X-RAY VARIABILITY OF HIGH-Z AGNS:
RESULTS FROM DEEP SURVEYS AND PROSPECTS FOR FUTURE X-RAY MISSIONS

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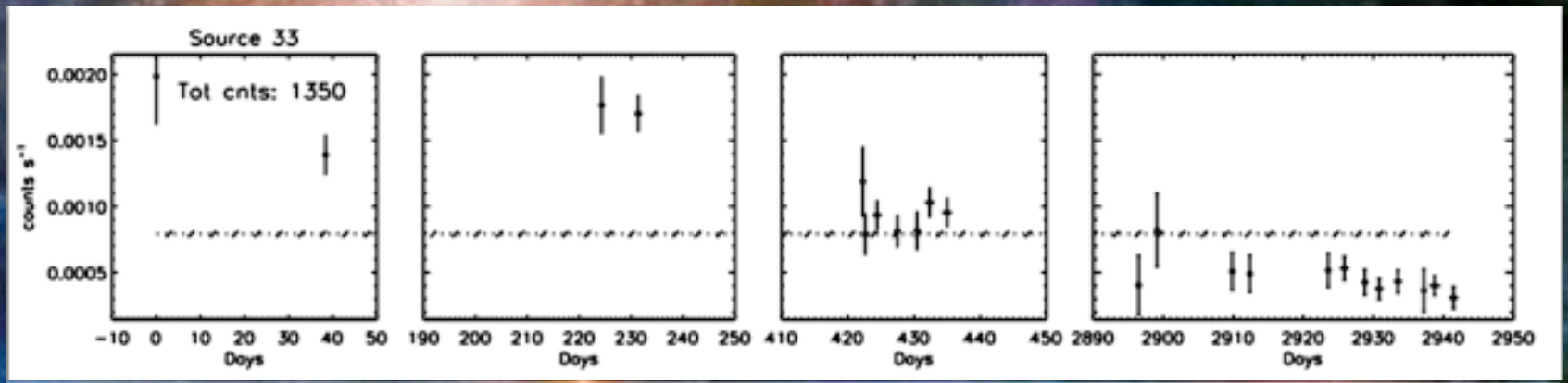
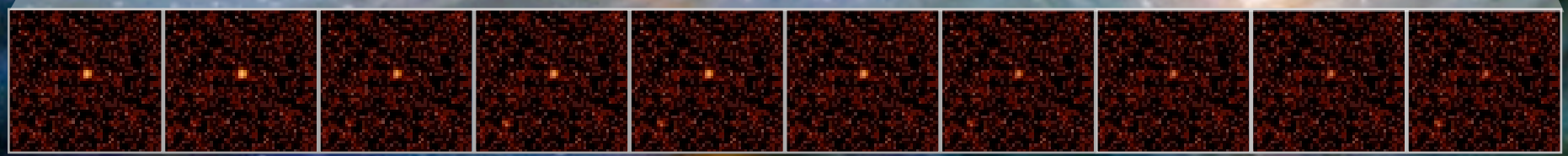
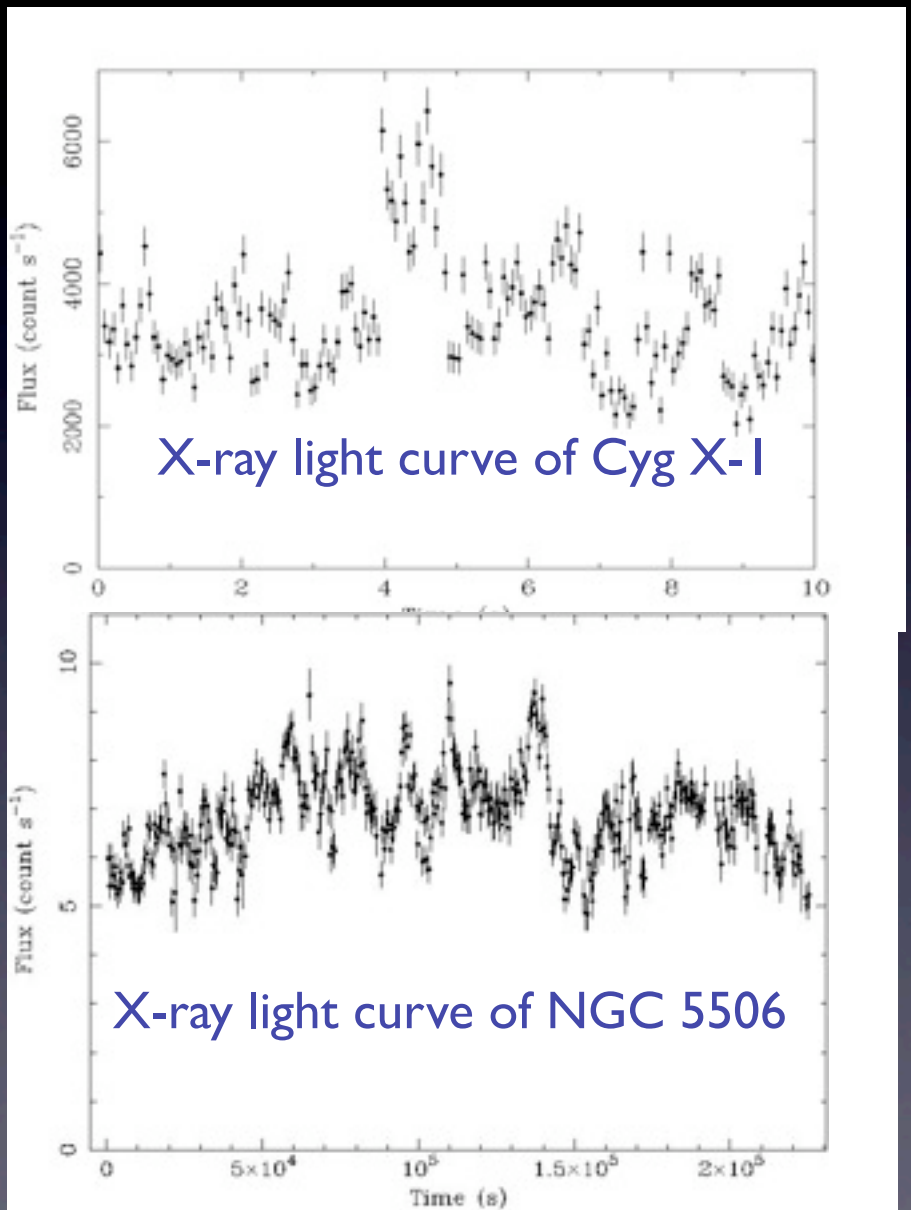




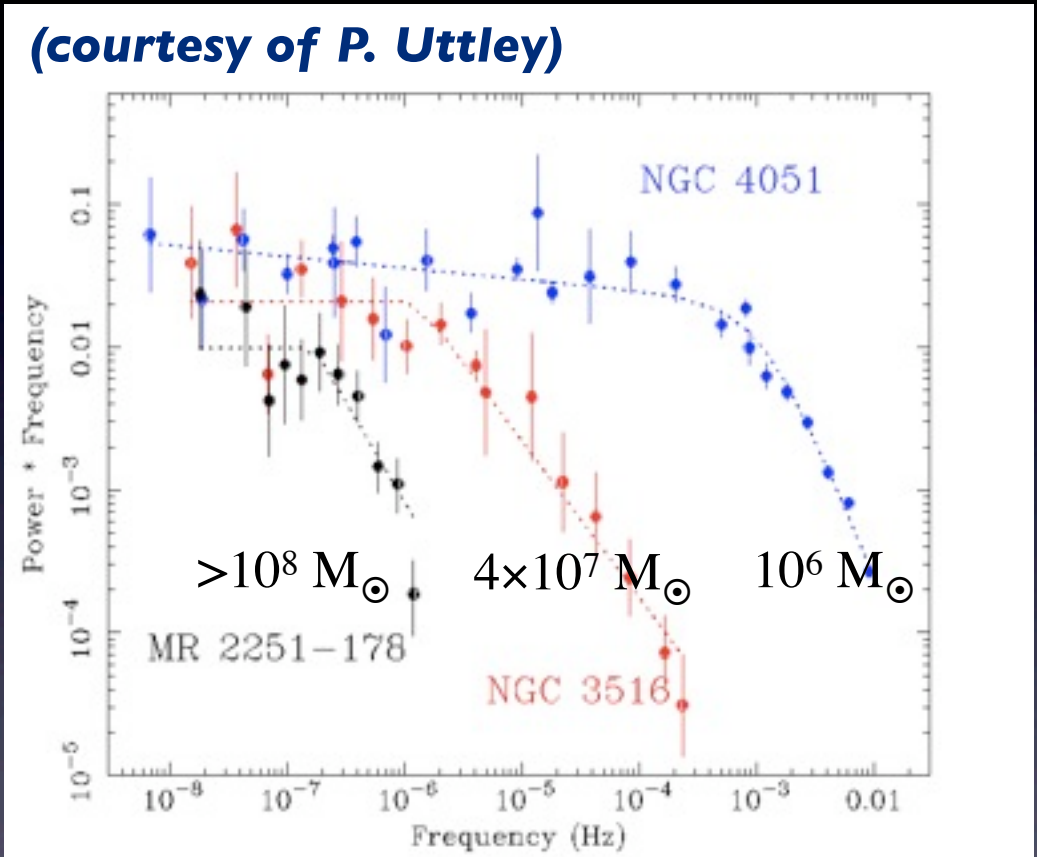
X-ray variability in accreting black hole systems

