Spectral Variability of Type 1 AGNs Observed with Suzaku

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Based on Ph.D. thesis by Hirohiko Inoue
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AGN spectral variability

Trend

**Brighter**

--> apparent spectrum becomes **softer**

Physical origin unknown

Possible origins of spectral variability:
1. pivoting (intrinsic spec. changes)
2. Two component
   - constant flat spec.
   - + variable steep spec.
3. Variable absorption along L.O.S.

**NGC 5548**

RXTE; Markowitz, Edelson, & Vaughan 2003
X-ray Spectral Components and Variability in AGNs

AGN spectral components -
- Power law, Compton reflection, Fe-K line etc.

Hard X-ray (>10 keV) essential for unambiguous interpretation of continuum and broad Fe line

Possible origins of spectral variability:
1. pivoting (intrinsic spec. changes)
2. multi component
   - constant flat spec.
   - + variable steep spec.
3. Variable absorption along L.O.S.

Broad-band & time resolved Spectroscopy with Suzaku
Broad-band Spectral Variability with Suzaku

MCG-6-30-15  Miniutti+ 07
Net exposure ~300 ks

Brighter ---> steeper spectral slope

Small amplitude at higher energies

Averaged spectrum:
- Power law + relativistic line
- Blurred reflection
Difference Spectrum

High - Low flux state

Difference spectrum: well fitted with simple power law photon index $\sim 2.1$

Only normalization of power-law varies

Reflection comp. remains constant

$$\Rightarrow \text{“Two component picture”}$$
The Sample

Type 1 AGNs in SWG and AO-1 program
Net HXD exposure ~ 70-110 ks (250 ks for MCG-6)

5 Seyfert 1s
MCG-6-30-15
MCG-5-23-16
NGC 3516
Ark 120
NGC 7314*

3 Narrow-line Seyfert 1s
NGC 4051
PG1211+143*
1H0707-495*

3/8 (*): ver. 1 HXD PIN no detection
see Yaqoob+ poster
Light Curves

NGC 4051

NGC 7314

NGC 3516

Ark 120

$10^5$ sec
Difference Spectra

6/8 objects: Difference spectrum well represented by a simple power law.

Photon indices agree with observed in mean spec.

2/8: Curvature in difference spectrum (variable absorbed power law)
Two Component Model Fits

Power-law + reflection continuum + Fe line

Simultaneous fits to high/low flux spectra

Common parameters except for normalization of power law

----> excellent fit

Typical limits on variability

\[ \Delta \Gamma < 0.1 \]

\[ \Delta \text{Fe intensity} < 10\% \]

\[ \Delta \text{reflection cont.} < 40-100\% \]

Two Component behavior (6/8 obj.)

Variable power law + constant reflection on time scales of ~ day
Is There Fe-K line from Inner Part of Accretion Disk?

- **Suzaku examples**
  - Taken from papers
  - Ark 120 fig and parameters
  - Short term variability + broad line
  - support high/soft analogy
  - N.B. Rin ~ 3 does not necessarily required
  - Nandra+07 results --- w/ much better data.
Fe-K line: Short-term Variability

MCG-5-23-16
Fe-K line profile: Variable in ~ a few 10 ksec

Do not simply follow continuum variation
--> variability NOT significant in spectra averaged over high/low flux states

Monte carlo simulation --- significant at > 99.9% conf.
Fe-K line: Short-term Variability

20 - 30 ksec slices; Suzaku

Many more detections in ASCA/Chandra/XMM Observations.

Fe-K line varies on time scales <30 ksec

At least part of Fe-line should come from inner part of accretion disk

Spectral fits to time averaged spectra:

- broad : narrow
  \[ \sim 100 \text{ eV} : 70 \text{ eV} \]
  \[ \sim 1 : 0.7 \]
  (on average)

Detailed number depends on obj.,.
Decomposing Distant and Inner Matter

- Spectral fits to averaged spectra
- Fe line (narrow Gaussian + Disk line)
Summary: Origin of Constant and Variable Components

(1) AGN variability (~ day) … "Two component model"
Variable power law + constant reflection
((photon index remains nearly constant)
(cf. MCG-6: Extremely small contribution from distant matter)

(2) Fe-K line varies (~a few 10 ksec)
(Fe-K line: intensity & profile do NOT simply follow continuum as suggested by many previous obs.)

(3) Broad & narrow components contribute to Fe-K nearly equal amount

See Nandra+07; poster using XMM spectra.
Summary

- AGN spectral variability:
  - Variable power law + constant reflection
    (~day average) (+ Variable absorption)
  - + Variable reflection (Fe-K)
    (< 30 ksec)
- Both distant matter and Inner disk contribute to reflection/Fe-K