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Characterising the timing and spectral properties of ULXs

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Ultra-luminous: $L > 10^{39}$ erg s^{-1} up to 10^{42} erg s^{-1}

IMBH solution: $10^{2\text{-}5} M_{SUN}$

$$\dot{m} < \dot{m}_{EDD}$$

New physics required for formation

XRB solution: $10 M_{SUN}$

$$\dot{m} \geq \dot{m}_{EDD}$$

Extreme mass accretion isn't rare but not well understood

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Basic spectral predictions for sub-Eddington behavior:

L/Ledd	X-ray spectra
< a few %	Hard tail, cold disc
A few – tens %	Hotter disc with softer tail (<~2.2)
~tens %	Disc dominated

(See Tomaso Belloni's talk/work on IMS)

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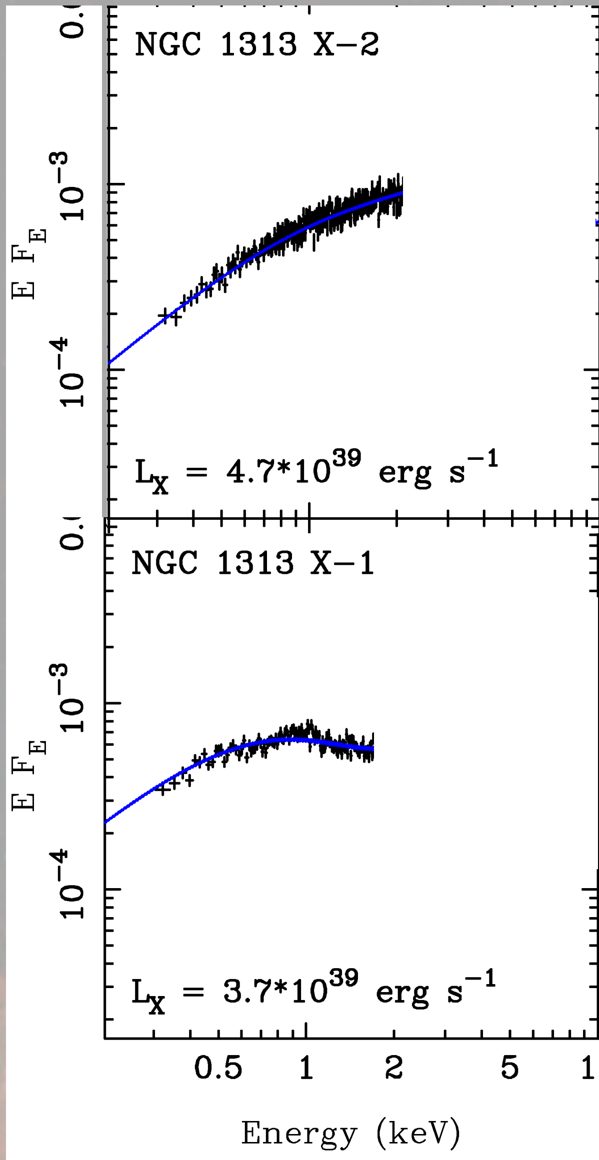
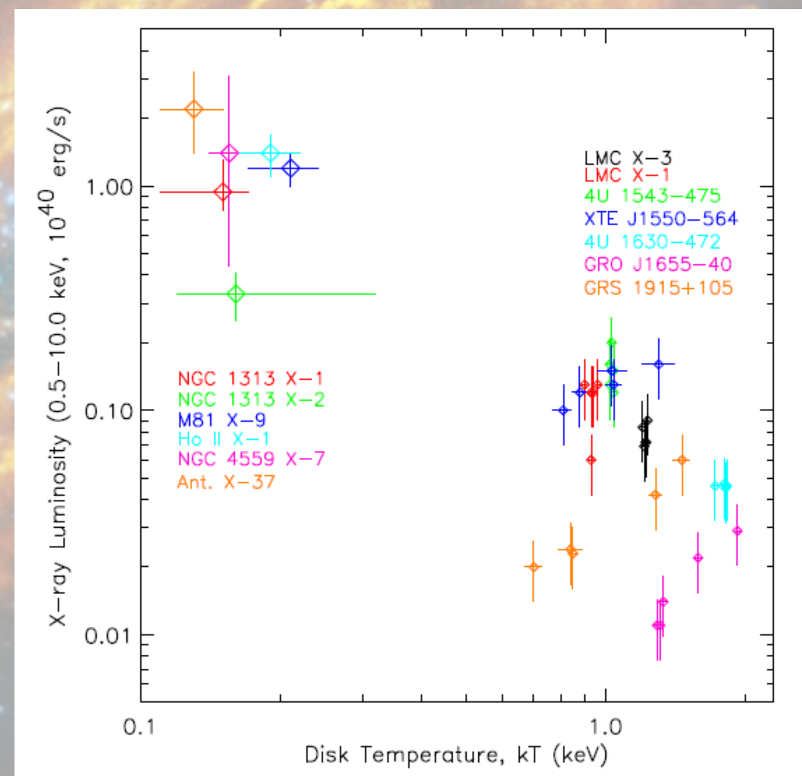
	10,000	3000	100
1e39 : L/L_{EDD}	0.008%	0.26%	8%
1e40: L/L_{EDD}	0.08%	2.6%	80%