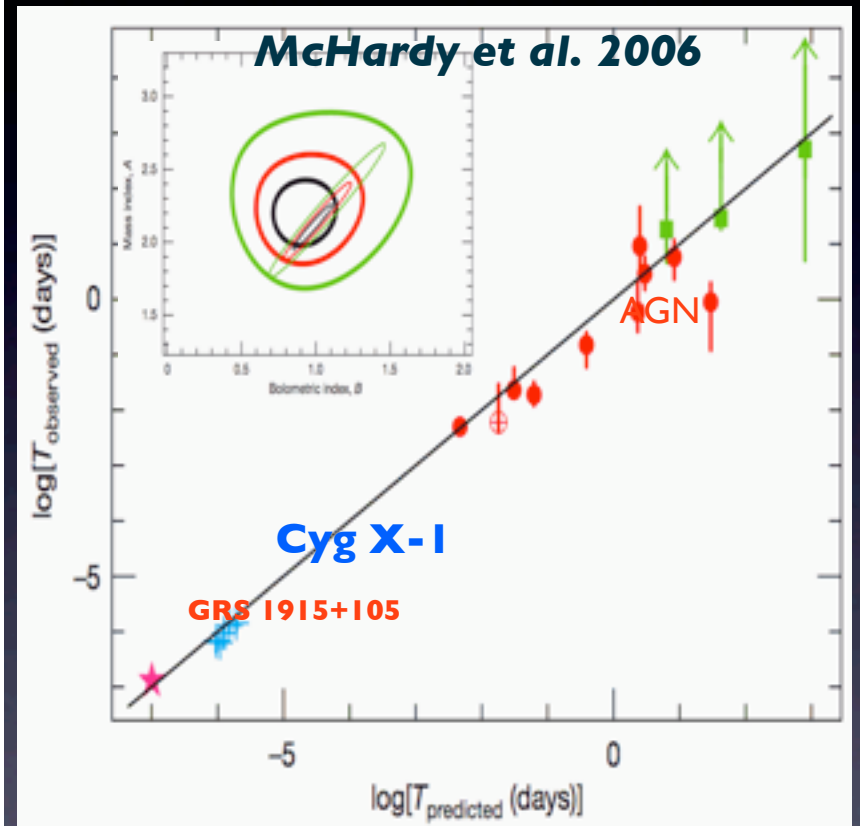
Most informations we have about AGN variability comes from nearby objects:

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



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





Probing mass and accretion rate

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

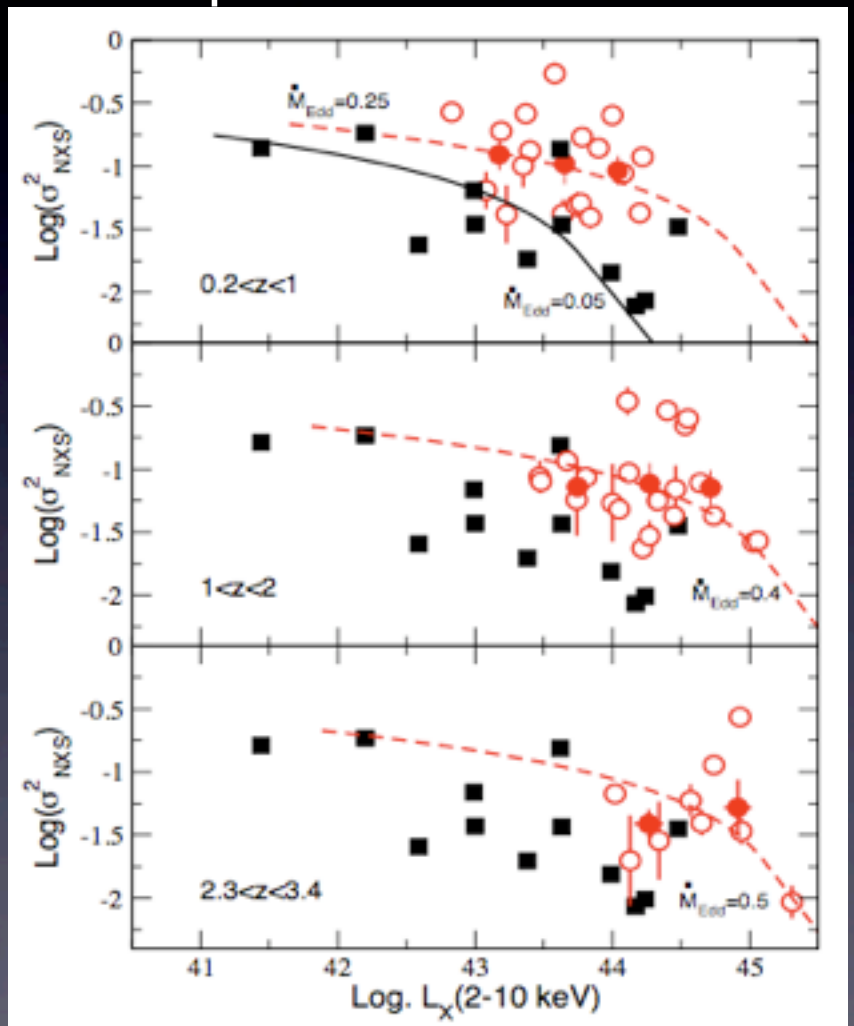
$$L_{bol} = 1.3 \eta \dot{m}_{Edd} 10^{39} (M_{BH}/M_{\odot}) \text{ erg/s}$$

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

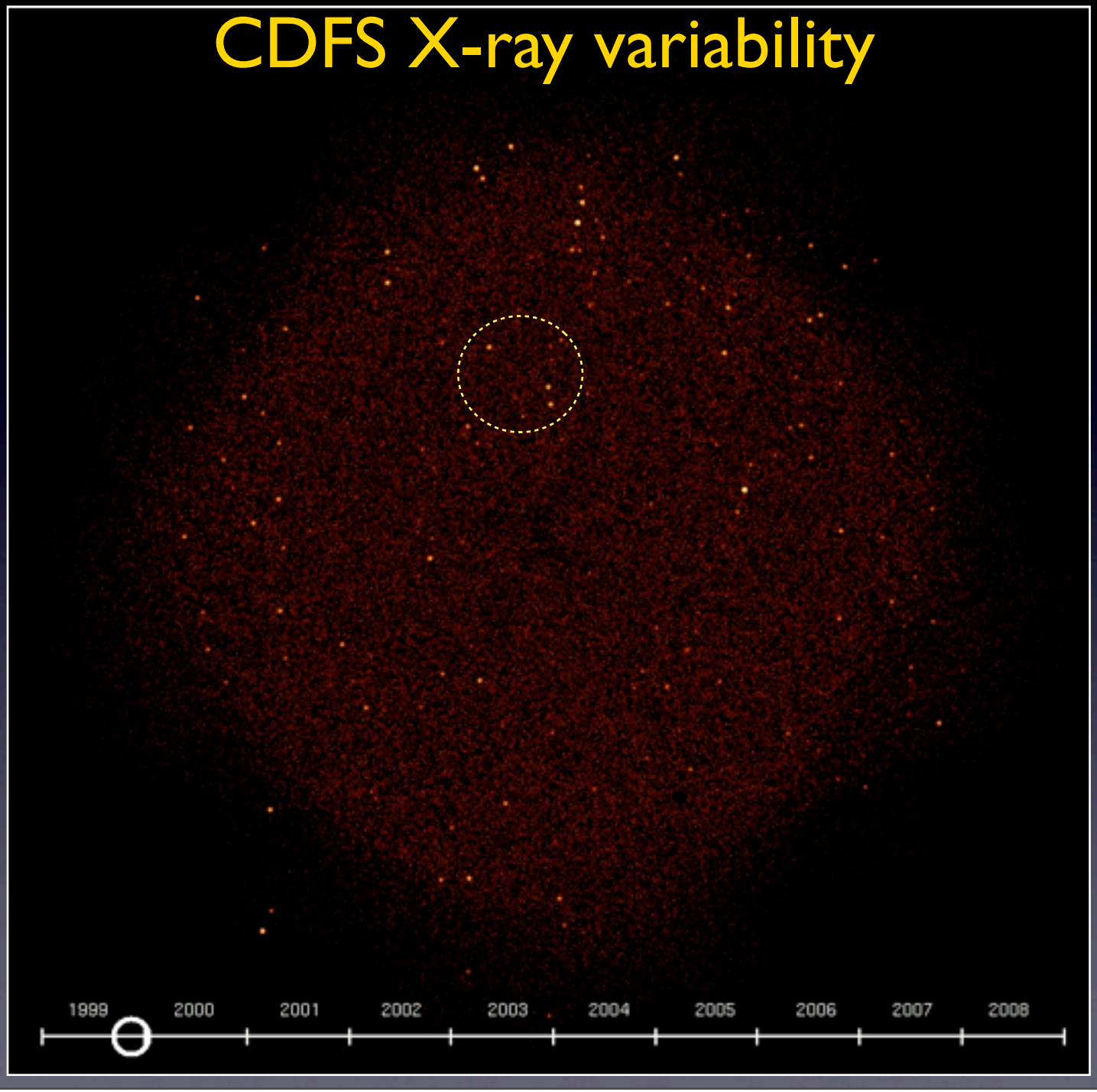
However we need high-quality, well sampled data

