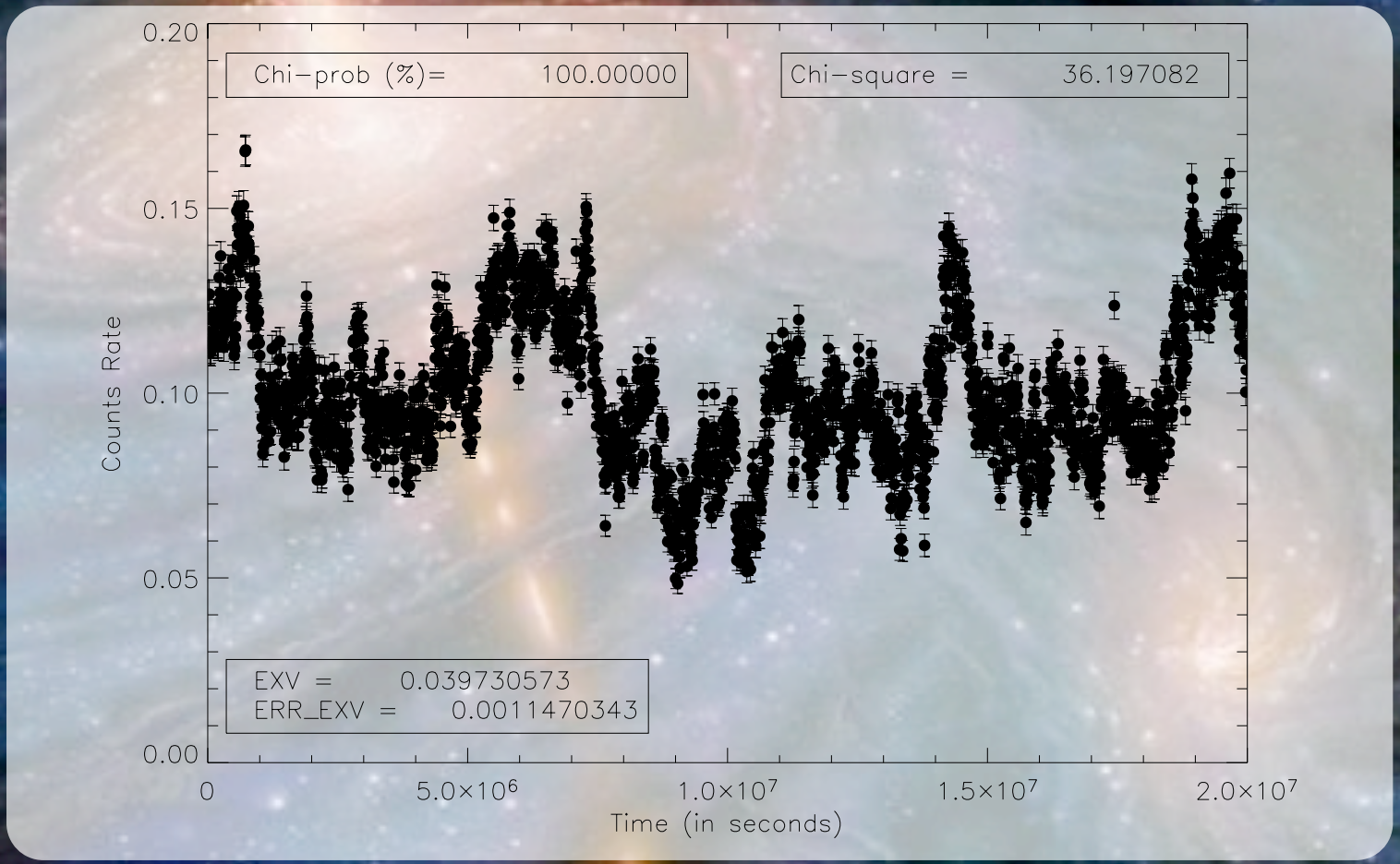
AGN variability across cosmic time:

X-ray variability with WFXT

Maurizio Paolillo - *Univ.Federico II of Naples, Italy*

in collaboration with **Viola Allevato, Ciro Pinto, E. de Filippis and the WFXT team**



Bologna - 25-26/11/09

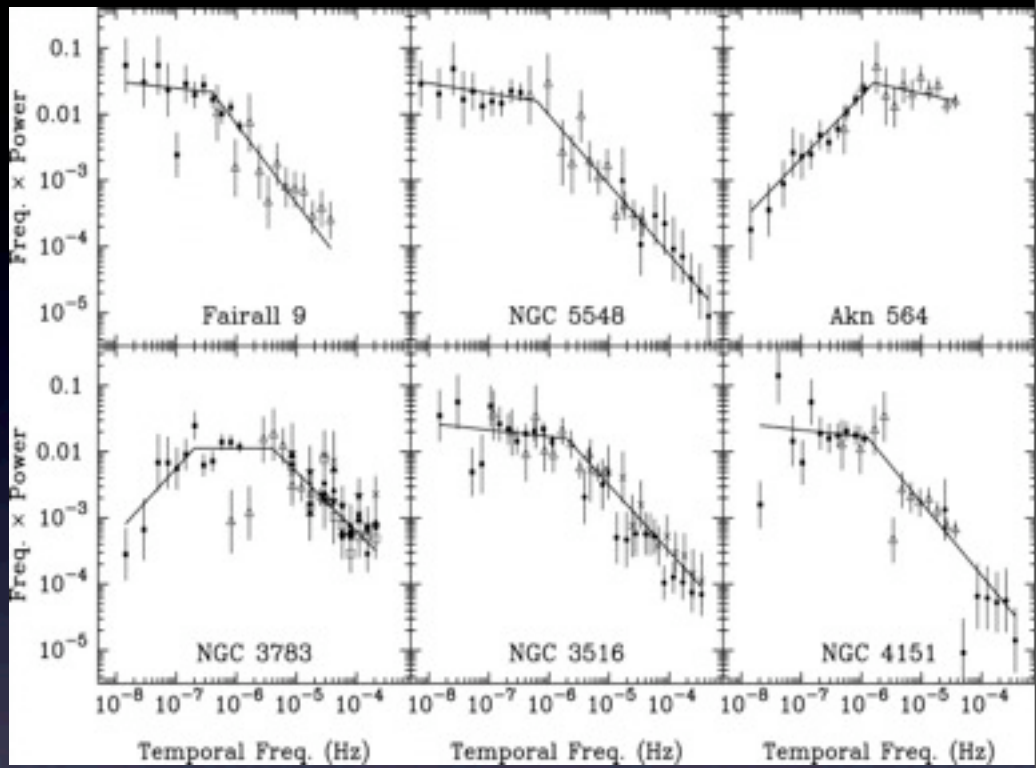
Why to look for variability with WFXT?

- **Discovery**: the rates of many transient are poorly characterized due to their elusive nature
- **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 at different wavelengths (Pann-STARRS, LSST, EXIST etc.)**

Variability properties of AGNs

The origin of variability is still unknown. Several models have been suggested:

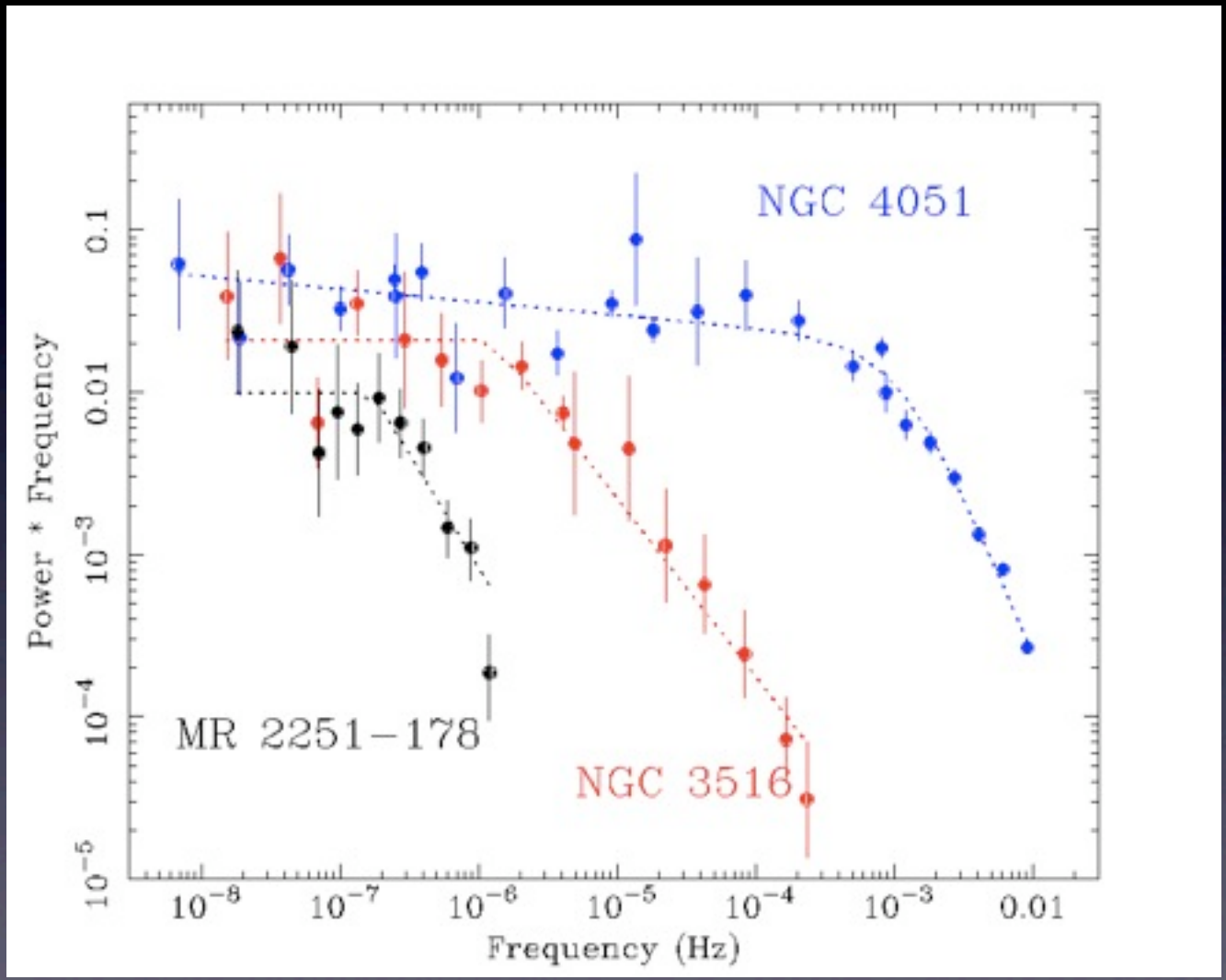
- Microlensing
- Instabilities in the accretion flow (MHD instabilities)
- Variations in accretion rates
- Variable obscuration (see G.Risaliti talk)



The Power Density Spectrum is dominated by 'red noise' (power law $\alpha \sim 1.5$).

