Investigating the Fast X-ray Variability of a NLS1 with XMM-Newton and NuSTAR

Unveiling the Physics Behind Extreme AGN Variability
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Overview

Motivation:
- Case study to probe extremes of AGN X-ray variability
- Informing longer-wavelength studies of CLAGN
X-ray Spectral Components of AGN

Power-law continuum ($\Gamma \sim 2$)

Strong Soft Excess (below 2 keV)

Iron Line Profile (6-7 keV)
- Narrow line - fluorescence from outer disk/torus
- Broad iron - smeared reflection from inner disk

Compton hump (10-80 keV)

Ricci 2011

Background Spectral Analysis Timing Analysis Conclusions
Absorption & intrinsic variability interplay

Example: NGC 1365 (Walton 2014)

**Background**

**Spectral Analysis**

Example: NGC 1365

- **XMM:** 0.3-10 keV
- **NuSTAR:** 10-80 keV

**Timing Analysis**

**Conclusions**
Case Study: 1H1934-063

- Bright and highly variable AGN (CAIXA, Ponti 2015)
- Radio-quiet (Condon 1998)
- NLS1 (Nagao 2001)
- $z=0.0102$ (Rodriguez 2007)
- $M_{\text{BH}}=3\times10^6 M_\odot$ (Malizia 2008)

- ~120 ks concurrent XMM-Newton EPIC PN and NuSTAR observation
- $L_{0.5-10\text{ keV}} = 9.2\times10^{42}$ ergs/s
- $F_{2-10\text{ keV}} = 2.2\times10^{-11}$ ergs cm$^{-2}$ s$^{-1}$
Case Study: 1H1934-063

- Bright and highly variable AGN (CAIXA, Ponti 2015)
- Radio-quiet (Condon 1998)
- NLS1 (Nagao 2001)
- $z=0.0102$ (Rodriguez 2007)
- $M_{BH}=3 \times 10^{6} M_{\odot}$ from $H_{\alpha}$ FWHM (Malizia 2008)

What causes extreme variability in this source?
Does it fit with expectations from other well-studied Seyfert 1s?
Possible Causes

- Line of sight obscuration
  - Clumpy torus
  - BLR clouds
- Intrinsic variability
  - Weak radio jet activity
  - “Crashing” X-ray corona
Counts s$^{-1}$

● Line of sight obscuration
○ Compton-thick absorption?
○ Clumpy torus
○ BLR clouds

● Intrinsic variability
○ Weak radio jet activity
○ "Crashing" X-ray emitter

Hypothesis

Compton-thick absorption is disfavored

➤ Change is intrinsic to X-ray emitter
Pivoting of power law continuum, confirmed with spectral fitting
Narrowing accompanied by continuum increase/ hardening (Baldwin 1977, Iwasawa & Taniguchi 1993)
Evidence from X-ray Spectroscopy

- Model: Galactic absorption*(relativistically broadened reflection+cutoff power law)
- Inclination $\sim 40^\circ$
- $a < 0.4$
- $h_{\text{corona}} \sim 2.5 - 4.5 r_G$
Timing Analysis
X-ray Reverberation Studies

- Long-timescale lag
  - XRB Cygnus X-1 (Miyamoto 1988)
  - interpreted as propagating fluctuations

- Short-timescale Reverberation lag
  - First robustly observed in 1H0707-495 (Fabian 2009)
  - Negative by convention

Background  Spectral Analysis  Timing Analysis  Conclusions
Lag Analysis of XMM-Newton data

- Soft Lag $\sim 20$ s $\Rightarrow h_{\text{max}} \sim 6.7$ r$_{G}$
- Hard Lag $\sim 293$ s
Lag Analysis of XMM-Newton data

**Background**

- **Hard Lag**
- **Soft Lag**

**Evidence of Iron**

- **Kα Line**
- **Reverberation**

**Spectral Analysis**

- **1H1934-063**

**Timing Analysis**

- **Ark 564**
- **Kara 2013**

**Conclusions**

- **Uttley 2014**
Summary

- This is the first X-ray spectral analysis of 1H1934-063
  - Reflection dominated spectrum, highly variable
- Fe K reverberation lag in the lag energy spectrum obtained by comparing the time lag between hard and soft emission (1/∼20 discovered)
- Decrease in flux during observation due to change in X-ray corona, not transient absorption event

Future Work

- What is the relationship between fast X-ray variability and Optical-UV BLR variability in CLAGN?

Still not many time lags measured, high SNR case study is important!
References


Extra Slides
Lag Analysis of XMM-Newton data

Background

Timing Analysis

Spectral Analysis

Lags during low flux state appear to move to lower frequencies

Evidence of Broad Iron Line Reverberation

- Soft Lag $\sim 20$ s $\Rightarrow h_{\text{max}} \sim 6.7 \, r_G$
- Hard Lag $\sim 293$ s

Preliminary