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

Papadakis et al. 2008



CDFS X-ray variability

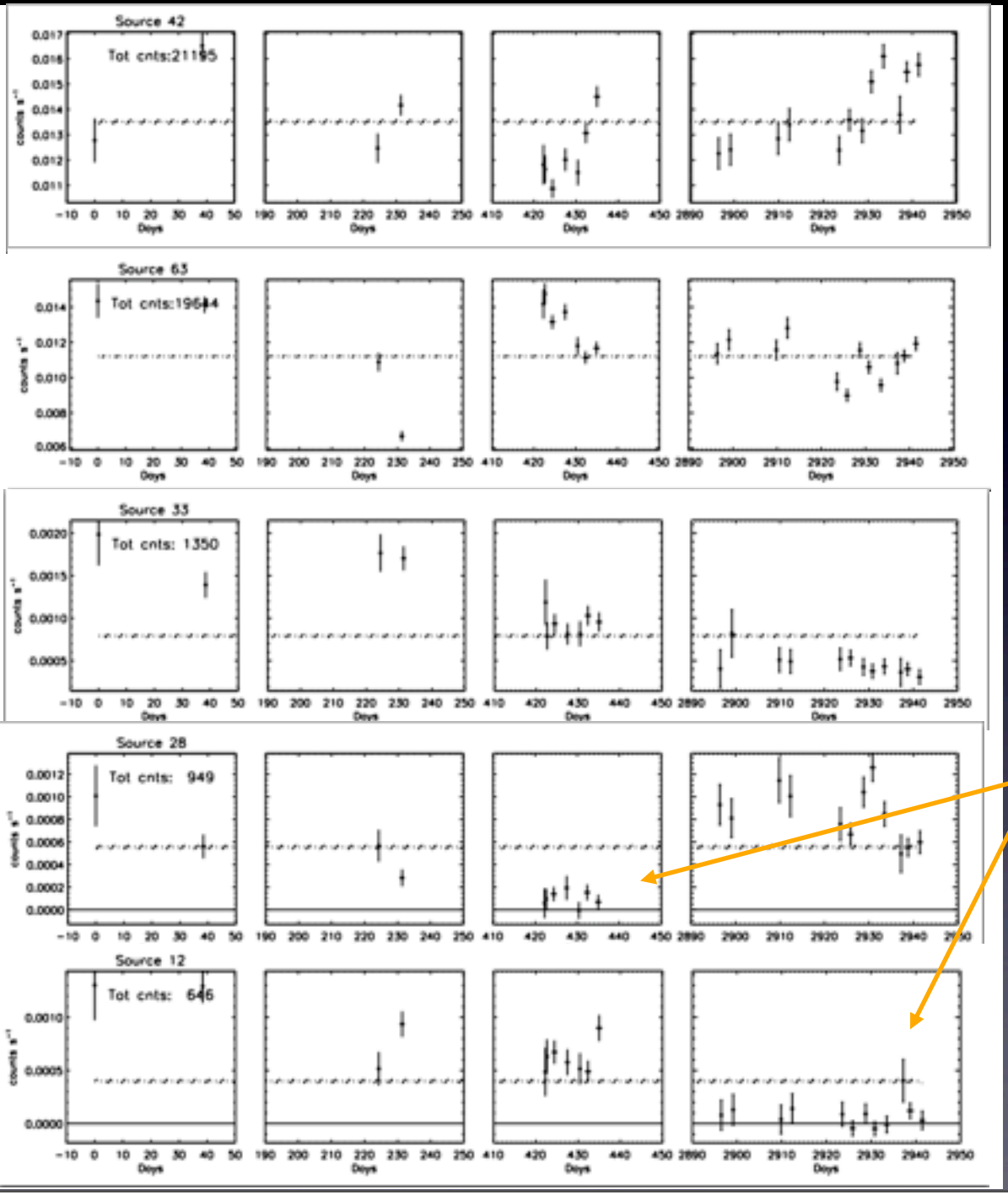


The 2 Ms CDFS dataset

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

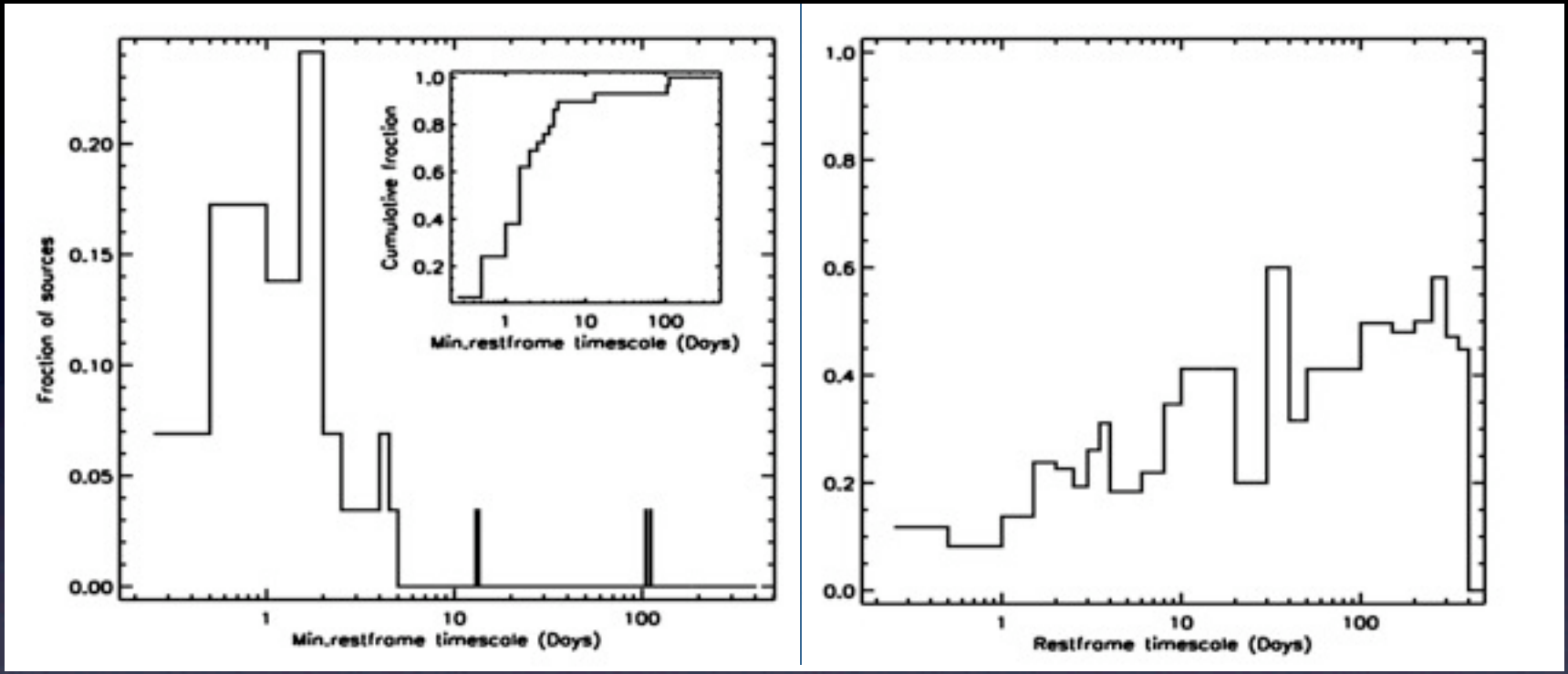
flickering of faint sources is due to noise