However breaks in the PDS at low ($\nu < 10^{-7}$, $t > 100$ days) and high ($\nu \sim 10^{-5 \div 6}$, $t < 10$ days) frequencies heve been detected in several nearby AGNs (Markowitz et al. 2003, O'Neil et al. 2005)

Characteristic time-scales scale with black hole mass



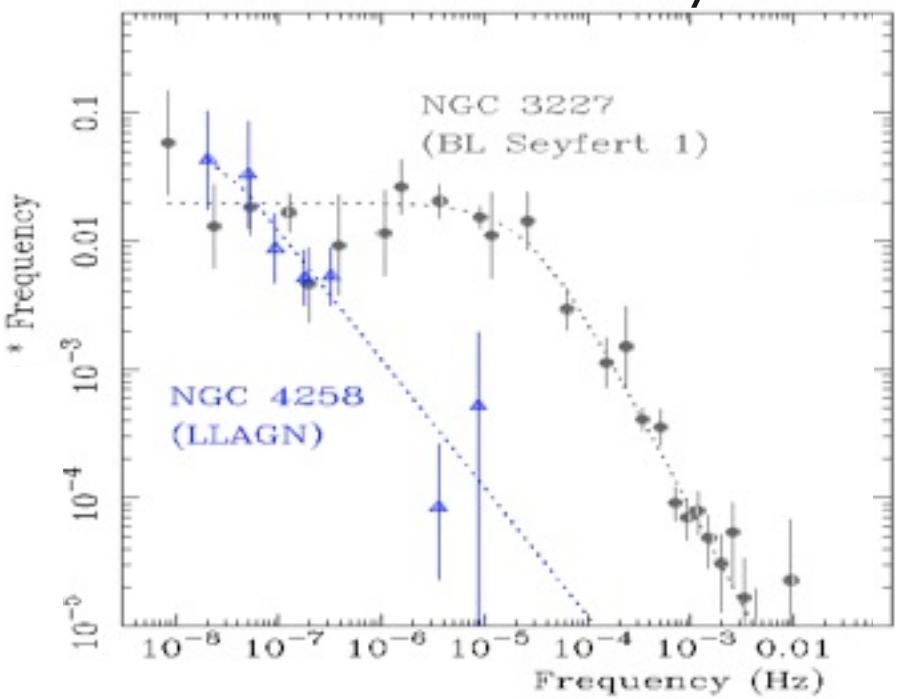
$>10^8\ M_\odot$ $4\times10^7\ M_\odot$ $10^6\ M_\odot$

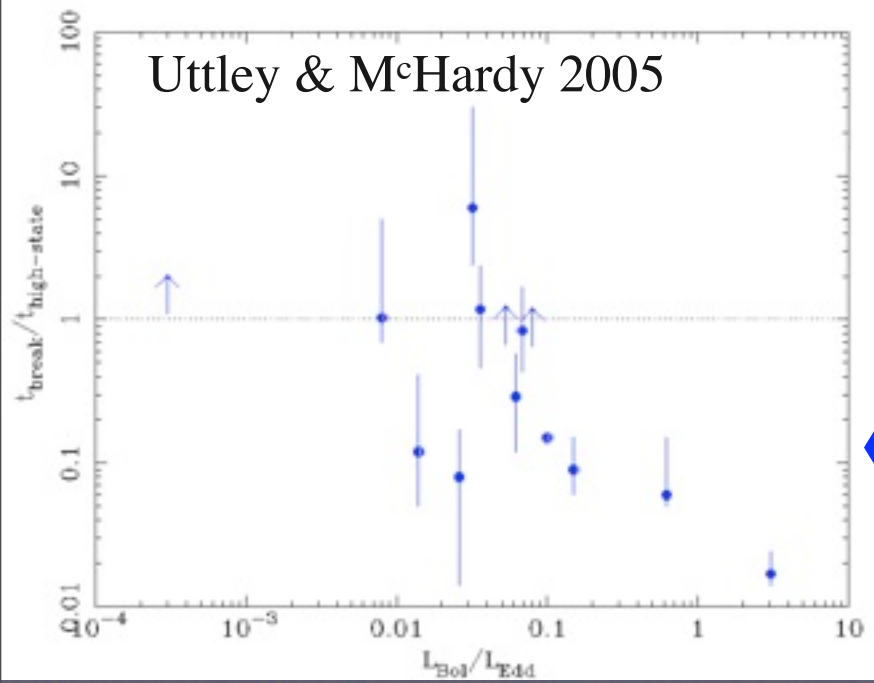
(courtesy of P. Uttley)

Characteristic time-scales scale inversely with accretion rate

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

Markowitz & Uttley 2005

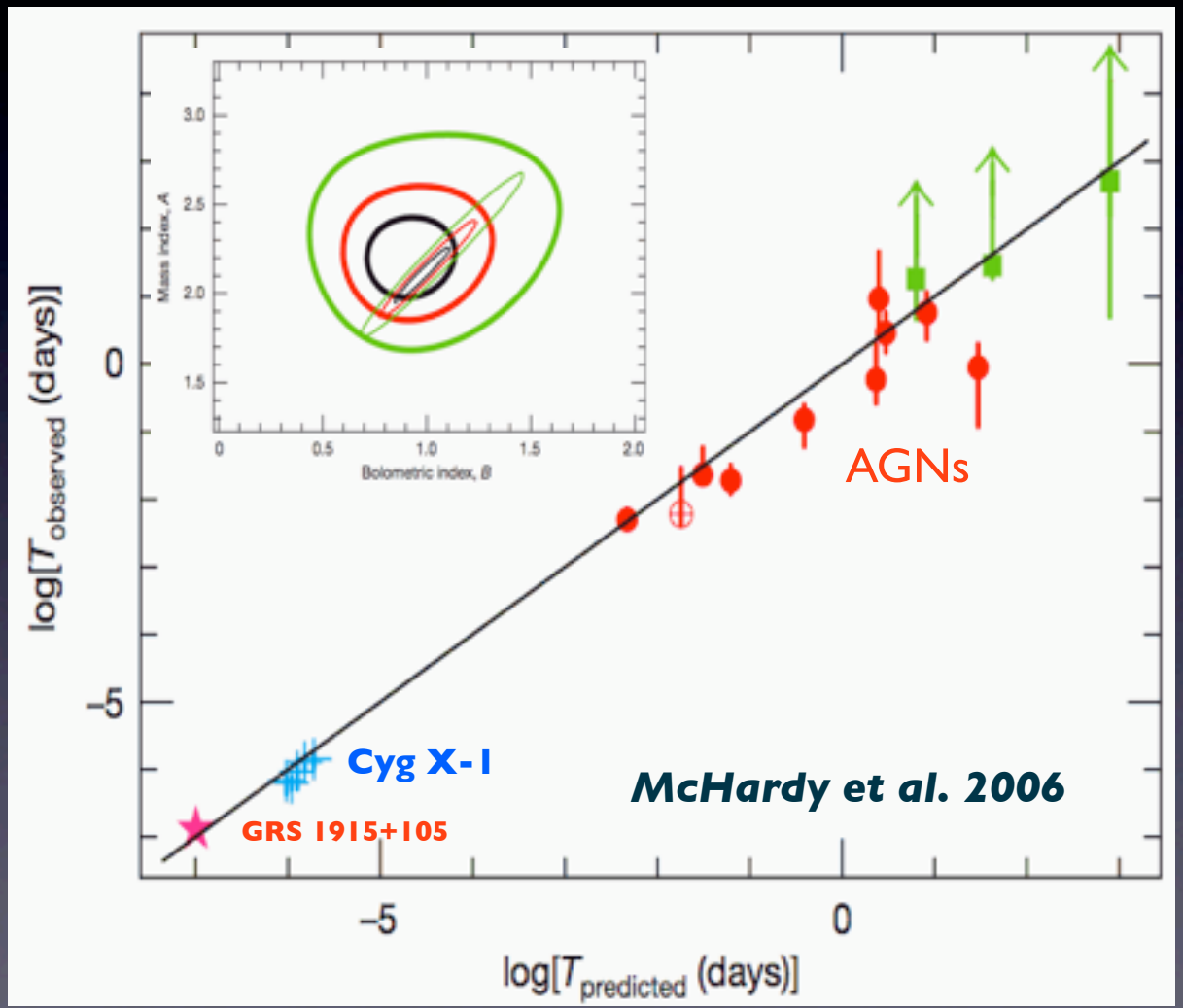




Time-scale normalised by BH mass scales inversely with L_{bol}/L_{Edd}

The BH variability fundamental plane: mass-luminosity-timescale

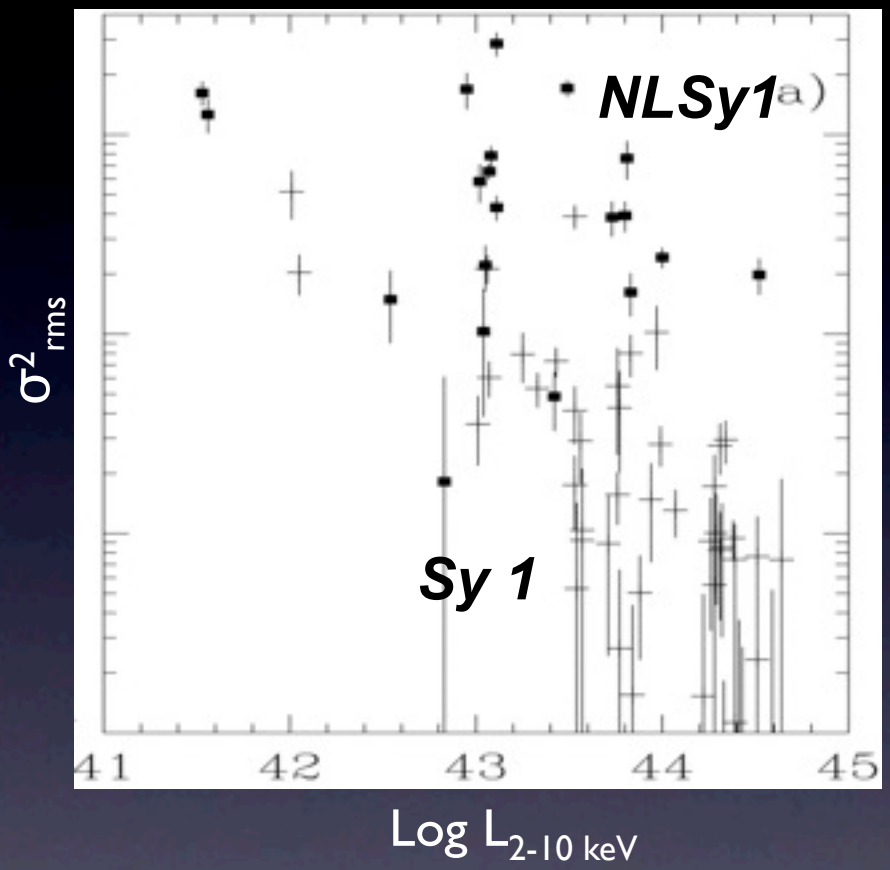
McHardy et al., Nature, 2006



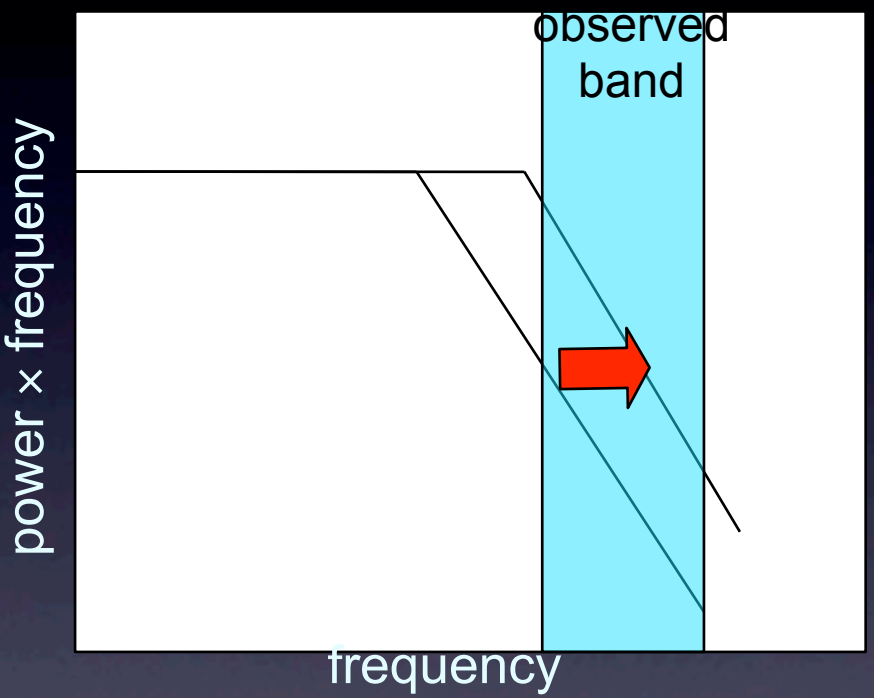
Now with more detailed fitting: Does break time-scale t_B scale with bolometric luminosity' of AGN?

