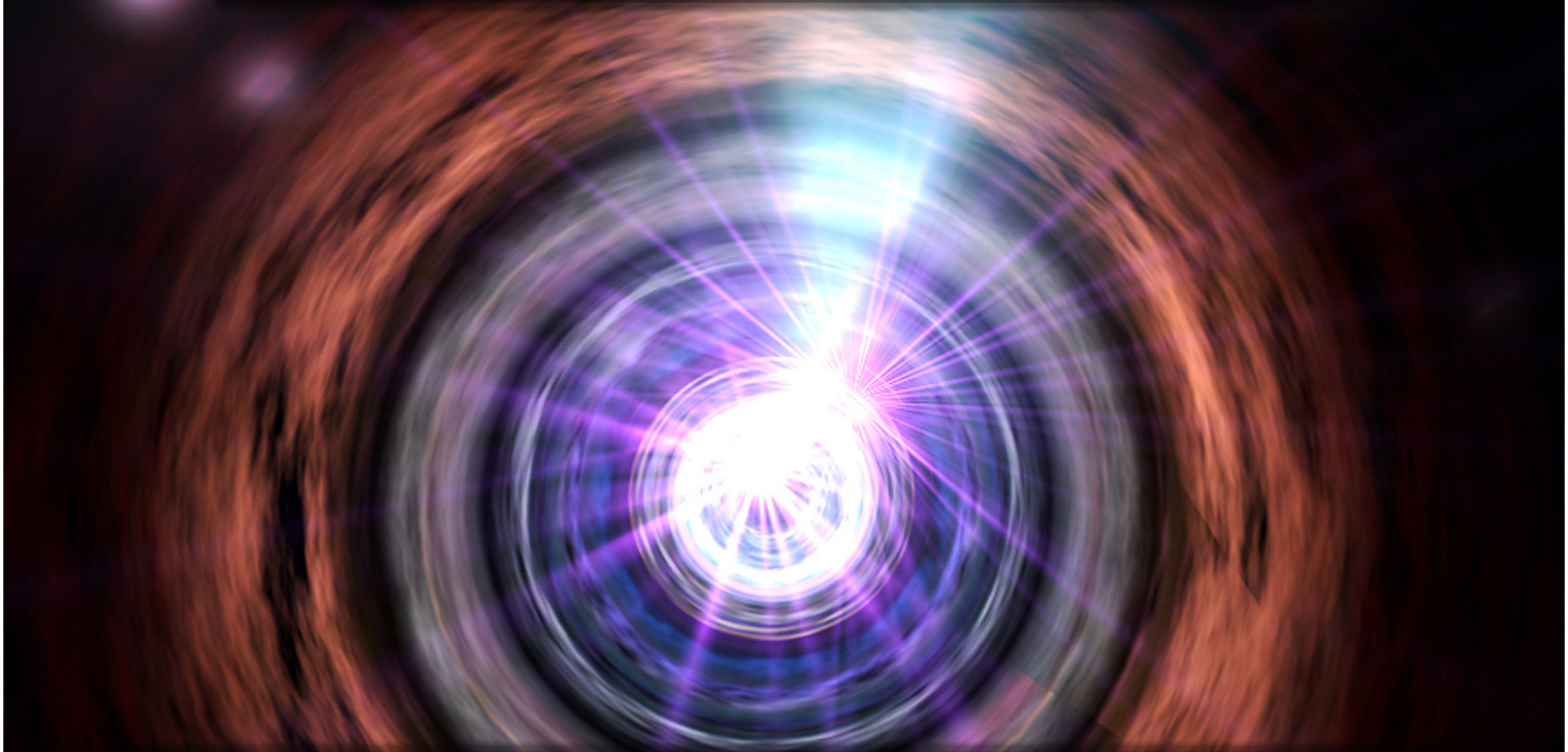
What can *LOFT* do for AGN?

Simon Vaughan (University of Leicester)

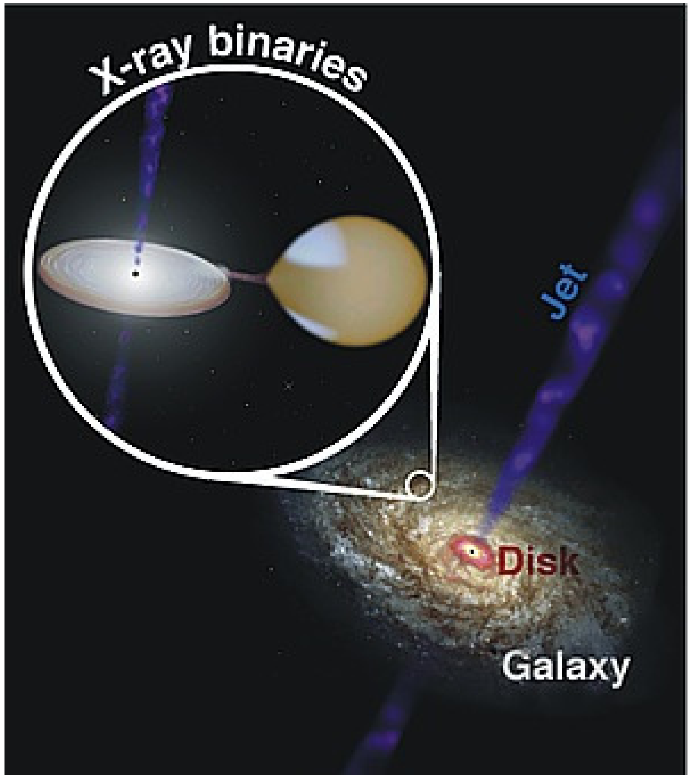


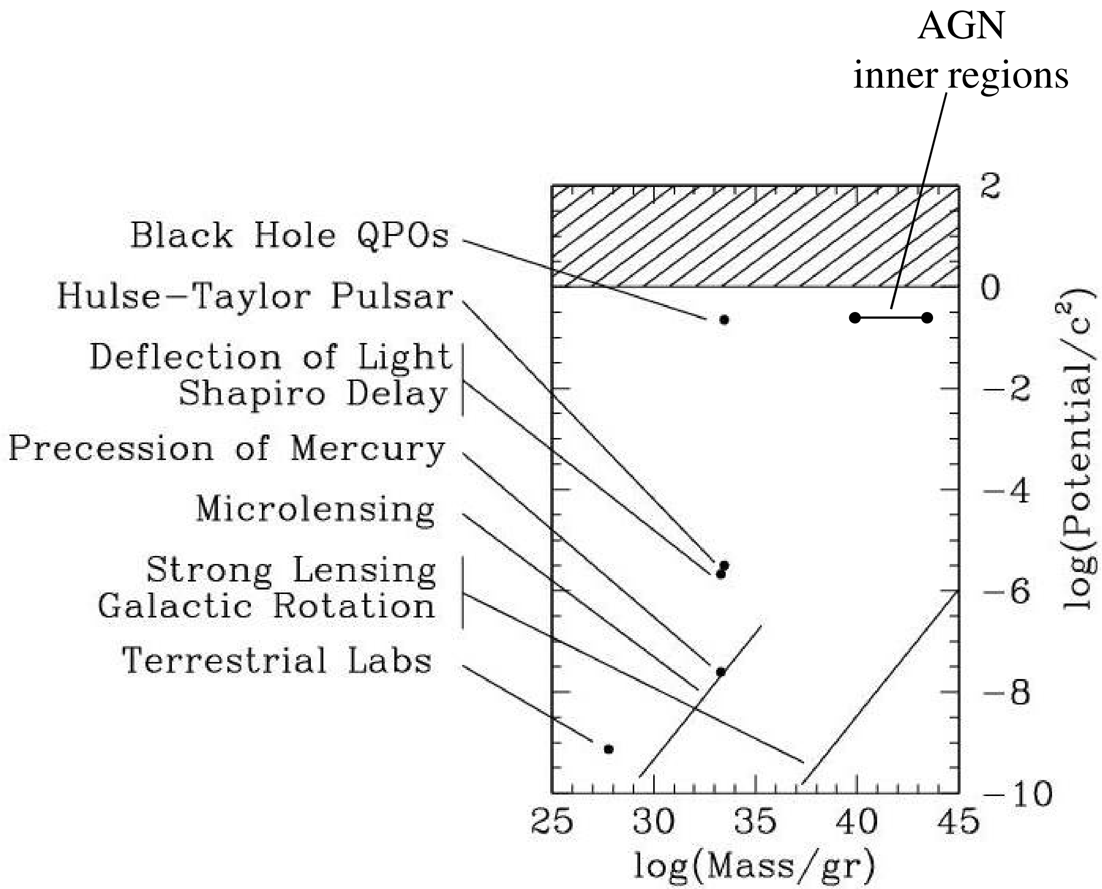
based on discussions with Alessandra de Rosa,
Phil Uttley, Ian M^{c}Hardy, Dimitrios Emmanoulopoulos

What can *LOFT* do for AGN?

Goals of studying of accreting black holes

Understand gravity in 'strong field' regime
How do accretion/ejection flows work?
How do they form? And how to they affect their environments?





What can *LOFT* do for AGN?

Goals of studying of accreting black holes

Understand gravity in ‘strong field’ regime
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How do they form? And how to they affect their environments?

Focus on AGN

To what extent are AGN scaled up BH XRBs?
Exploit access to very different (physical) timescales
What’s common (accretion, BH, GR)?
What’s different (spacetime curvature, microphysics, environments)?

[Small print: bias towards low z, RQ, unabsorbed AGN]

What can *LOFT* do for AGN?

What would be like to understand next?

BH parameters (mass, spin)
Mass accretion rate, mass/energy/momentum outflow rates
+ driving mechanisms
Geometry of the inflow/outflows in the inner region

How could we do this?

Profile of broad iron K line
Model emission spectrum from “reflection” (continuum + lines)
IDs, blueshifts, EWs of resonant absorption lines
Track emission (and absorption) response to changes in direct continuum
Characteristic timescales of X-ray variability
X-ray and multi-wavelength correlations, time delays

Despite intense efforts (with *RXTE*, *XMM*, *Chandra*, *Suzaku*)**, questions and problems remain, but we have made progress**

What can *LOFT* do for AGN?

The limitations of X-ray spectroscopy

Often not limited by photon statistics, but by systematic errors and degeneracies in modelling:

instrumental background, response calibration;
disentangling overlapping and weak features;
continuum uncertainty; AGN are "messy"

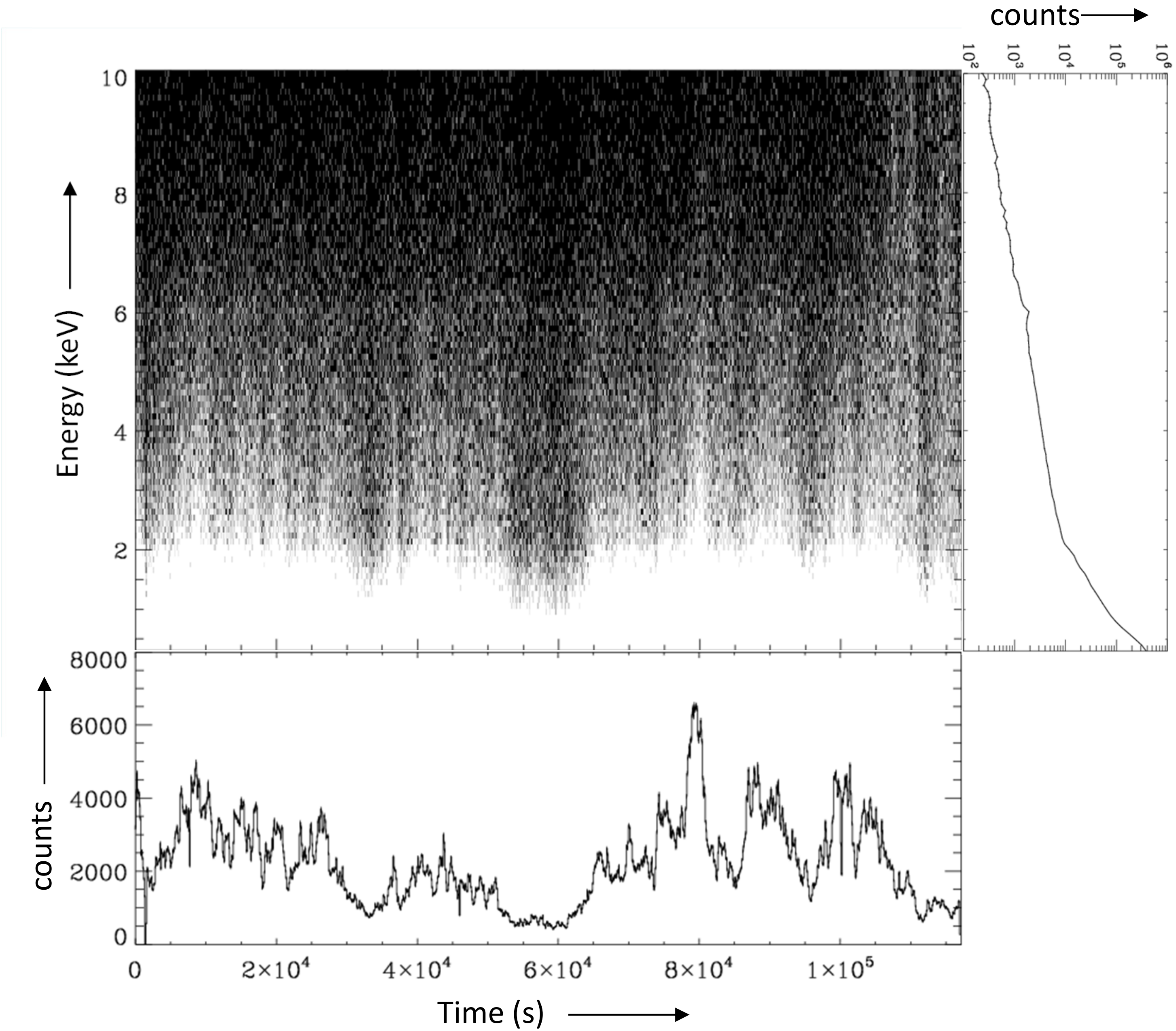
(some old arguments continue to rumble on…)

Where we *have* made clear progress

"Warm absorbers" resolved into "ionised outflows"
X-ray variability: power spectra, rms-flux connection
Multi-wavelength variability: short timescale X-ray - UV/opt correlation
X-ray time delays (hard lags since 2001-2003; soft lags since 2009)

Move from 1D spectral to 2D spectral-timing data/models

What can *LOFT* do for AGN?



