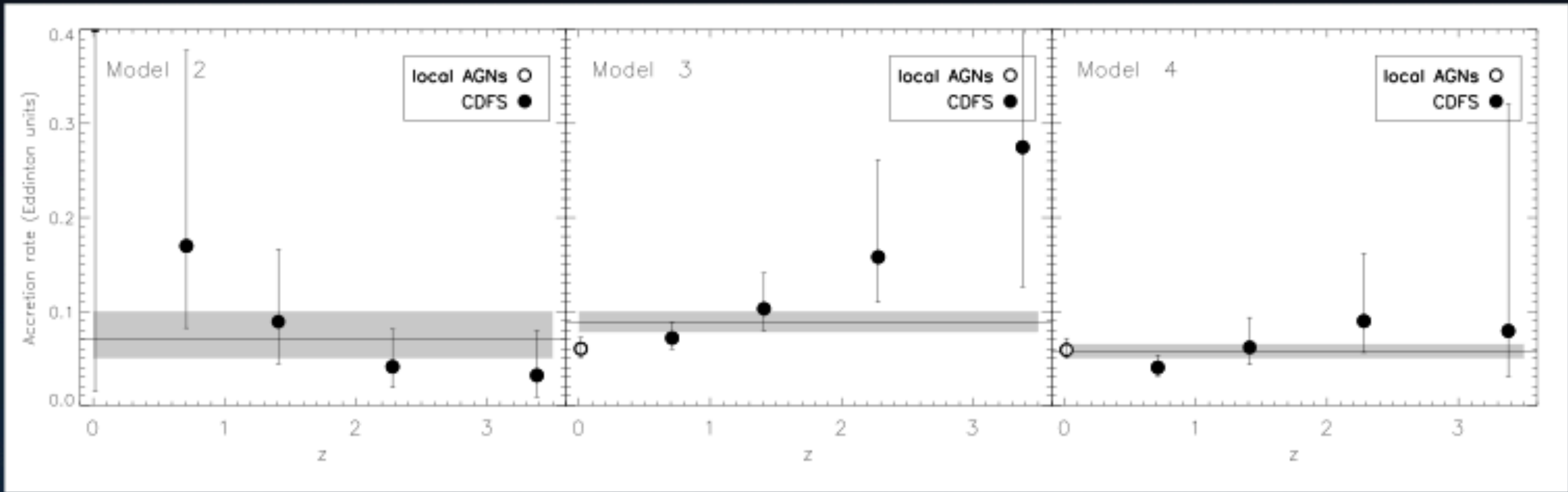
- bending frequency depends on BH mass and acc.rate through $\nu_b \propto L/M^2$ (McHardy et al. 2006)
- PSD normalization depends on λ_{Edd} (Ponti et al. 2011)

Model is acceptable at ~10% c.l.



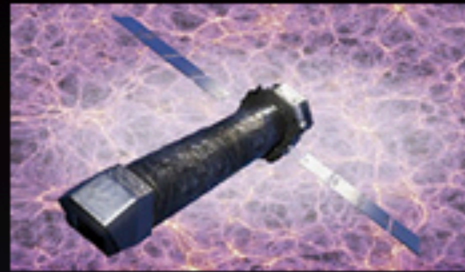
Accretion history results

- A constant $\lambda_{Edd} \leq 0.1$ is consistent with the data, although some models indicate a possible increase of $\lambda_{Edd}(z)$ increasing with redshift.
- The low redshift data are consistent with variability of local AGNs (Zhang et al. results).