$t_B \propto M_{BH}^{A}/L_{bol}^{B}$

Variability in poor statistics data



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

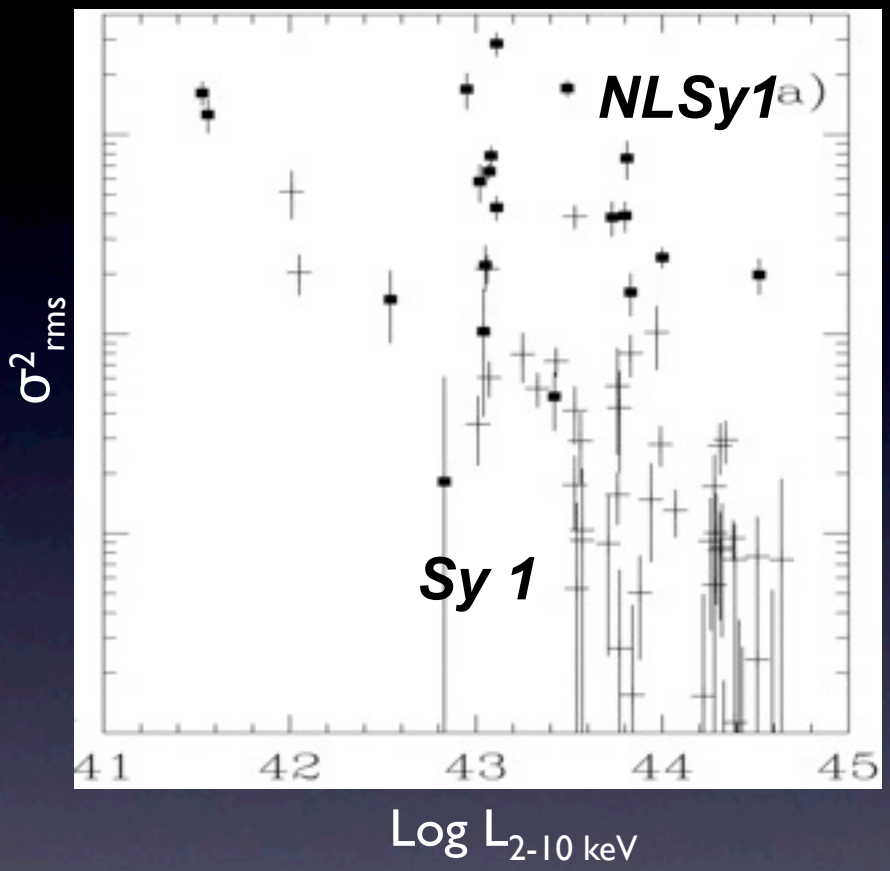


Can use 'excess-variance' to estimate mass [e.g. O'Neill et al., Gierlinski et al. 2007]

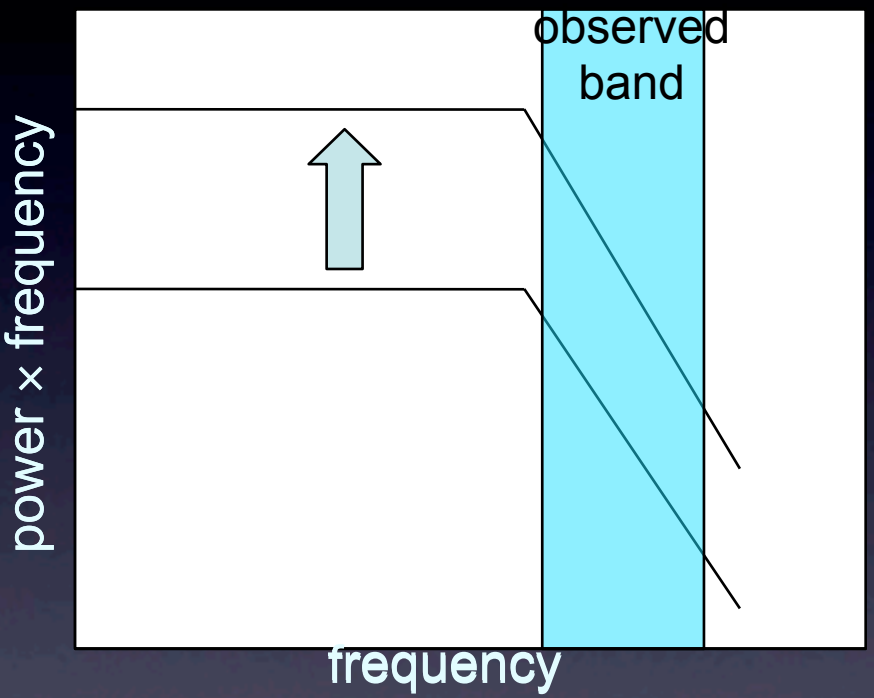
but should take accretion rate into account!

Bologna - 25-26/11/09

Variability in poor statistics data



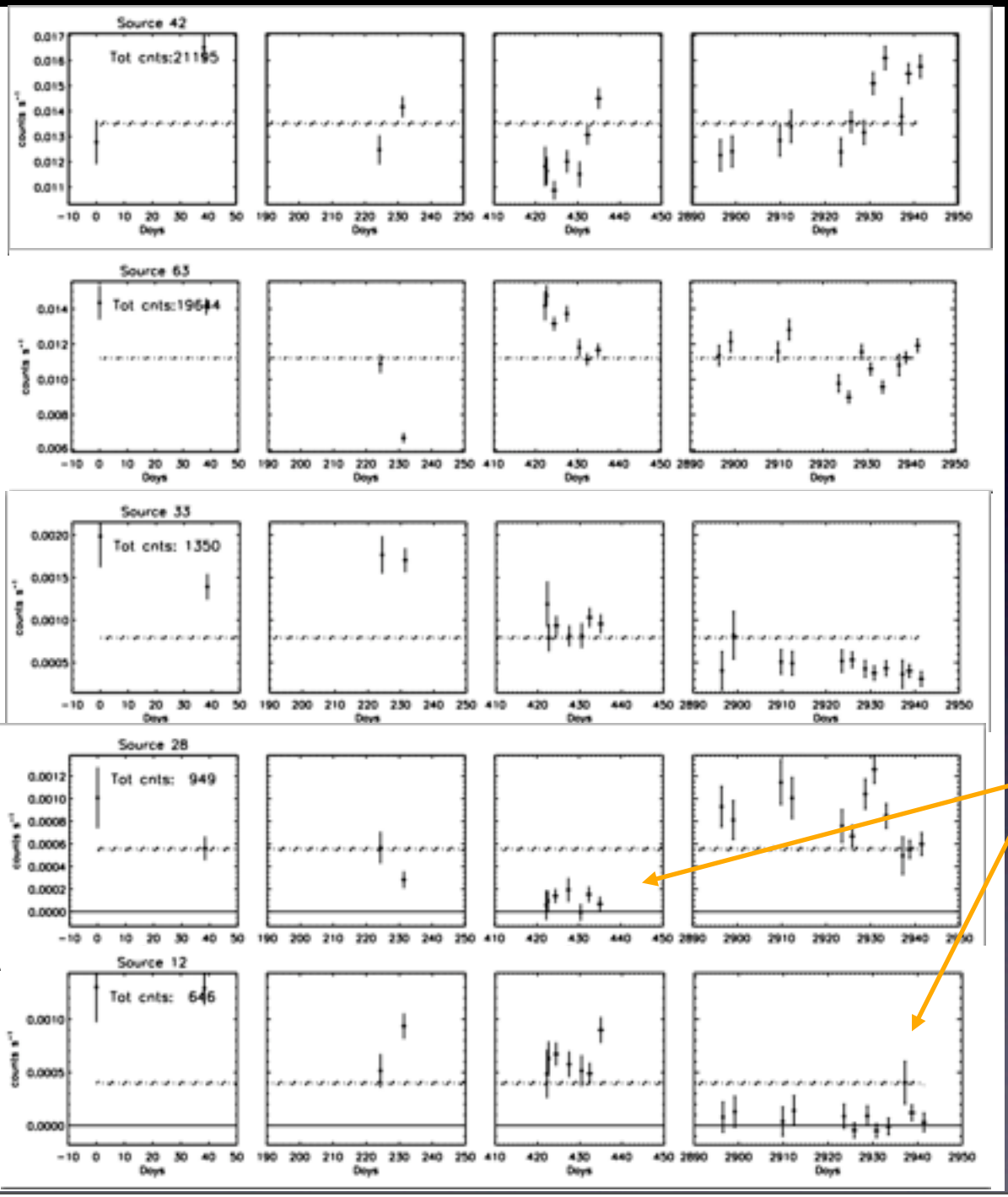
Black squares: NLS1, Crosses: BL Seyferts (Turner et al. 1999)



Can use 'excess-variance' to estimate mass [e.g. O'Neill et al., Gierlinski et al. 2007]

but should take accretion rate into account!