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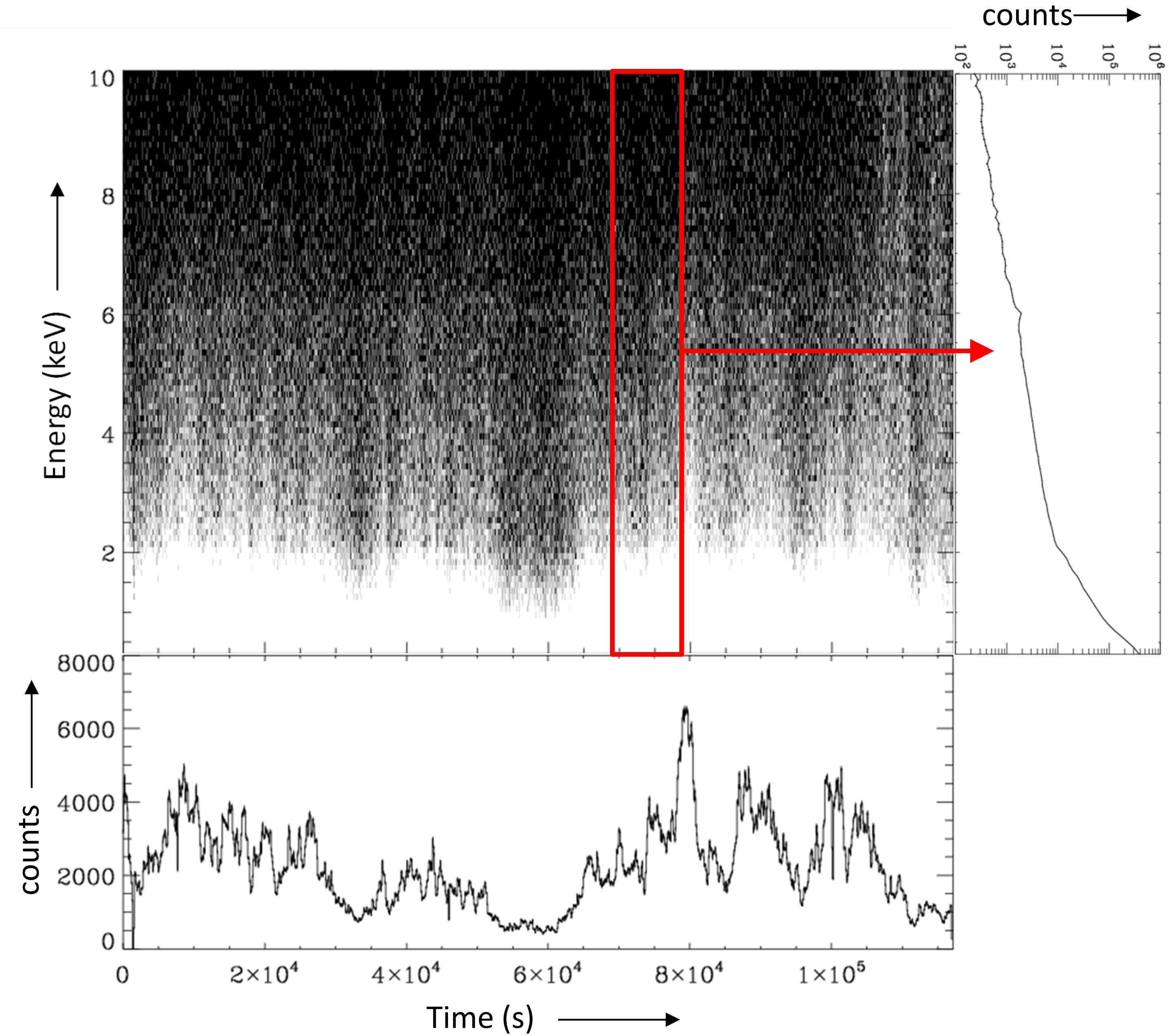

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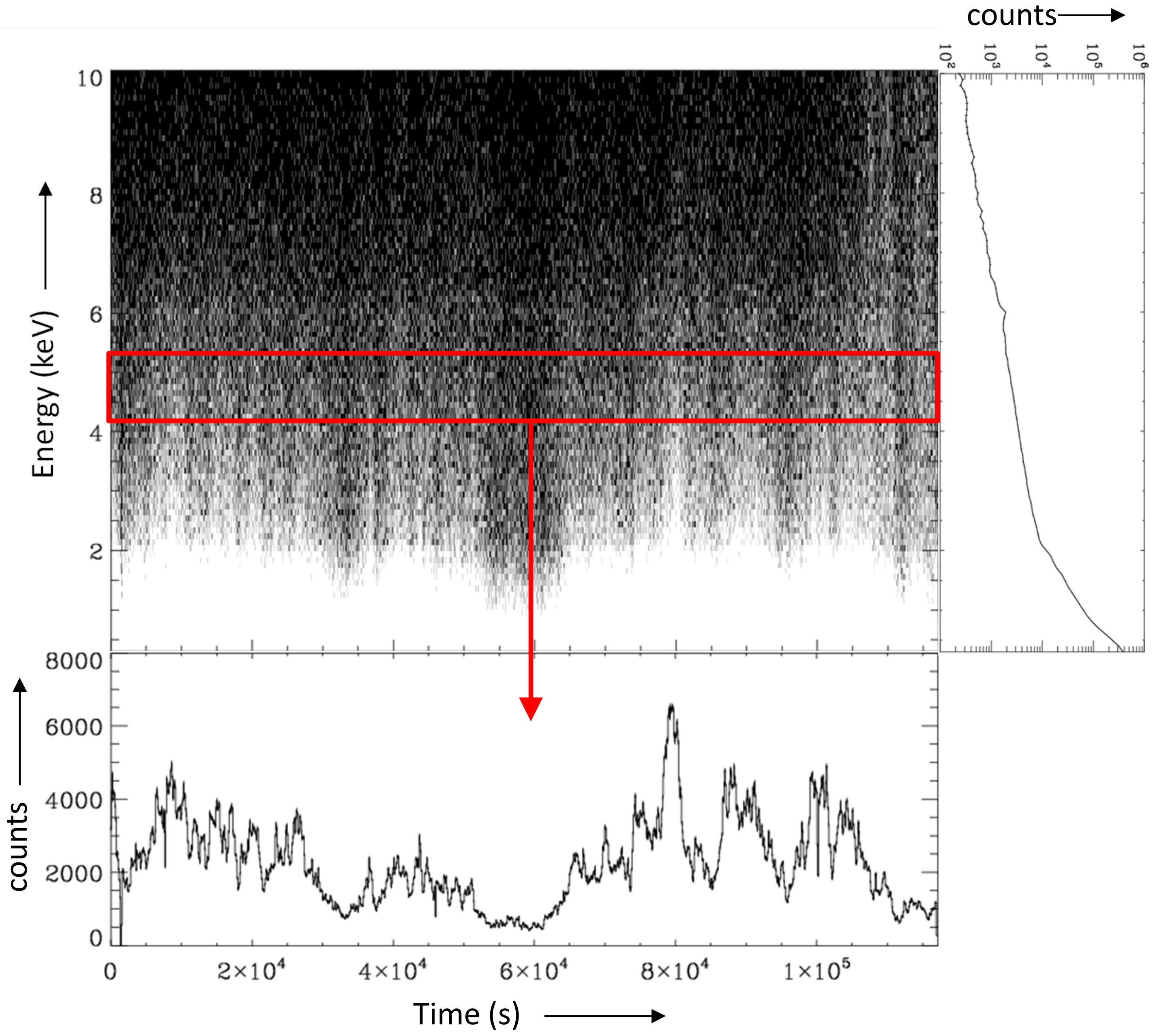

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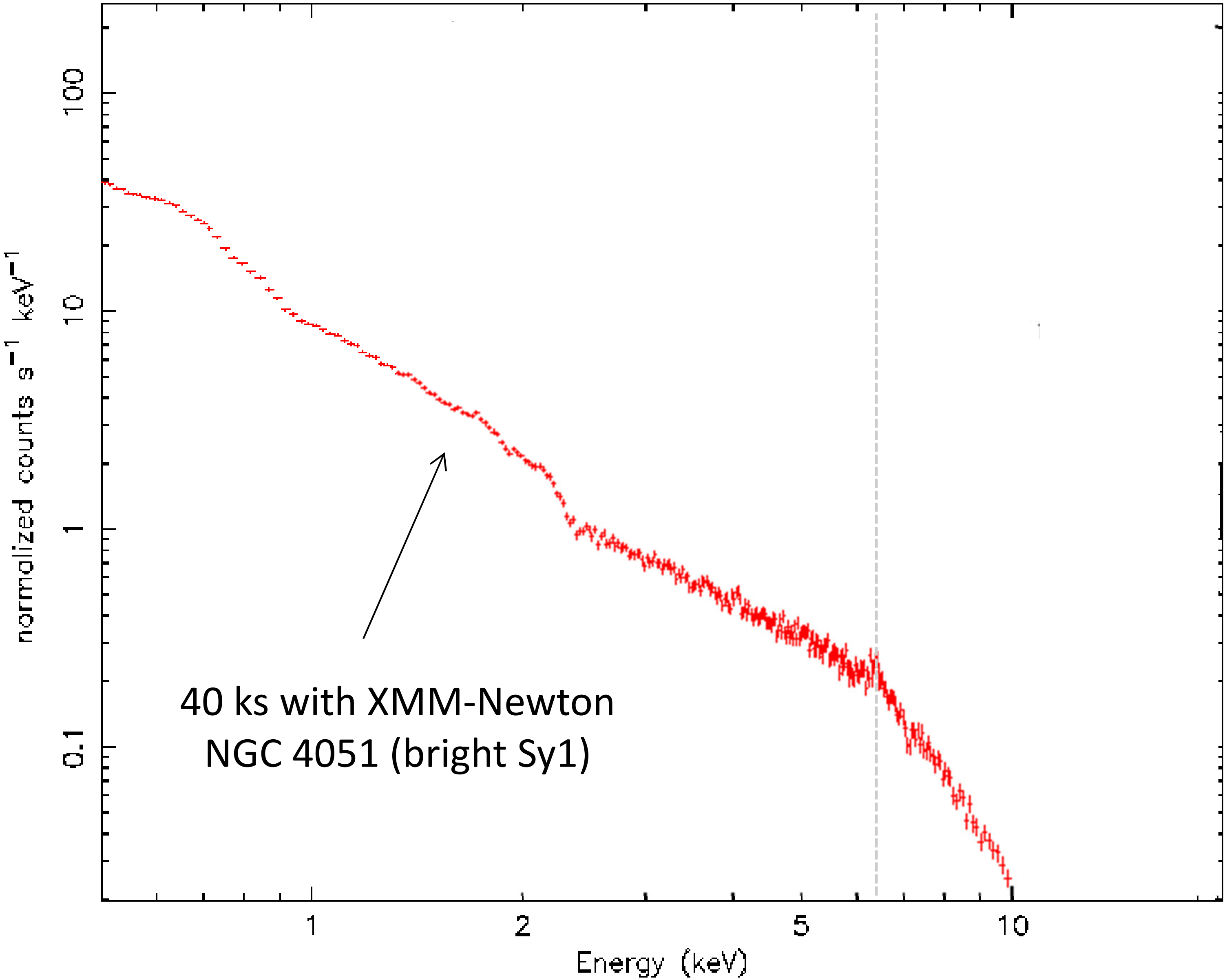