Miller, Fabian & Miller 2004

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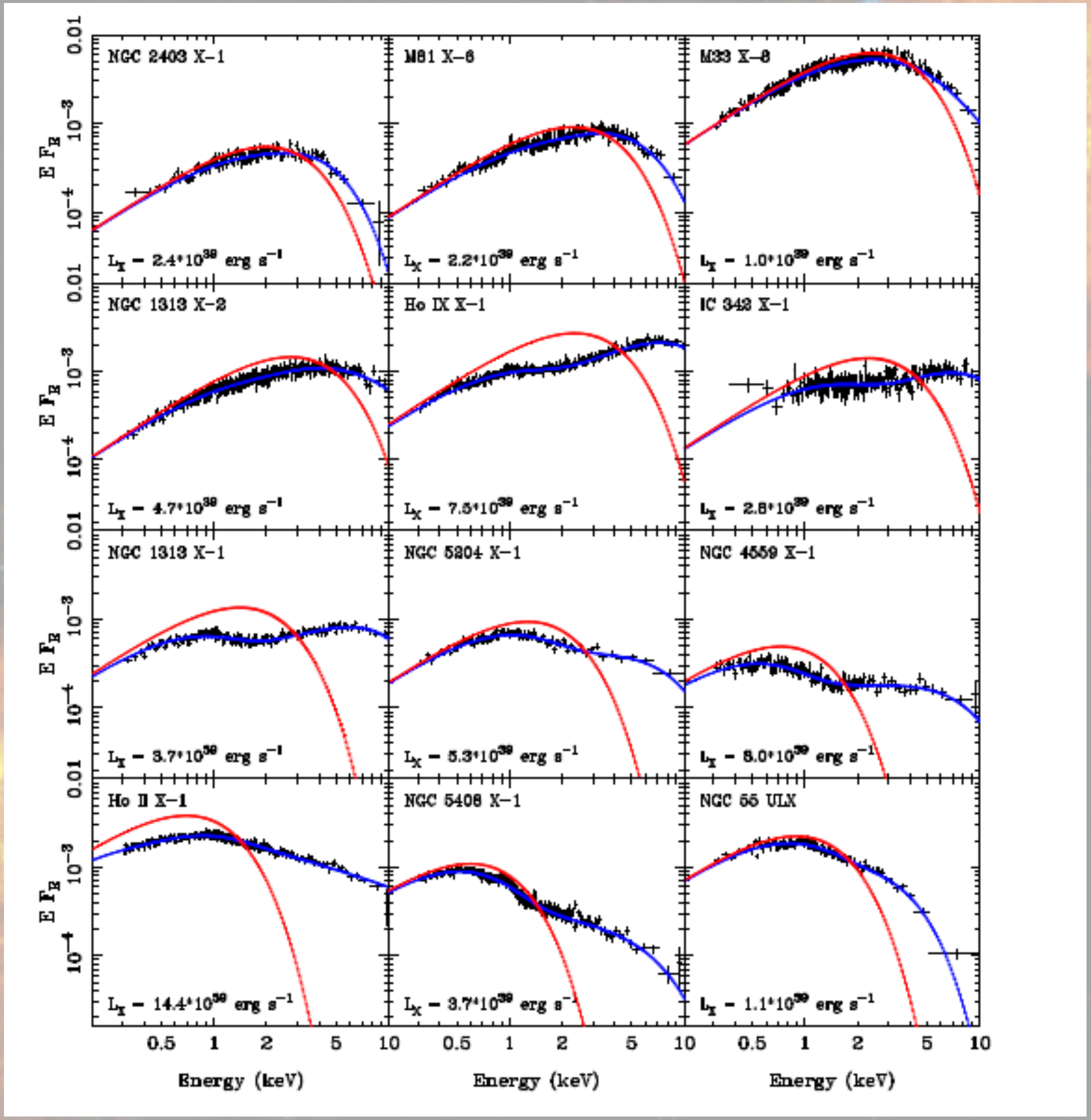
The bigger picture...



Gladstone, Roberts & Done 2009

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How to test for analogous behaviour: X-ray spectral fitting alone can be misleading...

Joint spectral & timing:

L/Ledd	X-ray spectra	Variability
< a few %	Hard tail, cold disc	Tail highly variable (disc the source of variability? Uttley et al. 2011; MRI in thick flow: Kris Beckwith's talk)
A few – tens %	Hotter disc with softer tail (<~2.2)	Stable disc, tail can have residual variability
~tens %	Disc dominated	Stable on all but very long timescales

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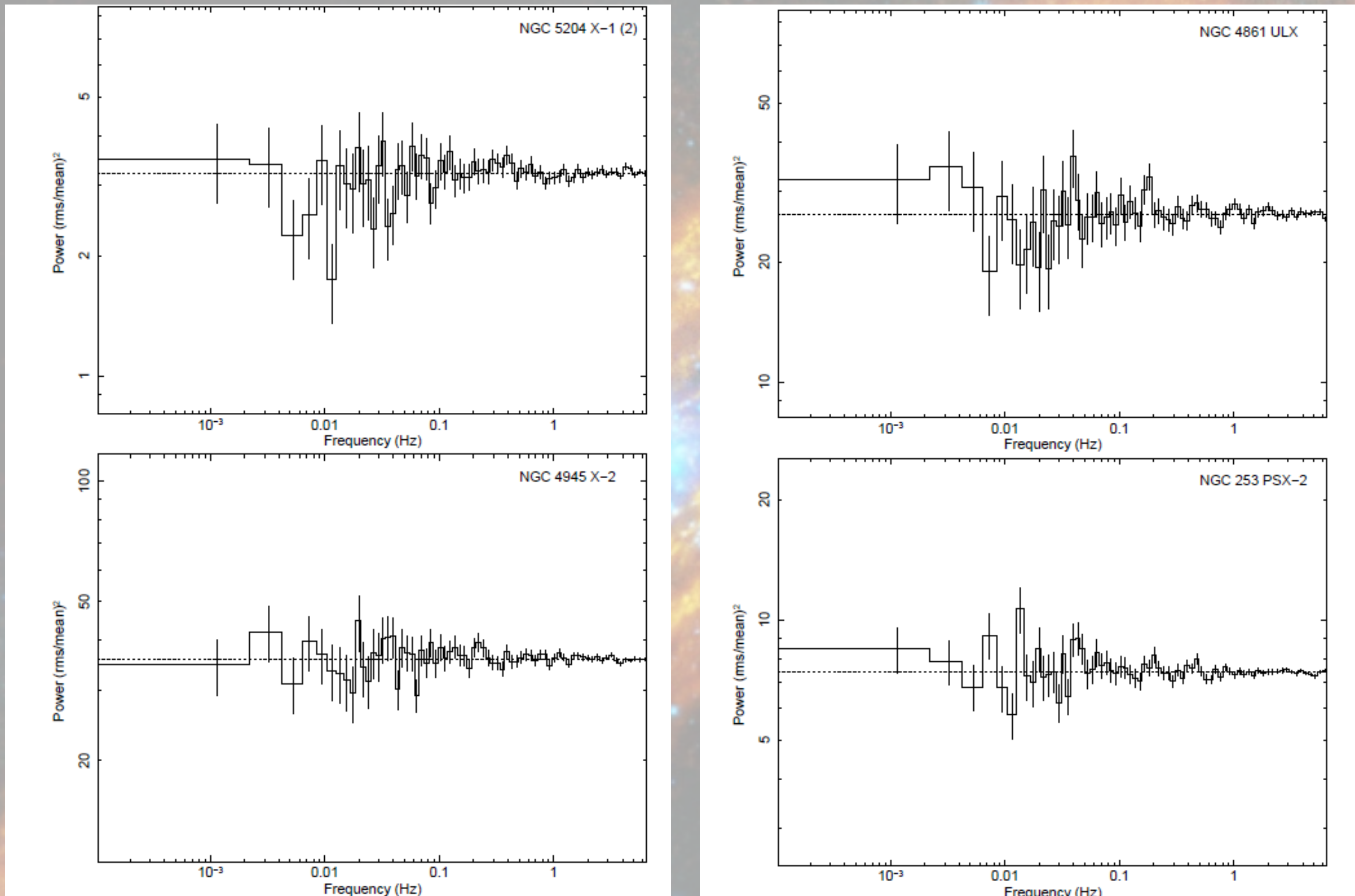