Bologna - 25-26/11/09

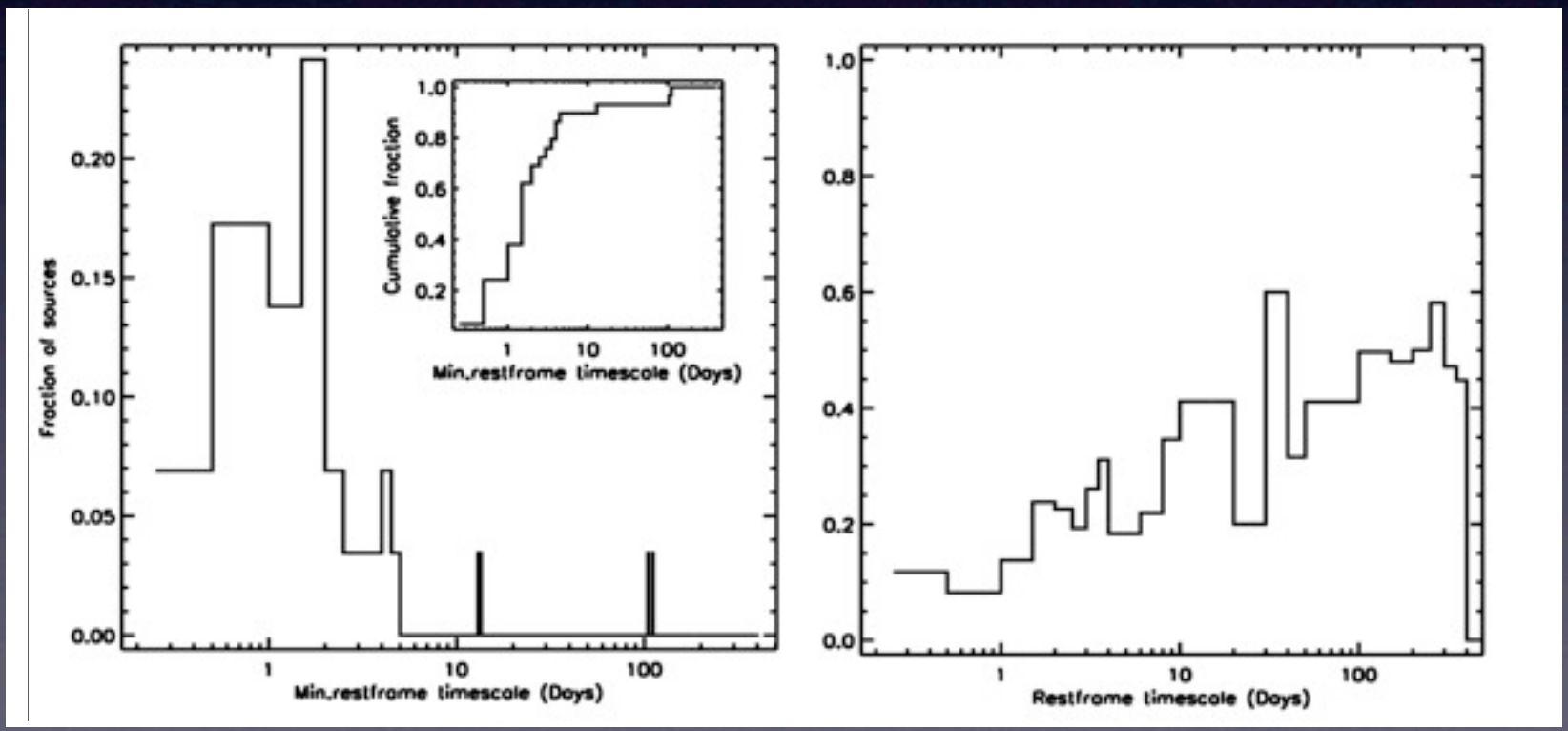


2Ms CDFS lightcurves

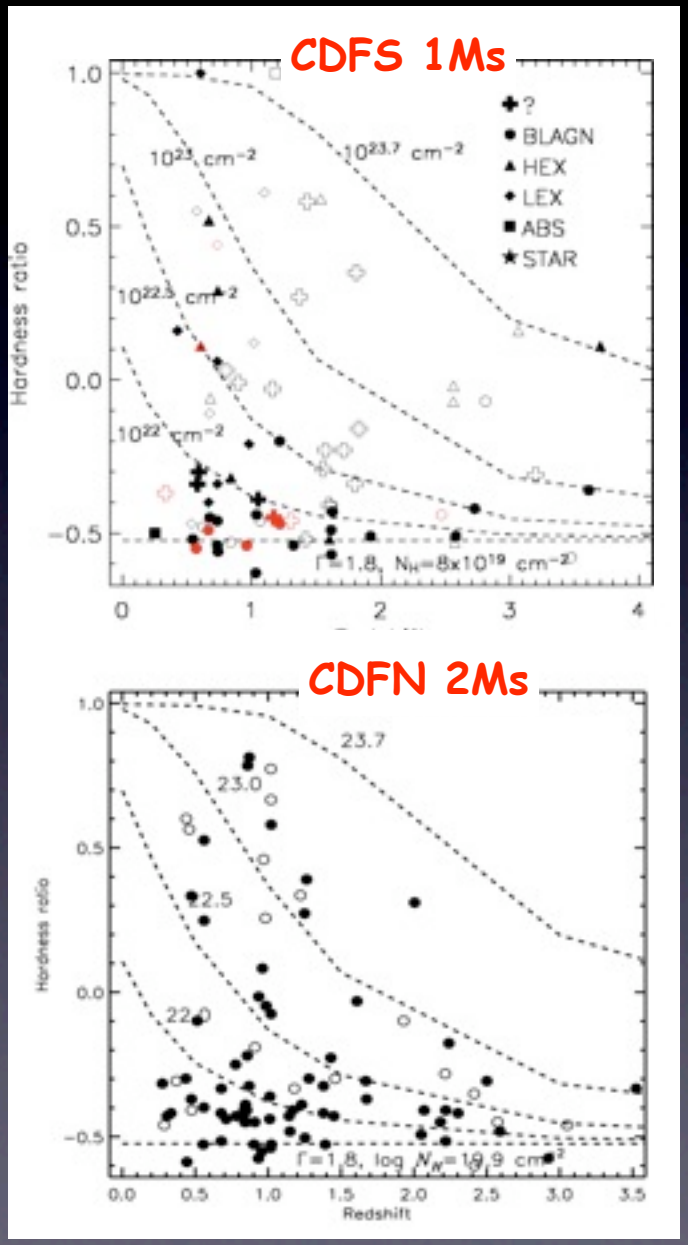
Some AGNs are undetected within observing campaigns of just a few days!

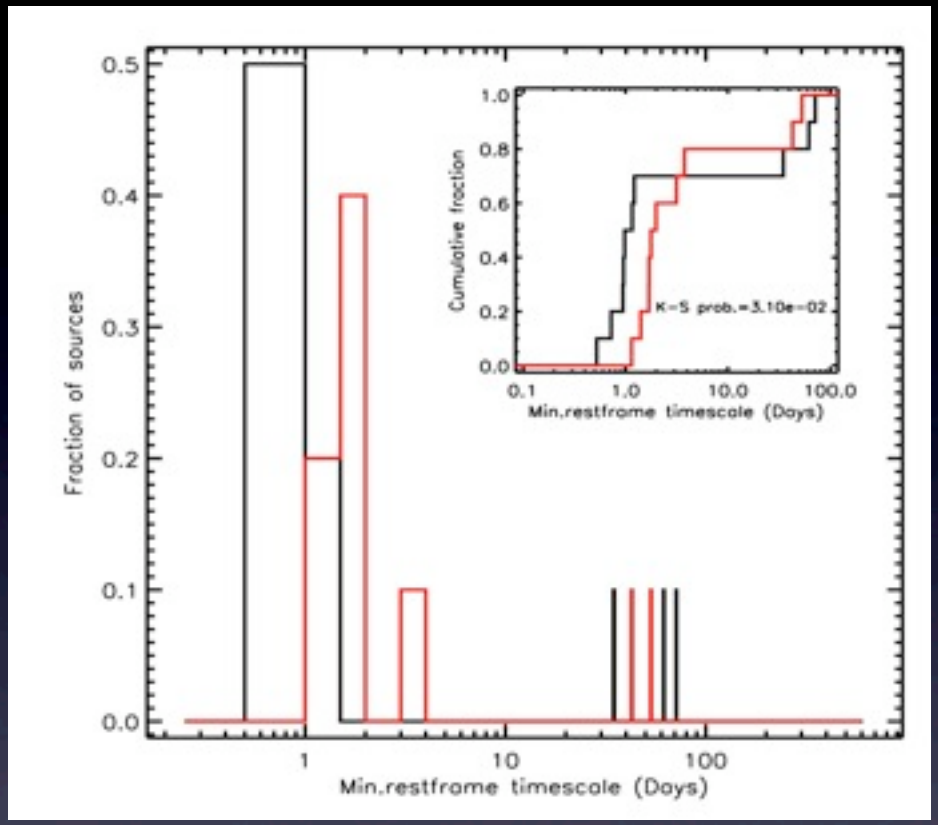
The lesson from CDFs monitoring

- 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



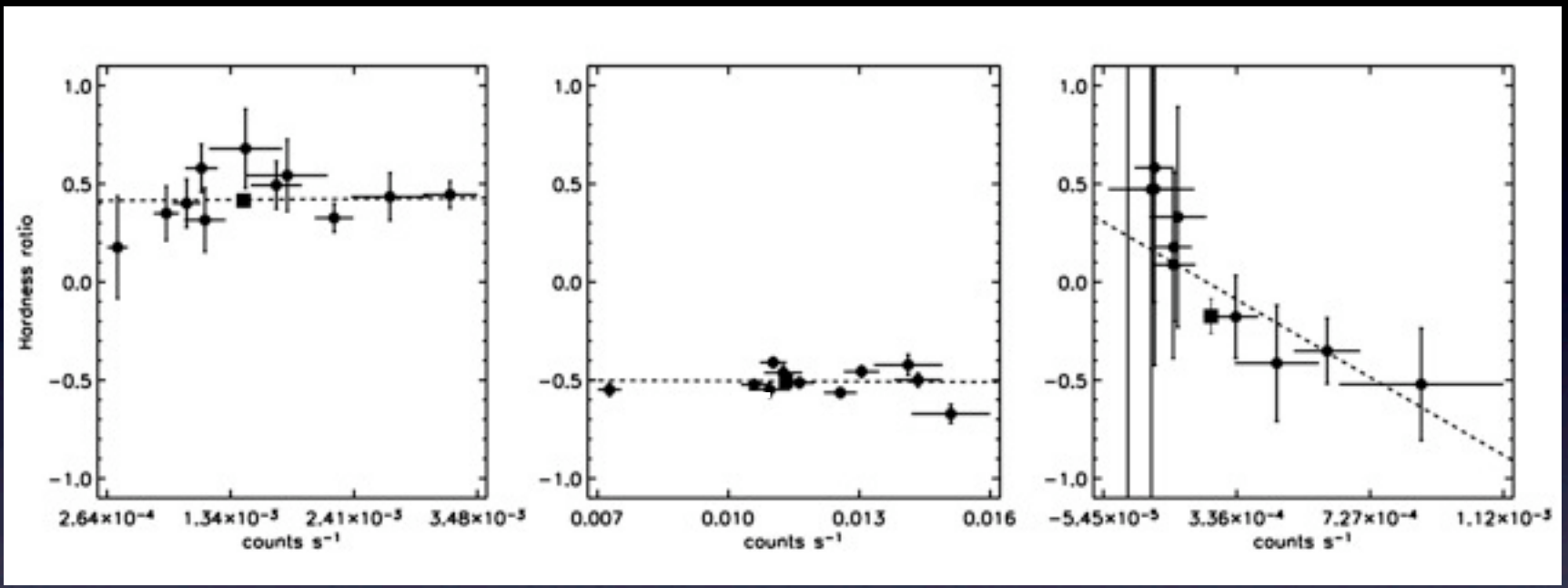


Soft (unabsorbed) sources are more variable than hard (absorbed) ones, and vary on shorter timescales =>

reprocessing component?

Bologna - 25-26/11/09

Spectral variability in CDFS



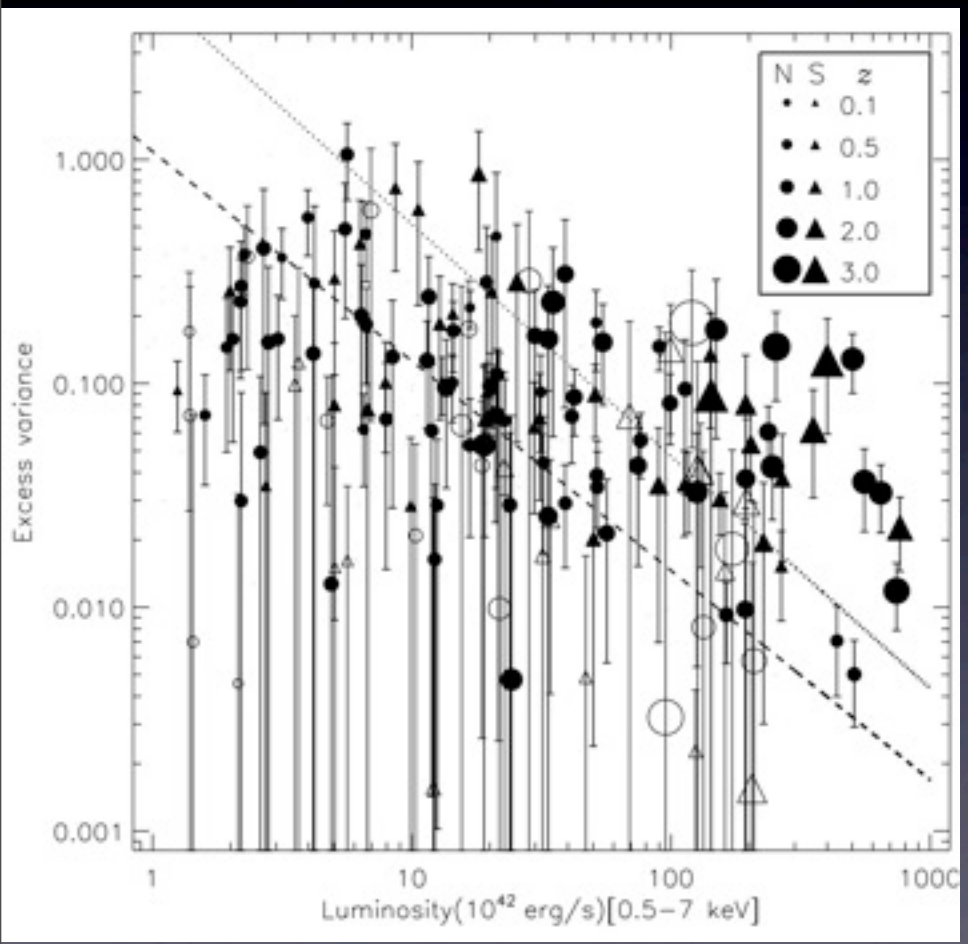
- 70% of our sources with > 500 counts show no sign of significant ($\Delta\Gamma>0.2$) spectral variability
- In half of the remaining sources the spectrum becomes softer as the flux increases.

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

Bologna - 25-26/11/09

L_X-variability correlation

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



High z sources are more variable than expected from an extrapolation of their lower z counterparts?

