RXTE
and AGN X-ray Variability

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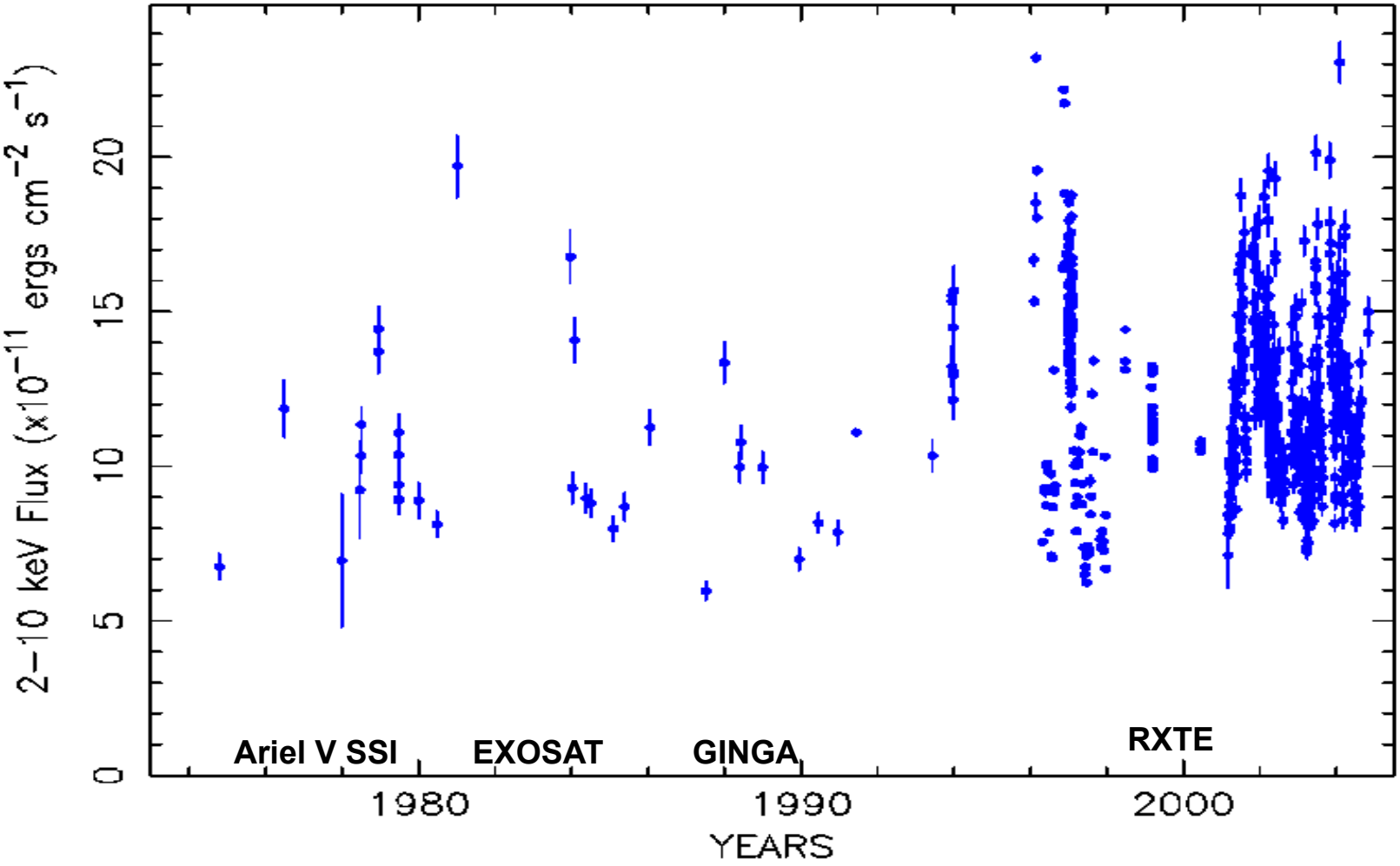
Talk Outline

1. AGN / binary `states'

2. Black Hole Timing unification

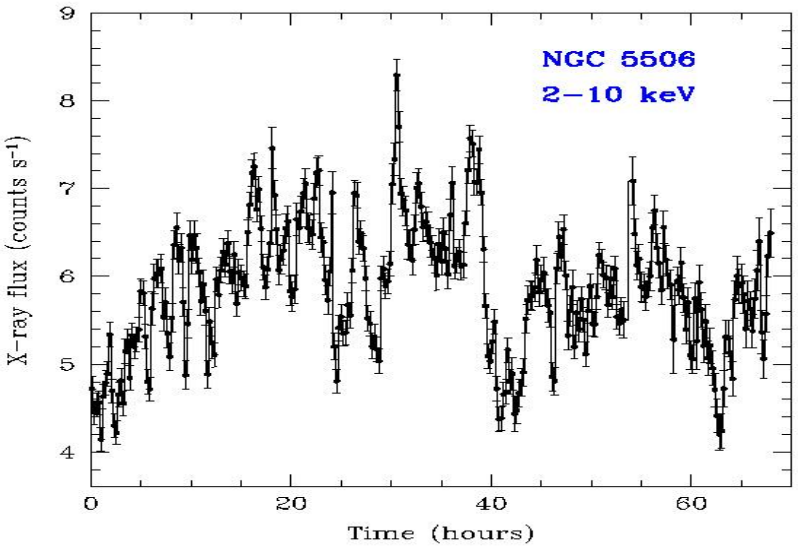
3. X-ray / optical variability

Historical lightcurves – eg 3C273



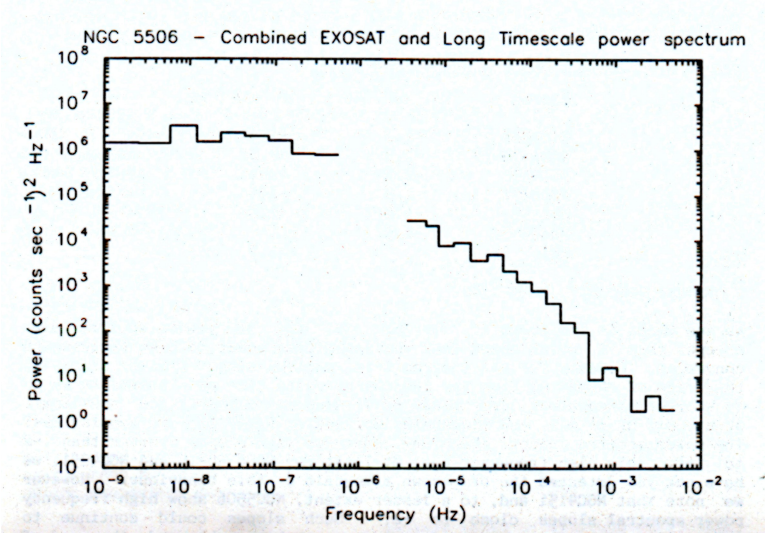
Previously, eg, Halpern 1982, Barr and Mushotzky 1986 – low luminosity, less variability

Historical Motivation – BH Masses from periodicities



- X-ray variability of Active Galaxies is `FRACTAL', or scale invariant, on short timescales

(McHardy and Czerny 1987)



- Scale invariance breaks on longer timescales.

(McHardy 1988)

- Are AGN just scaled up galactic black hole systems?