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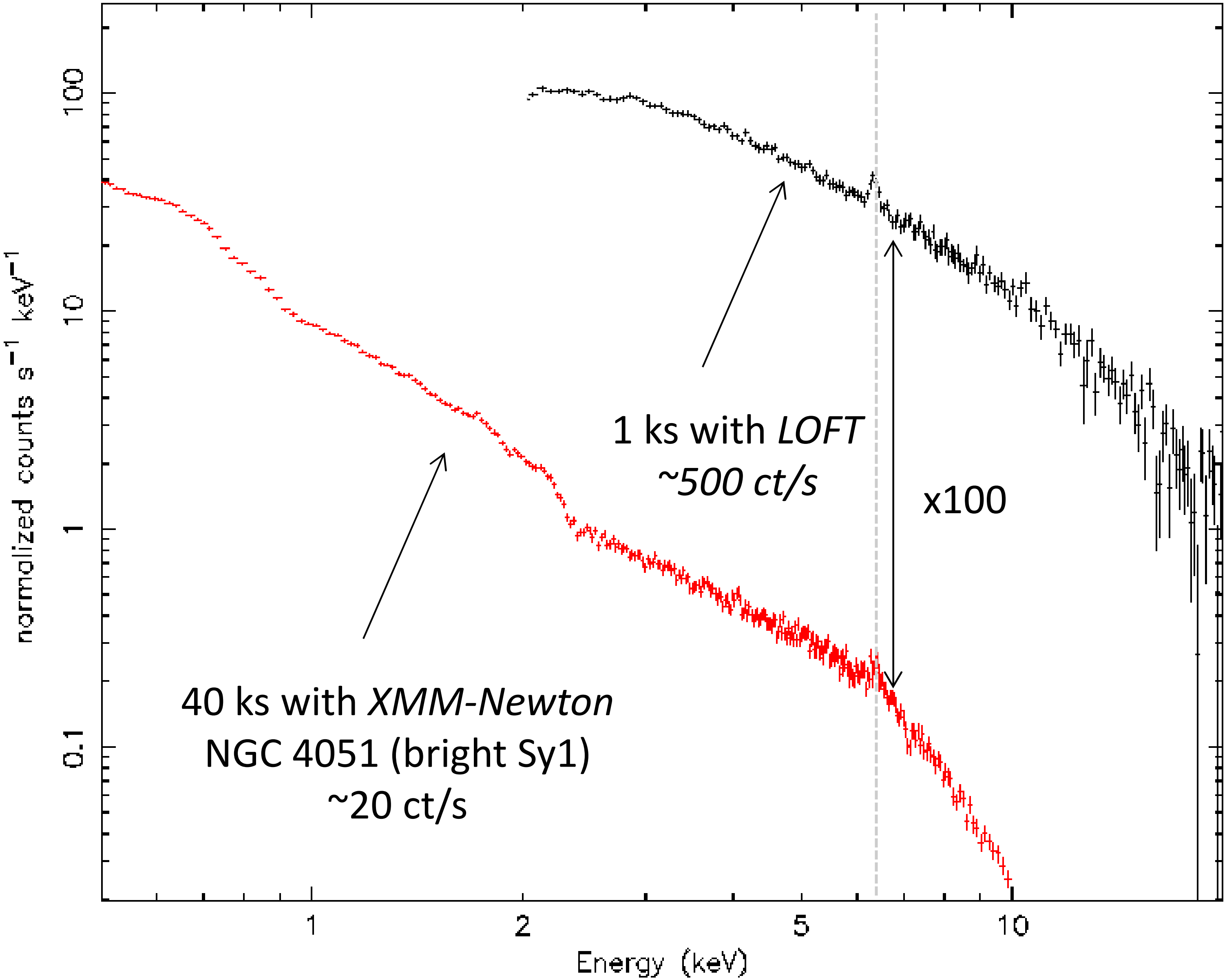

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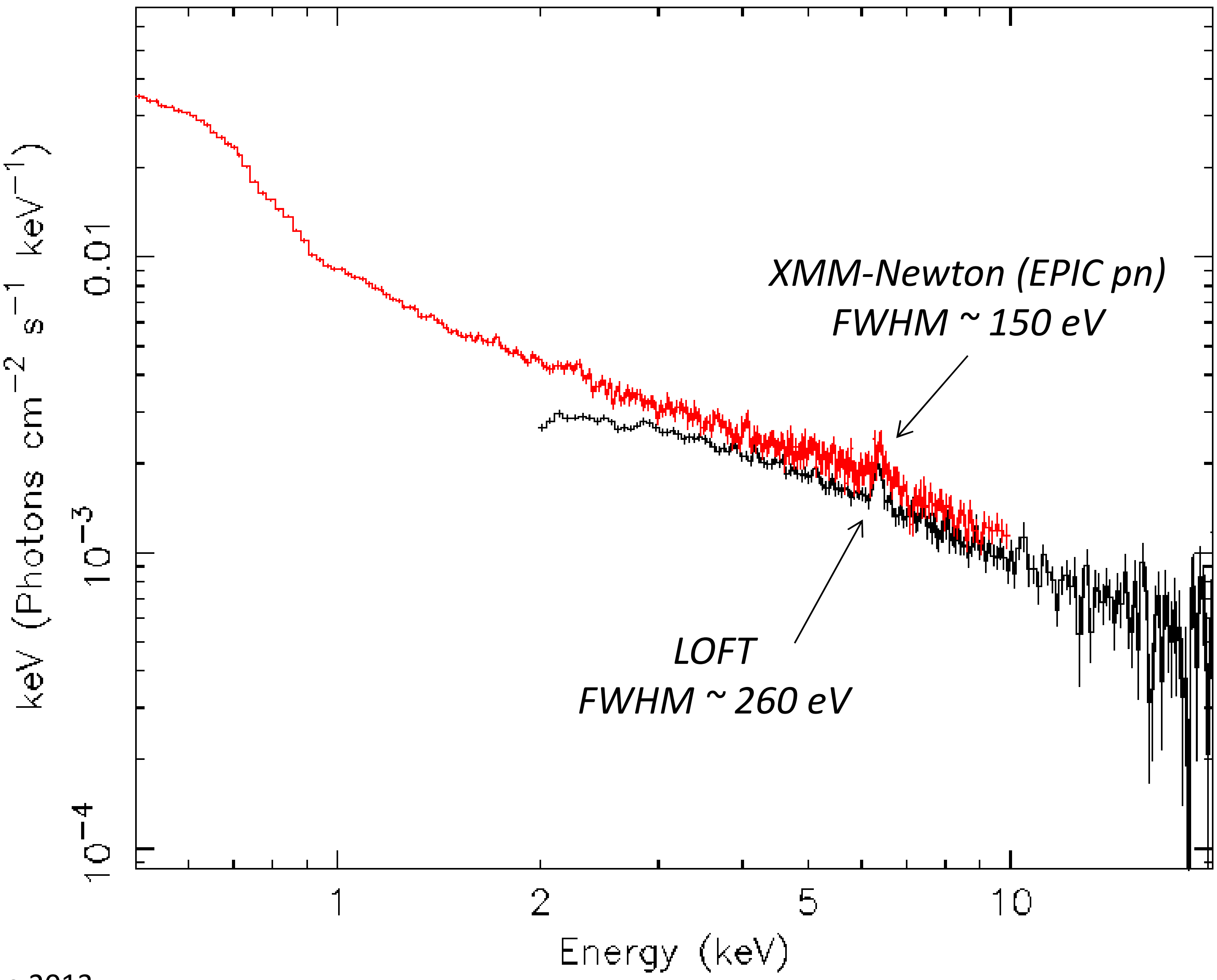

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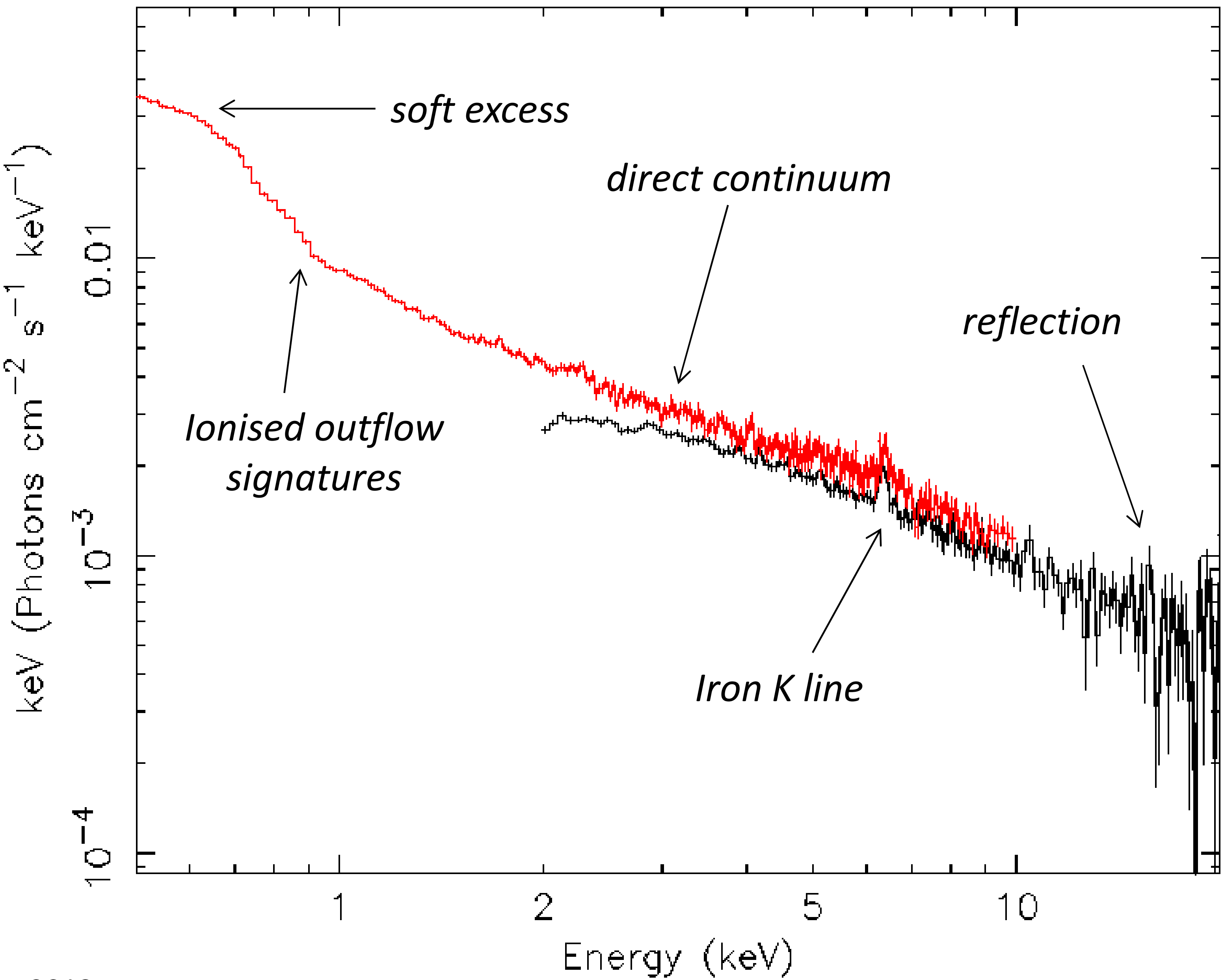

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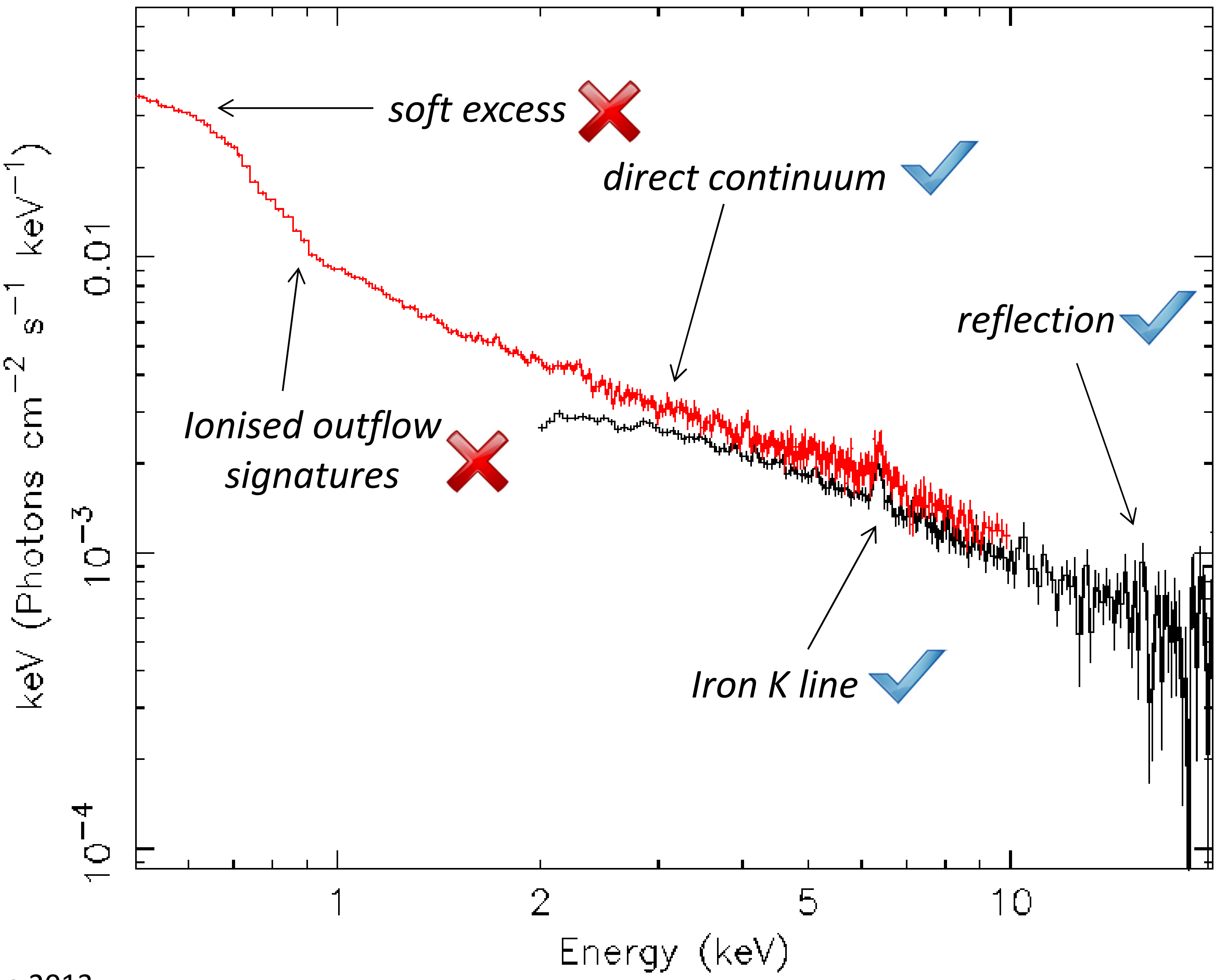