Probing mass and accretion rate

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

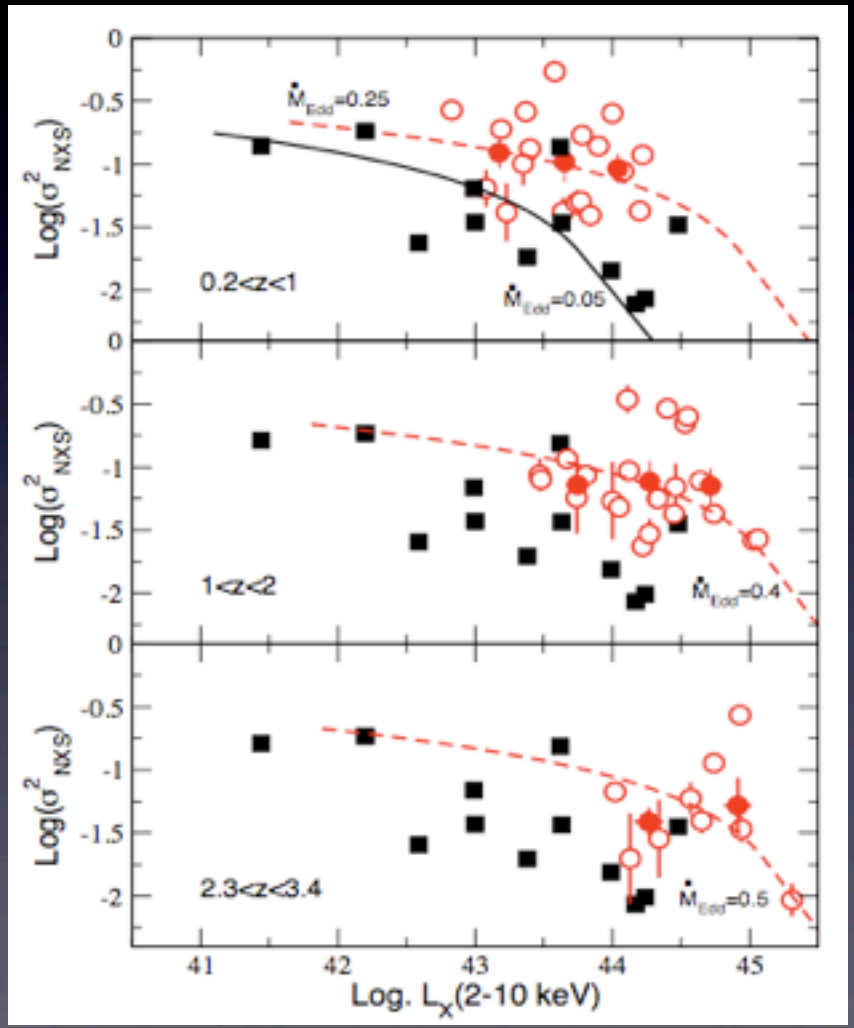
$$L_{bol} = 1.3 \eta \dot{m}_{Edd} 10^{39} (M_{BH}/M_{\odot}) \text{ erg/s}$$

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

However we need high-quality, well sampled data

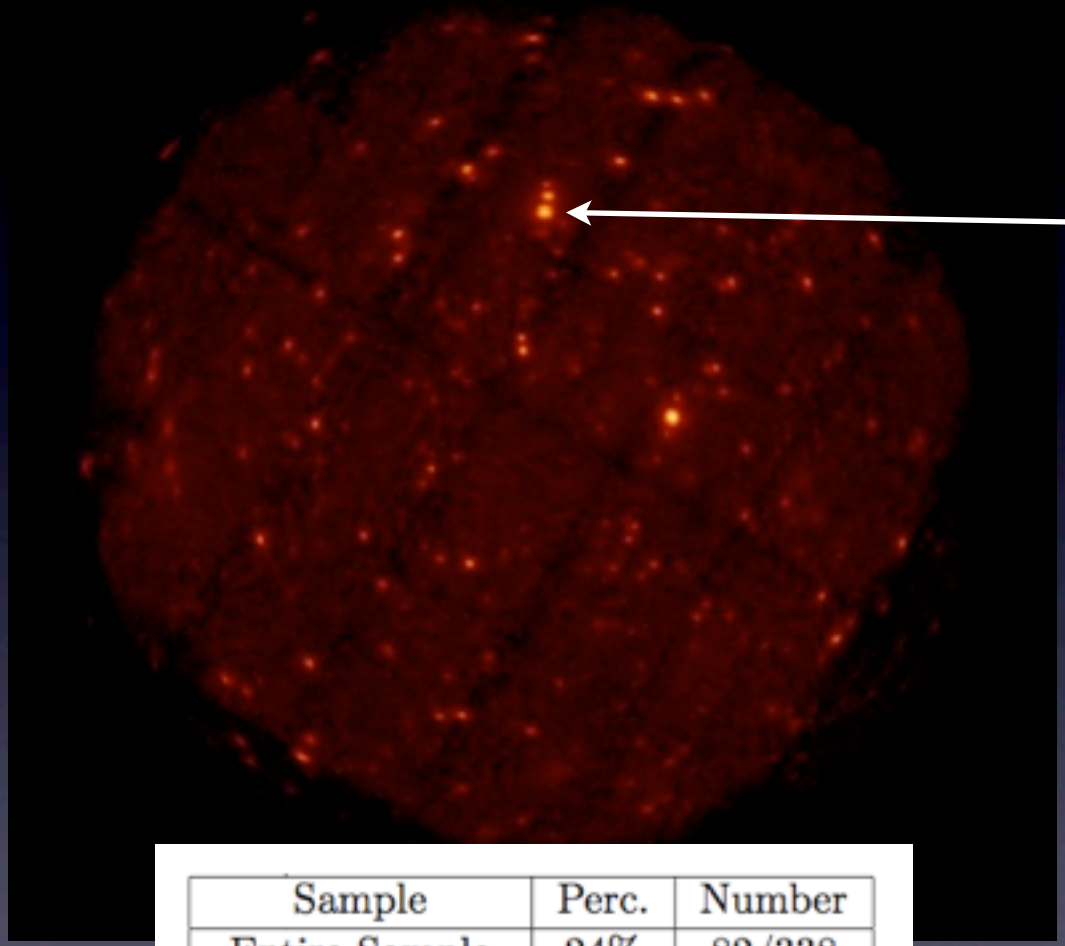
(also redshift change the effective sampled timescales and energy bands)

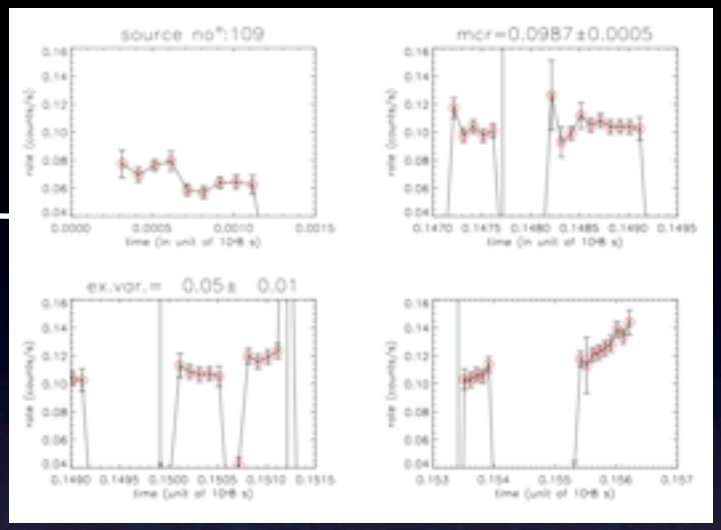
Papadakis et al. 2008



XMM CDFS observations

Pinto, C., Paolillo M. et al. (2010), in prep





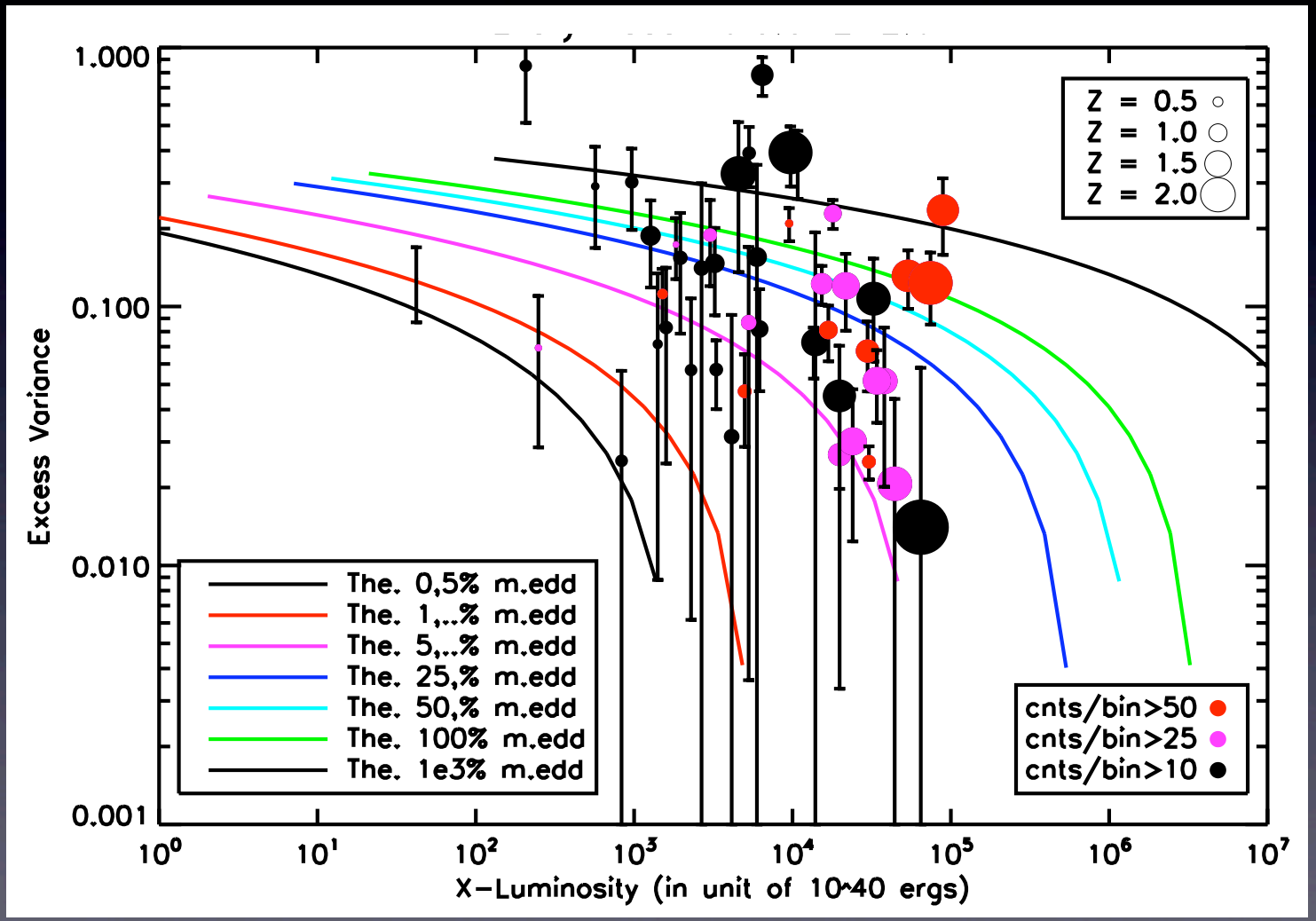
Sample	Perc.	Number
Entire Sample	24%	82/338
counts/bin>10	37%	59/161
counts/bin>20	50%	51/102
counts/bin>40	66%	37/56
counts/bin>100	94%	17/18