TYPICAL AGN X-RAY DATA….
Eg NGC4051 RXTE Long Timescale Observations

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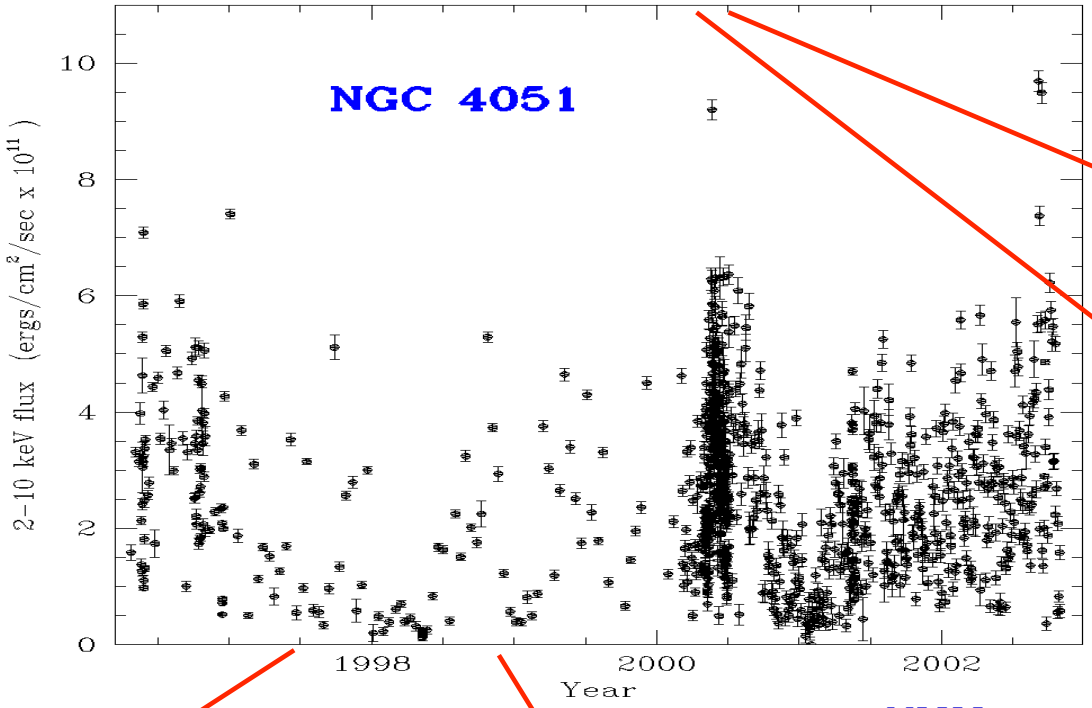
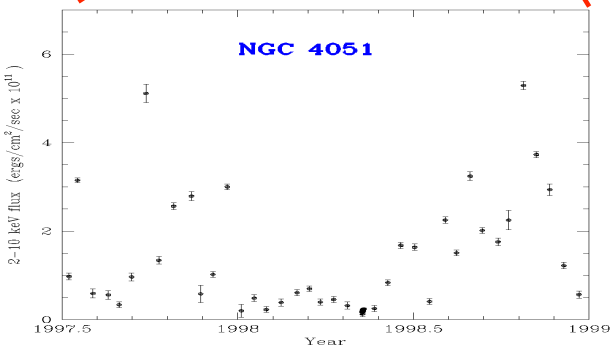
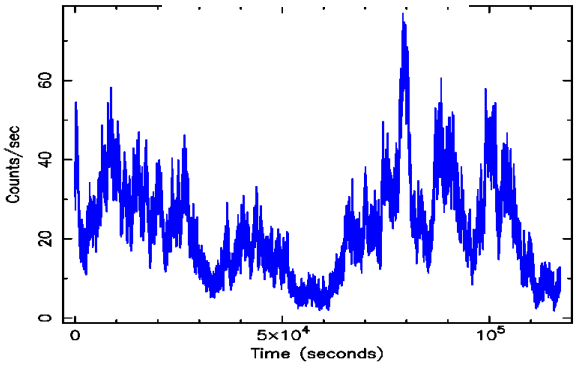
(McHardy et al 2004)

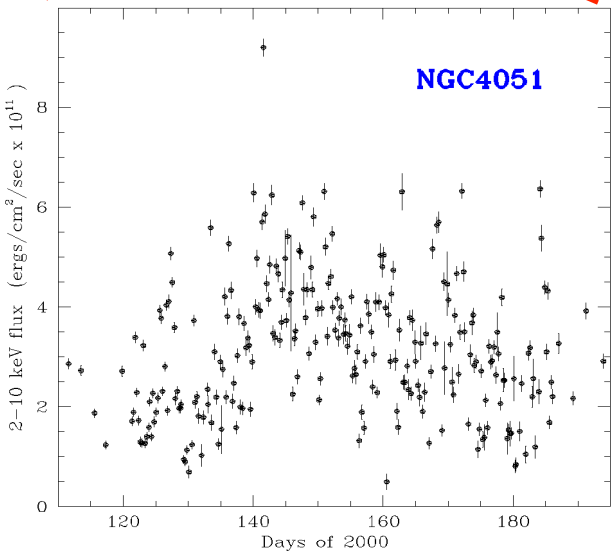


'low-flux period'



XMM

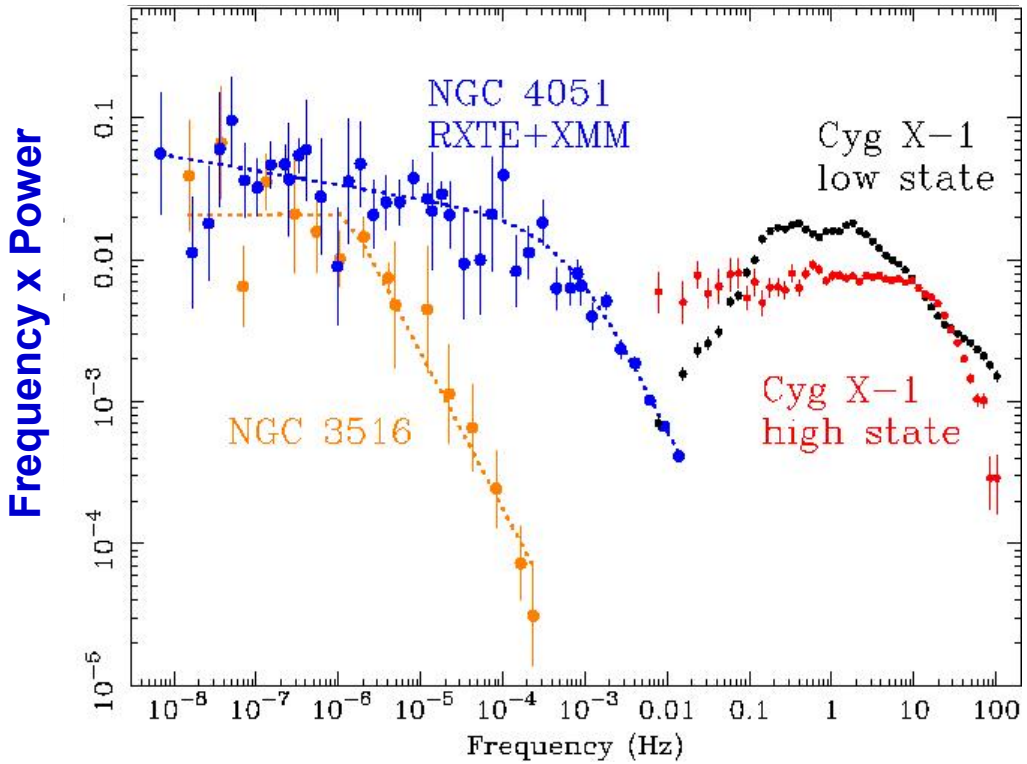




TIMING STATES

Frequency x Power

`Unfolded' Power Spectral Density (PSD)



Cyg X-1 Low-hard state PSD

•NGC4051 partly like Cyg X-1 low-hard state, but no second break

• More like high-soft state of Cyg X-1

(McHardy et al., 2004 See also, eg Edelson and Nandra 1999, Markowitz et al 2003 and others)

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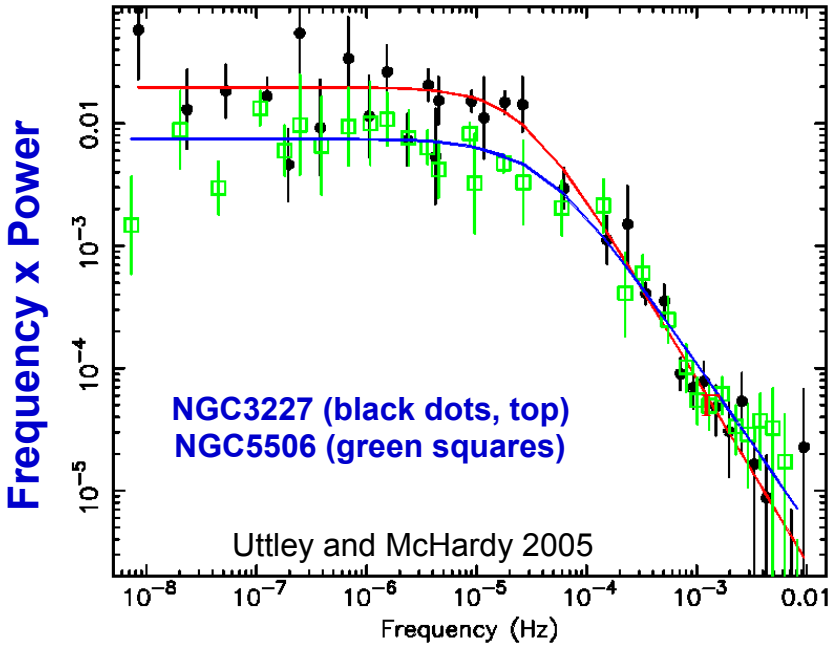
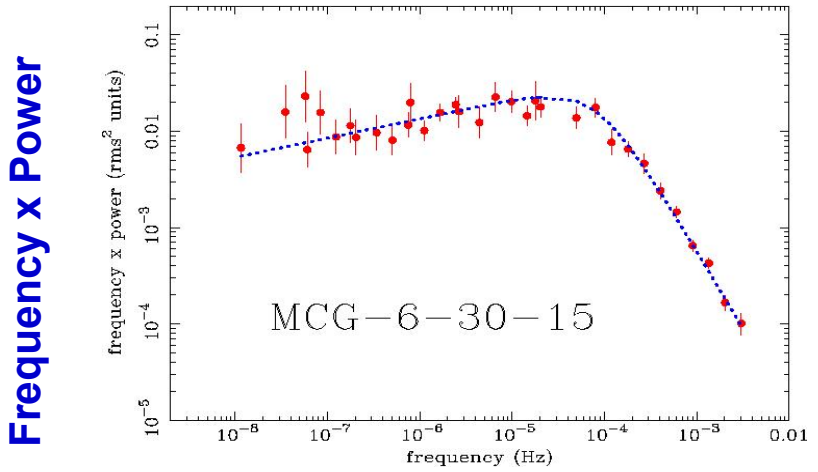
PSDs of some other AGN





Vaughan et al 2003
McHardy et al 2005

No (timing) hard states confirmed yet.