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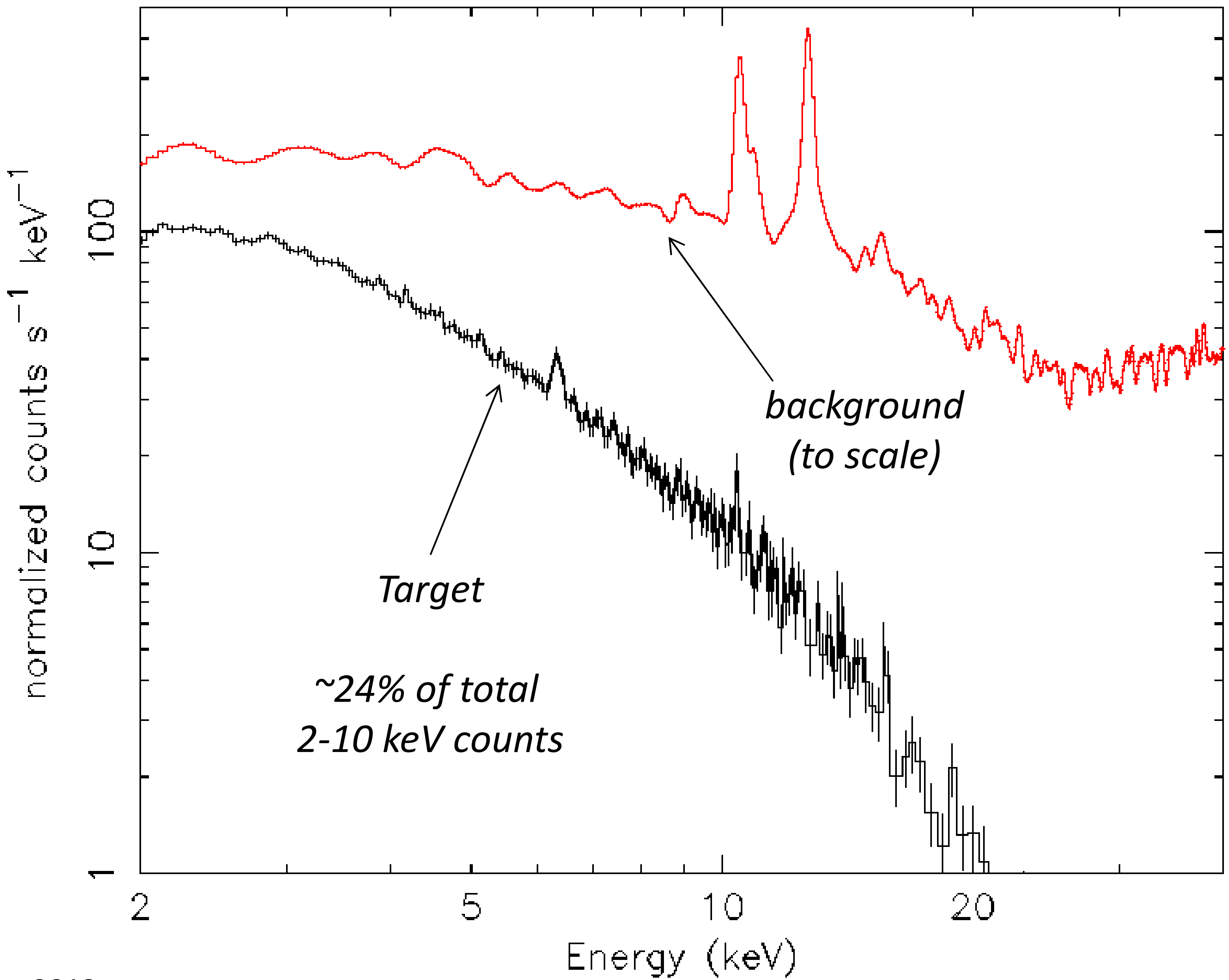
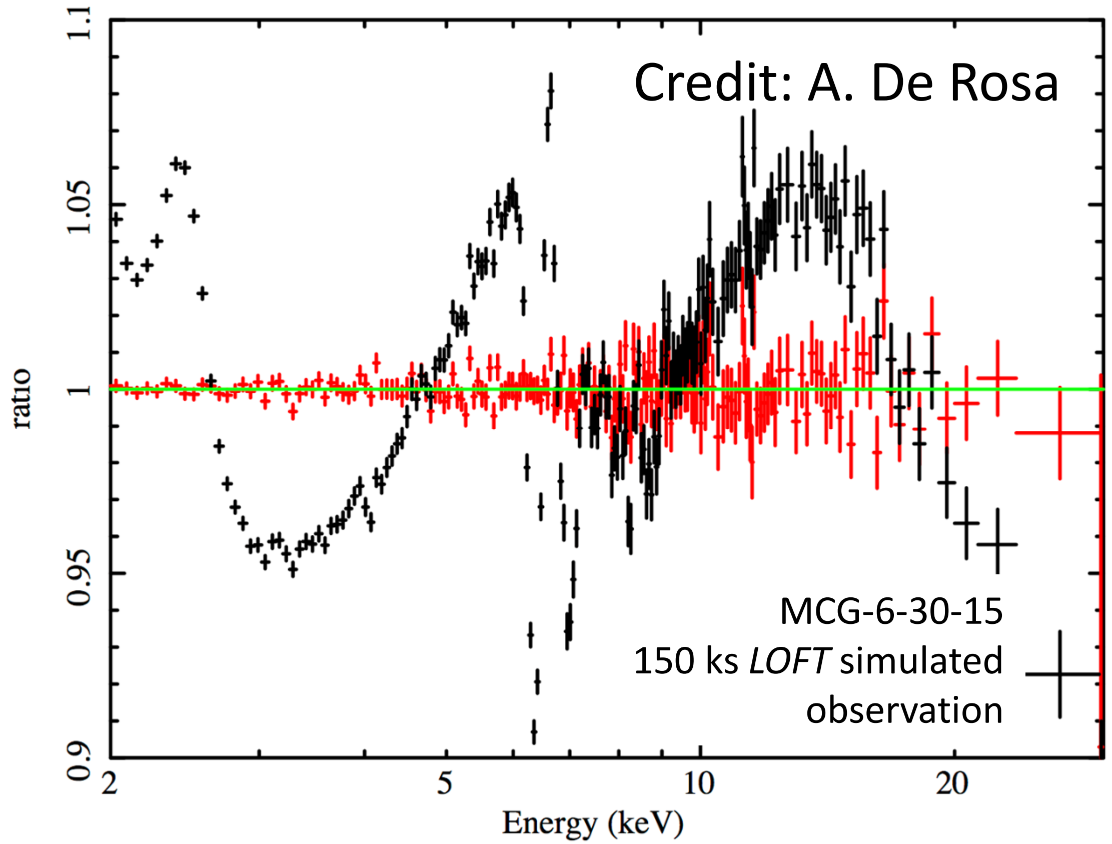


What can *LOFT* do for AGN?

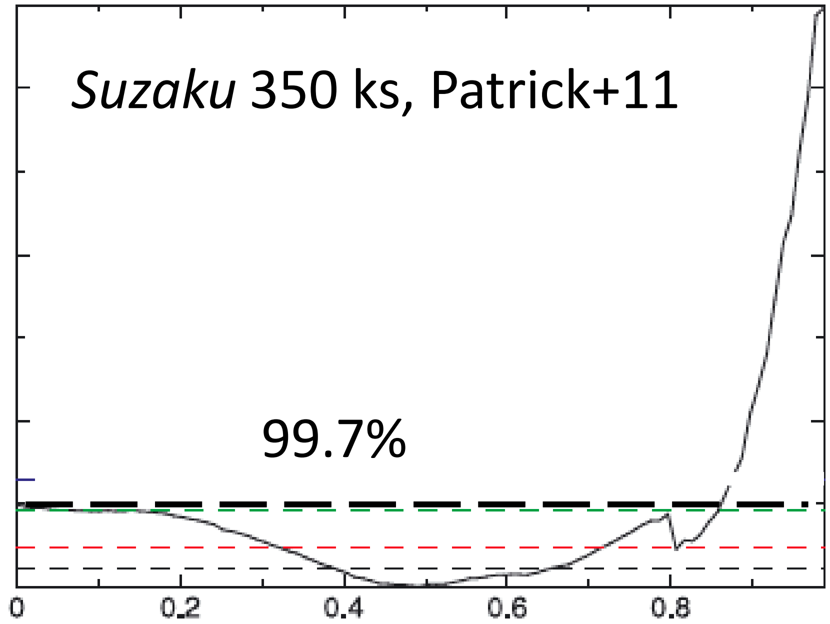
Reflection *vs* complex absorption model

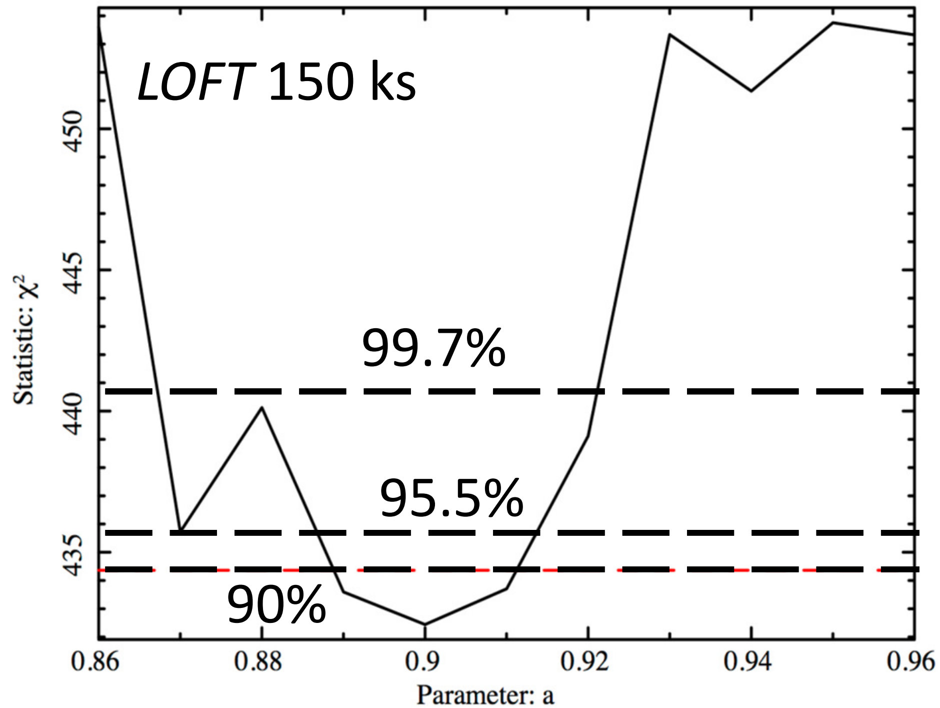


Reflection + blurred Fe line

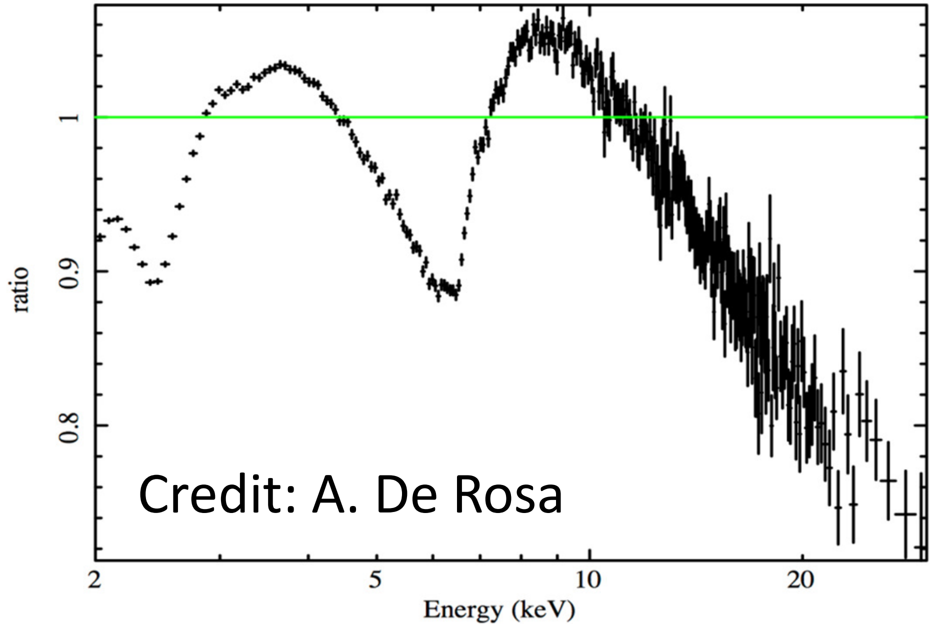
vs.

Complex absorption + distant reflection



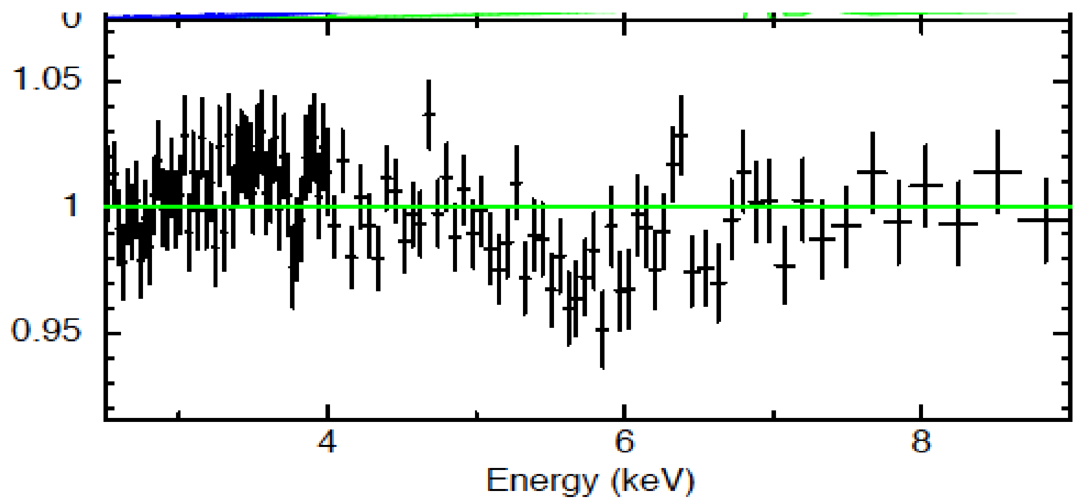


Spectral degeneracy: disc emissivity *vs* spin



Data: q_{in}=7.3, q_2=3, a=0.95
Model: q_{in}=q_2=3, a=0
LOFT, 150 ks

NGC 3783. *Suzaku* 250 ks, Reynolds+12



What can *LOFT* do for AGN?

$$f_{lc} \sim 2\times10^5 \left(\frac{r}{r_g}\right)^{-1} \left(\frac{M}{M_\odot}\right)^{-1} \mathrm{Hz} \qquad \left[\left(\frac{GM_\odot}{c^3}\right)^{-1} = 2\times10^5\right]$$

$$f_{dyn} \sim 2\times10^5 \left(\frac{r}{r_g}\right)^{-3/2} \left(\frac{M}{M_\odot}\right)^{-1} \mathrm{Hz} \sim 2\pi f_{orb}$$

$$f_{therm} \sim f_{orb}\alpha$$

$$f_{visc} \sim f_{orb}\alpha\left(\frac{h}{r}\right)^2$$

Timescale	10 M_{sun}	10^6 M_{sun}
Light crossing	3×10^3 Hz (0.3 ms)	30 mHz (30 s)
Orbital	200 Hz (5 ms)	2 mHz (500 s)
Thermal	20 Hz (50 ms)	0.2 mHz (5 ks)
Viscous	0.2 Hz (5 s)	2×10^{-6} Hz (500 ks)

[assuming $\alpha \sim 0.1$, $h/r \sim 0.1$, $r/r_g \sim 6$]

What can *LOFT* do for AGN?