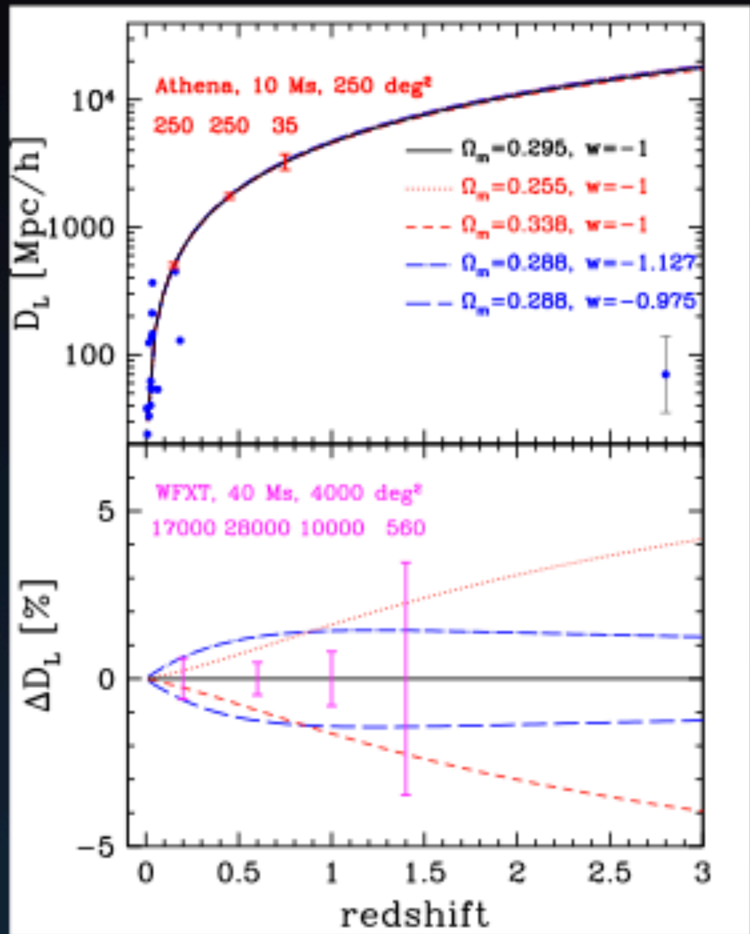


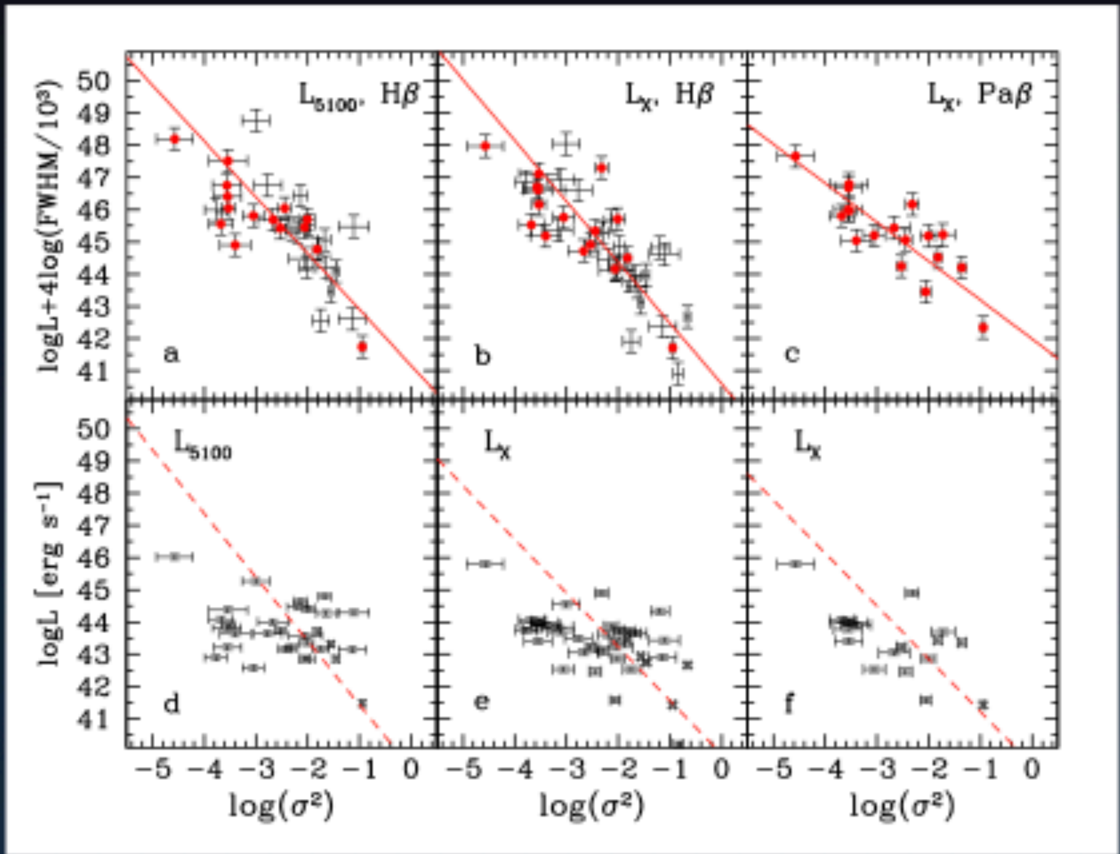
The future?

(*La Franca et al. 2014*)



Calibrated variability correlations can provide cosmological constraints. But what about other parameters (e.g. accretion rates)?





Conclusions

- Multi-epoch surveys offer the opportunity to investigate the timing properties of distant AGN populations.
- Luminosity-variability anticorrelation verified over large redshift range.
- High-z AGNs share similar PSD of local AGNs
- Variability dependence on both mass and accretion is favored
- With correct statistical approach and accounting for biases we can constrain the best physical model
- Variability allows to constrain the average accretion rate over cosmic time

Wide-field multi-epoch surveys may allow constrain the evolution of the AGN population.