Heil, Vaughan & Roberts 2009

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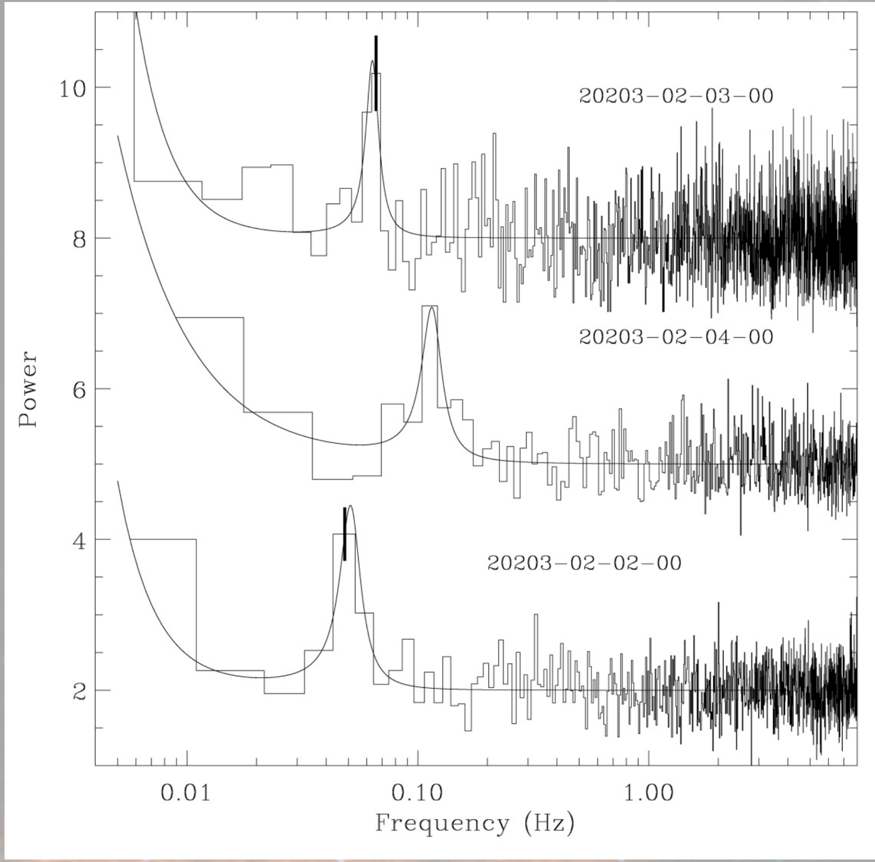
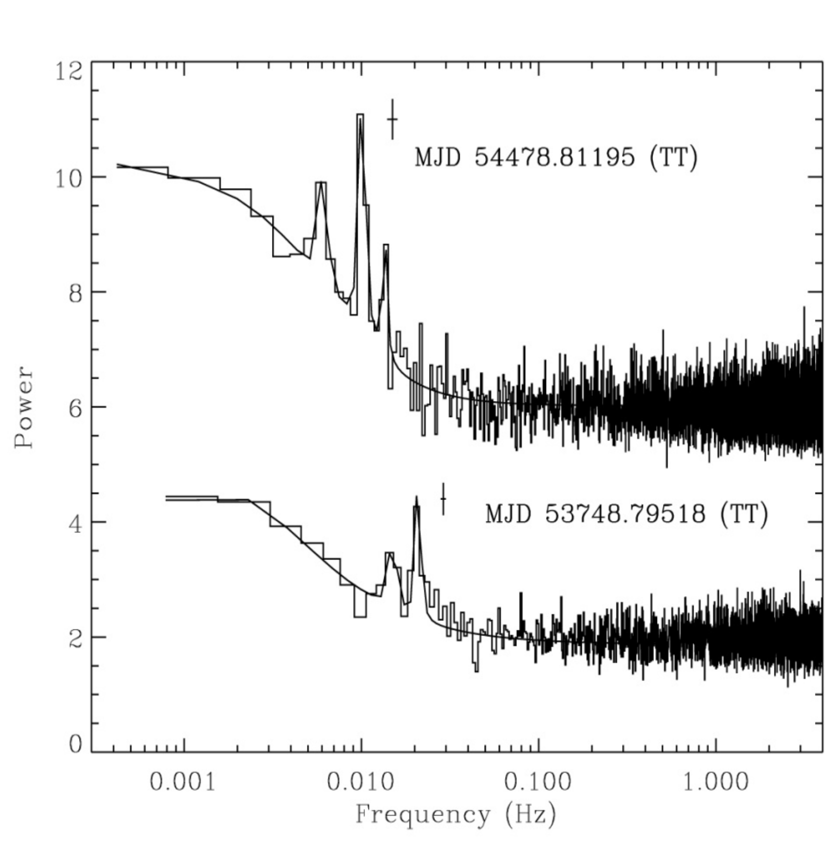
M82 X-1



Strohmayer & Mushotzky 2003

NGC5408 X-1



Strohmayer & Mushotzky 2009

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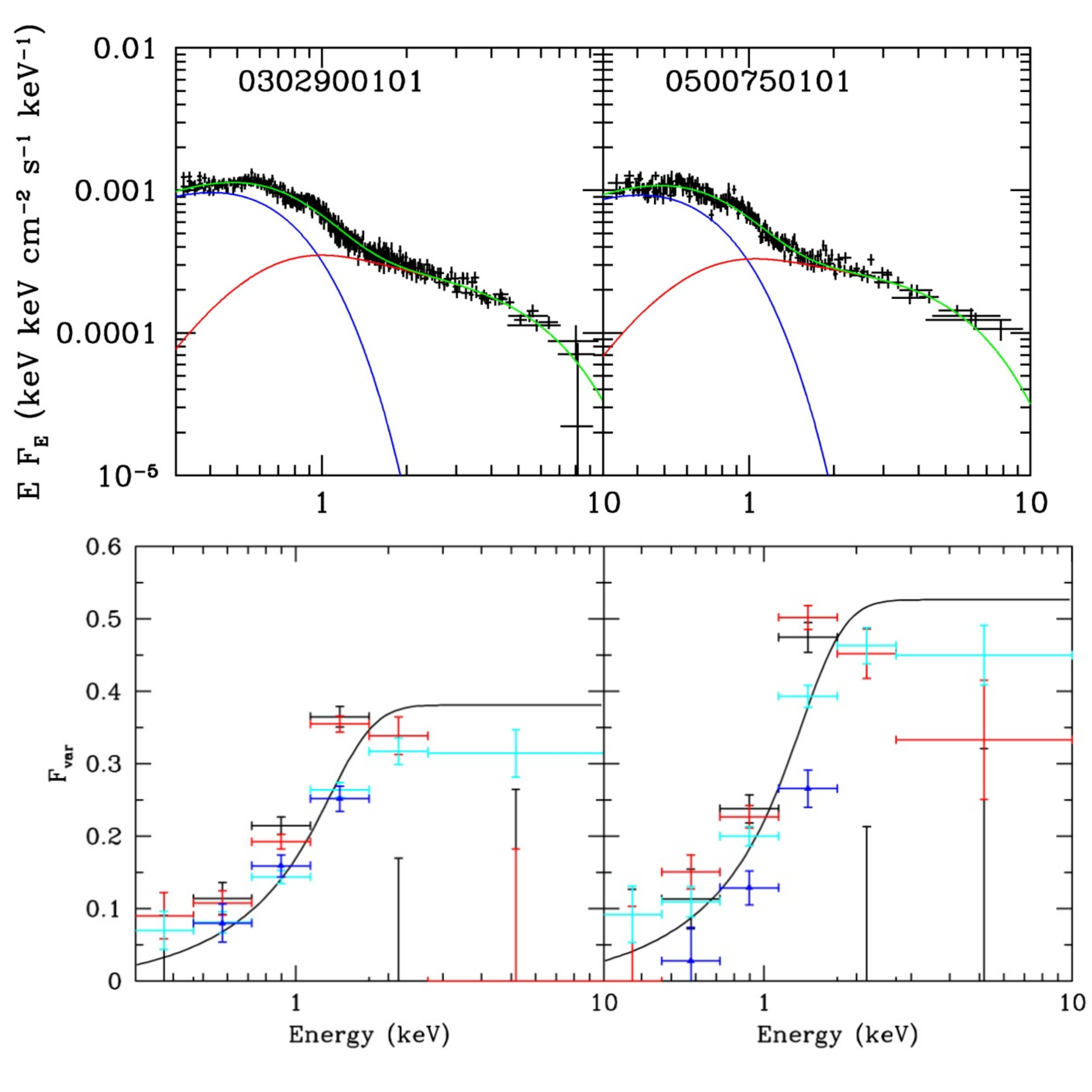

Middleton et al. 2011

Type C LFQPO places mass at >1000M_{SUN}

L~4e39erg/s

Gives L/L_{EDD} of <3%

Inconsistent spectra and timing!