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More photons/timescale in AGN than XRBs (~flux * M)

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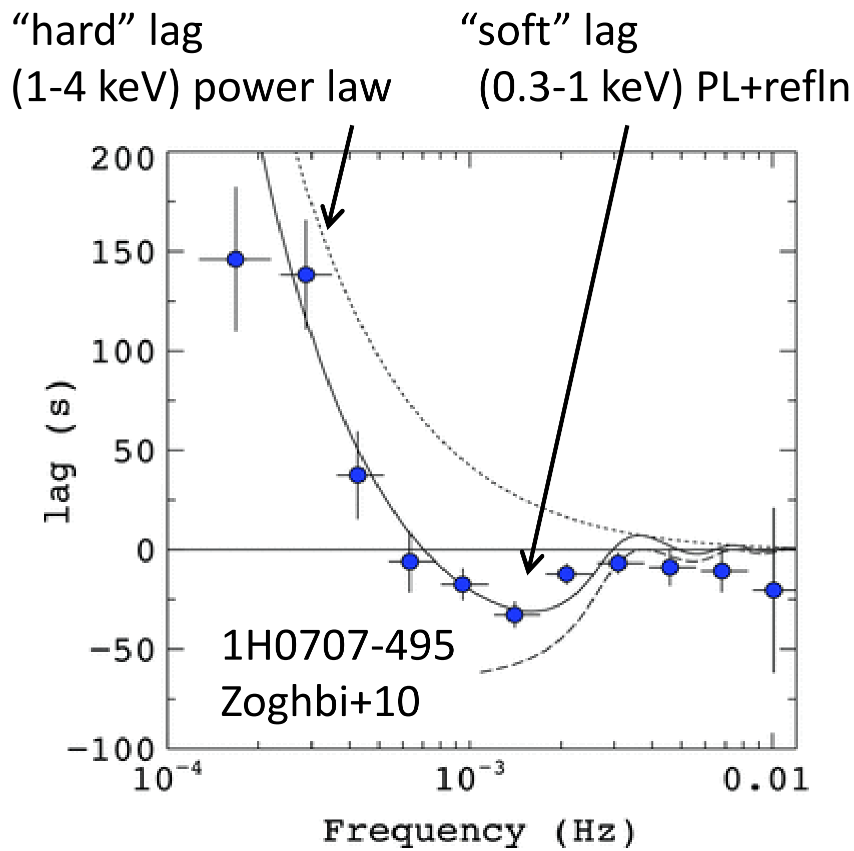
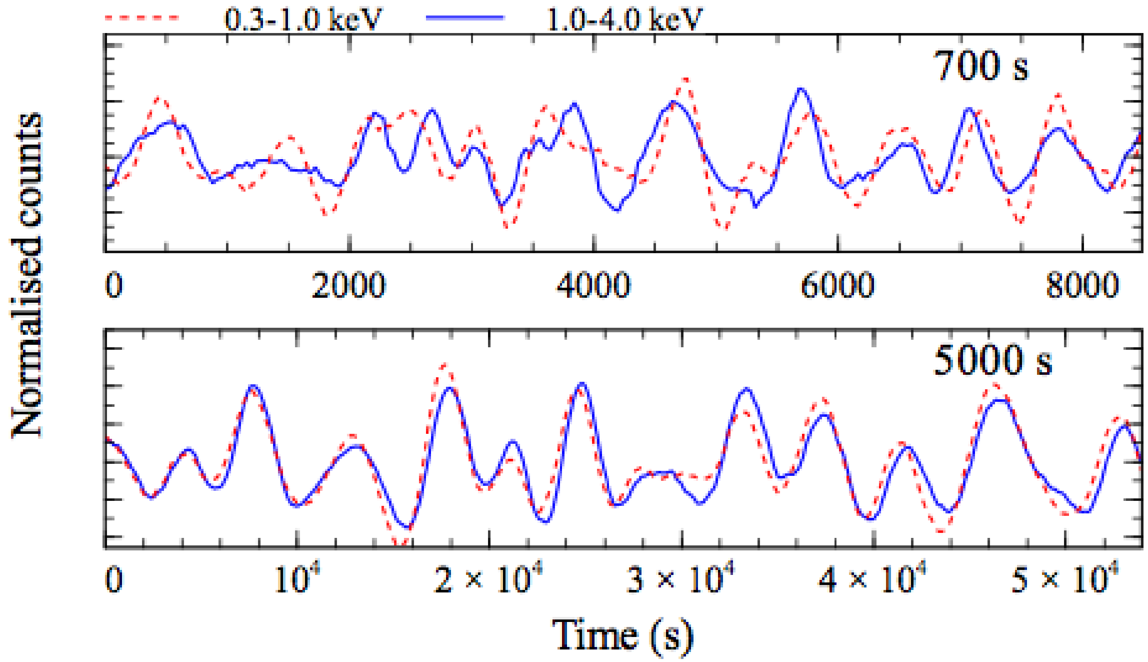
What can *LOFT* do for AGN?





Fabian et al. (2009); Zoghbi et al. (2010)

AGN
- lag due to reflection on timescales of τ ~ few 10s ~ few r_g/c
- "intrinsic" hard lag within PL continuum at lower freq
- Optical–X-ray (disc – power law) correlation on long timescales (+limits on lag)

XRBs
- Disc – power law lags at low freq (Uttley et al. 2011)
- "intrinsic" hard lag within PL continuum at lower freq
- reflection signal at higher freqs?

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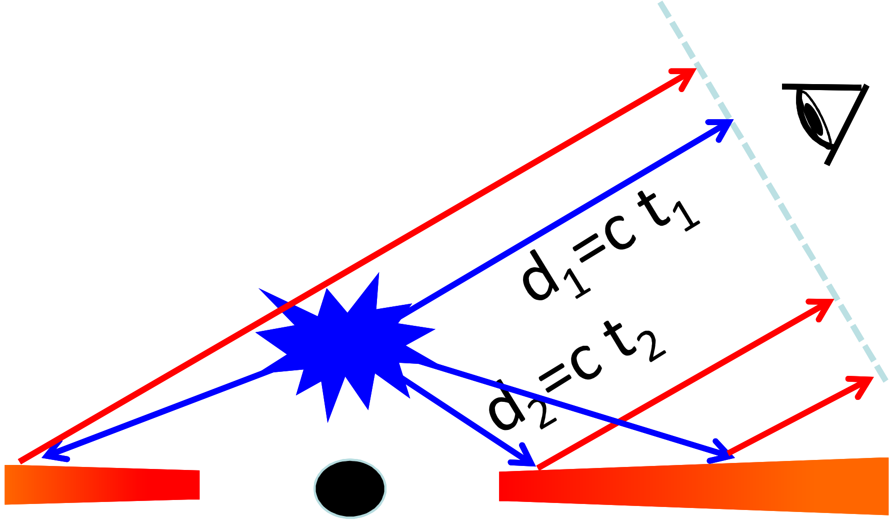
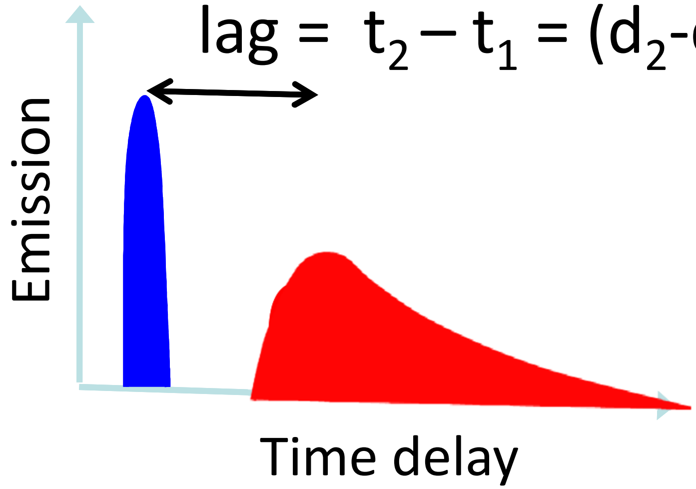
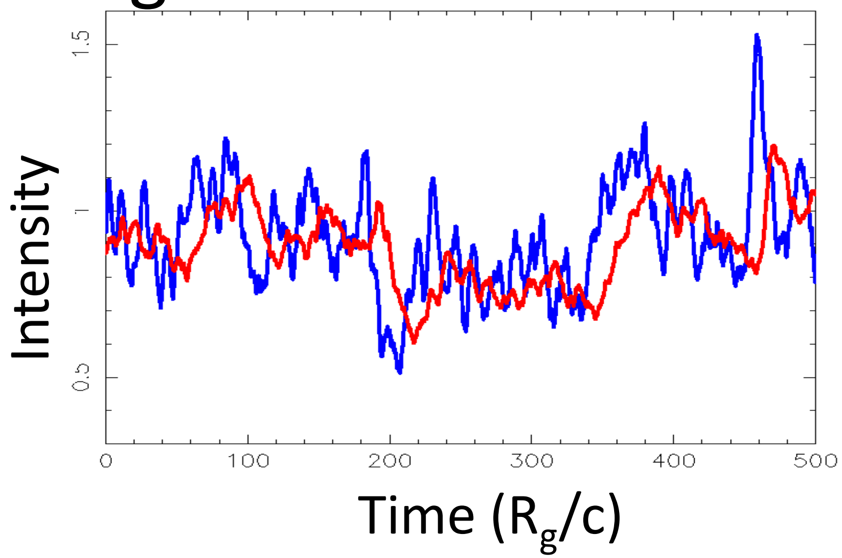
What can *LOFT* do for AGN?





Credit: P. Uttley

Light curves:



The light curve from the reflected/reprocessed disk component is a delayed and smeared out version of the continuum light curve

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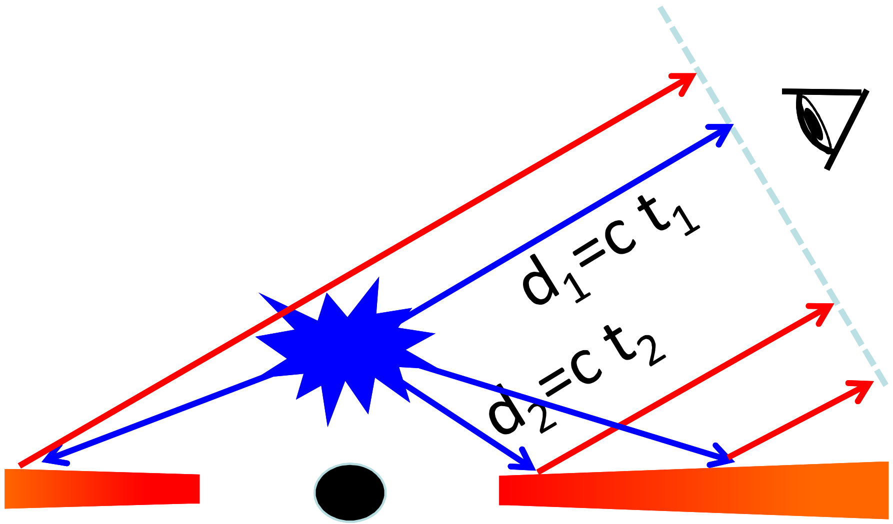

