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

(McHardy et al 2004)
TIMING STATES

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

( M"Hardy et al., 2004  See also, eg Edelson and Nandra 1999, Markowitz et al 2003 and others)
PSDs of some other AGN

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
Very High State – Akn564

RXTE Observations

XMM Observations

4 years

1 month

1 day

Akn564: VHS PSD and Time Lags

McHardy et al 2007

Also seen in binaries in hard or VHS state

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

(McClintock and Remillard 2006)
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?

(Note rough lines of linear scaling, not fits, from Cyg X-1 in its `low-hard' and `high-soft' states)
Proper 3D fit to $T_b$, $M$, $\dot{m}_E$

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

As $\dot{m}_E = \frac{L_{\text{Bol}}}{M}$
we fit to $T_b \sim M^A L_{\text{Bol}}^{-B}$

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 $T_b \sim M^{1.12} \dot{m}_E^{-0.98}$

(McHardy et al, 2006; Summons et al in prep)
AGN X-Ray Variability and Optical Linewidth

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

\[ T_B \sim V^{3.8 +/- 0.6} \]

Simple scaling relationships:

1. \[ L \sim M \dot{m}_E \]
2. \[ R_{BLR} \sim L^{0.5} \]
   (LOC - Kaspi et al 1996)
   Bentz et al 2006
3. \[ \nu^2 \sim GM/R_{BLR} \]

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


Gierlinski et al 2008

Kelly et al 2010
Low frequency PSD Normalisation

No mass dependence

Only radio quiet AGN with good dynamical or reverberation masses
Inverse dependence on accretion rate
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)
Optical Variability in AGN: Reprocessed X-rays or intrinsic disc variability?
Optical lags by 1.5+/- 0.5 d
(above 99% confidence)

Breedt et al 2010
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)
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
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.