2Ms CDFS lightcurves



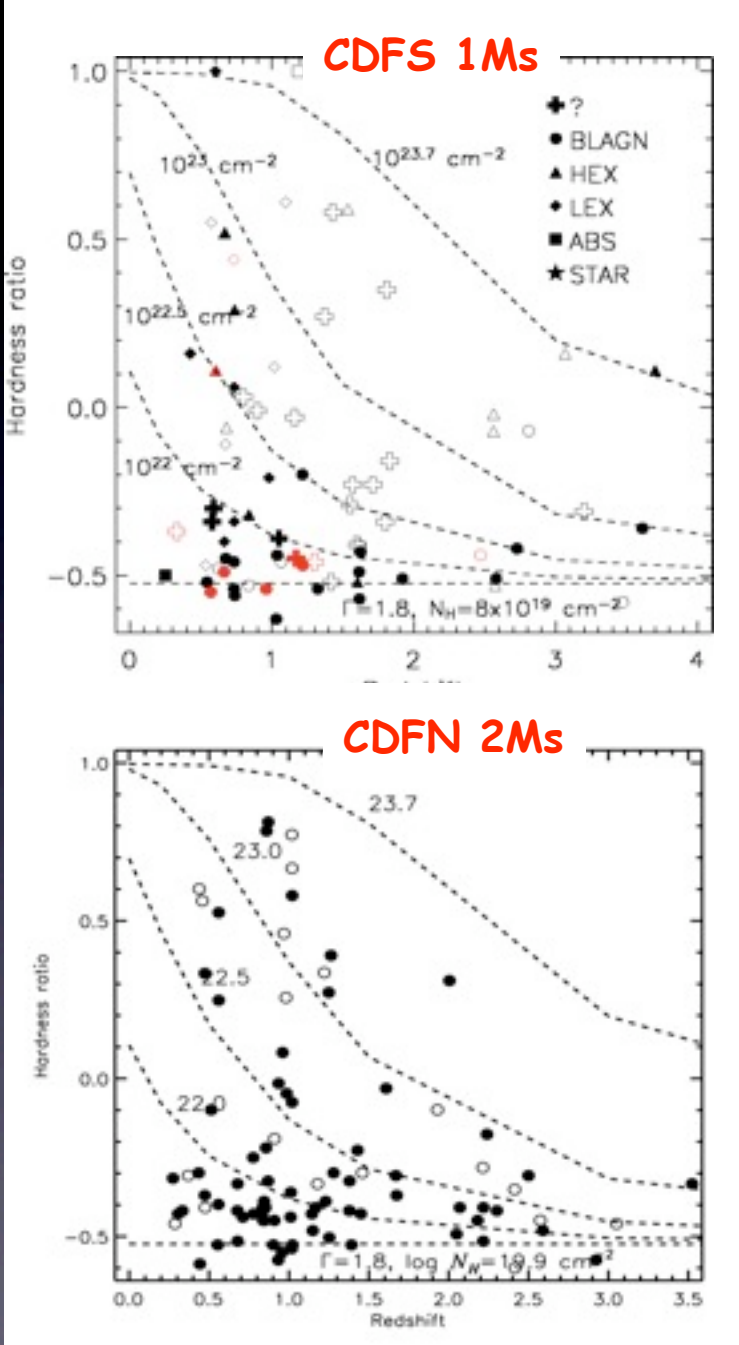
Some AGNs are undetected within observing campaigns of just a few days!

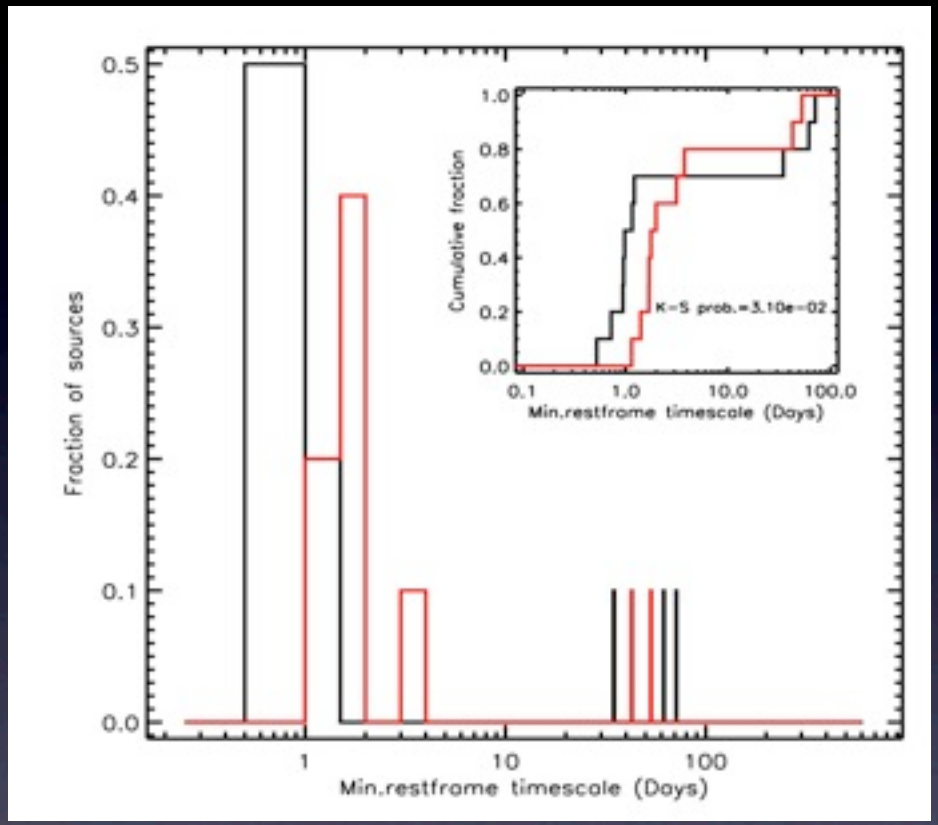
The lesson from 1Ms CDFs monitoring
(to be extended to the 4 Ms data)



- The majority of AGNs possess significant ($\Delta f/f > 10\%$) intrinsic variability (>90% accounting for sensitivity limits)
- We detect variability over timescales ranging from days to 1.5 years
- The CDFS lightcurves are dominated by long-term (weeks to years) variability.
- 70% of the sources possess short term variability on < 2 days.

Variability to probe AGN structure

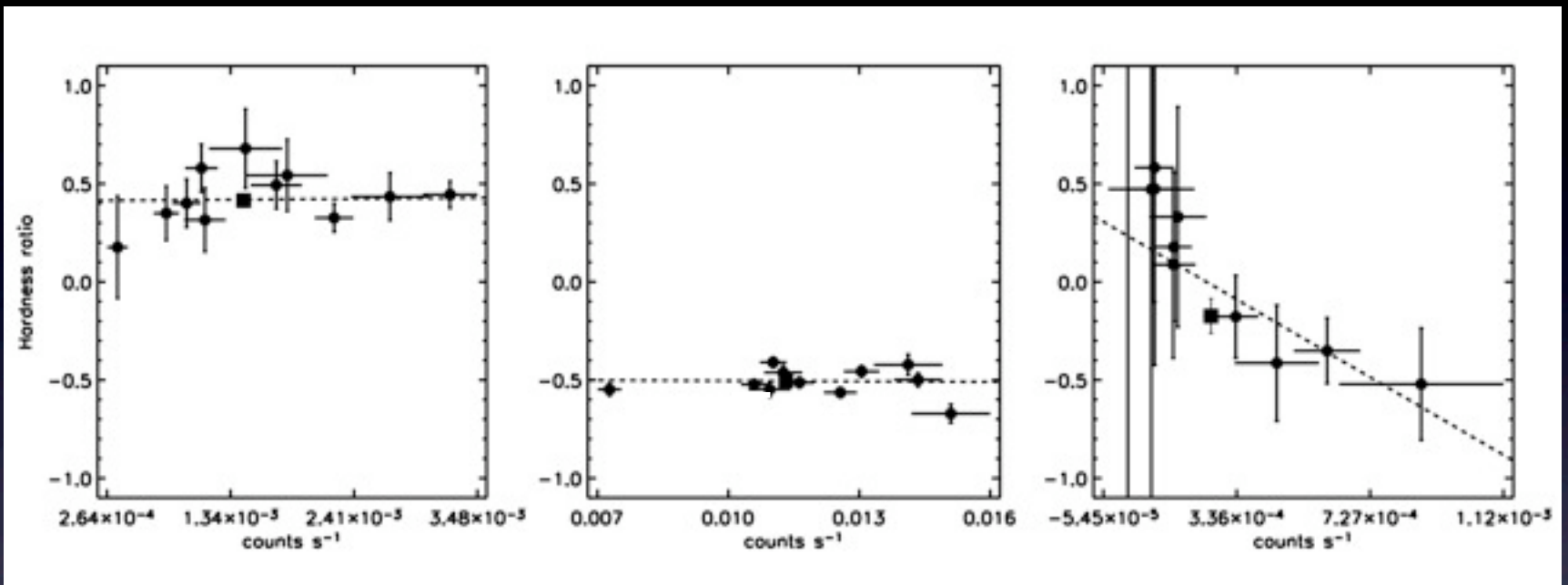




Soft (unabsorbed) sources are more variable than hard (absorbed) ones, and vary on shorter timescales.

reprocessing component?

Spectral variability in CDFS



- 70% of our sources with > 500 counts show no sign of significant ($\Delta\Gamma>0.2$) spectral variability
- In half of the remaining sources the spectrum becomes softer as the flux increases.

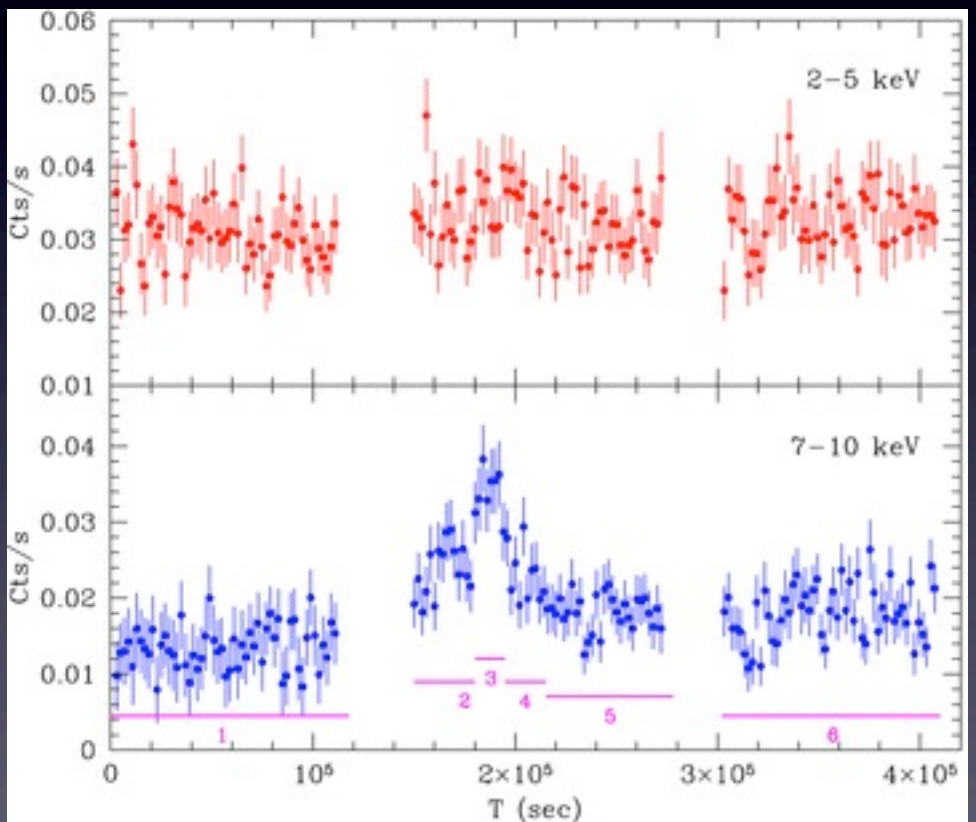
Need large eff. area to do proper spectral variability analysis !!