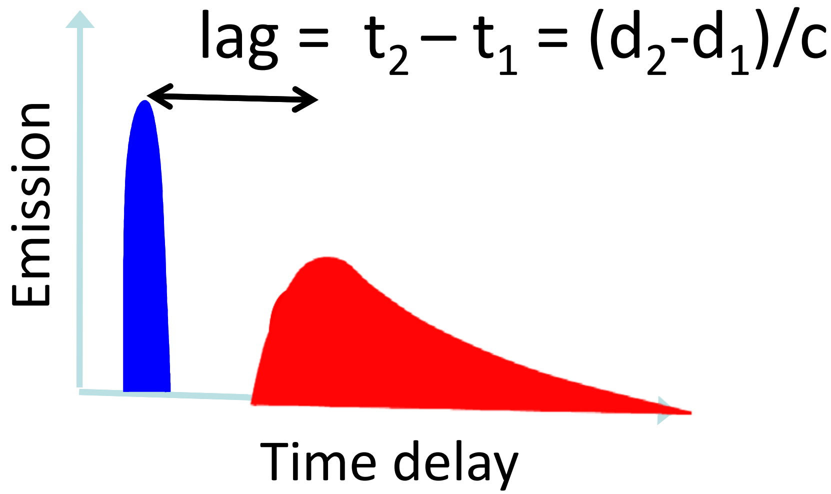

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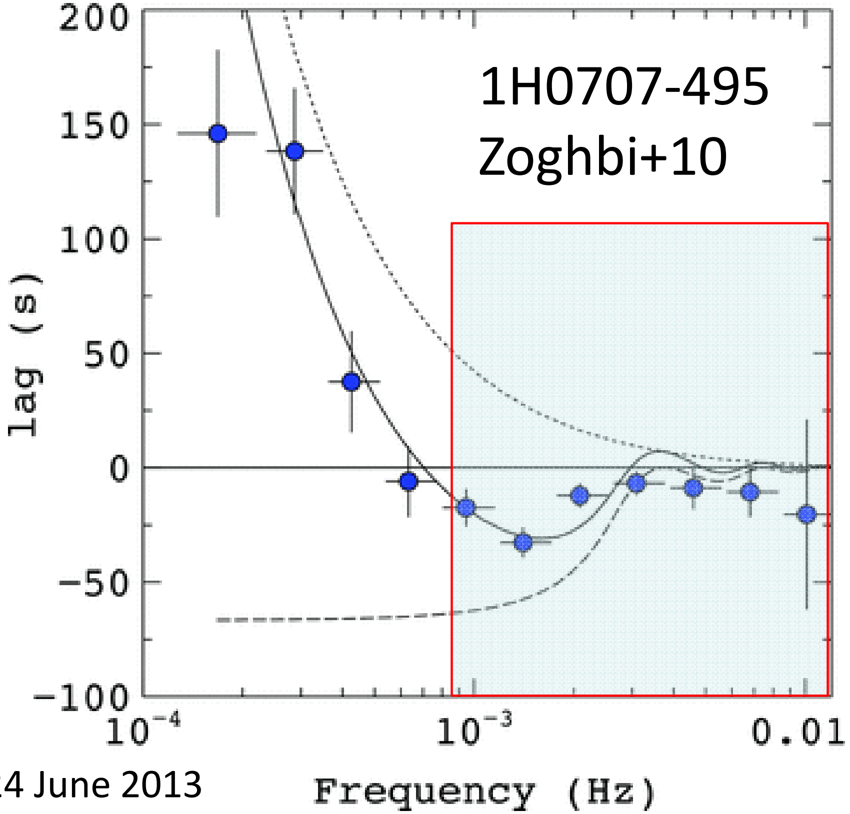

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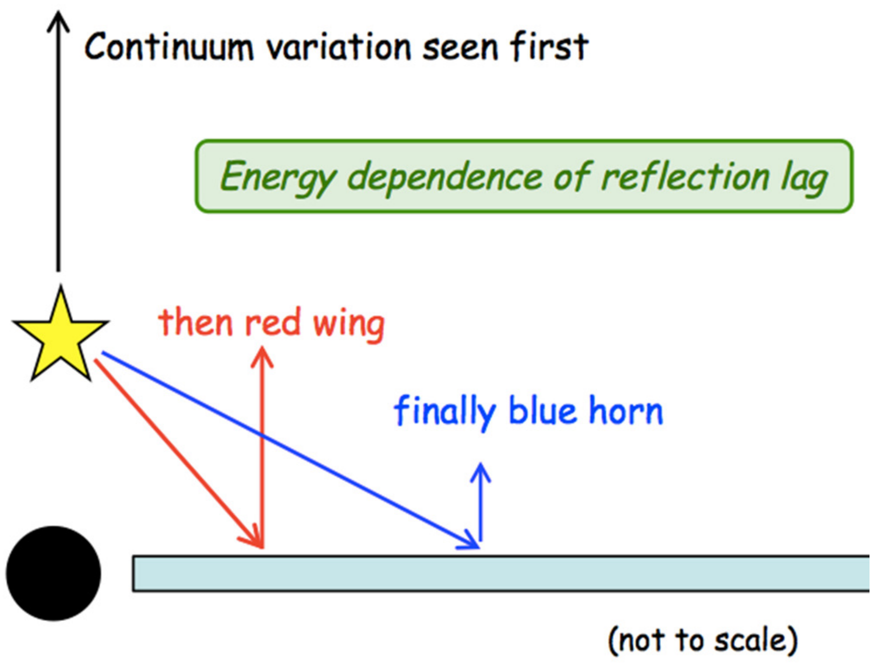
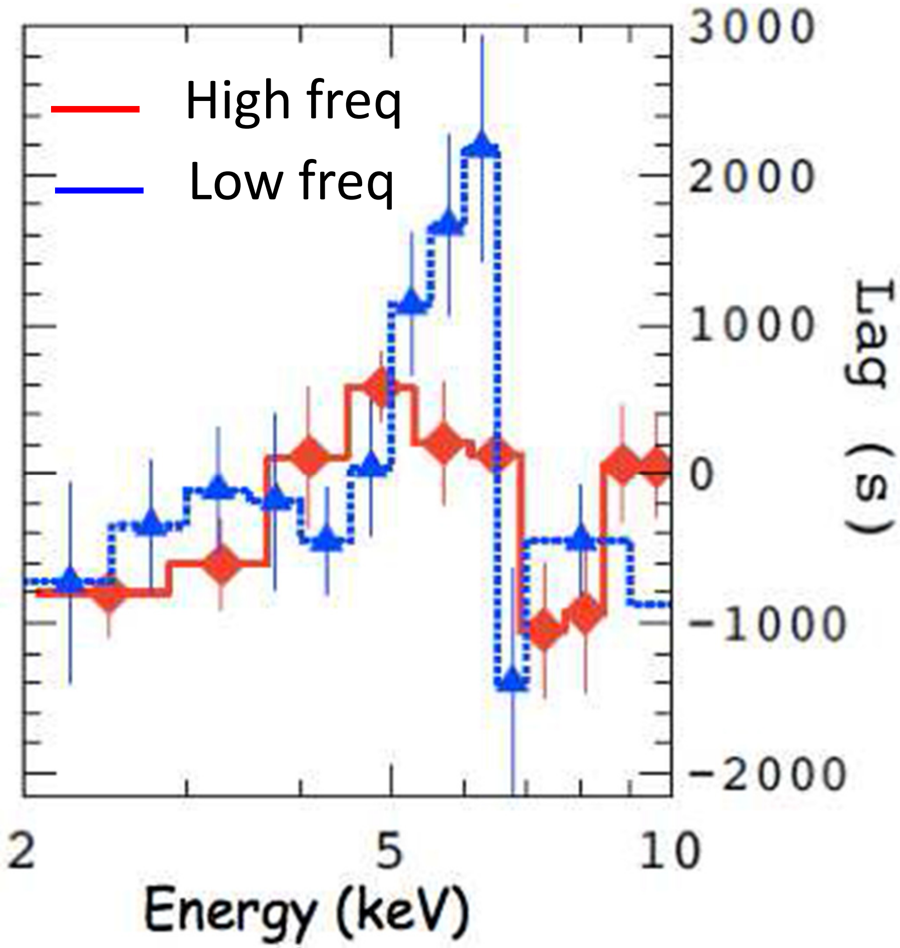
Fe line Reverberation – time lags



The shorter, high frequency lags (red) peak at 4–5 keV in the red wing of the lines, originating closest to the black hole, whereas the larger, lower frequency lags (blue) show a narrower spectral peak at 6–7 keV.

NGC 4151 Zoghbi+12



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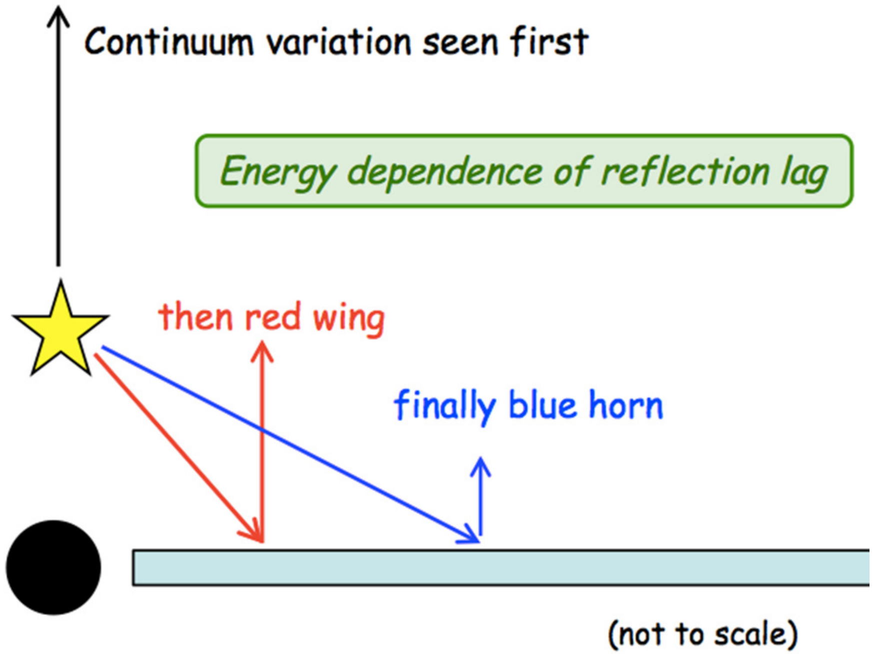

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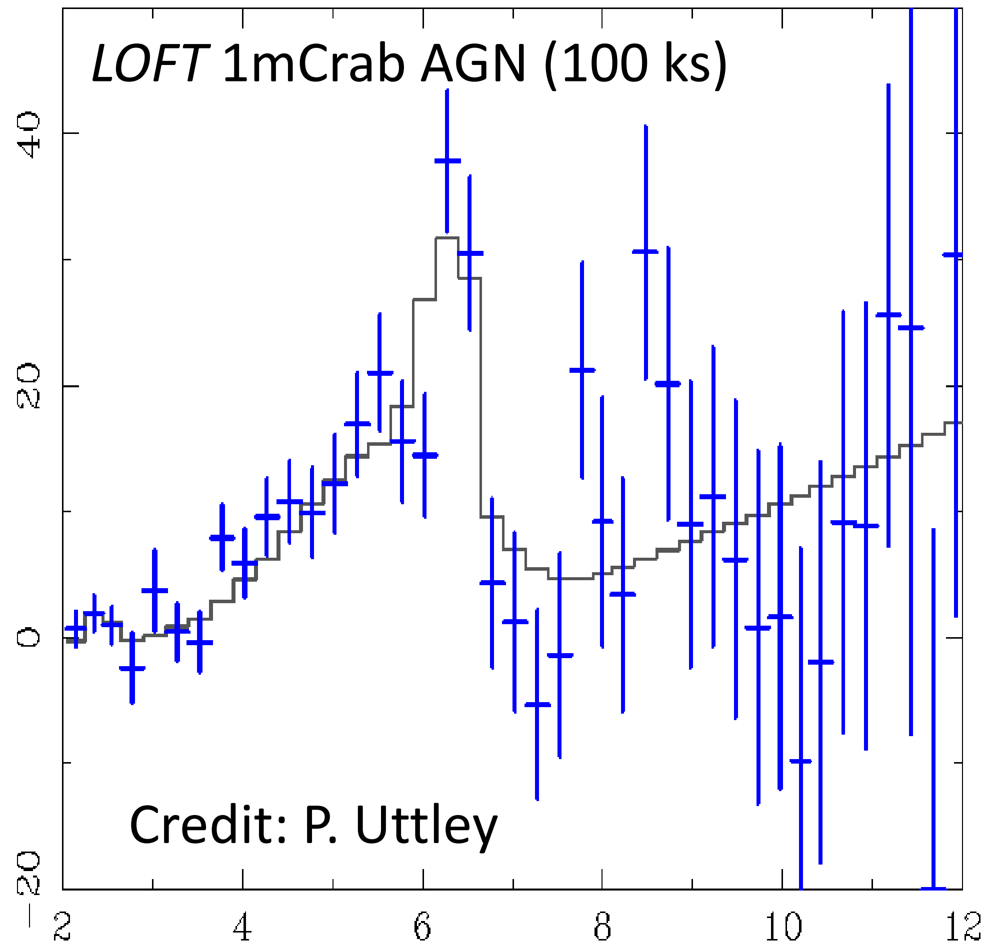
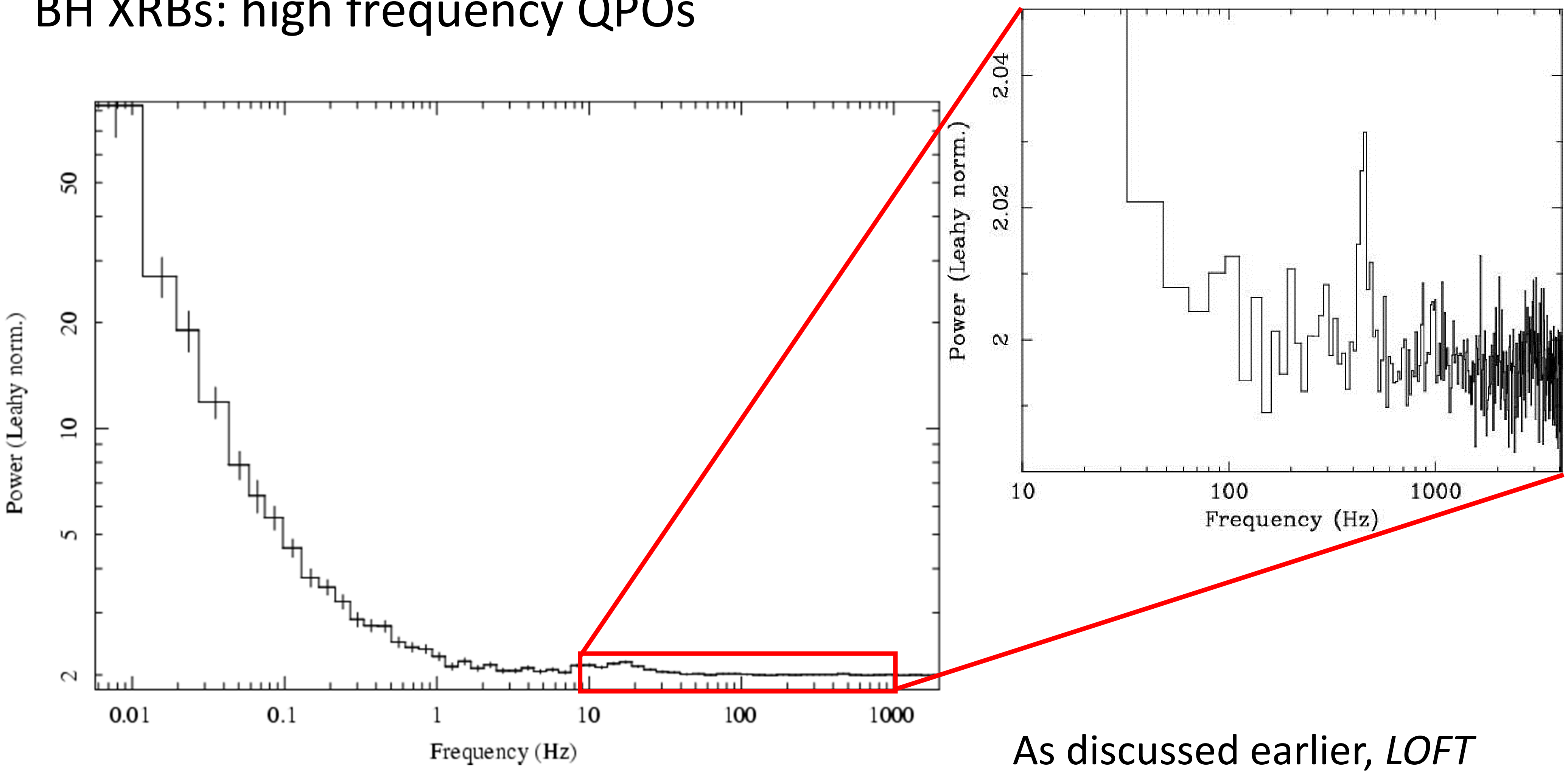