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If not sub-Eddington then how about super-Eddington?

L/Ledd	X-ray spectra	Variability
< a few %	Hard tail, cold disc	Tail highly variable (disc the source of variability? Uttley et al. 2011; MRI in thick flow: Kris Beckwith's talk)
A few – tens %	Hotter disc with softer tail (<2.2)	Stable disc, tail can have residual variability
~tens %	Disc dominated	Stable on all but very long timescales
>100%	**Slim disc/winds?**	**Extrinsic?**

NGC55 X-1: dipping source that has red noise PDS (Stobbart et al. 2004; Heil et al. 2009)

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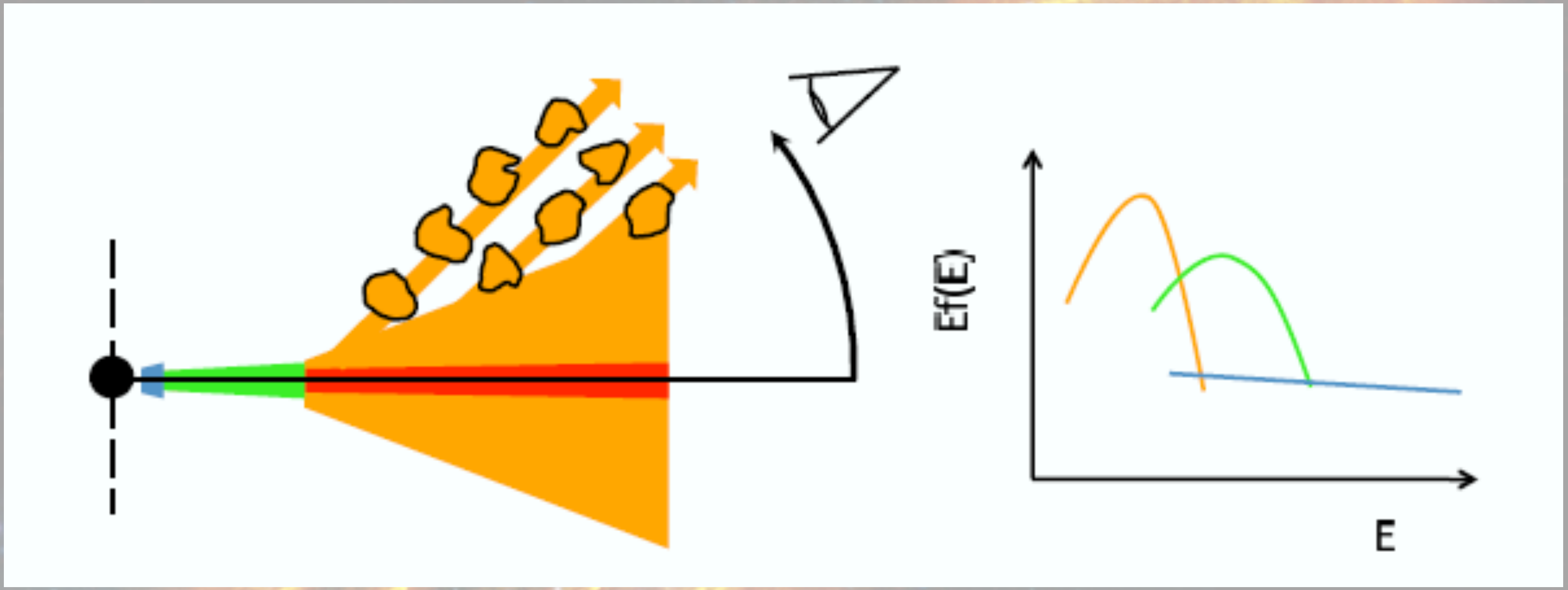
TOY model



Middleton et al. 2011

Driven by radiation pressure (Poutanen et al. 2007), could have magnetic driving (Dave Meier's talk)

Inner (hot) region stripped of loose material and may be artificially variable. Can lead to no variability through inclination angle

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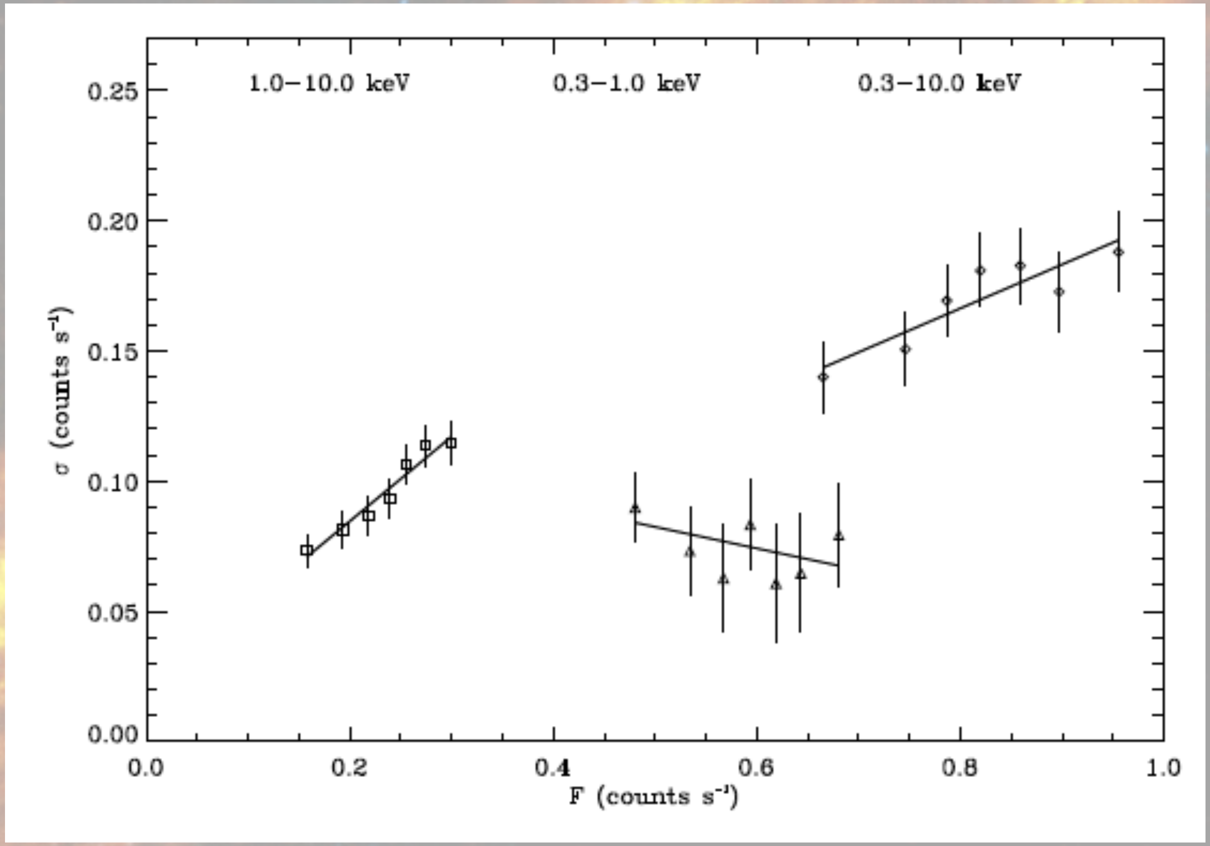
As radiation pressure scales with flux then we should get an approximately linear flux-rms relation → non-linearity (Uttley et al. 2005)