Is there more to look for?
Variable obscuration in AGNs

- Transition from reflection dominated to lower obscuration state observed in several nearby AGNs: N1316, N4151, N4388

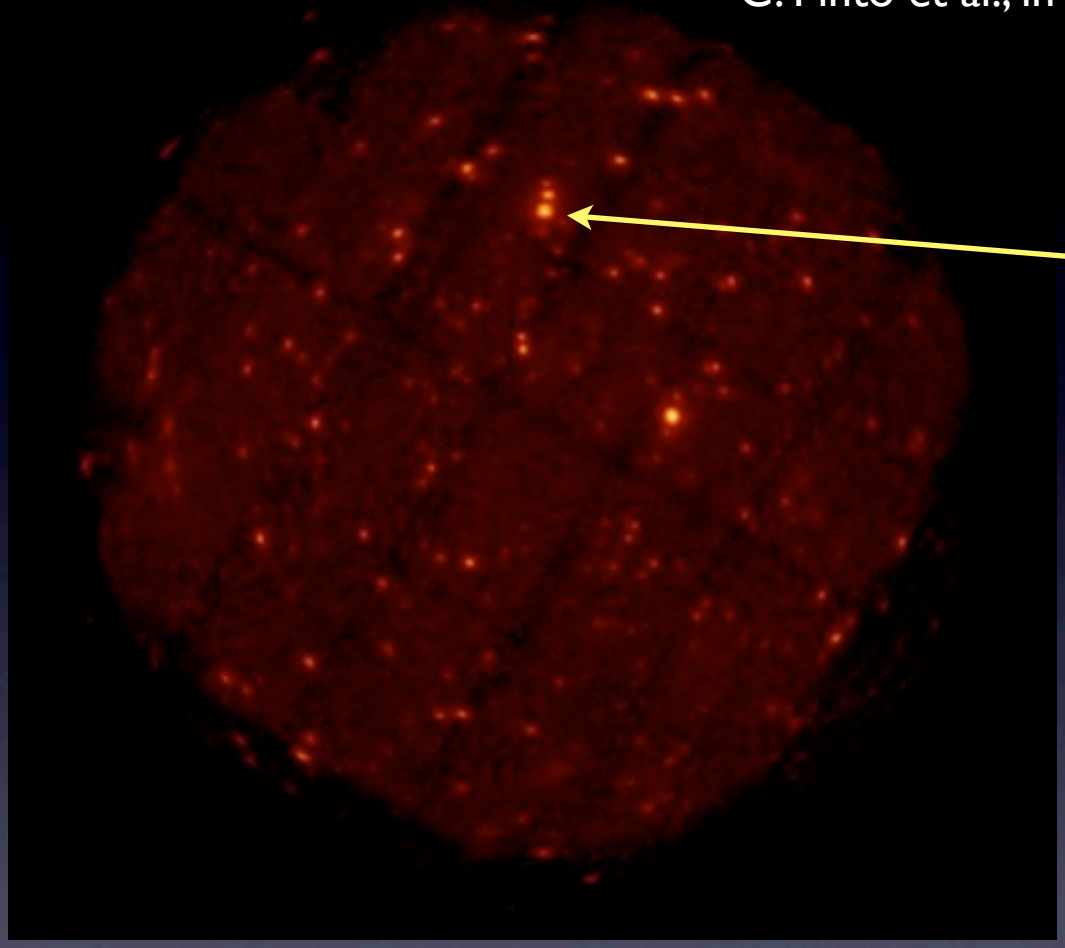
- Allows to constrain the structure and density of the obscuring material.(Risaliti et al. 2008, Puccetti et al. 2008, Elvis et al 2004)

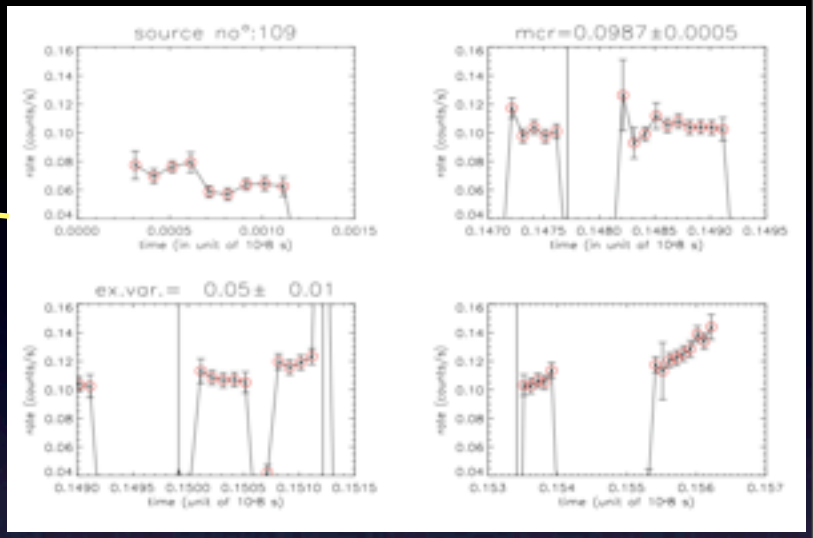
- What about distant AGNs?



XMM CDFS observations

C. Pinto et al., in prep



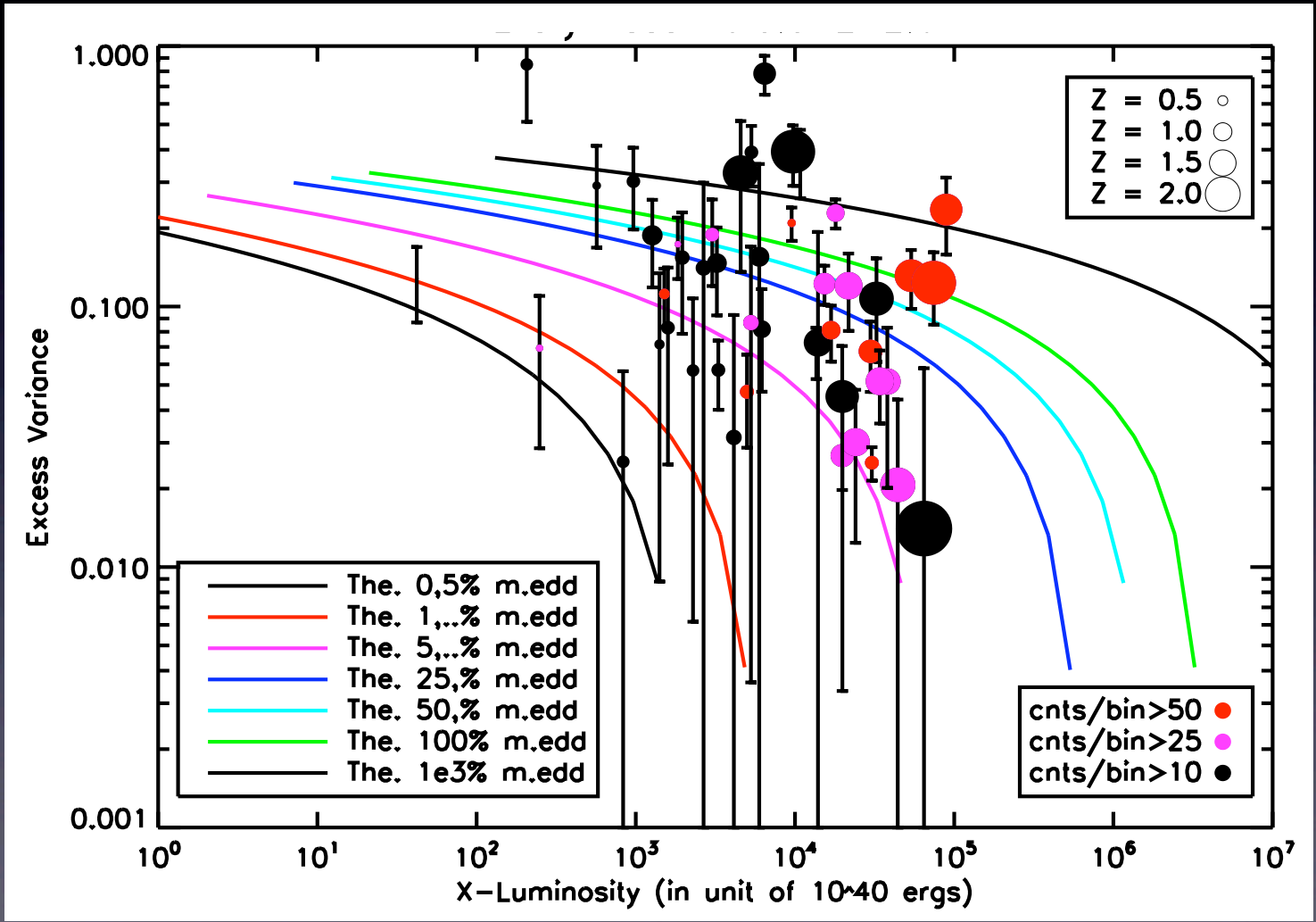


Sample	Perc.	Number
Entire Sample	24%	82/338
counts/bin>10	37%	59/161
counts/bin>20	50%	51/102
counts/bin>40	66%	37/56
counts/bin>100	94%	17/18

- Preliminary analysis using 350 ks from 2001-2002 observations.
- We plan to extend our analysis to the additional **2.5 *Msec*** XMM dataset (PI A. Comastri).