BH XRBs: high frequency QPOs

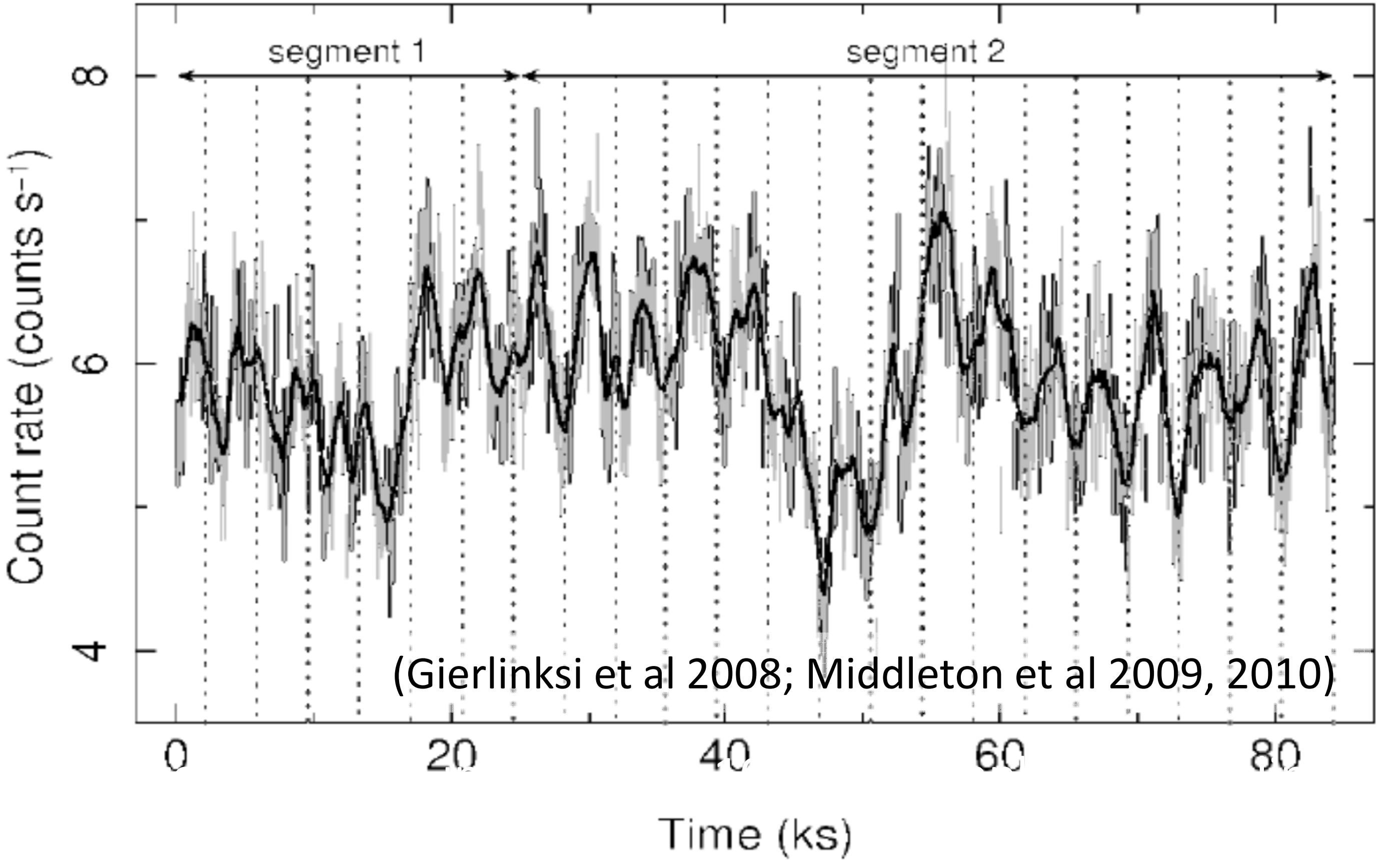


450 Hz QPO in GRO J1655-40 (Strohmayer 2001)
f_{ISCO} = 270–400 Hz (for non-spinning M_{BH}=5.5-7.9 M_{sun})

As discussed earlier, *LOFT* will be excellent for HF QPO studies in BH XRBs.
But what about AGN…?

What can *LOFT* do for AGN?

AGN QPO: RE J1034+396



Photons/sec is not the issue.
Sampling and number of “cycles” are what matters.
Anything, including LAD, could see this QPO – but so far unique..

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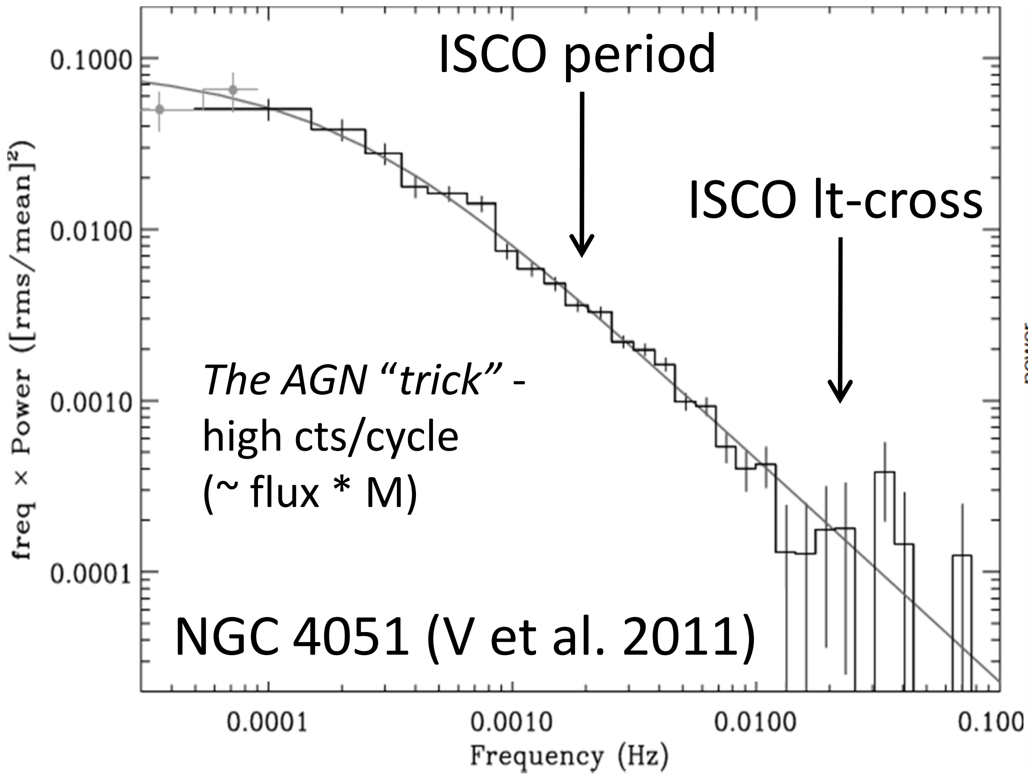
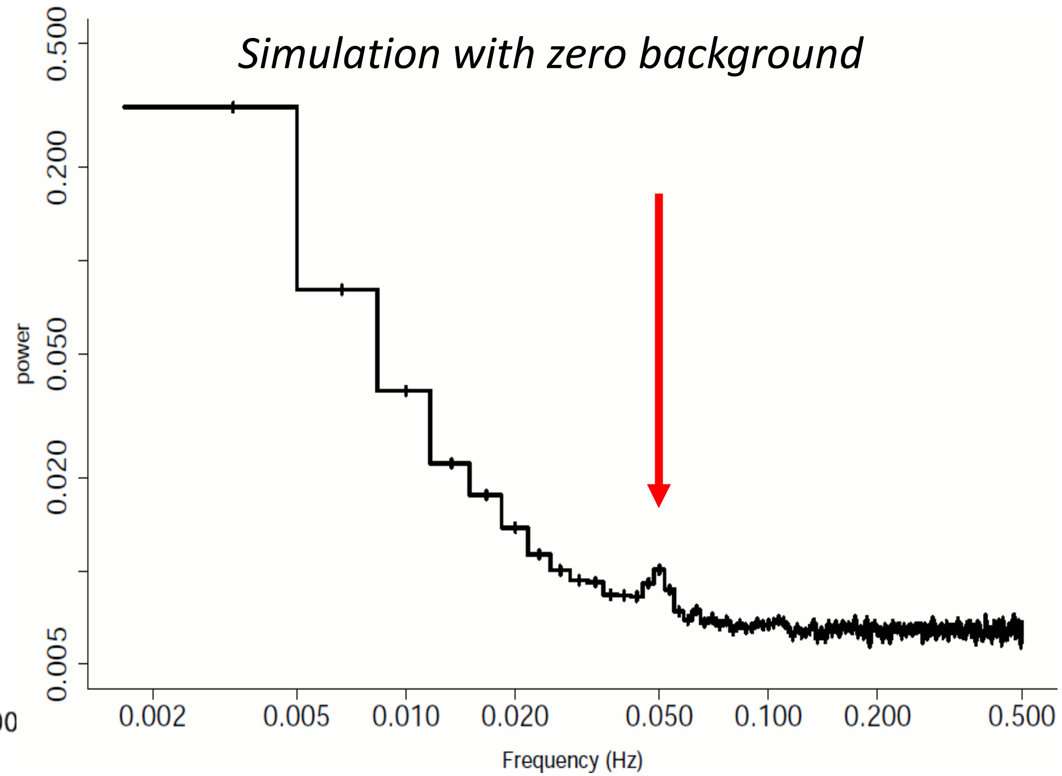
What can *LOFT* do for AGN?

Best high frequency PSD from *XMM-Newton*





500+ ks data (0.3-10 keV)

ISCO frequency ~ 10^{-3} - 10^{-2} Hz

Reach equivalent of >1 kHz for BH XRB

300 ksec LAD simulation (2-10 keV)
(i.e. 100 * 3 ks snapshots for $3x10^{-11}$ cgs)

QPO: f = 50mHz
rms = 1% rms (XMM limit),
Q=10

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What can *LOFT* do for AGN?