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

Bologna - 25-26/11/09

XMM CDFS observations vs models

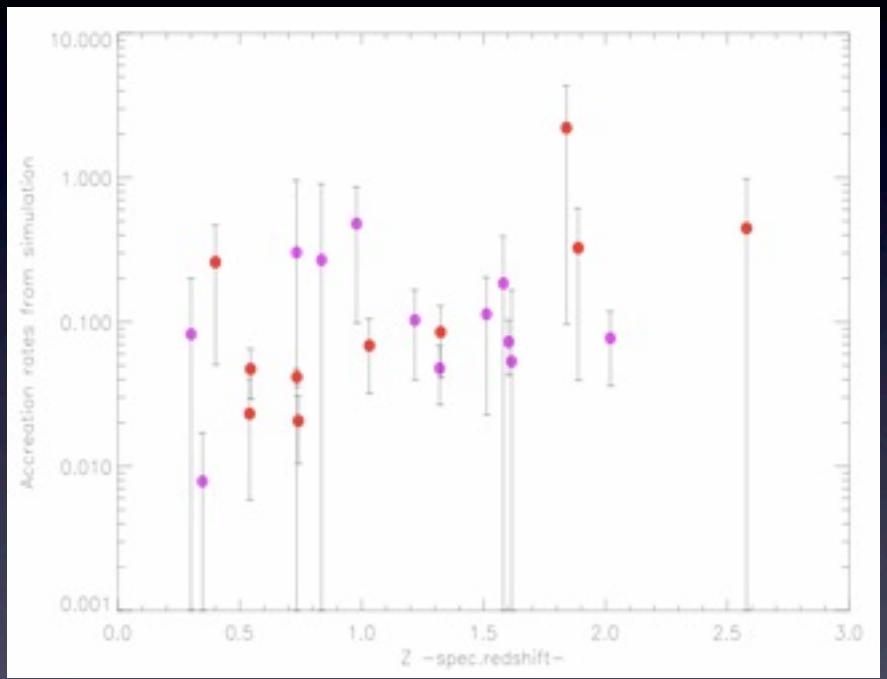
C. Pinto, M. Paolillo et al., in prep



Bologna - 25-26/11/09

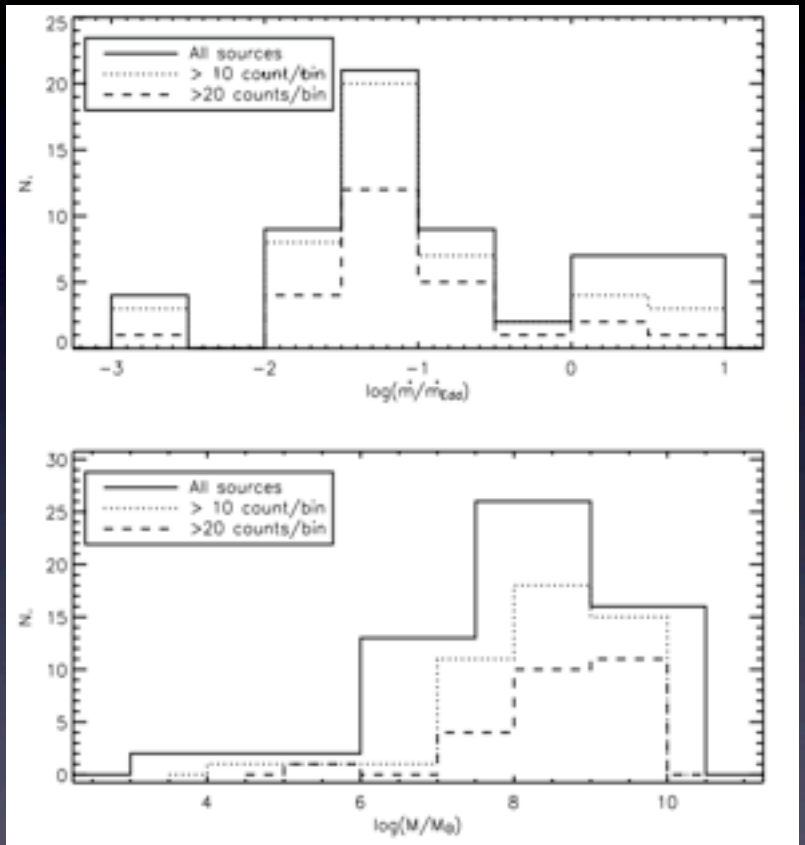
XMM CDFS: accretion rates estimates

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



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

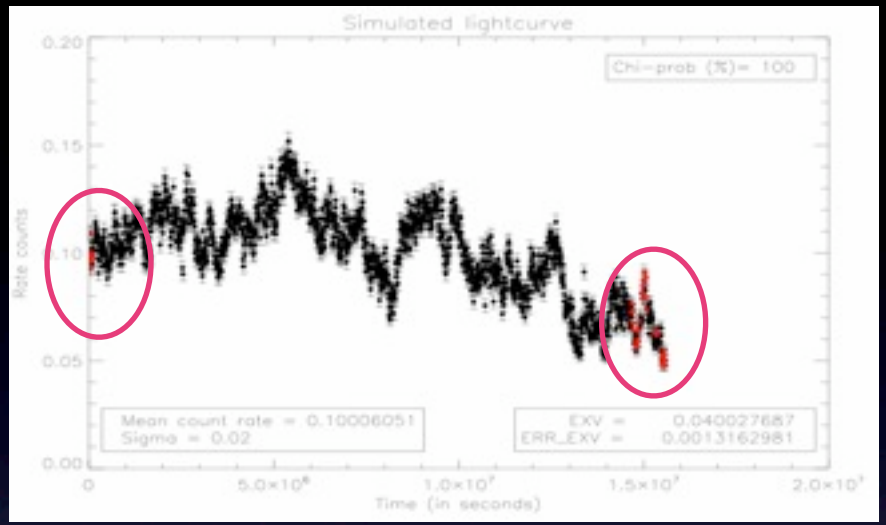
z

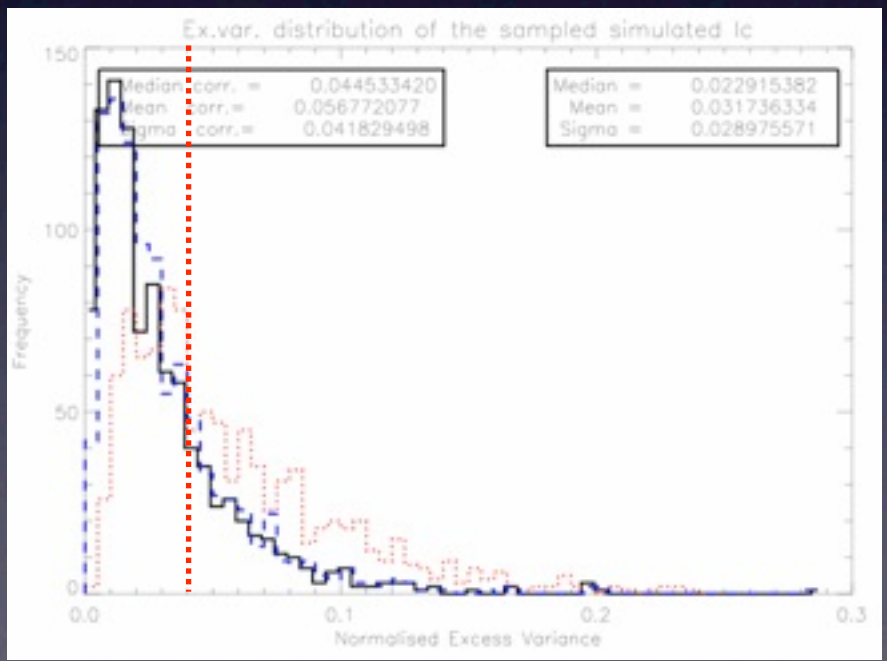


Bologna - 25-26/11/09

Dependence of Variance estimates on Sampling

- We simulated red-noise lightcurves with intrinsic count rate and variance of source 109.
- Baseline covers observations obtained in 2002/03.
- Sparse and irregular sampling results in biased estimates and large uncertainties: individual lightcurves are useless and need to be averaged (but difficult interpretation)
- The main problem is due to a biased mean flux estimate

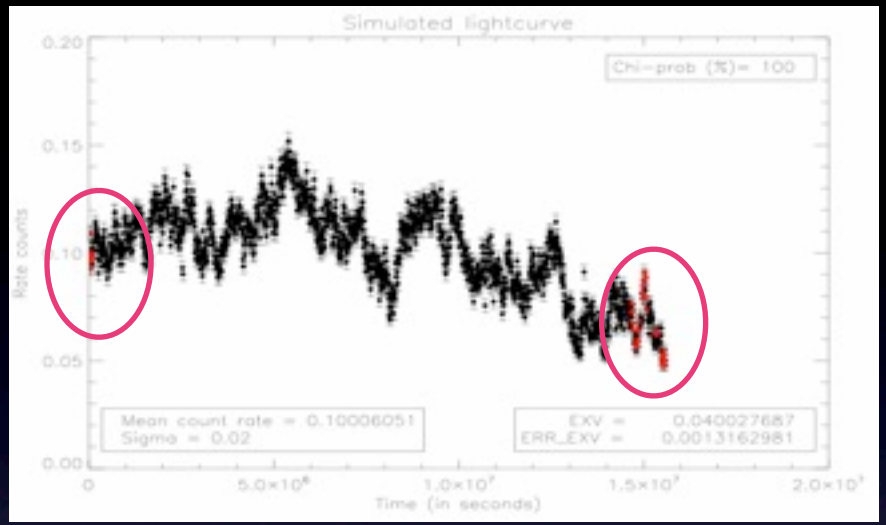


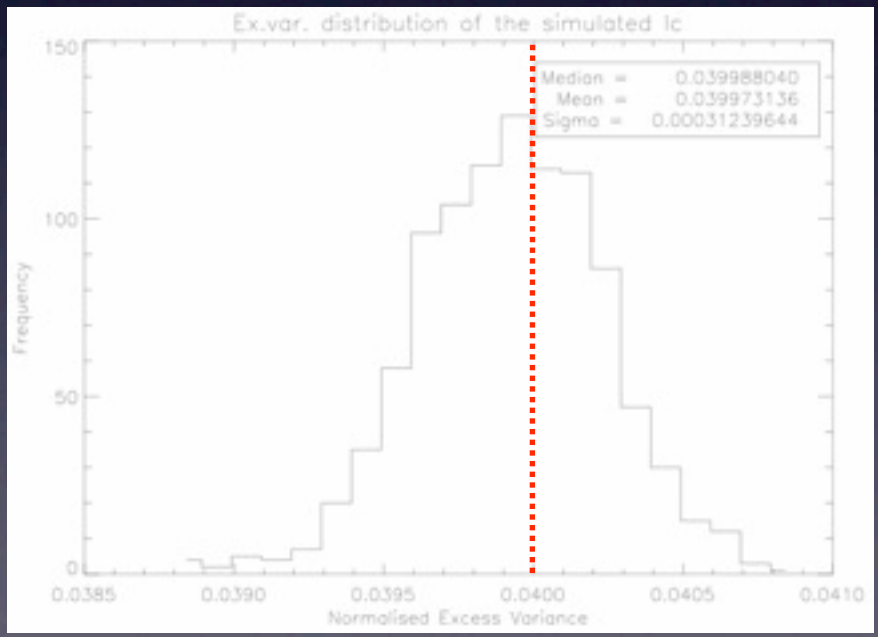


Bologna - 25-26/11/09

Dependence of Variance estimates on Sampling

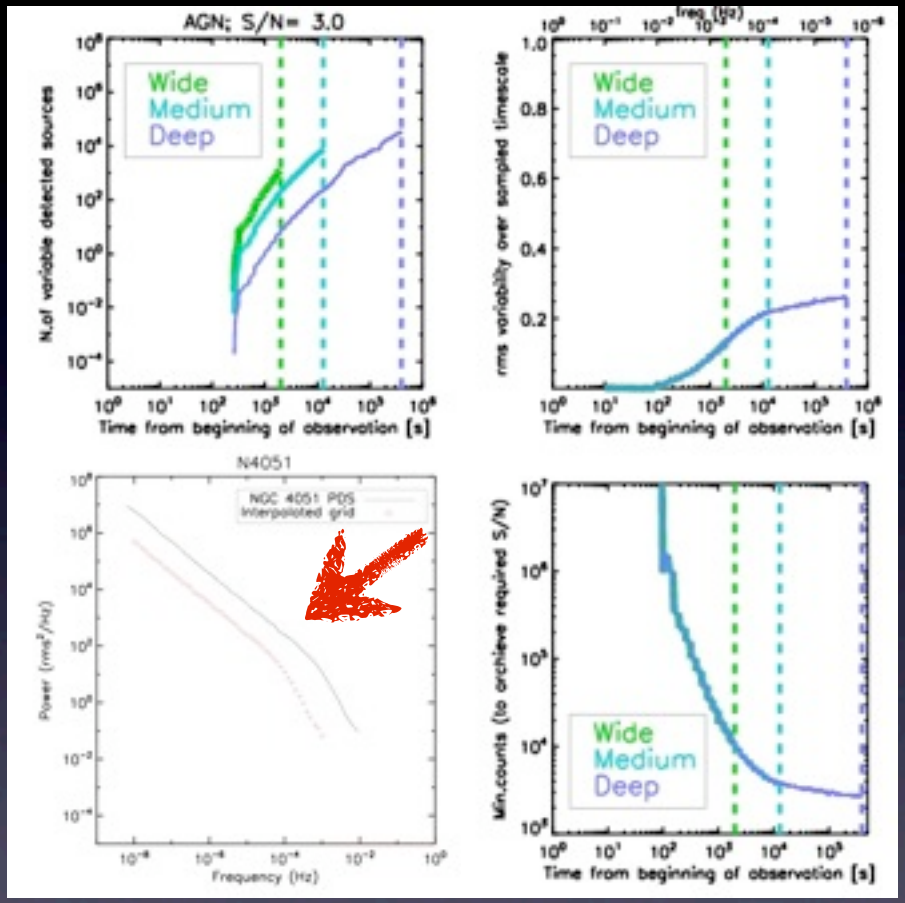
- We simulated red-noise lightcurves with intrinsic count rate and variance of source 109.
- Baseline covers observations obtained in 2002/03.
- Sparse and irregular sampling results in biased estimates and large uncertainties: individual lightcurves are useless and need to be averaged (but difficult interpretation)
- The main problem is due to a biased mean flux estimate