Heil & Vaughan 2010

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500ks of XMM-Newton data shows that the spectral properties don't match the LFQPOs of XRBs (see Dheeraj Pasham's talk at Berlin online)

→ QPO looks broad (fairly low coherence)
→smeared by beaming (Andrew King's talk)?
→ **covariance** spectrum (Wilkinson & Uttley 2009) below the QPO looks same as continuum (Middleton & Uttley in prep)
→could be a **characteristic timescale** related to the wind mechanism?

If made via extrinsic means then don't compare the PDS to those with intrinsic power: XRBs, AGN!

Need joint spectral and timing simulations....watch this space

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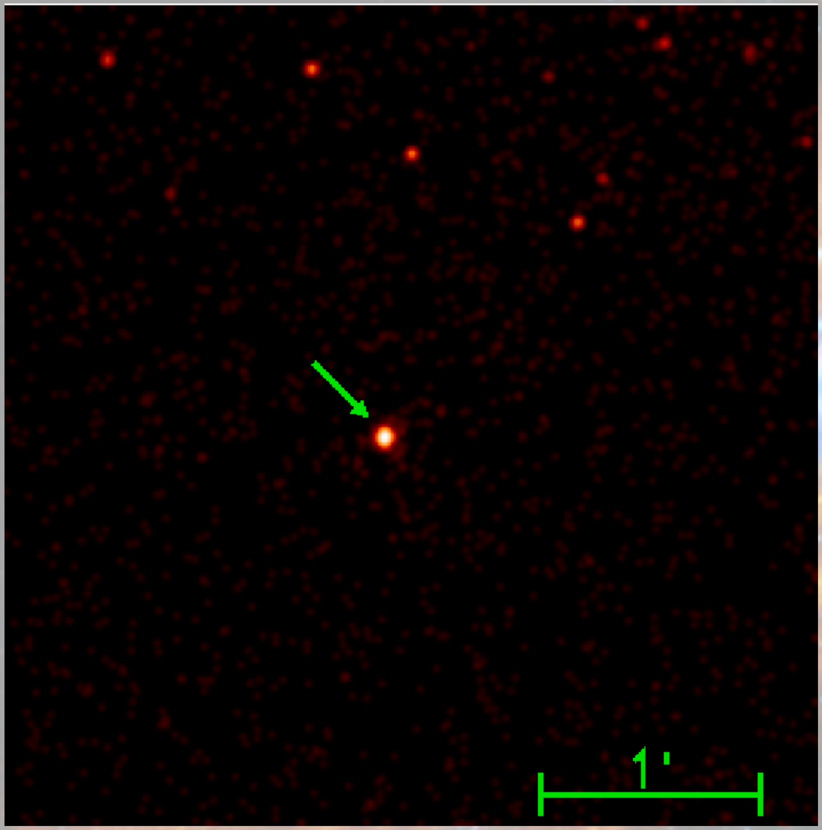
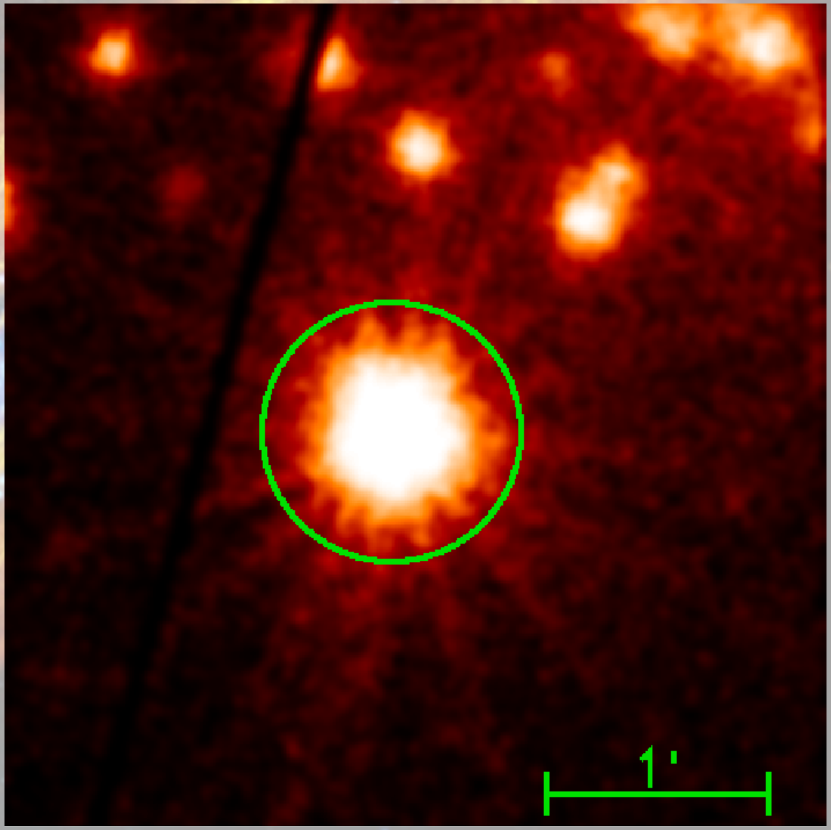
M31 ULX-1 (CXOM31 J004253.1+411422)

