X-ray and multiband variability of AGN with Swift

Ian McHardy

University of Southampton

with Tom Dwelly and Duncan Cameron (posters)
University of Southampton

and also Elme Breedt, Phil Uttley, Joey Richards
Talk Outline

Concentrating on monitoring campaigns on

- NGC4395 (low luminosity Seyfert 1 galaxy, $M_{BH} \sim 10^5 M_\odot$)
- M81 (liner/LLAGN) $\dot{m} \sim 10^{-3} \dot{m}_E$

Impossible with other observatories.

1. NGC4395 and the origin of optical variability in Seyferts

2. NGC4395 and X-ray spectral variability
   - including the surrounding absorber

3. M81 and the emission process in liners:
   - isotropic or jet?

4. Characteristic timescales in jet sources
Optical Variability in AGN: Reprocessed X-rays or intrinsic disc variability?

NGC3516, intermediate mass ($\sim 2 \times 10^7 M_\odot$) Maoz et al 2002
Hint of short timescale X-ray/optical correlation

NGC4051
(Mason et al 2003)

OM (UV) lags X-rays by \( \sim 0.2\)d
(at 85% confidence)

Low mass BH – \( 10^6 \) M\(_0\)
X-ray reprocessing model for optical variability

\[ T \propto M_{BH}^{-1/4} \dot{M}^{1/4} R^{-3/4} \]

Solid line gives fit of lags between optical bands to reprocessing model

(Cackett et al, 2006; Sergeev et al 2005,6)
Strong short term correlation but different long term trends

(Breedt et al, 2009, MNRAS)

higher mass BH – $10^{7.7} \, M_0$
On short timescales the optical always just lags the X-rays by ~day or so.
X-ray/optical peak correlation coefficient vs. black hole mass

Breedt et al (in preparation)
X-ray/optical peak correlation coefficient vs. accretion rate
X-ray/optical peak correlation coefficient vs. disc temperature

Correlation looks tighter than with mass, but is statistically very similar.

\[ T \propto M_{BH}^{-1/4} \dot{M}^{1/4} R^{-3/4} \]

Temperature correlation explained by solid angle subtended by the optical emitting region at X-ray source.
NGC4395 (~$10^5$ solar mass BH) - Swift
NGC4395 lightcurves

[Graph showing UVOT and XRT lightcurves]
SWIFT - second 4 months

XMM 130ksec
Swift: NGC4395

Blue B-band
Black 2-10 keV
Swift X-ray/B-band CCF

No measurable lag
NGC4395: Shorter timescale (hours- days)

X-RAYS

B-BAND
NGC4395: Shorter timescale (hours - days)

X-RAYS
B-BAND
NGC4395: Short timescale CCF

Very small lag < 45min
again indicating reprocessing
How does NGC4395 fit the M, T correlations?

SWIFT observations of NGC4395 shows that disc temperature controls short timescale optical variability in AGN.
UV/optical variations reasonably explained by disc temperature variations
NGC4395  X-ray Spectral Variability
- Hardness ratios

When brightest, no big changes in hardness with flux
Swift monitoring spans huge luminosity range

Strong softening of the spectrum with increasing flux.

Deep absorption features visible at lower fluxes

[Spectra scaled such that $\Gamma=2$ is flat.]
**PARTIAL COVERING**

Vary only covering fraction of cold absorber (cf Miller et al. 09)
- Terrible fit.

- Vary continuum also, almost acceptable fit P=1%

**CONSTANT ABSORBER VARYING IONISATION**

Constant absorbing column.
Vary normalisation and slope of ionising continuum.
Better fit. (P=45%)
Very hard at low luminosity.
Derived ionisation parameter consistent with luminosity
M81 - LINER

Very low accretion rate, \( \sim 10^{-3} \) Eddington,

Narrow permitted optical emission lines

Emission process - isotropic corona or jet?
M81 X-ray lightcurves
**M81 X-ray spectra**

- **X-ray spectrum HARDENS as flux increases**
- Opposite to Seyfert galaxies, but like jet sources
- Mainly a change in spectral index.
- No significant change in absorbing column. Just a small increase in ionisation parameter of the warm absorber with increasing flux.
X-ray / radio correlation

15GHz from OVRO by Richards, Pearson and Readhead
M81 X-ray/Radio relationship

Radio lags by about 60 days

In agreement with jet models (eg Markoff et al 2008)
(Only part of the W2 data: some aspect corrections to be attended to.)
M81 X-ray vs UV (w2)

Very little, if any, correlation.

Disc is probably highly truncated
Seyfert galaxies broadly follow

$$T_B \sim \frac{M}{\dot{m}_E}$$

(McHardy et al 2006)

But SgrA* (IR timescale, from jet) has a much shorter timescale.

(3C273 fits Seyferts but is also a jet source)

Do jet sources follow only a simple mass-scaling?
Combined Swift and XMM PSD

Work in progress..

Current unfolded PSD shows a bend around 1 day, but could be considerably longer within the errors. Need more data, particularly between $10^{-5}$ and $10^{-6}$ Hz.
M81 Timescale scaling

Green cross – expected position from Seyfert scaling

Red line – current estimate of timescale
Conclusions

Disc temperature is the crucial parameter which determines the strength of short-timescale optical variability in Seyferts.

Ionisation-dependent absorber variations greatly affect the observed X-ray spectrum on short timescales.

Multi-band variations (X-ray hardening with increasing flux, radio correlation and lag, very limited uv correlation) of very low accretion rate AGN M81 imply a jet origin for the radio and X-rays.

Jet systems may follow a different timing scaling relation.

Only SWIFT can carry out these important programmes!