Lack of low state systems is probably a selection effect.
Present targets are X-ray bright - higher accretion rates

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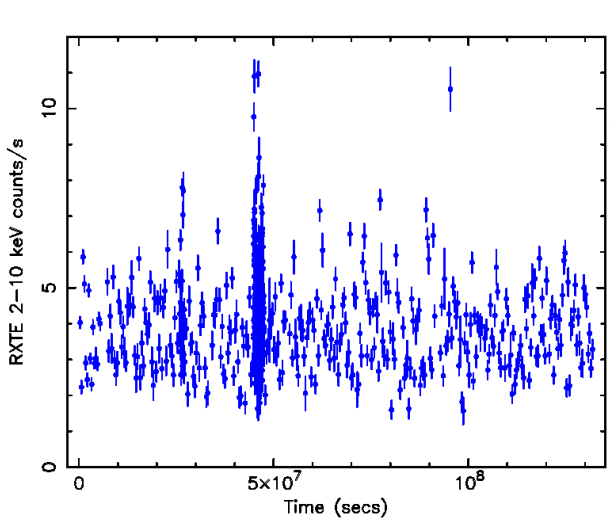
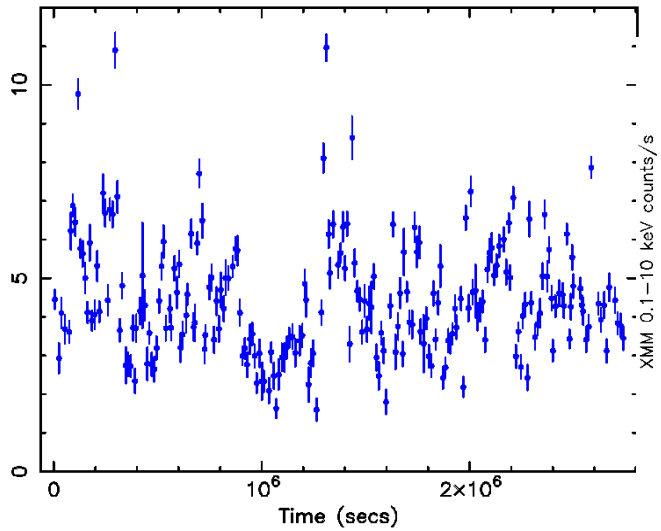
Very High State – Akn564

RXTE Observations

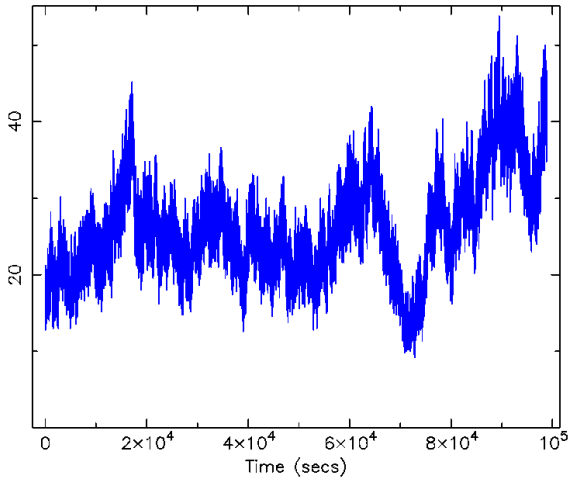


4 years



1 month

XMM Observations

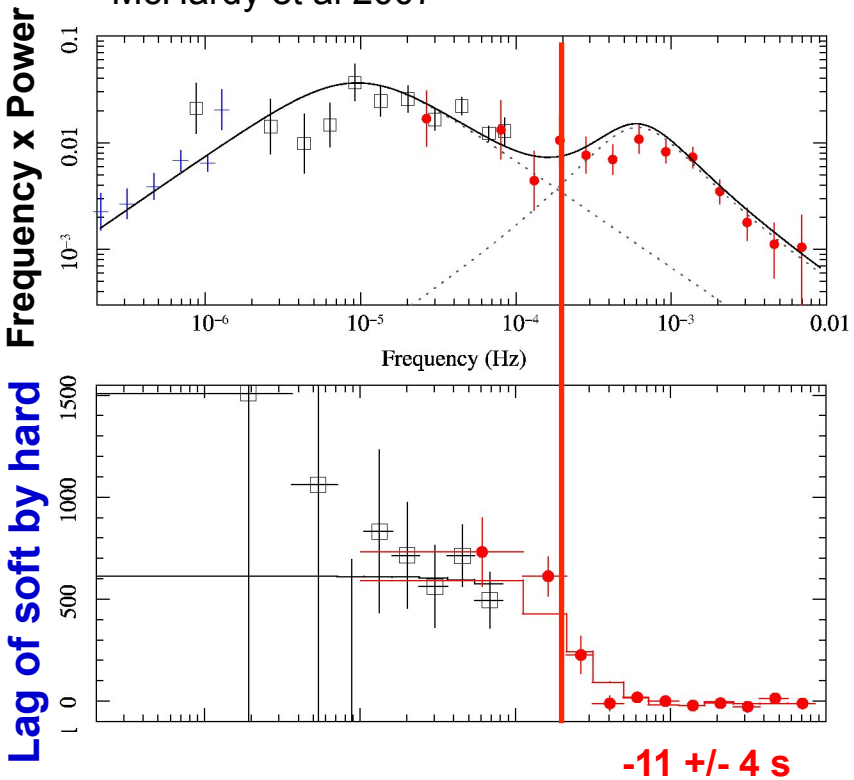


1 day

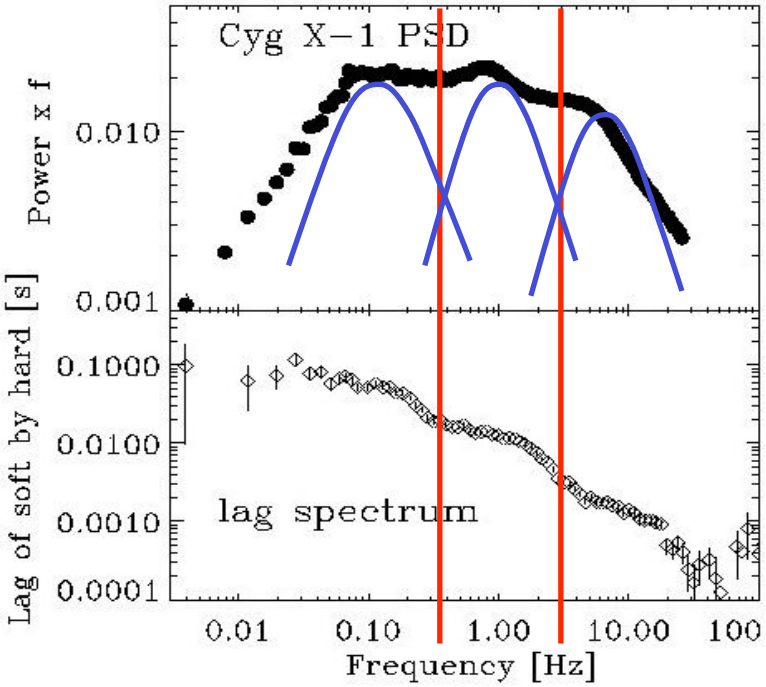
(Many papers including Pounds et al 2001; Edelson et al 2002; Papadakis et al 2002; Markowitz et al 2003; Vignali et al 2004, Arevalo et al 2006, Papadakis et al 2006)

Akn564: VHS PSD and Time Lags

McHardy et al 2007



-11 +/- 4 s
Negative at high frequency
- reprocessing

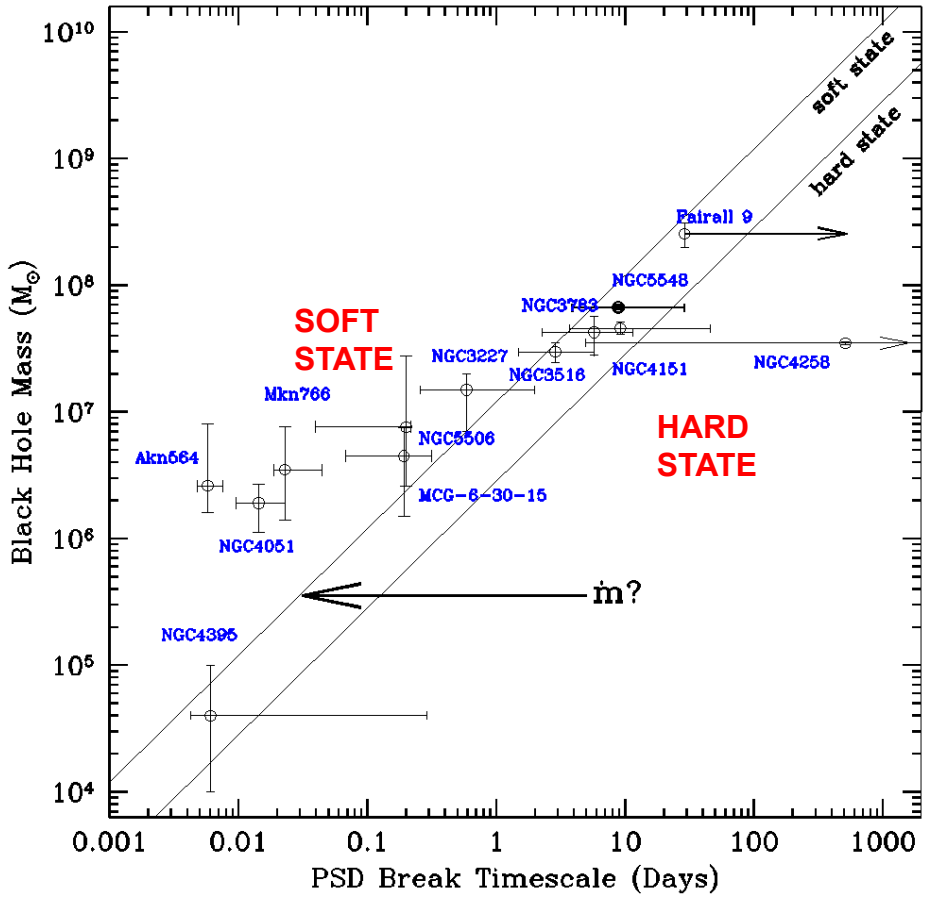


(McClintock and Remillard 2006)

Also seen in binaries in hard or VHS state

As $\dot{m}_E > 1$ implies VHS, not `hard' state for Akn564

Scaling of Characteristic Timescales: Black Hole Mass vs. PSD Break Timescale (T_B)



AGN with narrower lines and higher accretion rates have shorter T_B.