Middleton et al. in prep



Chandra



XMM-Newton

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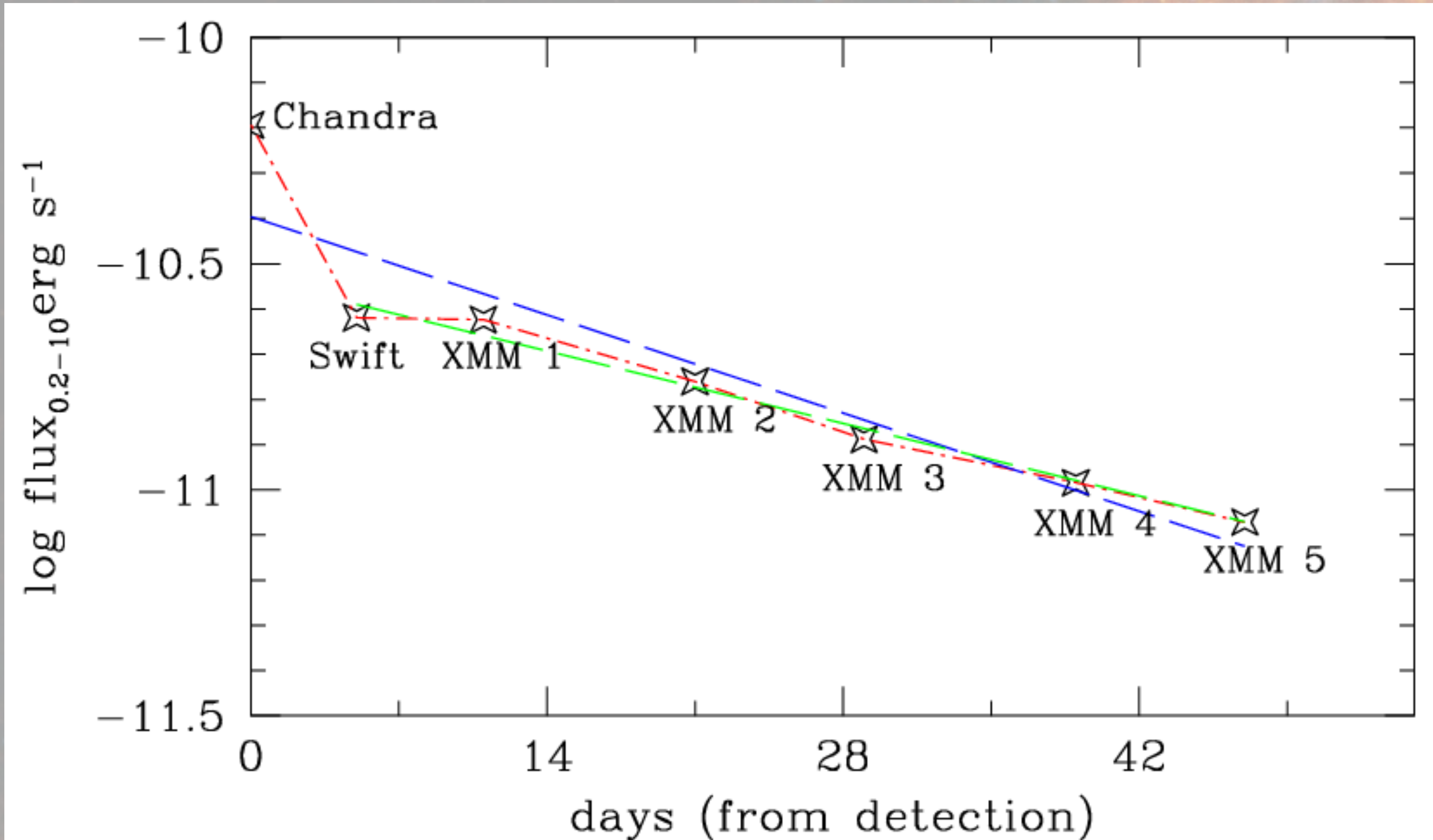
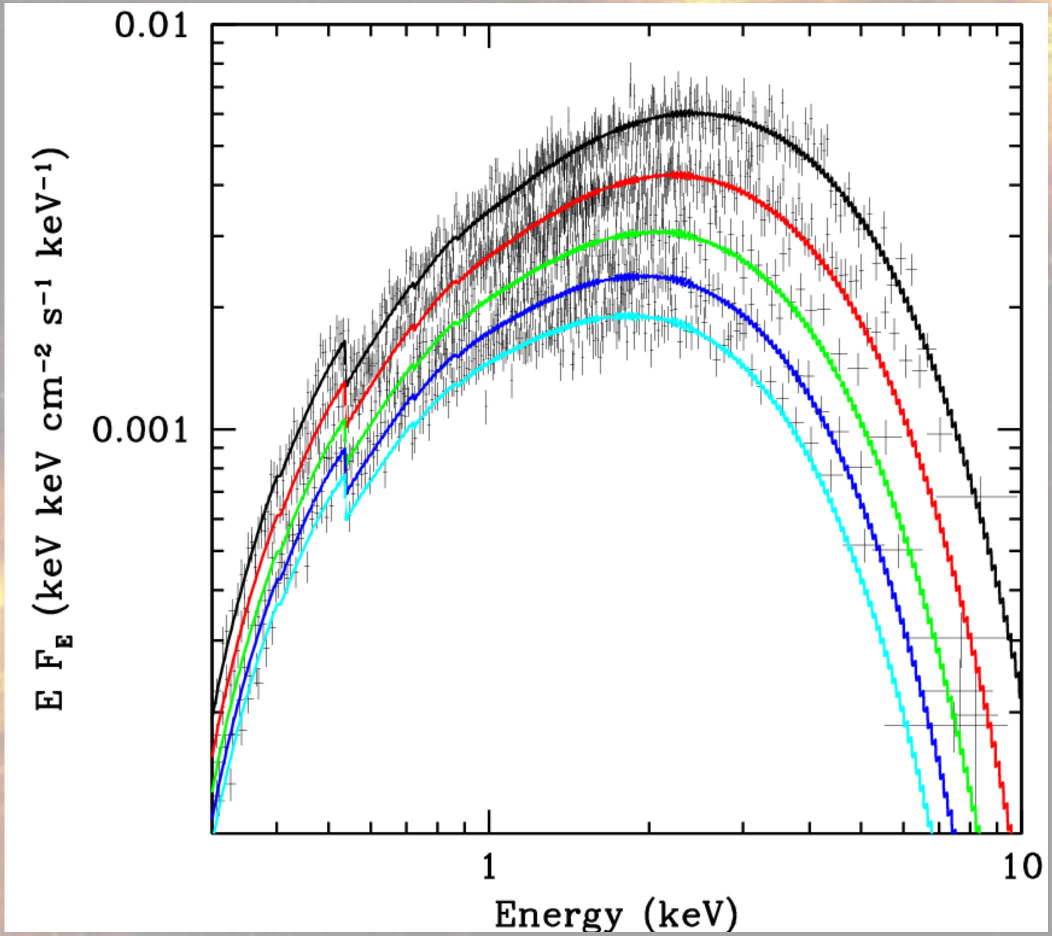


Middleton et al. 2011 in prep

efold time 30-40 days: consistent with X-ray novae (Mineshige, Yamasaki & Ishizaka 1993)

If mass of object is ~20M_{SUN} then can describe as a thin disc (BHSPEC: Shane Davis's talk) with T^4 behaviour (constant inner radius) but requires approx no intrinsic absorption.