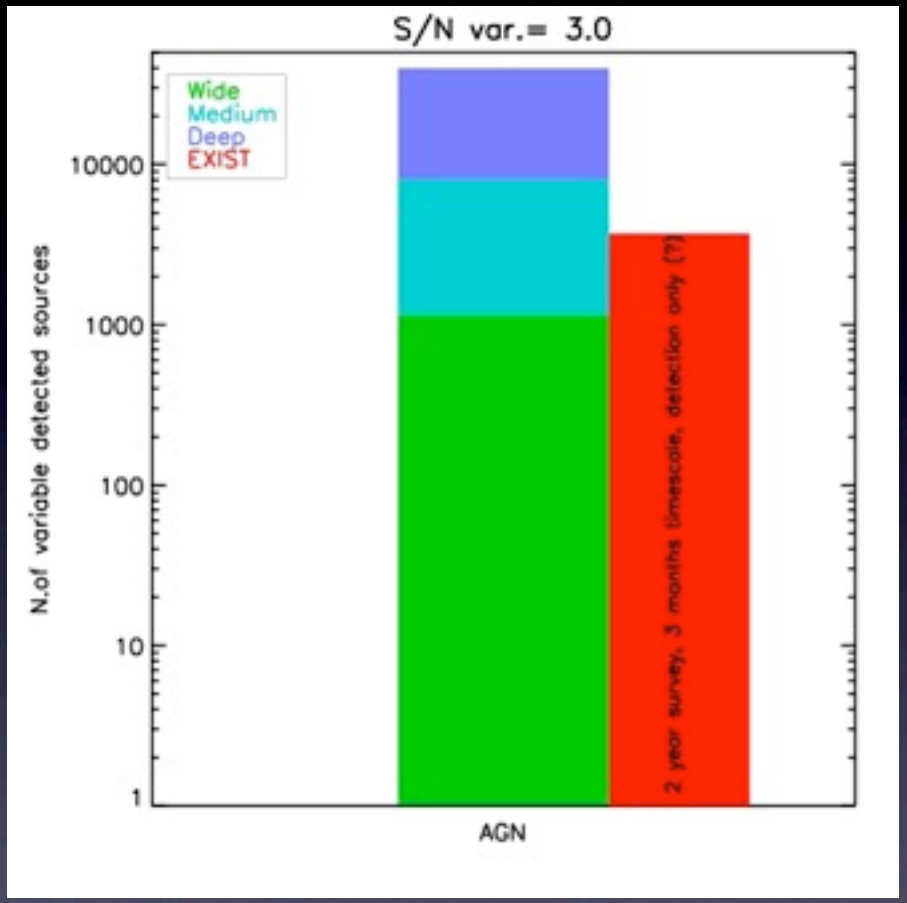




Bologna - 25-26/11/09

AGN variability detection with WFXT

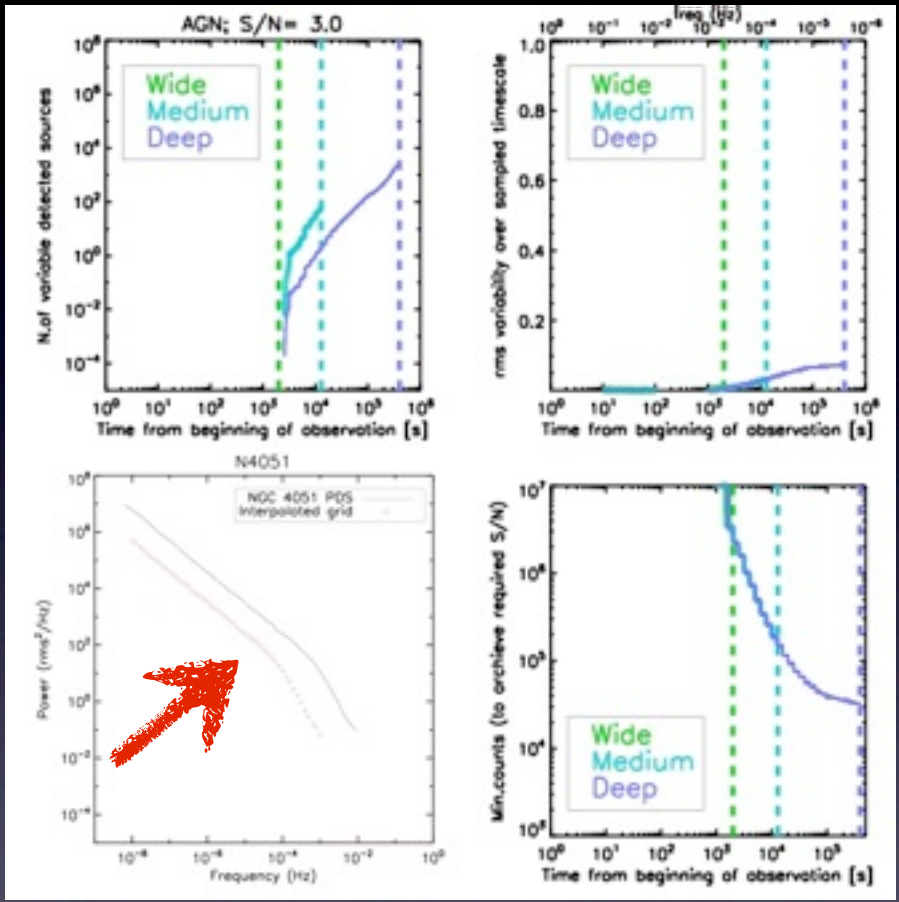


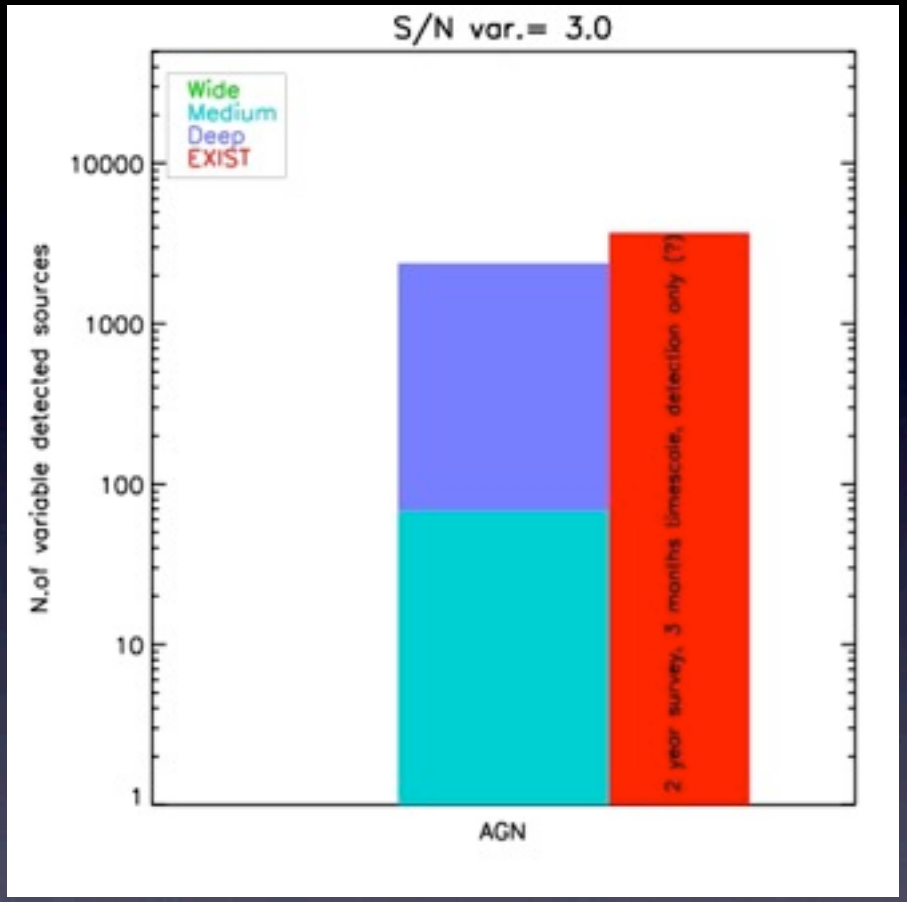


These AGNs will have enough counts to allow spectroscopy (> few thousand counts)

Bologna - 25-26/11/09

AGN variability detection with WFXT





Proposed strategy:

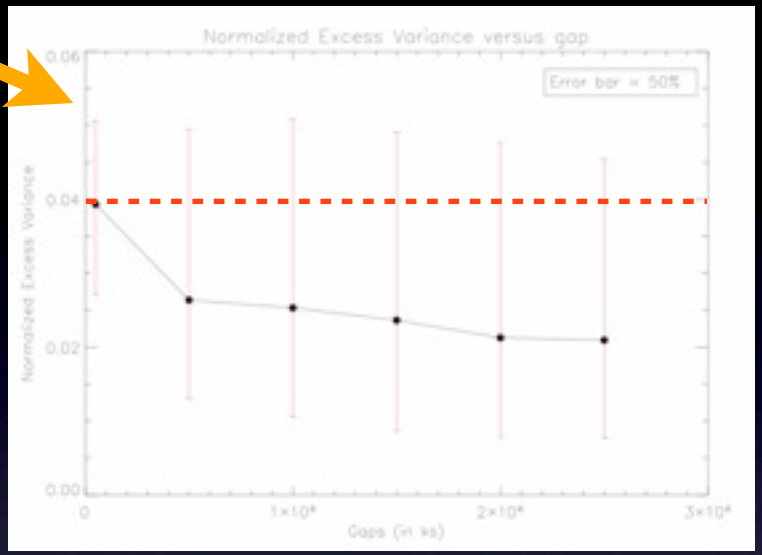
multiple 50 ks observations spread over 6 months-1 year

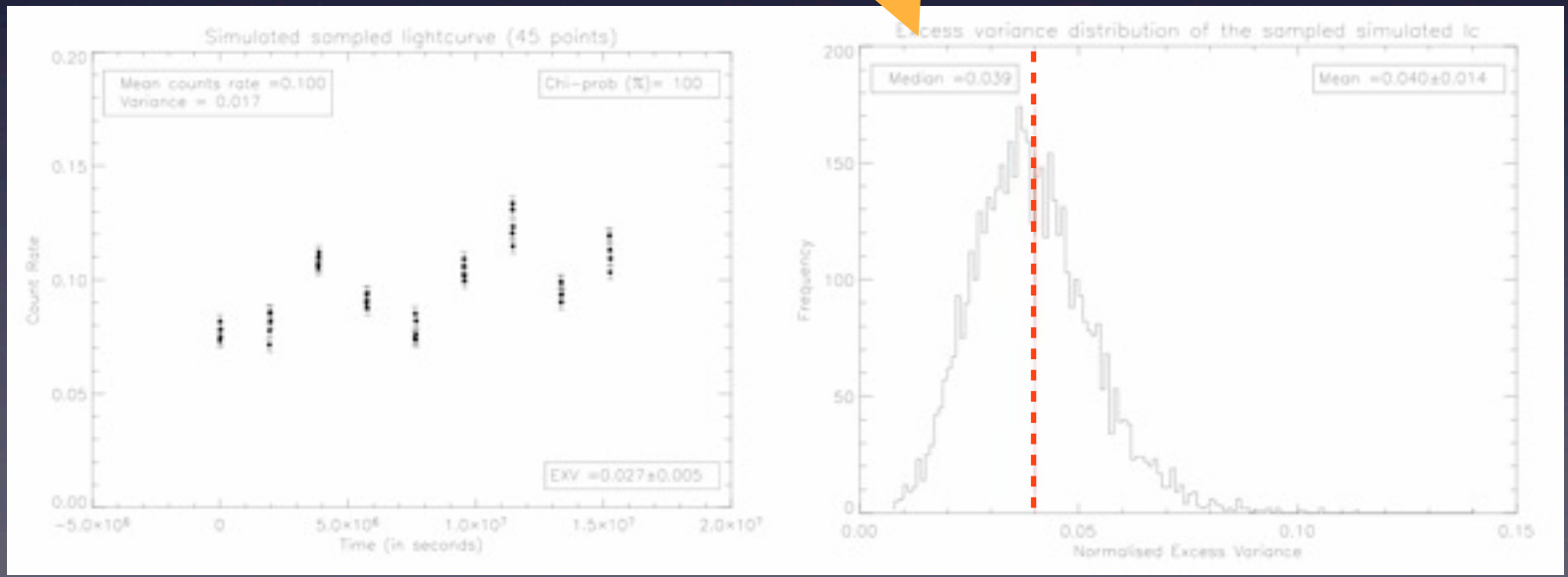
(access the $<10^{-7}$ Hz regime)