T_B associated with inner edge of disc?

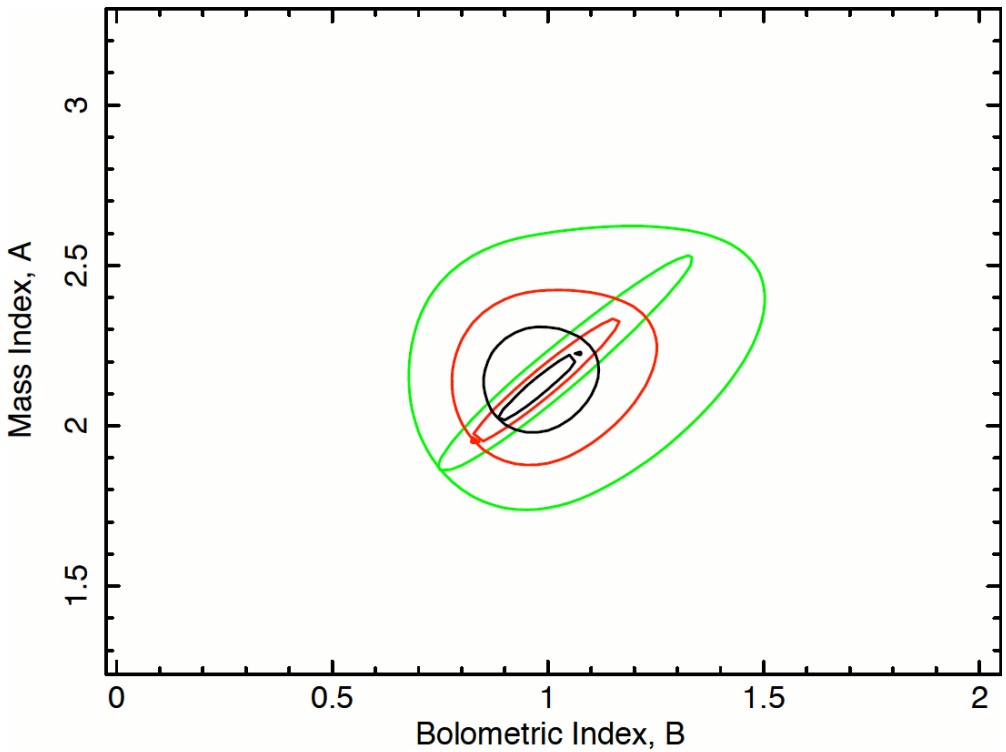
Higher accretion rate pushes in disc?

(McHardy et al 2004, 5. See also Markowitz et al 2003)

(Note rough lines of linear scaling, not fits, from Cyg X-1 in its `low-hard' and `high-soft' states)

Proper 3D fit to T_b, M, $\dot{m}_E$

(McHardy et al, 2006; Summons et al in prep)



Large contours, just to AGN (20)
(mostly soft state)

As $\dot{m}_E$ **= L_{Bol} / M**

we fit to **$T_B \sim M^A L_{Bol}^{-B}$**
-observables

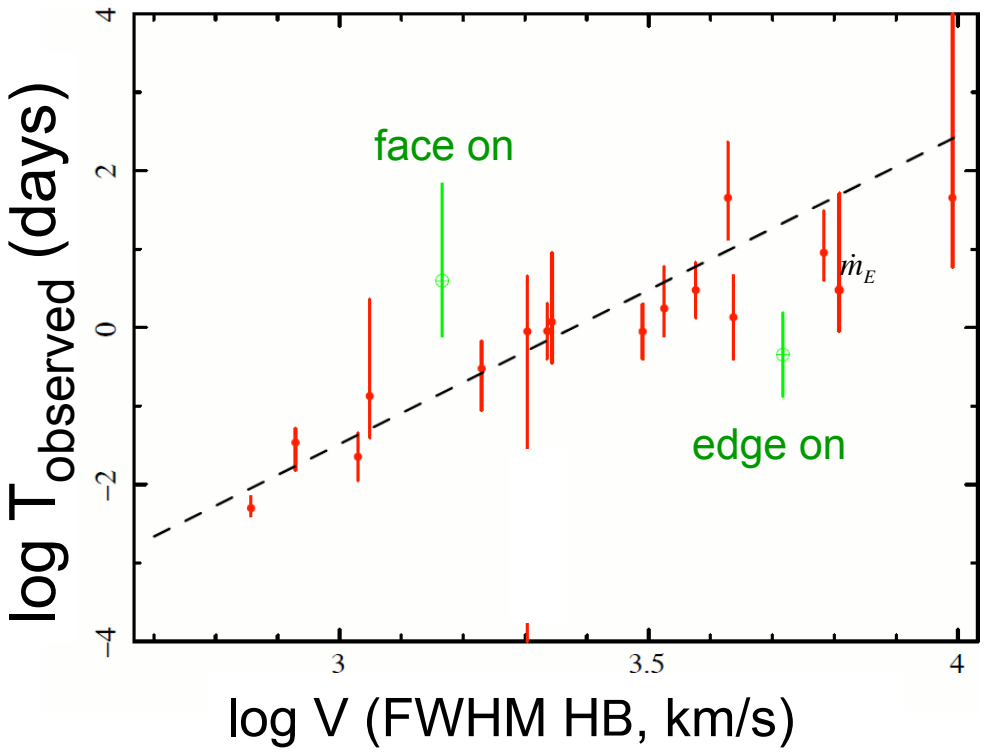
Smaller contours include soft state binaries, GRS1915+105 and Cyg X-1

AGN $T_B \sim M^{1.28} \dot{m}_E^{-0.85}$

AGN+binaries $T_B \sim M^{1.12} \dot{m}_E^{-0.98}$

AGN X-Ray Variability and Optical Linewidth

(McHardy et al, 2006; Summons et al in prep)



$T_B \sim V^{3.8 \pm 0.6}$

Simple scaling relationships:

1. $L \sim M\dot{m}_E$
2. $R_{BLR} \sim L^{0.5}$ **(LOC - Kaspi etal 1996)** Bentz etal 2006
3. $v^2 \sim GM/R_{BLR}$

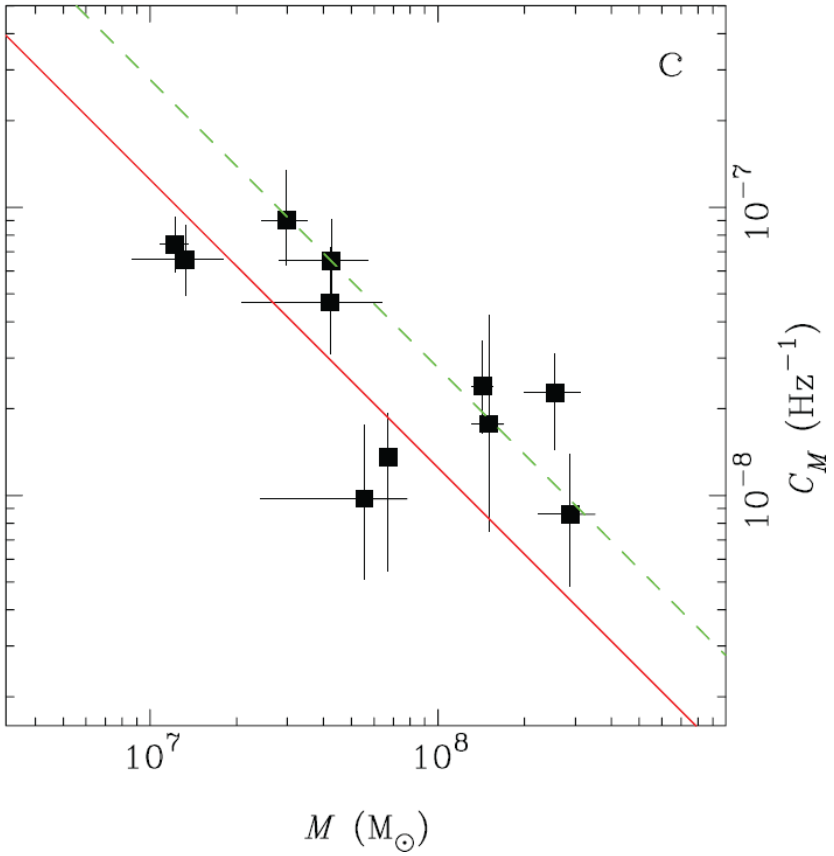
Then expect $V^4 \sim \frac{M}{\dot{m}_E}$