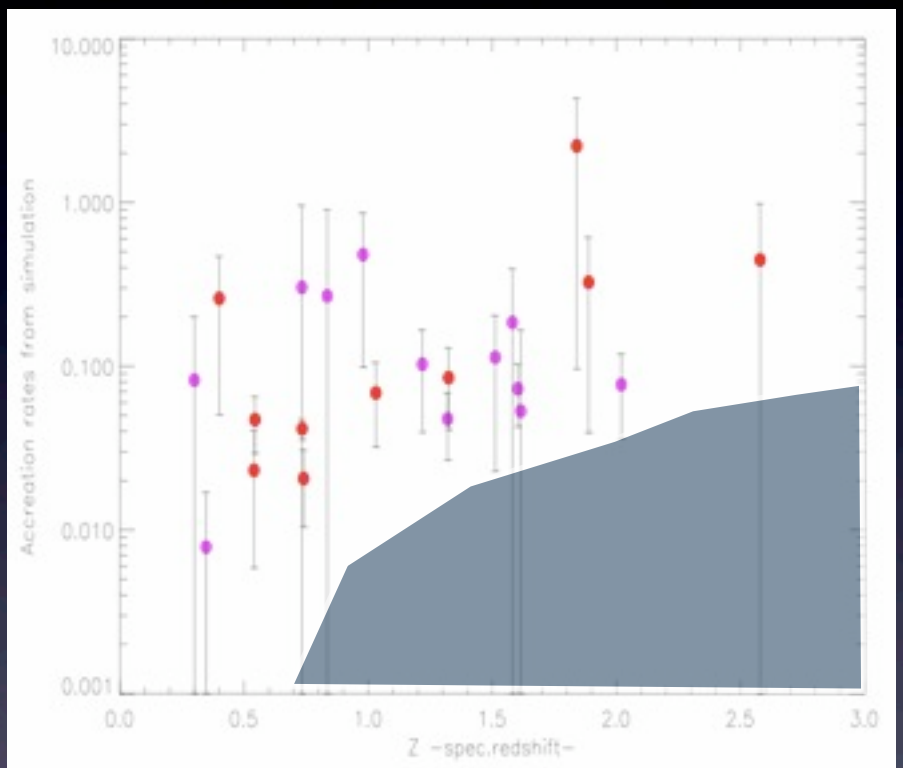
XMM CDFS observations vs models

C. Pinto, M. Paolillo et al., in prep



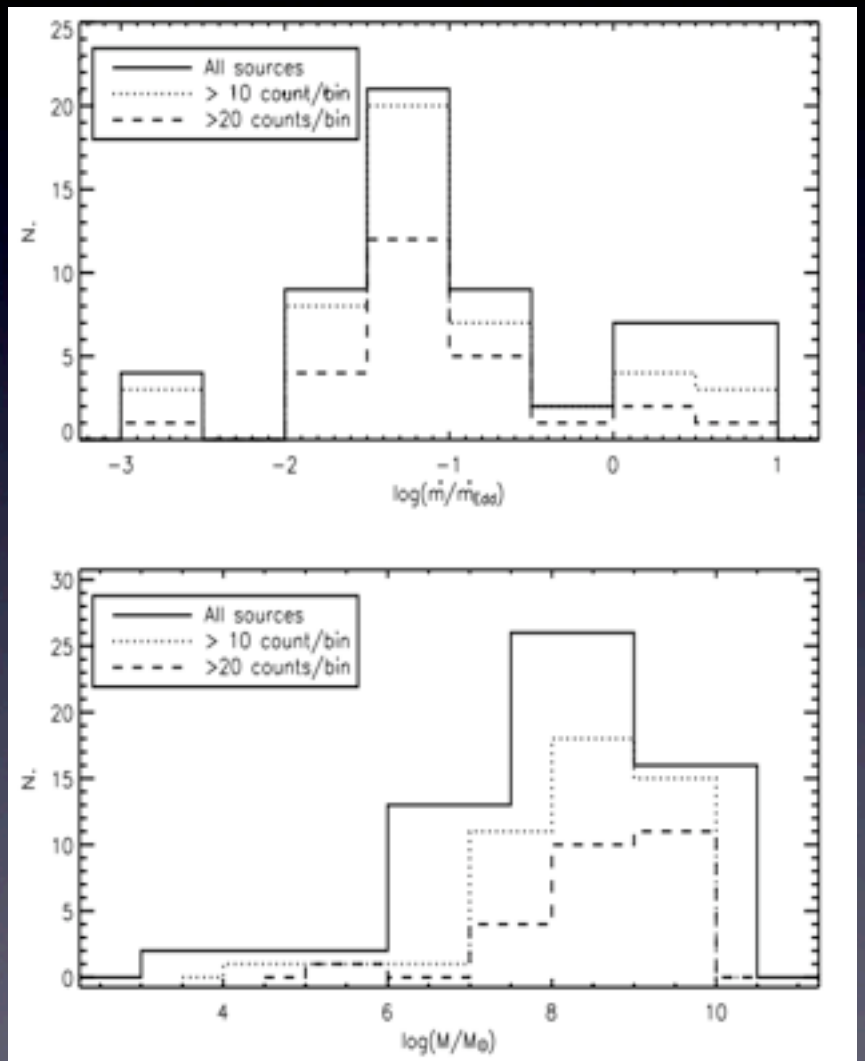
XMM CDFS: mass and accretion rates estimates

(C. Pinto et al., in prep)



$\dot{M}/M_{Edd}$

Z

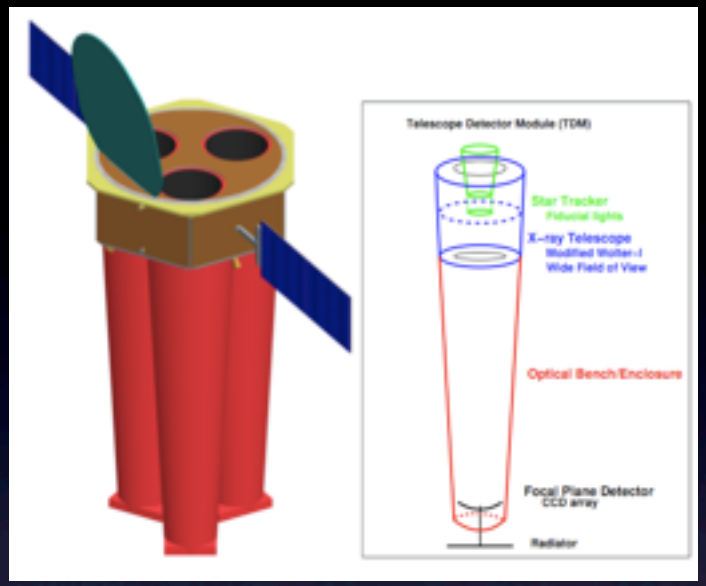


Why to look for X-ray variability with next generation wide-field missions?