Middleton et al. 2011 in prep

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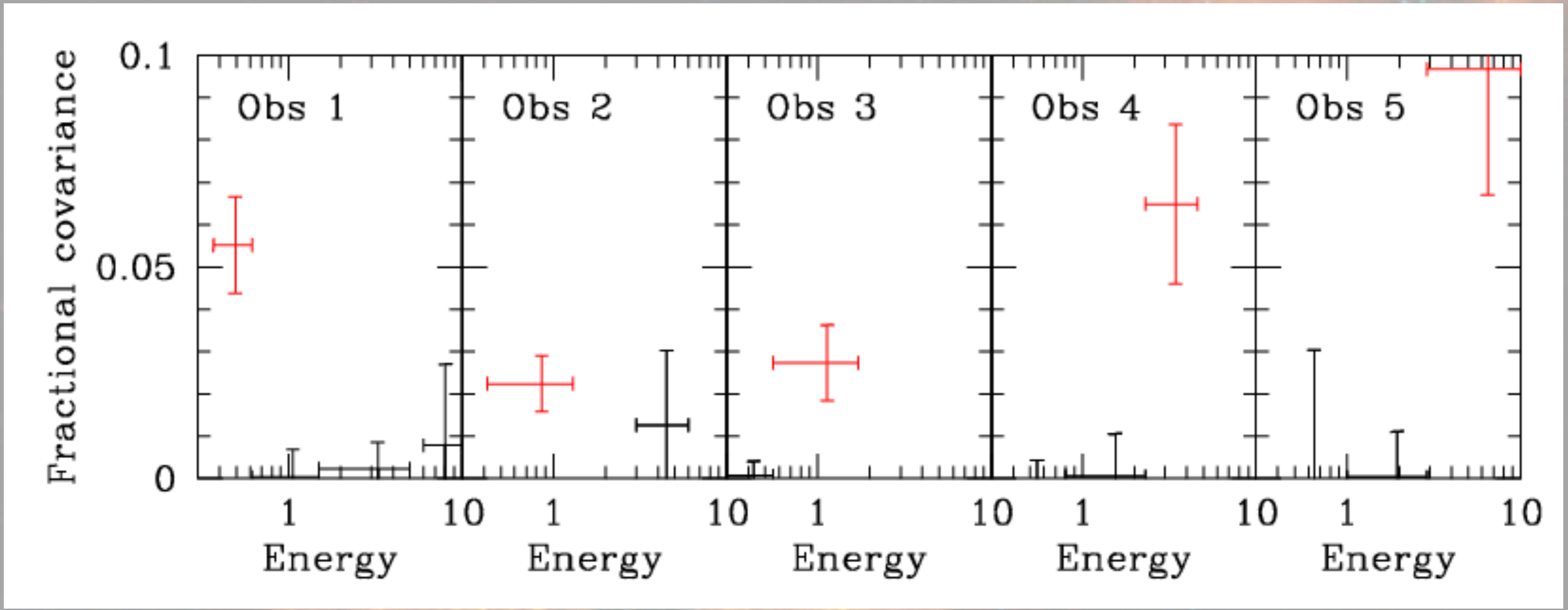

No correlated variability: how to make this in just a disc? Instability at ~Eddington that propagates inwards with dampening at all other radii? Contrived?

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Lower luminosity than NGC5408 X-1 – wind & slim disk?

$$T_{in} \propto R_{in}^{-p}$$

for a thin disc, p = 0.75, advection dominated, p=0.5

As luminosity drops, R2 should move in, disc inner edge moves inwards so hotter disc, weaker wind component

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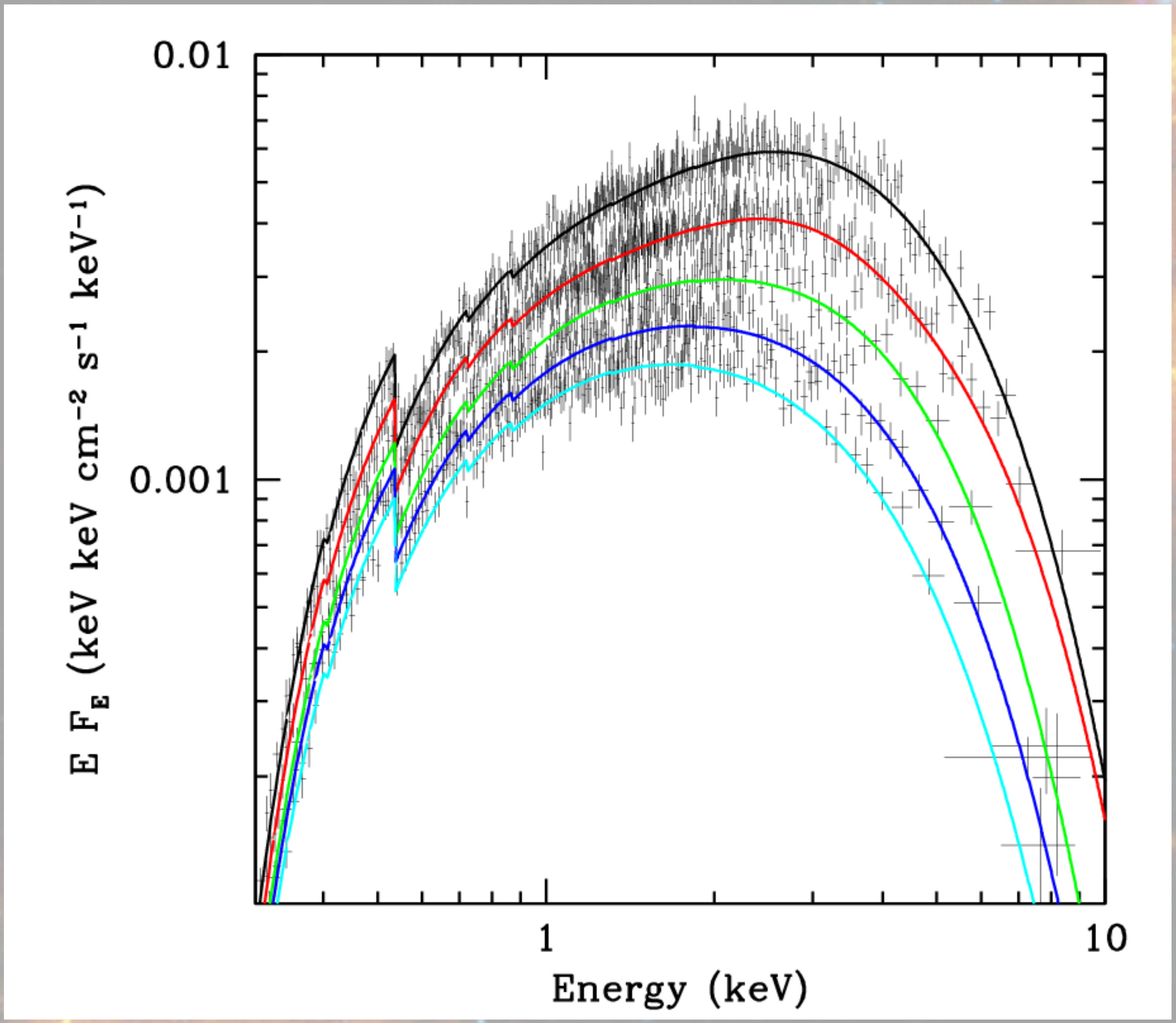

With **decreasing** luminosity the disc gets hotter and more advection dominated, the ‘wind’ component gets hotter and less important