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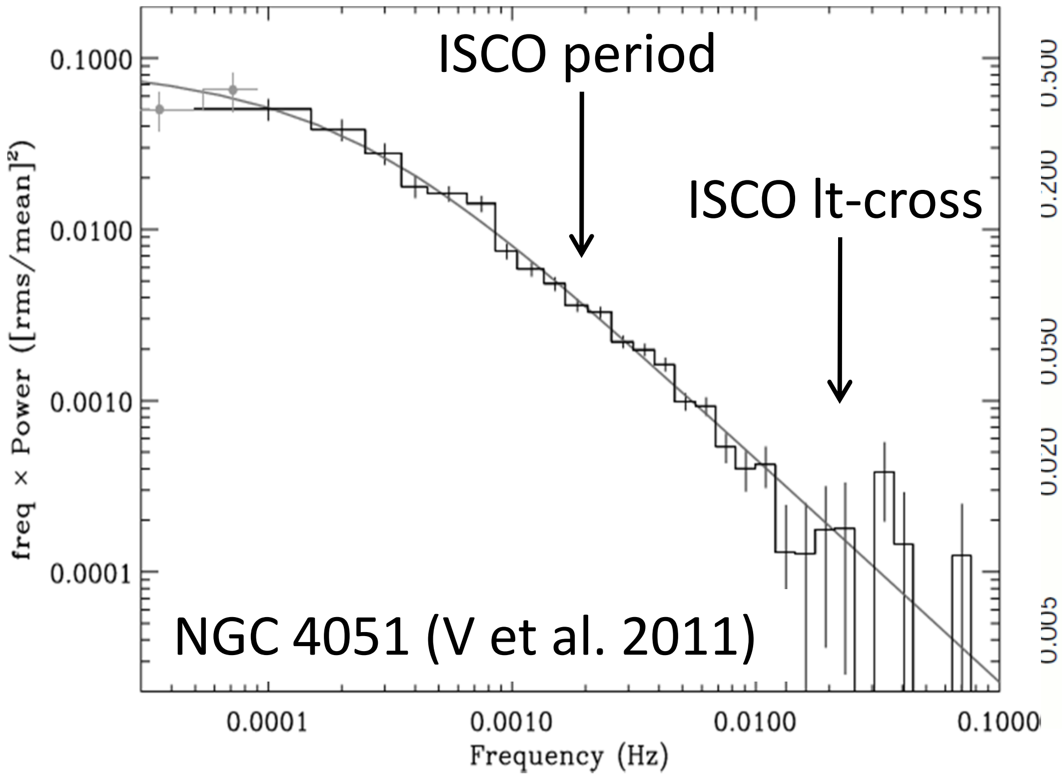

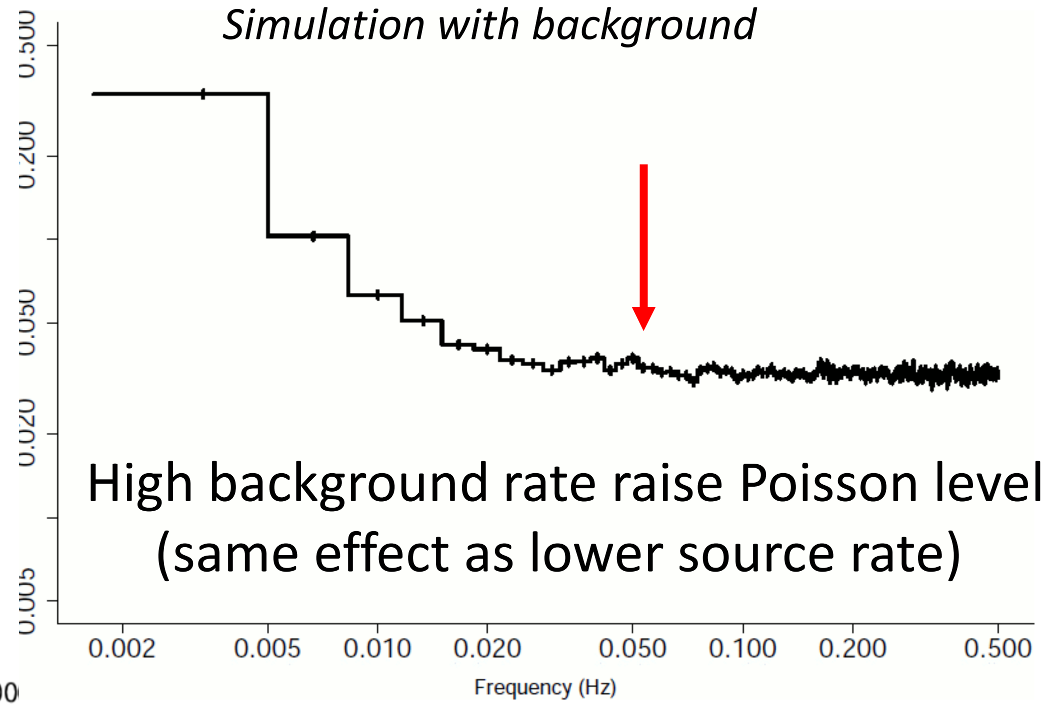

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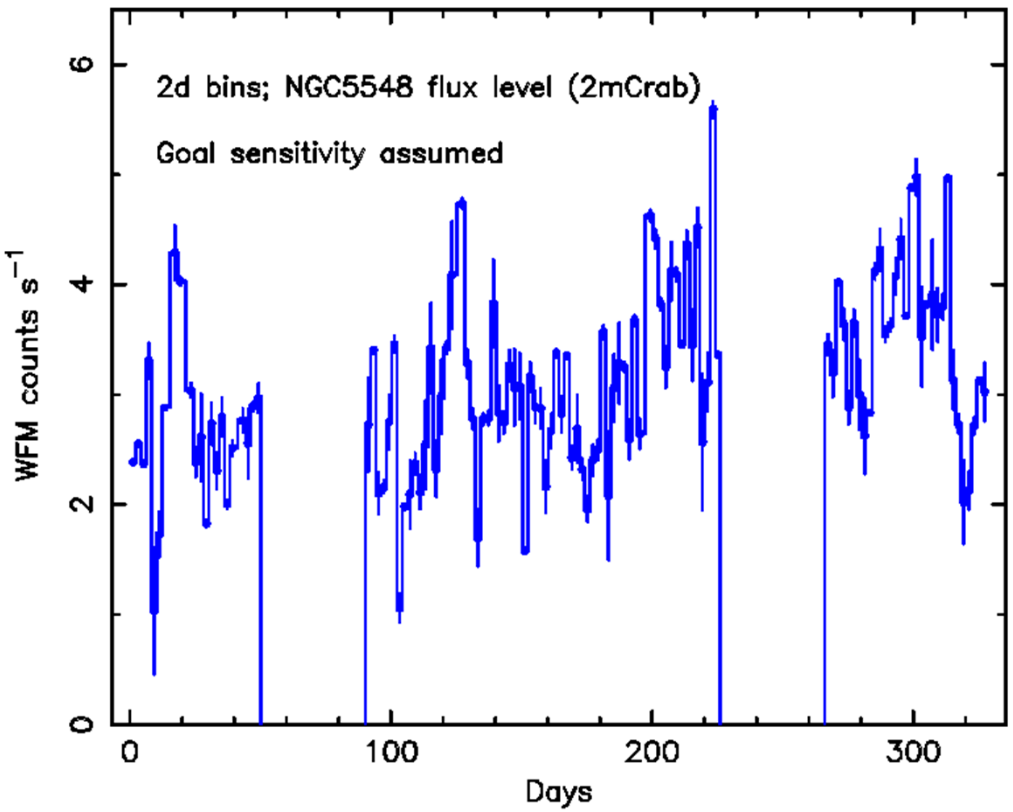
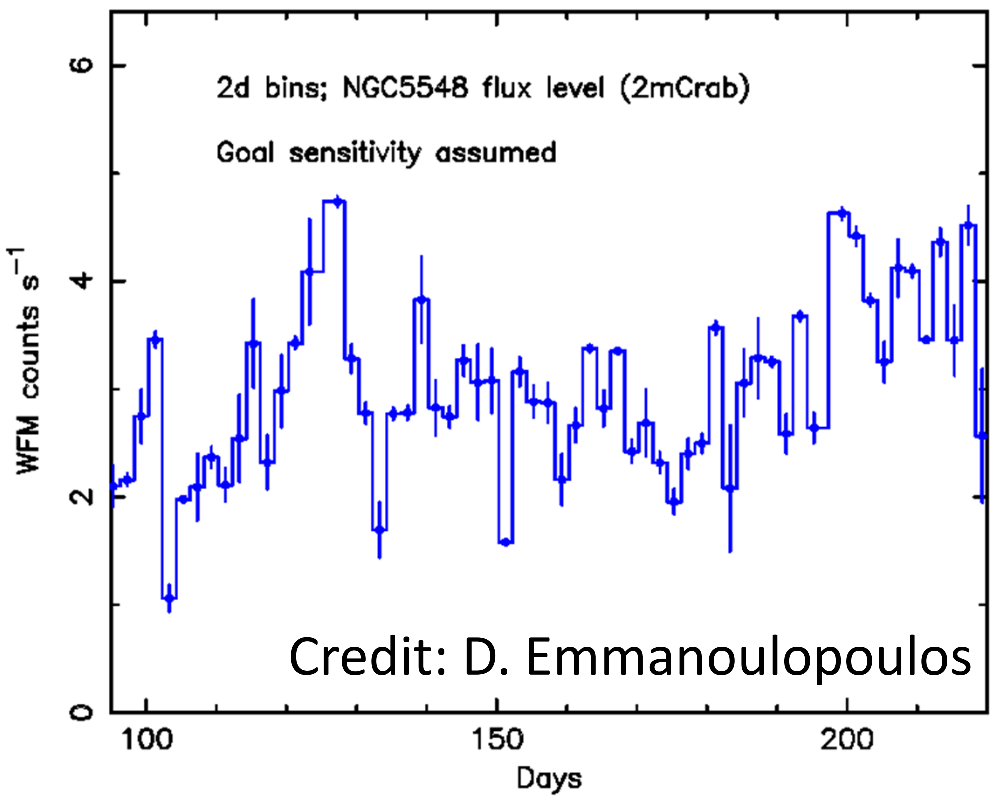
What can *LOFT* do for AGN?

WFM monitoring of Seyferts





Follow long timescale variations in X-ray brightest Seyferts, blazars
Better sensitivity than *RXTE* ASM, better duty cycle than *RXTE* PCA pointings

Measure ~days timescale lags (Papadakis & Nandra 2001), inter-band correlations
Long timescale (low frequency) QPOs (see Vaughan & Uttley 2005)

Long timescale monitoring of Seyferts with LAD / WFM

WFM could (probably) study long term X-ray and X/optical-radio variability, and measure lags, for brighter Seyferts and blazars.

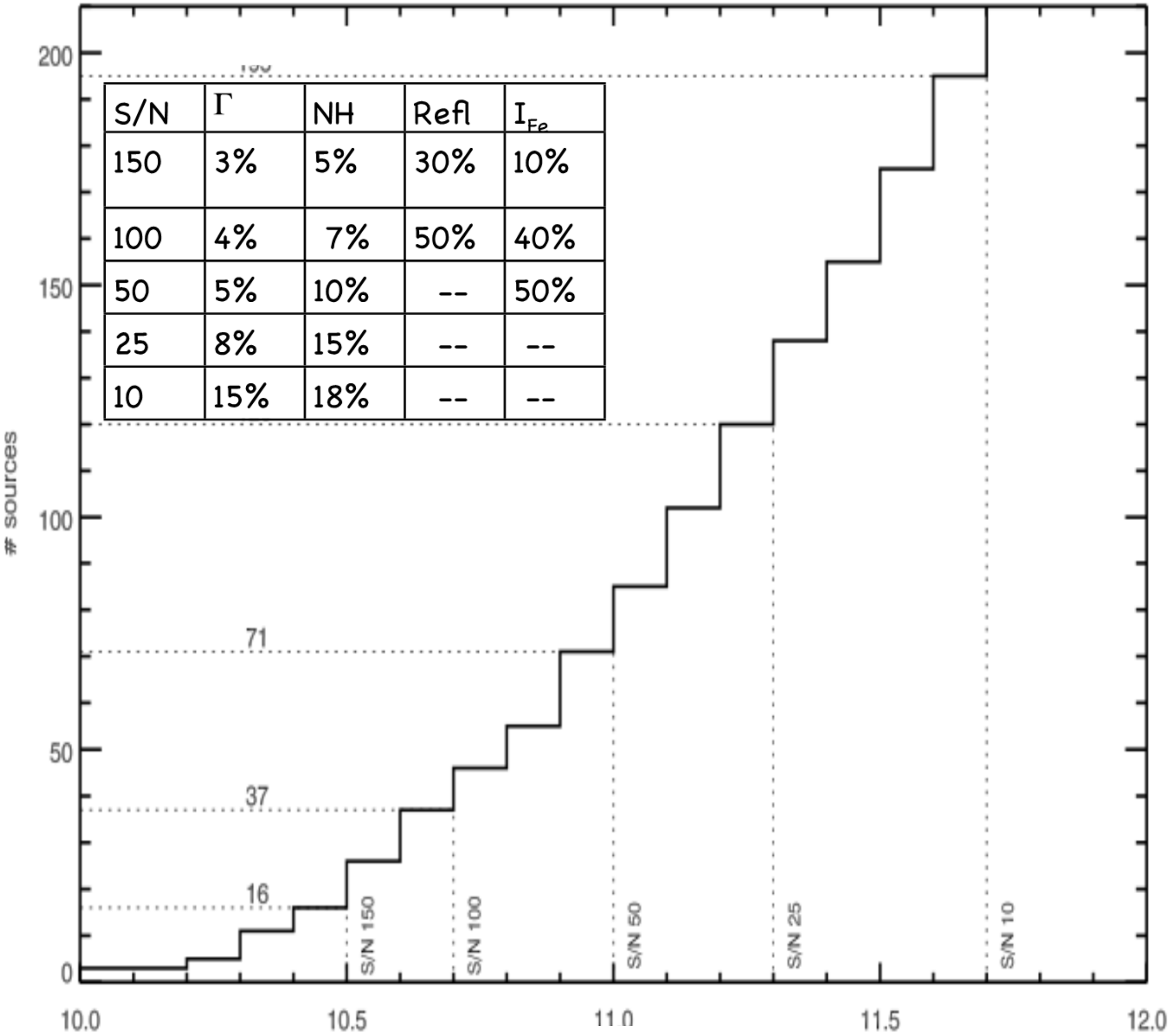
Much higher on-source time compared to e.g. *RXTE* snapshot monitoring

→ big reduction in sampling distortions

Depends on sky coverage (?), LAD monitoring (*RXTE*-style)?

Depends on slew rate, visibility windows, and scheduling.

LOFT as an observatory for RQ AGNs



S/N	Γ	NH	Refl	I_{Fe}
150	3%	5%	30%	10%
100	4%	7%	50%	40%
50	5%	10%	--	50%
25	8%	15%	--	--
10	15%	18%	--	--

$-\log(F_{2\text{-}10})$

1. Absorption variability
2. X-rays eclipses
3. Narrow Fe line reverberation
4. Continuum parameters distribution

Credits S. Bianchi

What can *LOFT* do for AGN?

Takeaway messages:

X-ray spectra or timing analyses in isolation will not (I predict) make much more progress

In many ways AGN nicely complement XRBs for 'strong gravity' investigations

LOFT's real strength is in spec-timing around Fe K

Potential for good AGN from LAD and WFM