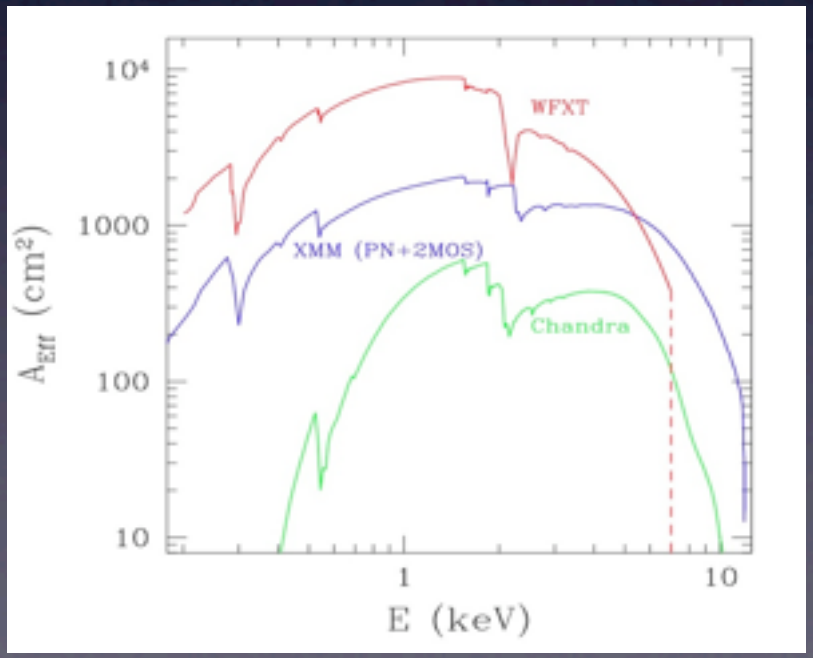
- **Discovery**: variable sources are compact
- **Physics:** variability studies provide clues to the nature of the physical processes, the sizes and the correlations between the different regions producing the observed emission.
- **It comes (almost) for free:** Natural outcome of sensitive, large area, long-term surveys

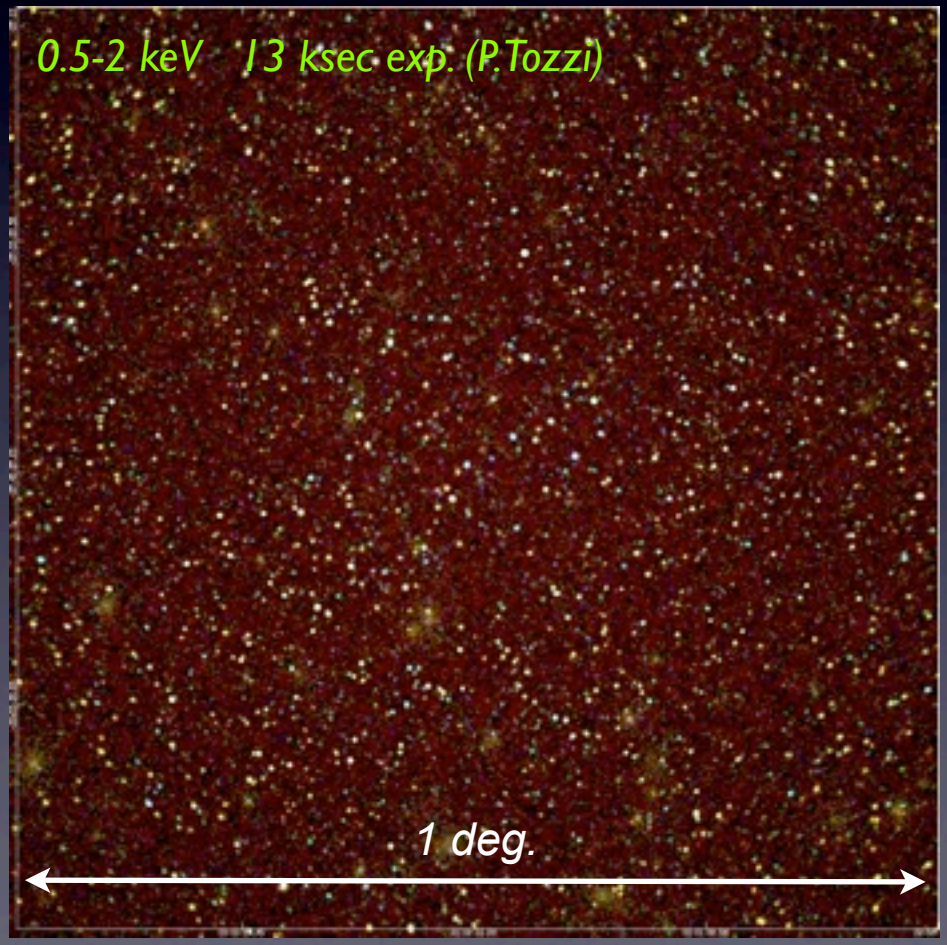
Time domain is rapidly opening for astronomical studies on very large areas at different wavelengths (Pann-STARRS, LSST, Swift, EXIST etc.)

Wide Field X-ray Telescope



- Submitted to the Decadal Survey
- 3 mirror modules, 1 m^2 eff.area
- Wide-field optics: 1 deg FOV, 5" HEW <u>across the whole field</u>

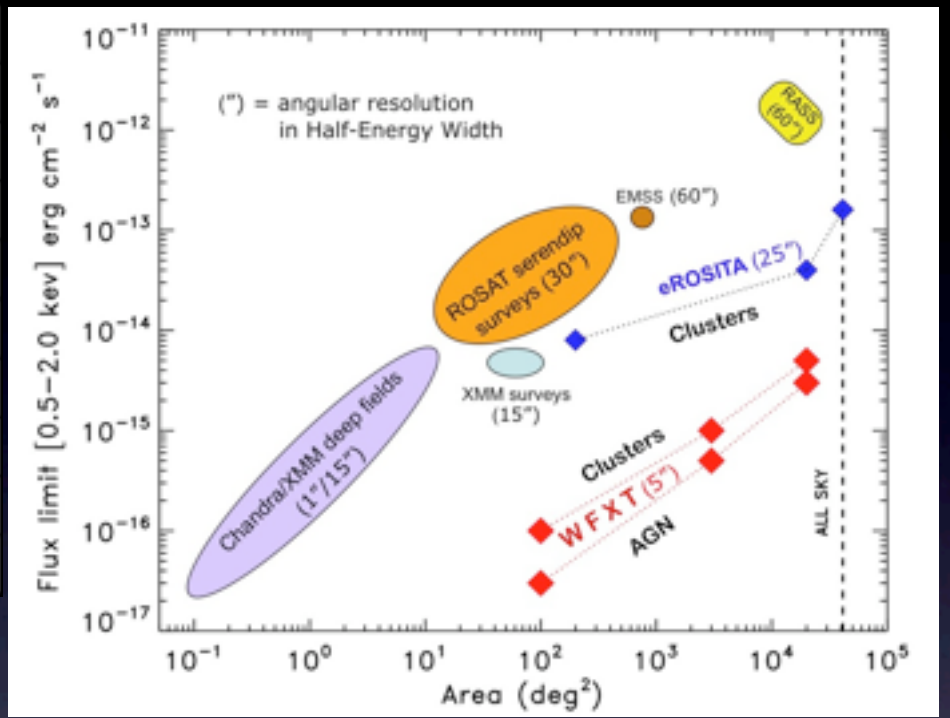




WFXT extragalactic surveys

Quantity	Survey		
	Deep	Medium	Wide
Ω (deg²)	100	3000	20,000
Exposure time	400 ks	13 ks	2 ks
Total time	1.67 yr	1.66 yr	1.67 yr
S_{min} (point-like) (*)	3×10^{-17}	5×10^{-16}	3×10^{-15}
Total AGN detected	5×10^{5}	4×10^{6}	1×10^{7}
S_{min} (extended) (*)	1×10^{-16}	1×10^{-15}	5×10^{-15}
Total clusters/groups	3×10^{4}	2×10^{5}	3×10^{5}

(*) Flux limit in erg cm² s⁻¹ (0.5-2 keV band) at 5σ detection



- **Wide survey**: 2 ks per field, 20000 sq.deg - main issue: very short time sampling for supermassive black holes (assuming continuous monitoring)
- **Medium survey**: 13 ks per field, 3000 sq.deg - few hours monitoring, samples less massive BH and higher accretion rates (assuming continuous monitoring)
- **Deep survey**: 400 ks per field, 100 sq.deg - with correct monitoring strategy will allow to sample homogeneously broad range of masses and timescales.