Consistent with $T_B \sim M / \dot{m}_E$

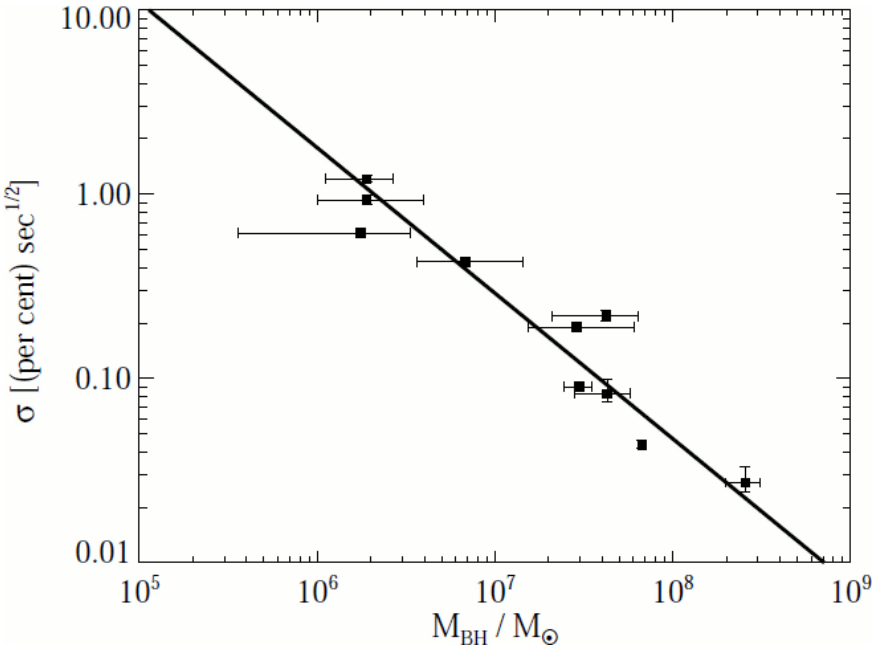
IMPLICATION: NLS1 same as other AGN but have smaller ratios of $M / \dot{m}_E$
Small masses are selection effect as $\dot{m}_E$ can't easily exceed unity

The high frequency PSD: Mass scaling

(eg McH 1988; Green et al 1993; Hayashida et al 1998; Gierlinski et al 2008; Kelly et al 2010)



Gierlinski et al 2008



Kelly et al 2010

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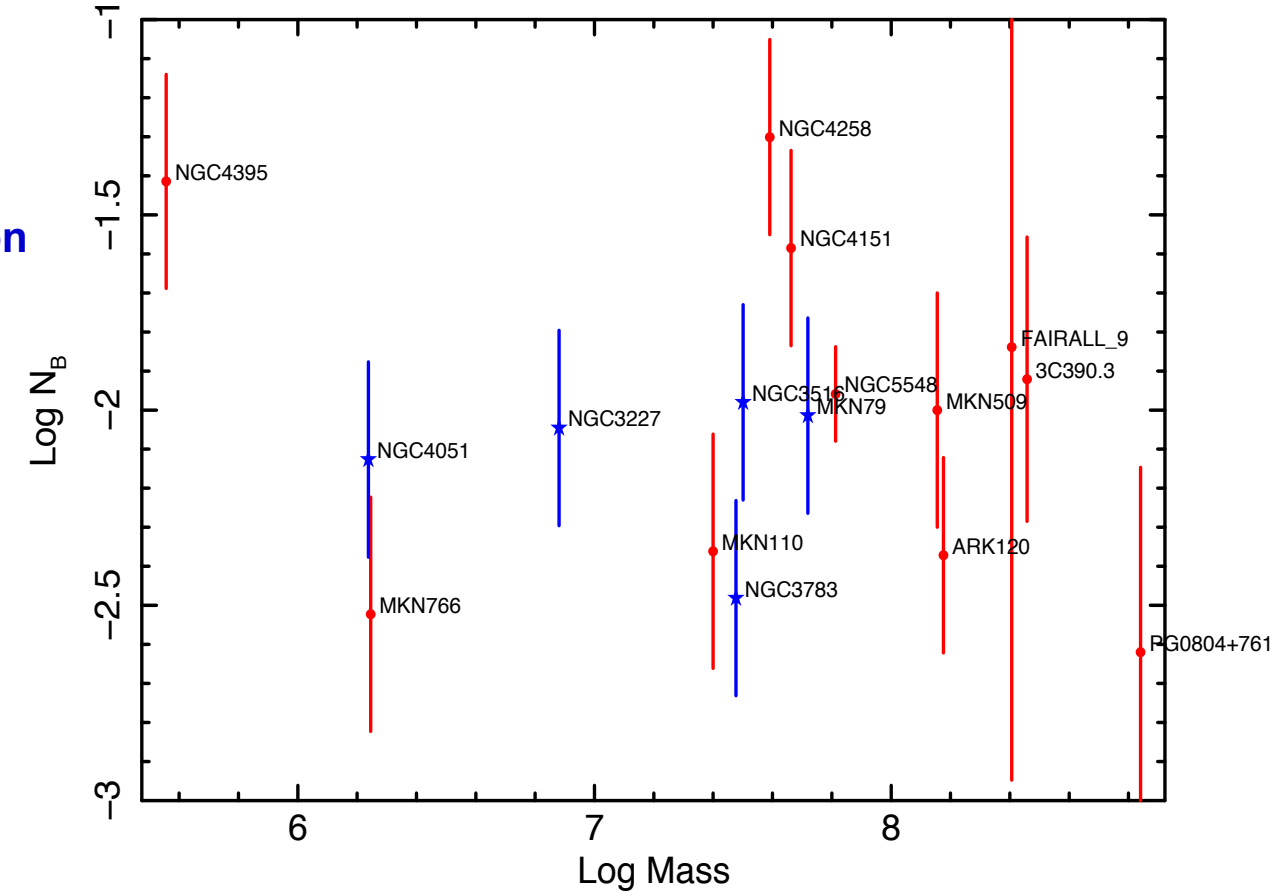
Low frequency PSD Normalisation

N_B, Normalisation at PSD bend



No mass dependence

Only radio quiet AGN with good dynamical or reverberation masses

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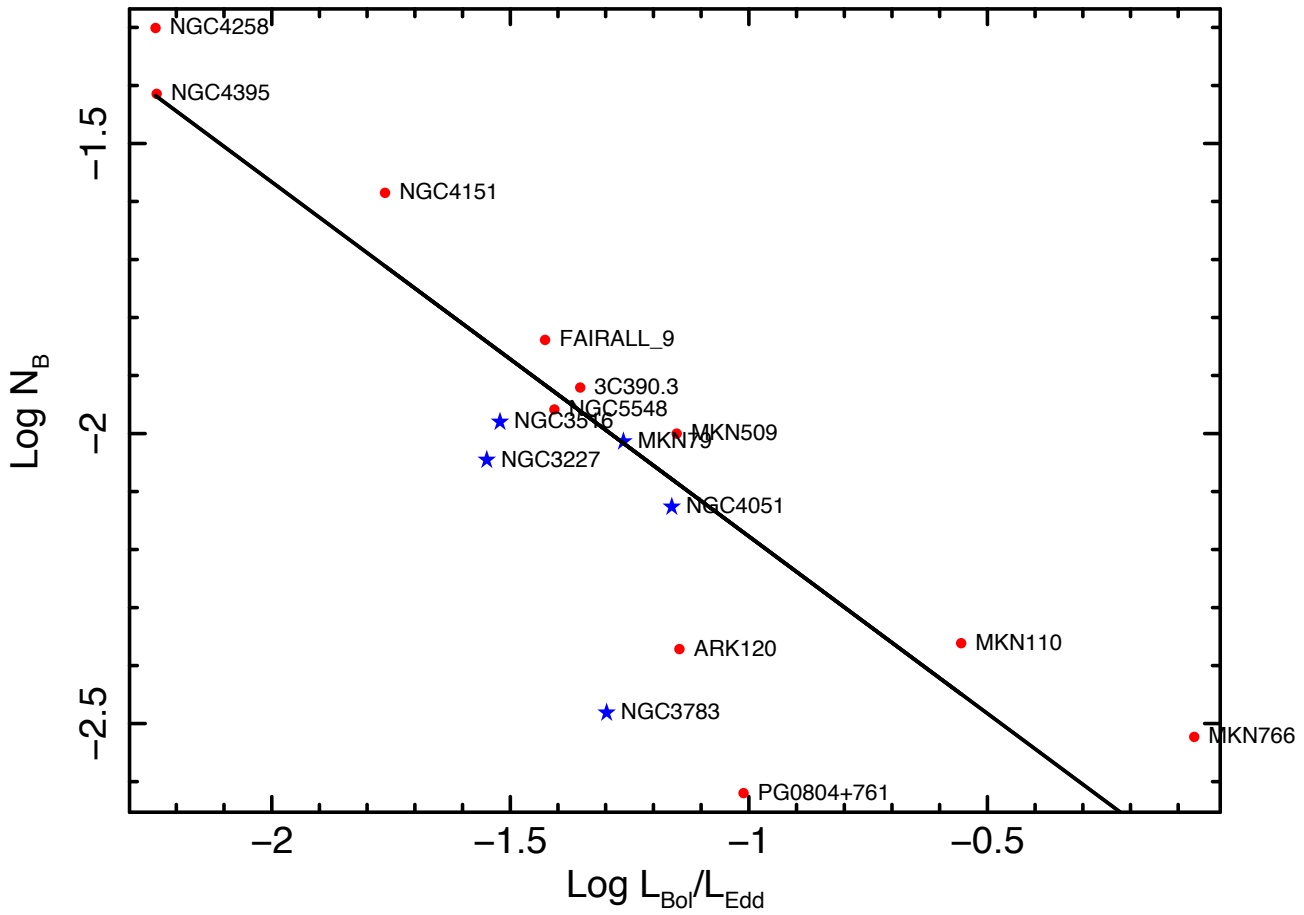
Low frequency PSD Normalisation