Middleton et al. 2011 in prep

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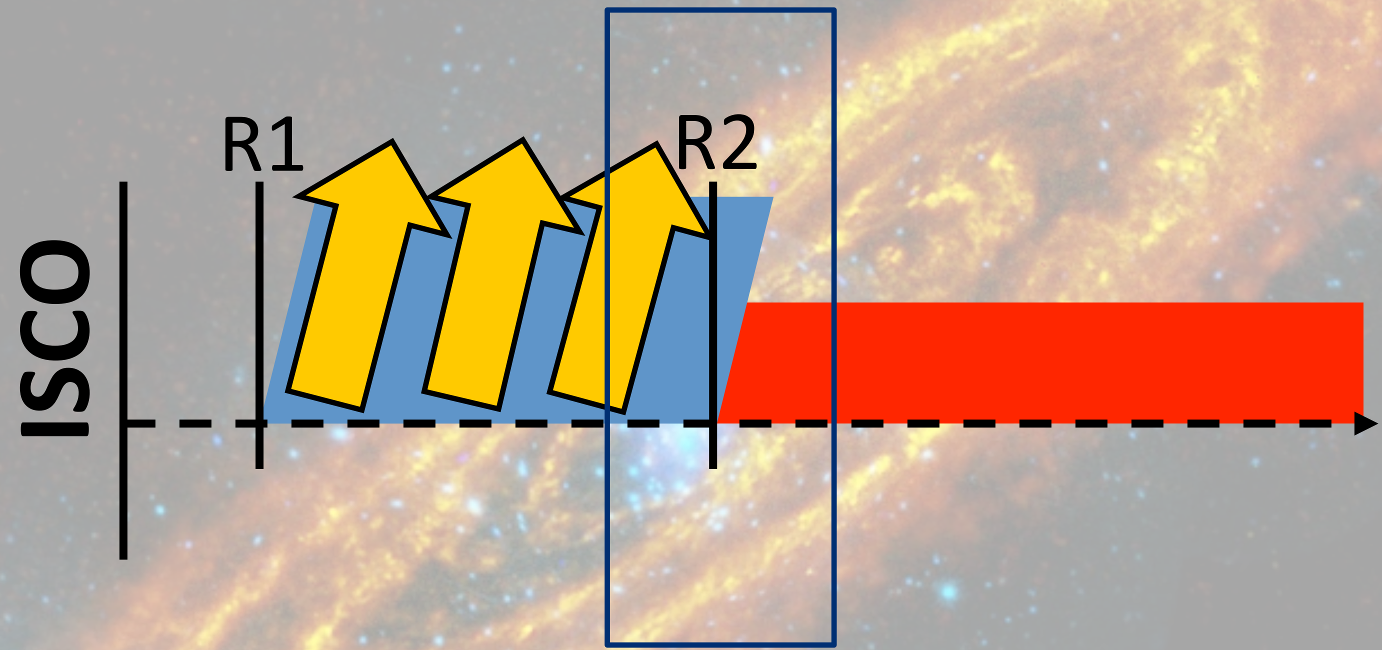

Variability at the edge of the cool disc is a possibility if the expelled wind/photosphere is strong enough and intercepts the disc in the line-of-sight? Consistent with X-ray spectral models.

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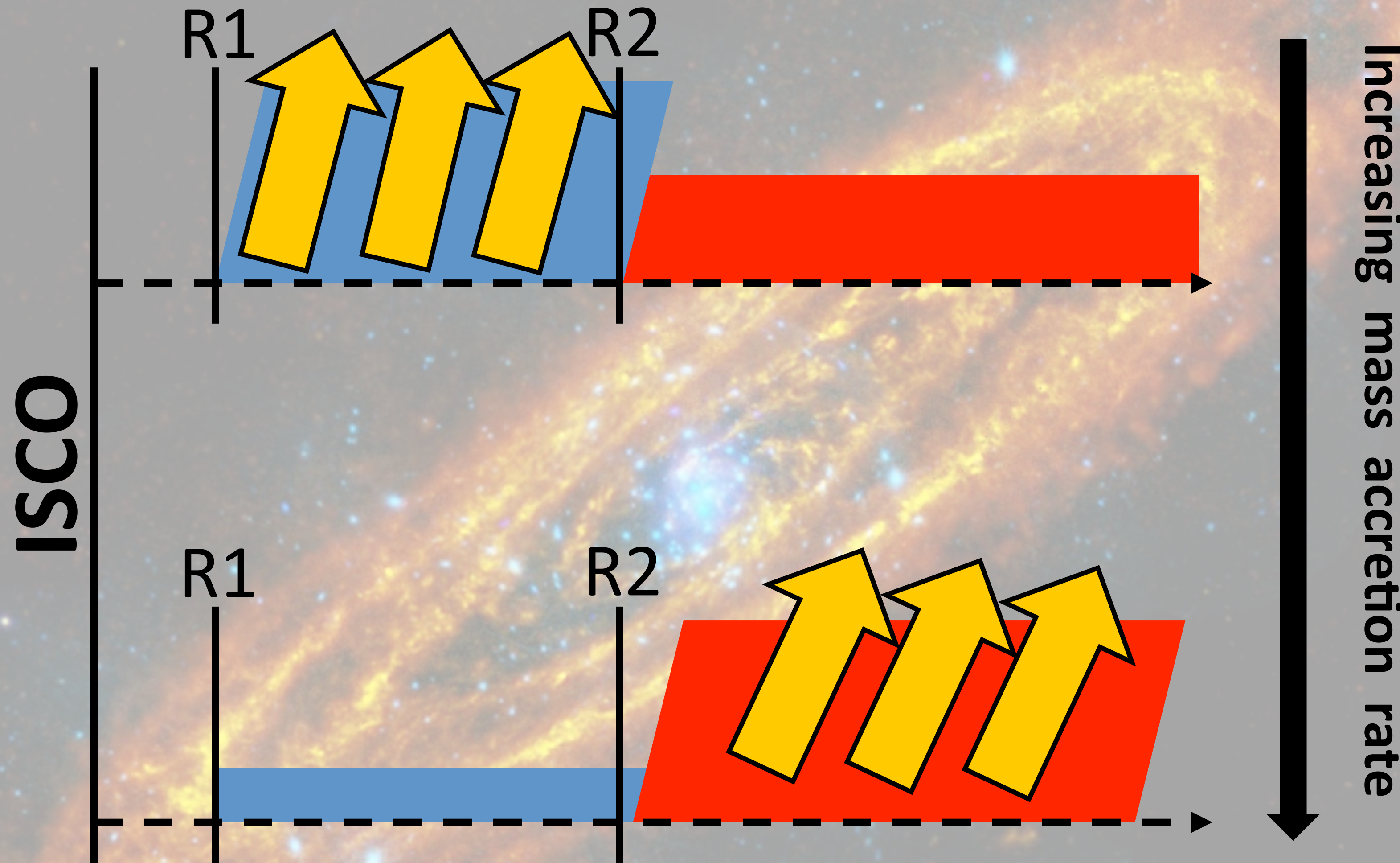

Middleton et al. 2011 in prep

Possible degeneracy in model via viewing angle.

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SUMMARY

- Sub-Eddington description probably incorrect except in the very brightest ULXs (e.g. HLX-1, Natalie Webb's talk)

- Can describe spectra using two-component wind/photosphere + deformed disc model

- Variability is therefore extrinsic – can produce linear rms-flux relation? Can also explain 'suppressed variability'.

- Can't compare PDS of XRBs/AGNs to ULXs if this is the case

- e.g. QPO in NGC5408 X-1 doesn't look like LFQPO – maybe indicative of wind mechanism characteristic frequency?

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