AGN Variability with WFXT

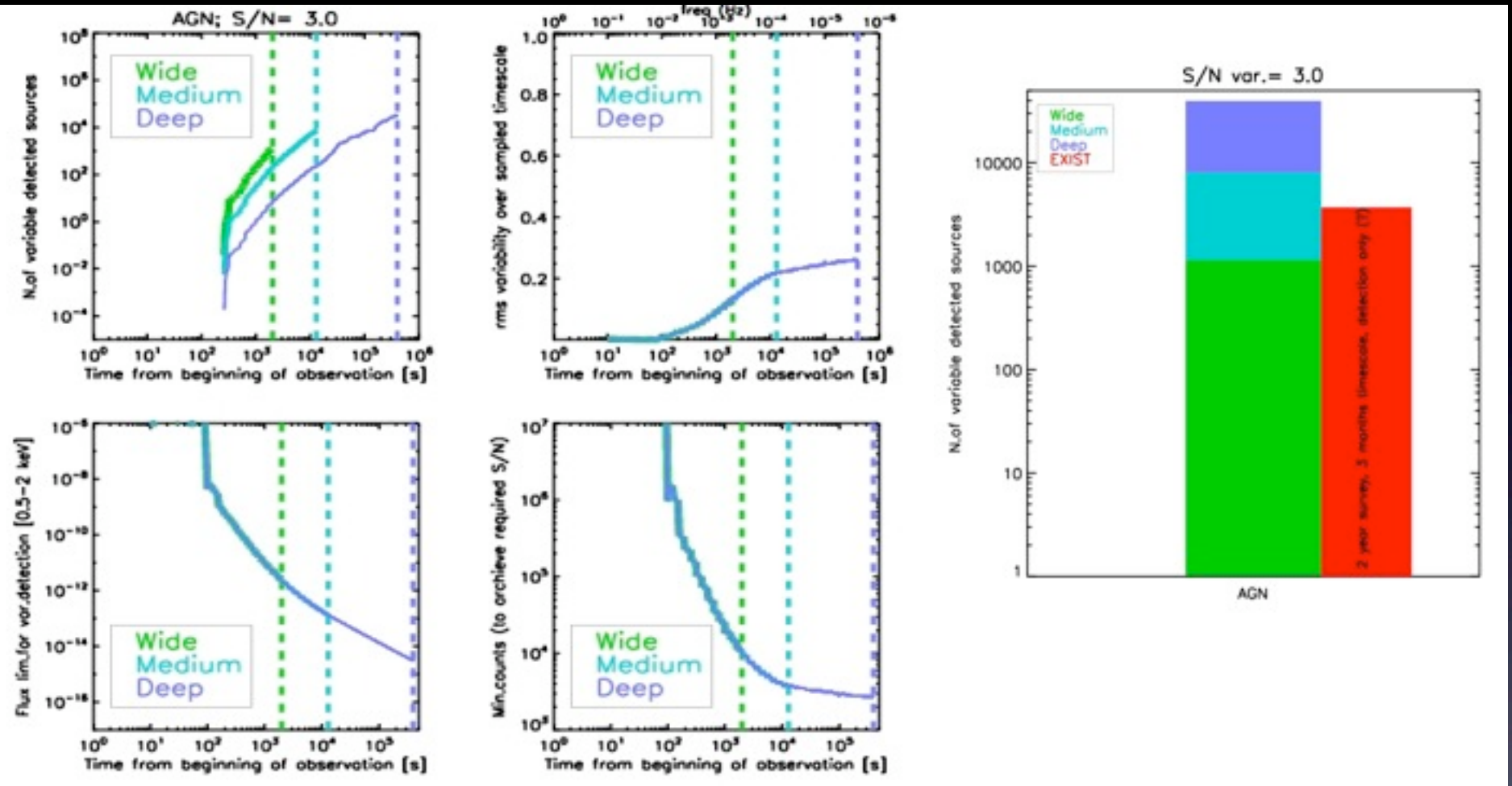
WFTX advantages:

- **Large collecting area**: needed for short temporal sampling independently of time devoted to targets.
- **Spatial resolution**: crowding will become a serious issue for faint AGNs and make cross-identification hard, thus reducing number of targets suited for variability studies
- **Temporal coverage**: 400 ks per field, 100 sq.deg - with correct monitoring strategy will allow to sample homogeneously broad range of masses and timescales.

Are variability studies of high-z AGNs and transients accessible with current X-ray missions?

Maybe, but the trade off between sky coverage and observing time do not allow a uniform coverage of the parameter space (different time sampling, flux limit, covered area).

AGN variability detection with WFXT

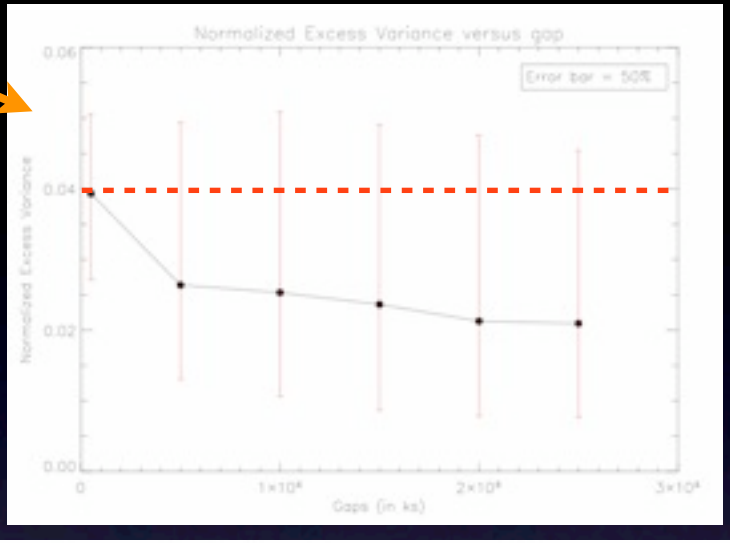


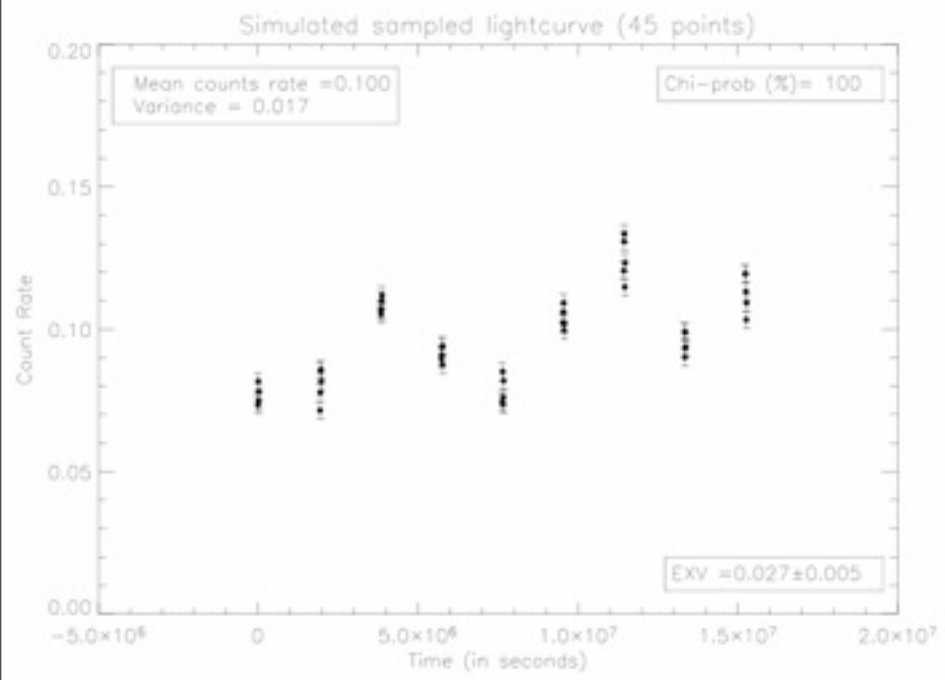
Requirements: >10 data points, $S/N_{det}>5$, $S/N_{var}>3$

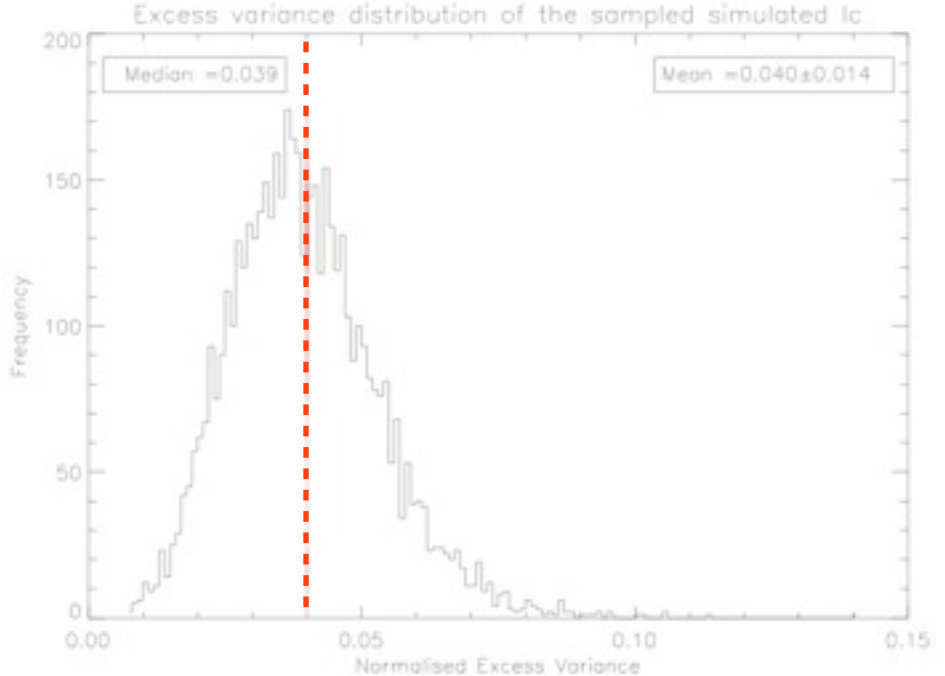
AGNs with accurate variability estimates are the same as those allowing accurate spectroscopic analysis (> few thousand counts)

WFXT Deep Survey strategy

- 420 ks split in 2 observations: 500 ks,1 Ms, 1.5 Ms,..... gaps
- More realistic samplings for WFXT: 9x50 ks observations split over ~6 months
- Using a regular sampling pattern we remove bias; the uncertainty is of the order of 35%.
- Similar results for progressive sampling







Conclusions

- Deep multi-epoch surveys offer the opportunity to investigate the structural properties of distant AGN populations.
- Variability may allow to trace BH mass and accretion rates with lookback time.
- So far such studies are limited to deep-surveys and thus require an accurate estimate of the biases introduced by low statistics, sparse and irregular sampling.
- Future missions with large effective area/wide field of view will provide large samples with good statistics thus allowing to derive much better constraints.

Need to plan the observing strategy to minimize observational biases in the time domain.