Inverse dependence on accretion rate

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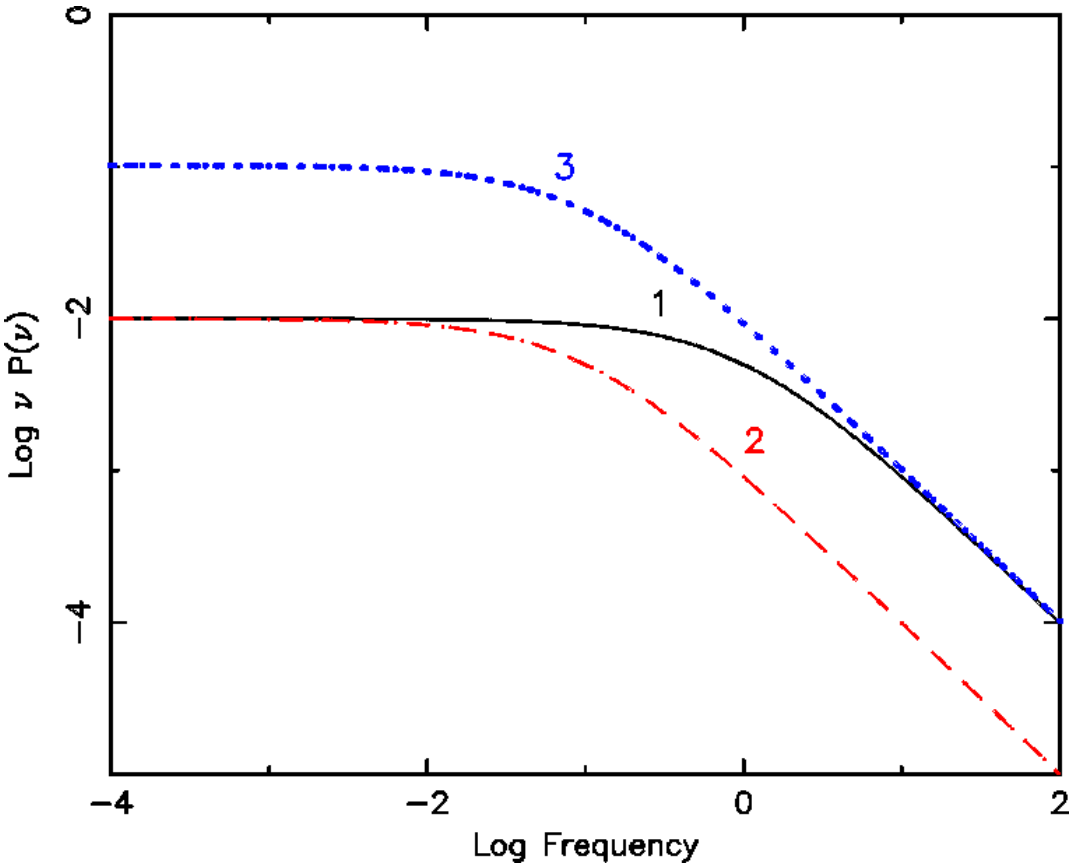
Unified Description of AGN X-ray Variability



1 and 3 have same mass, but 3 has lower accretion rate

- **higher normalisation and**
- **lower bend frequency**

1 and 2 have same accretion rate, but 2 has lower mass

- **same normalisation**
- **lower bend frequency**

(McH et al, in prep)

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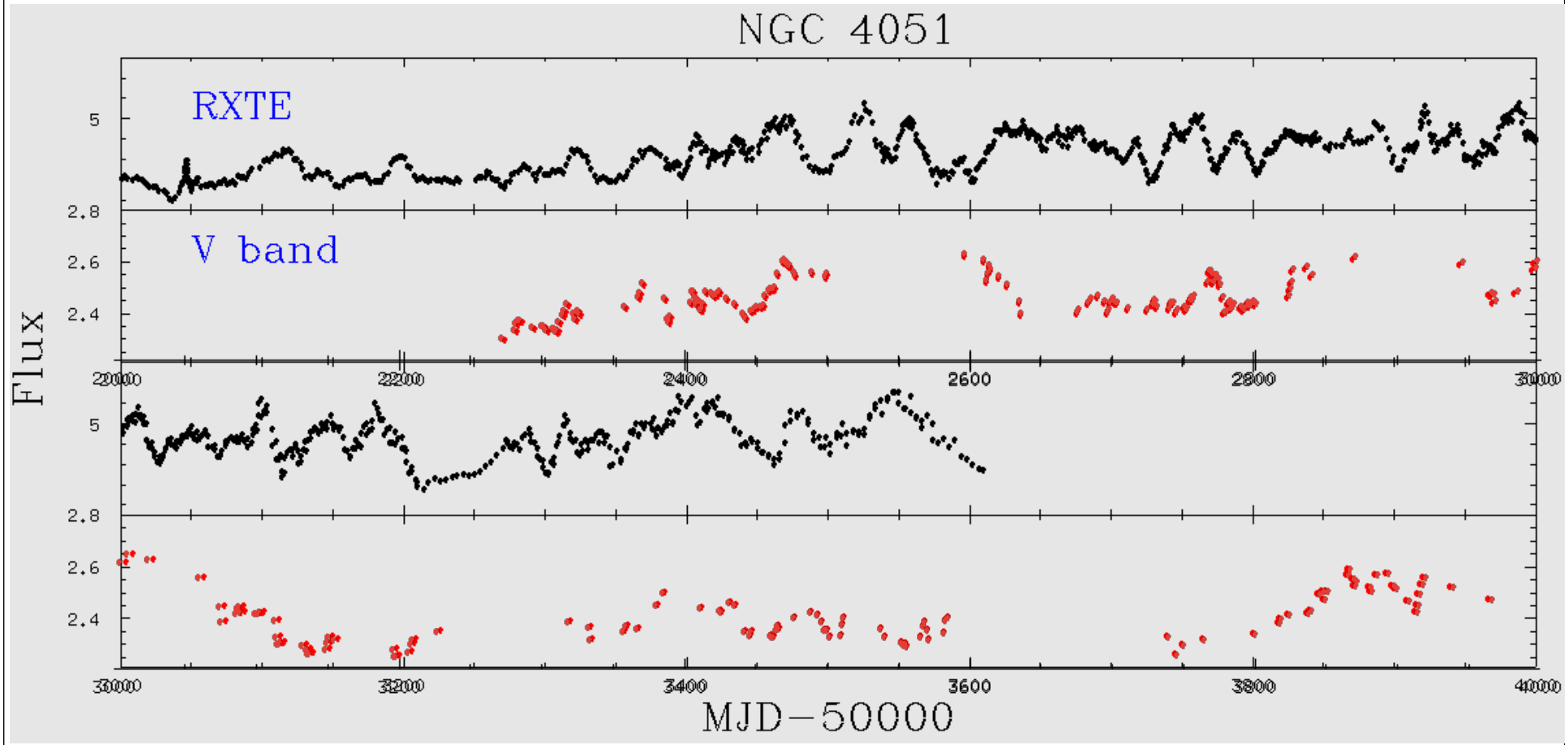
Optical Variability in AGN:
Reprocessed X-rays or intrinsic disc variability?