Bologna - 25-26/11/09

WFXT Deep Survey strategy

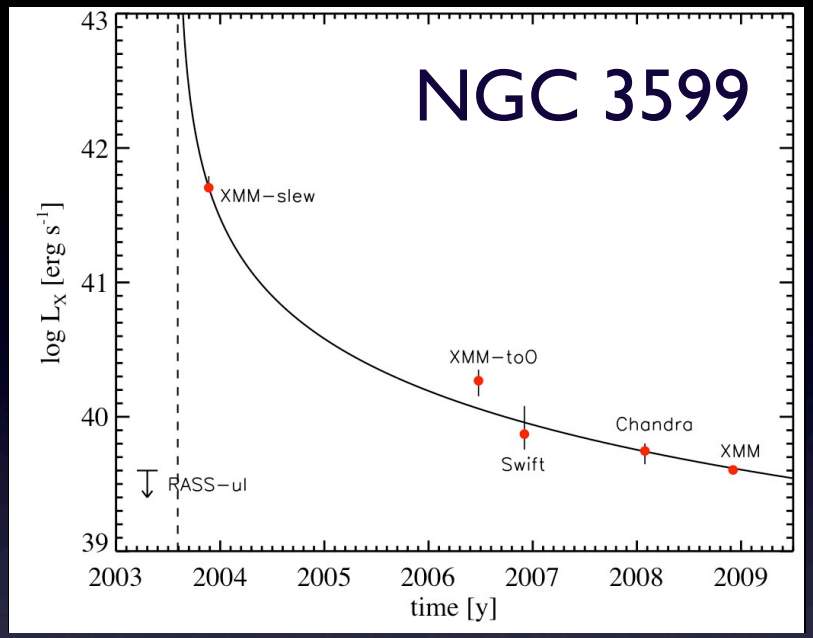
- 420 ks split in 2 observations: 500 ks, 1 Ms, 1.5 Ms,..... gaps
- More ralistic samplings for WFXT: 9x50 ks observations split over ~6 months
- Using a regular sampling pattern we remove bias; the uncertainty is of the order of 35%.
- Similar results for progressive sampling

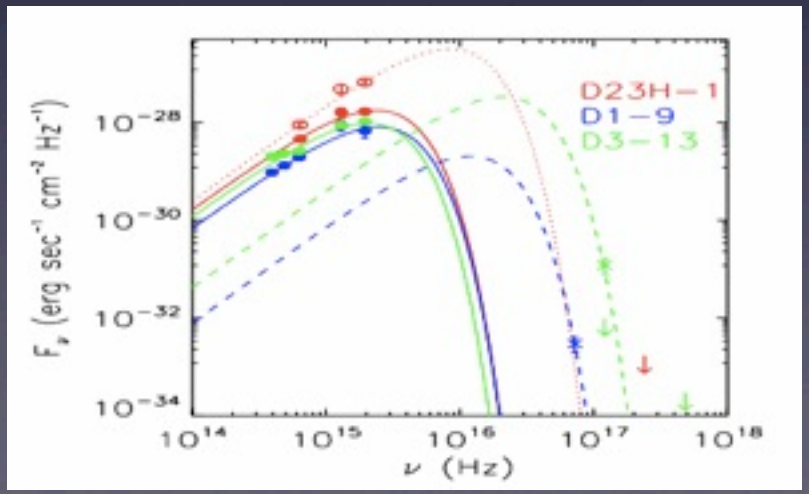




Tidal disruption events

- Could offer unique opportunities to detect quiescent BH
- A dozen candidates observed with ROSAT, XMM and Galex: e.g. ROSAT detected $10^{42\text{-}44}$ erg/s bursts
- UV/X-ray properties suggest emission arises from accretion disk: very soft spetrum with kT=0.1 keV
- Should have exponential decay timescales of the order of months $\propto t^{-5/3}$, luminosities close to the Eddington limit.
- Low detection rates (10^{-5} yr^{-1} Mpc^{-1}) require sensitive surveys with large grasp
- **Not clear:** X-ray contribution? Need of multiwavelenght follow-up?

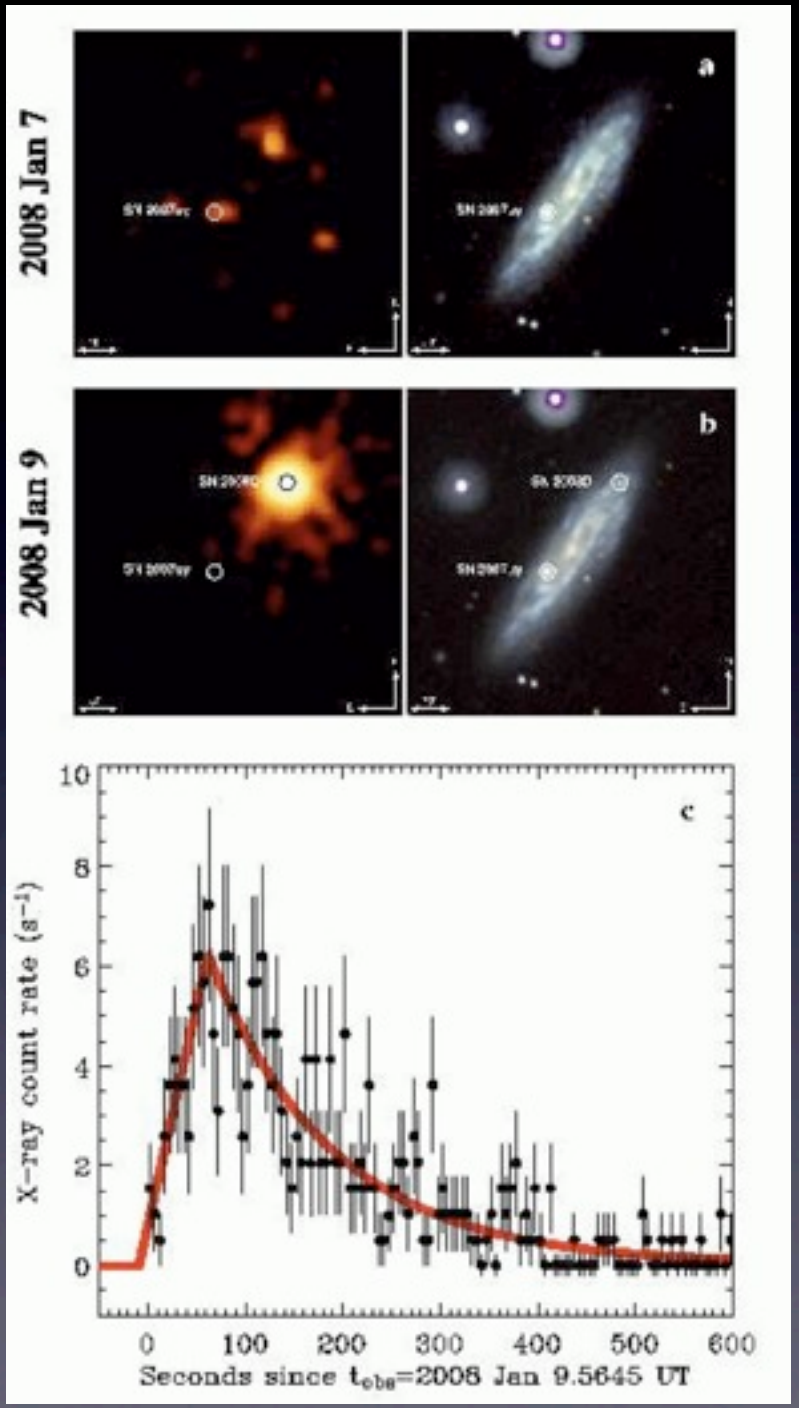




Faint GRBs/X-ray Flashes
(S.Campana,M. Della Valle, L.Stella talks)

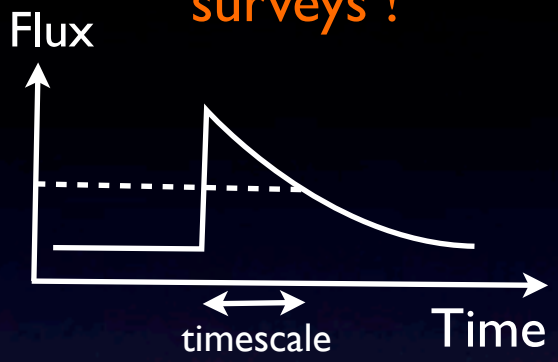
- SNe precursors
- GRBs
- GW sources

Need multiwavelenght follow-up to be properly characterized?



Transient X-ray source estimates for WFXT

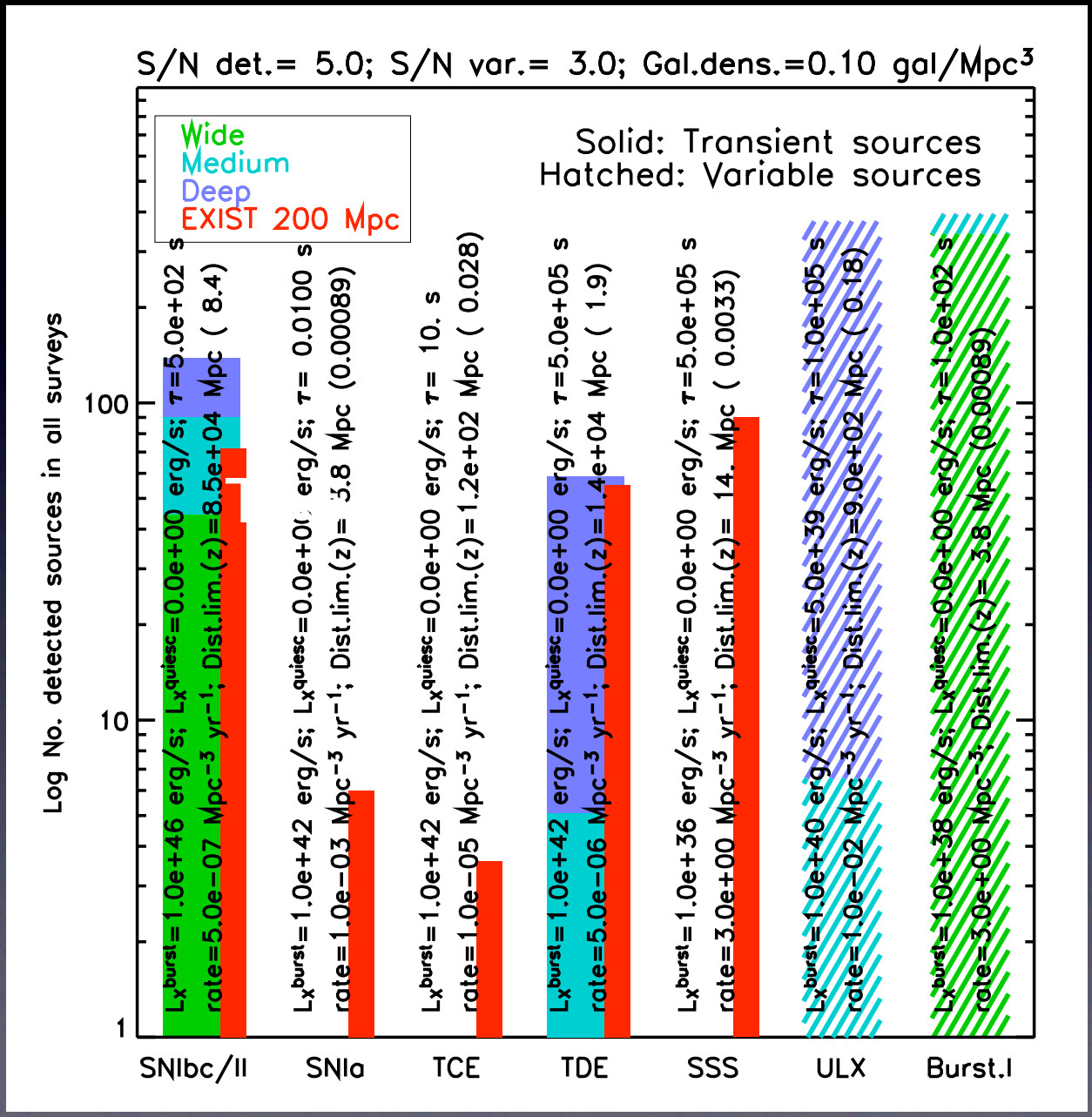
N.B. Only Extragalactic surveys !



These transients will have enough counts to allow rough/good spectroscopy (> few hundred counts)

Also talks by S. Campana, M.della Valle, L. Stella etc.

Bologna - 25-26/11/09



Online calculator soon in Naples ***DAME*** website:
dame.na.infn.it or
people.na.infn.it/paolillo/Software

Please provide your favorite transient/variable candidates !
(basically provide lum, rate, timescale)