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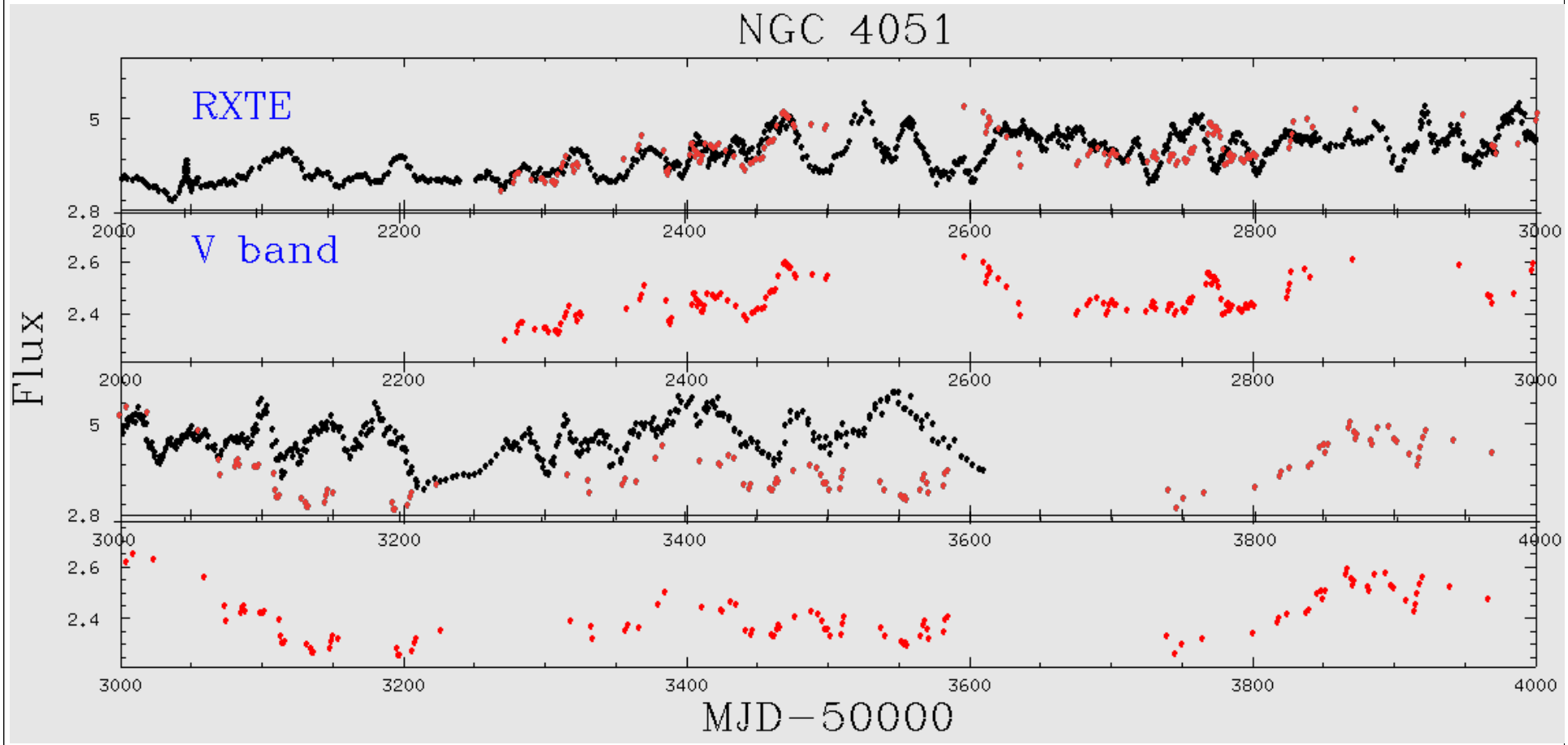
NGC 4051



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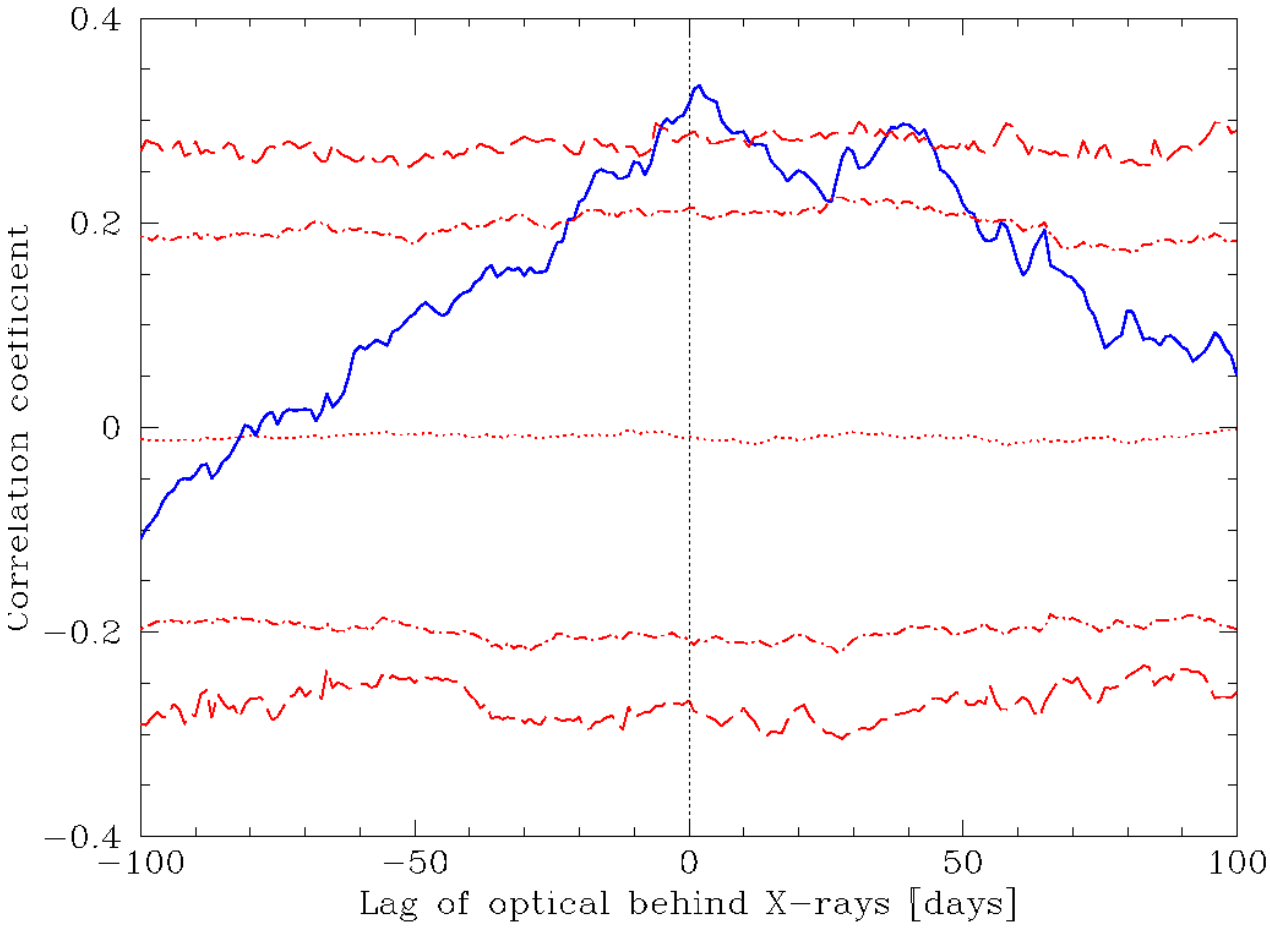
NGC4051



Optical lags by 1.5+/- 0.5 d (above 99% confidence)

Breedt et al 2010

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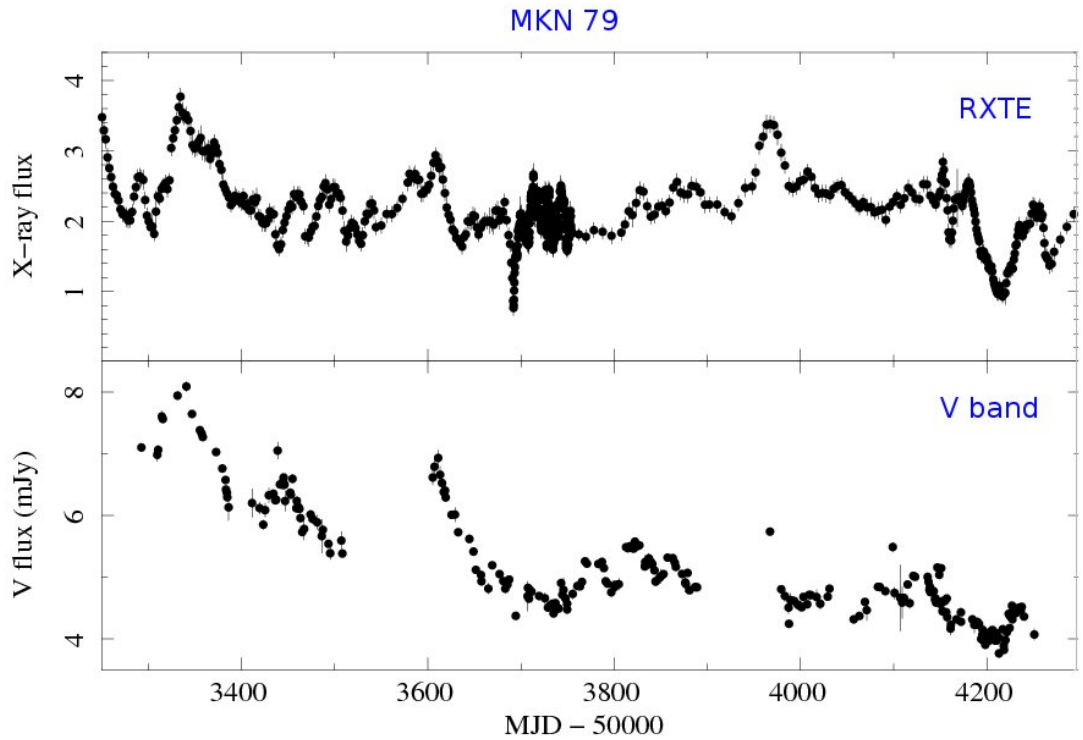
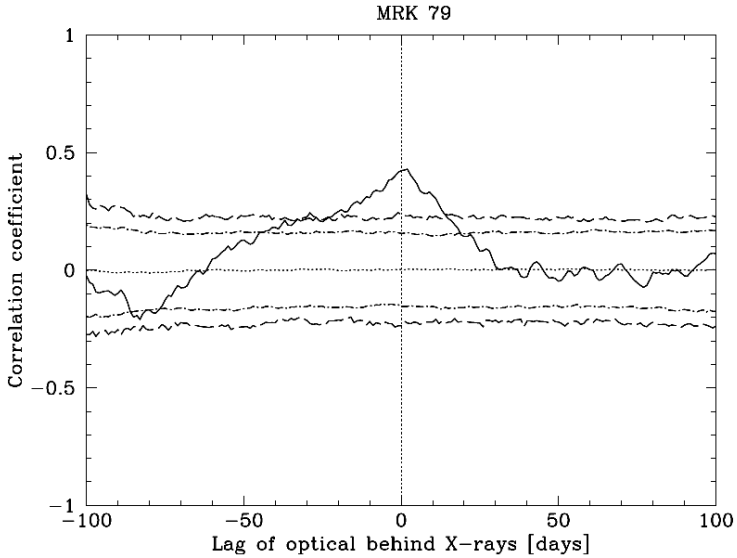
MKN 79





Short term correlation but different long term trends

Optical probably a combination of X-ray reprocessing and intrinsic disc variations (inwardly propagating fluctuations)

(Breedt et al, 2009, MNRAS)

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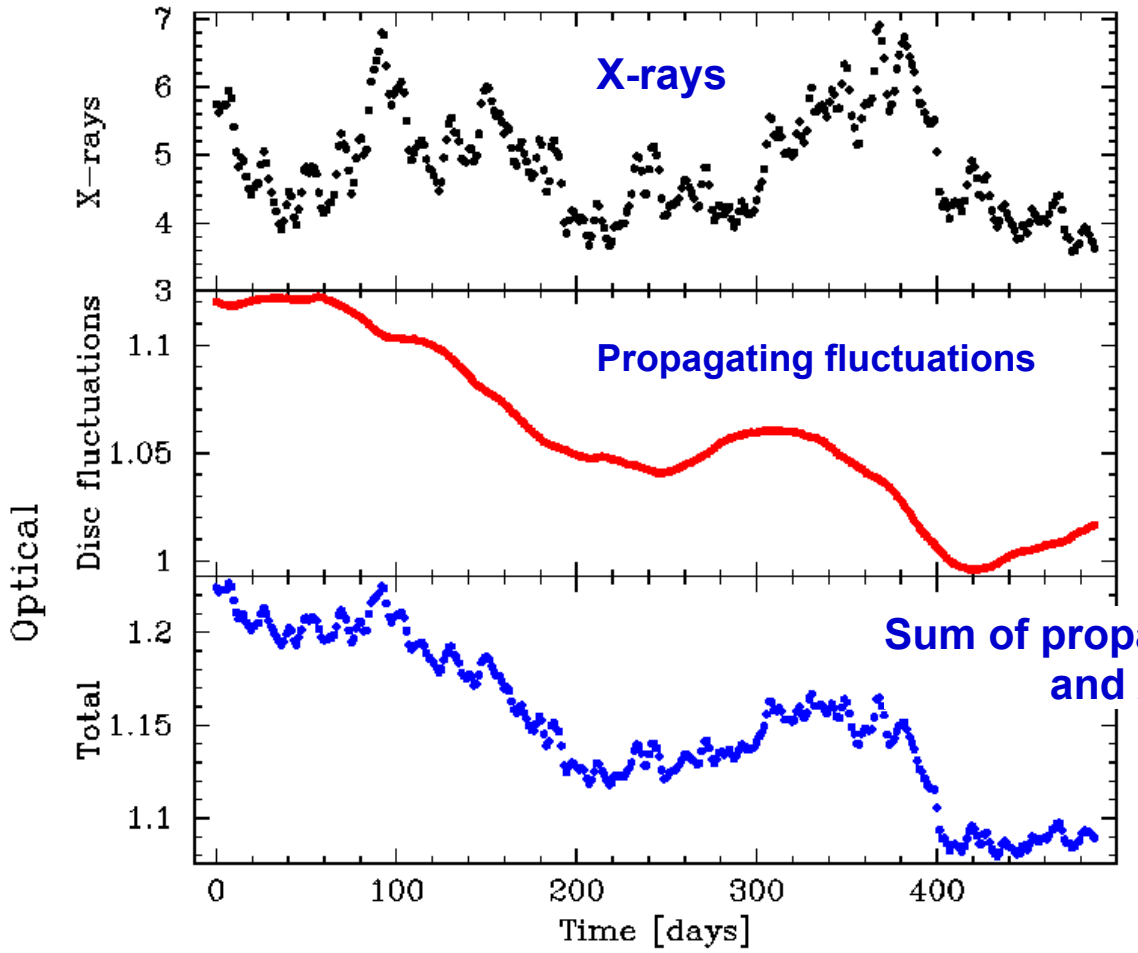
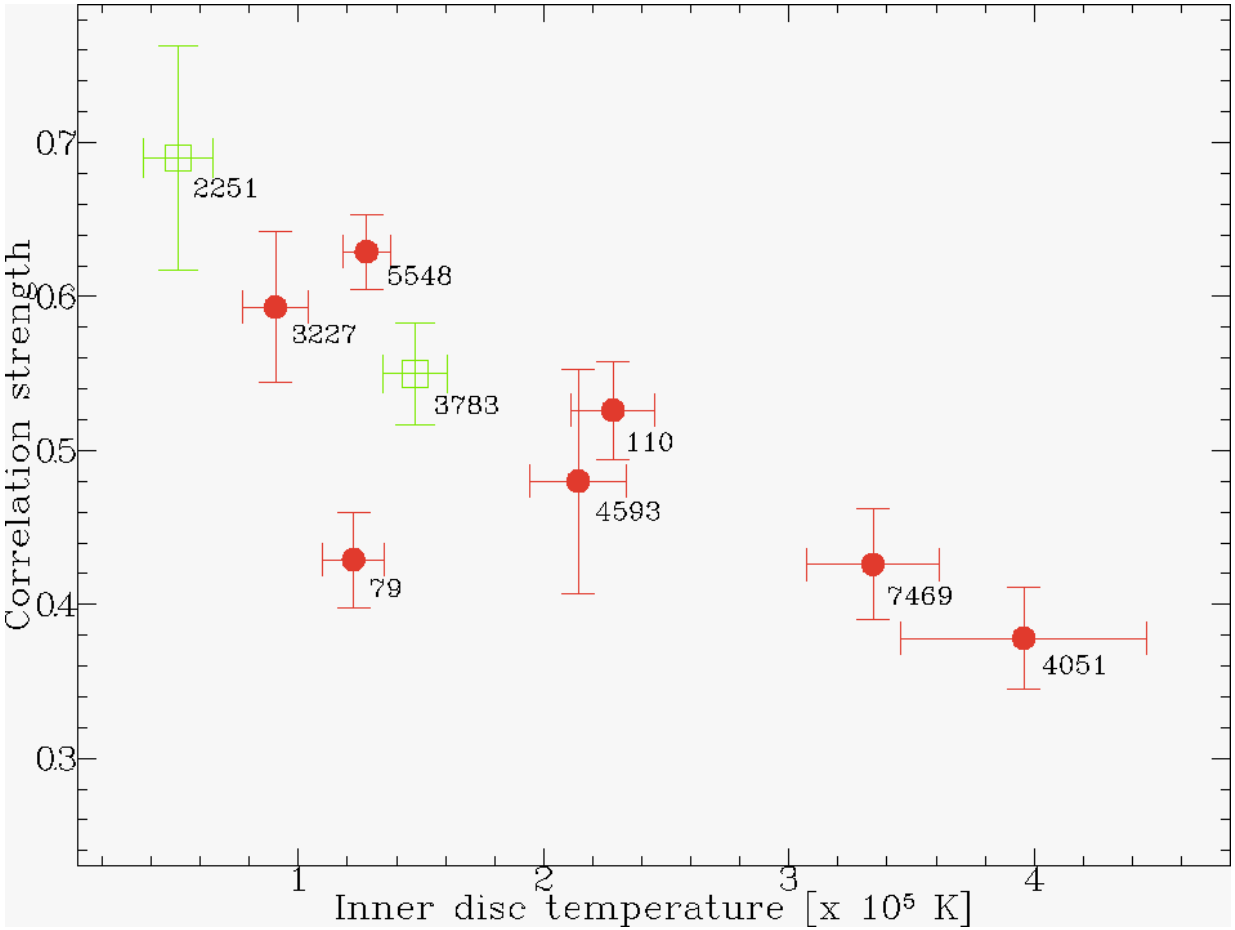
Simulated Optical Lightcurves

Propagating fluctuations plus X-ray reprocessing



(from Arevalo et al 2008)

X-ray/optical peak correlation coefficient vs. disc temperature



Optical emission region in cool disc is closer to black hole and subtends larger solid angle at X-ray source

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CONCLUSIONS

AGN probably occupy same states as GBHs, but no hard states confirmed yet.

Timing unification:
PSD bend timescale depends on M / $\dot{m}_E$
HF psd normalisation depends on M
LF psd normalisation depends inversely on $\dot{m}_E$

Short timescale optical variability in Seyferts dominated by reprocessing of X-rays - dependent on disc temperature.