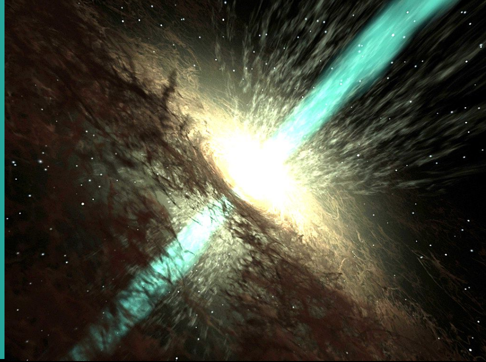
Investigating the Fast X-ray Variability of a NLS1 with XMM-Newton and NuSTAR



Unveiling the Physics Behind Extreme AGN Variability

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Overview

Background → Spectral Analysis → Timing Analysis → Conclusions

Motivation:

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

X-ray Spectral Components of AGN

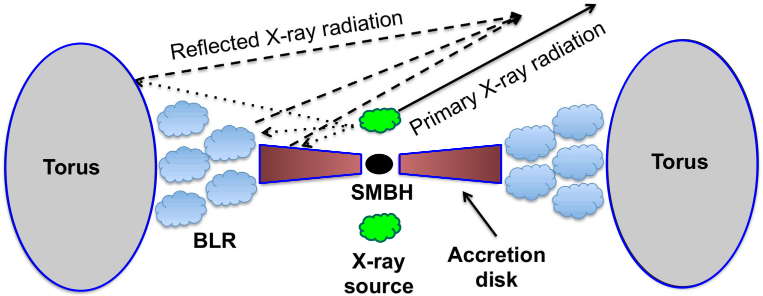
Power-law continuum (Γ~2)

Strong Soft Excess (below 2 keV)

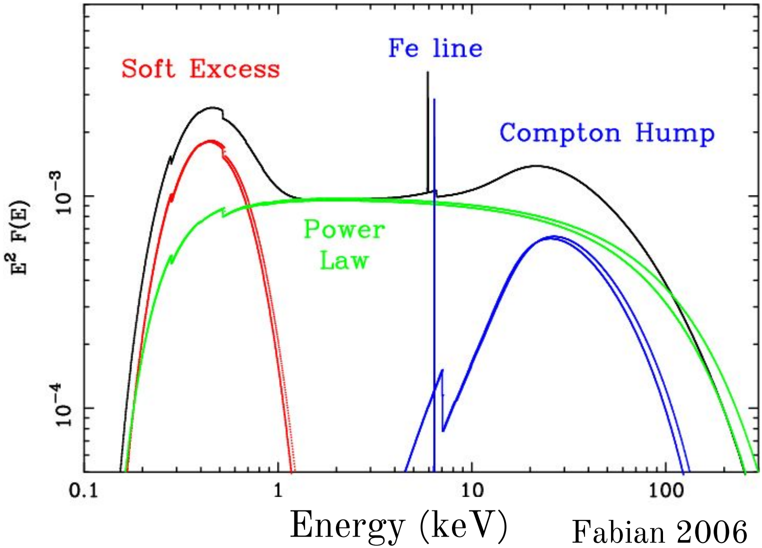
Iron Line Profile (6-7 keV)

- Narrow line - fluorescence from outer disk/torus
- Broad iron - smeared reflection from inner disk

Compton hump (10-80 keV)



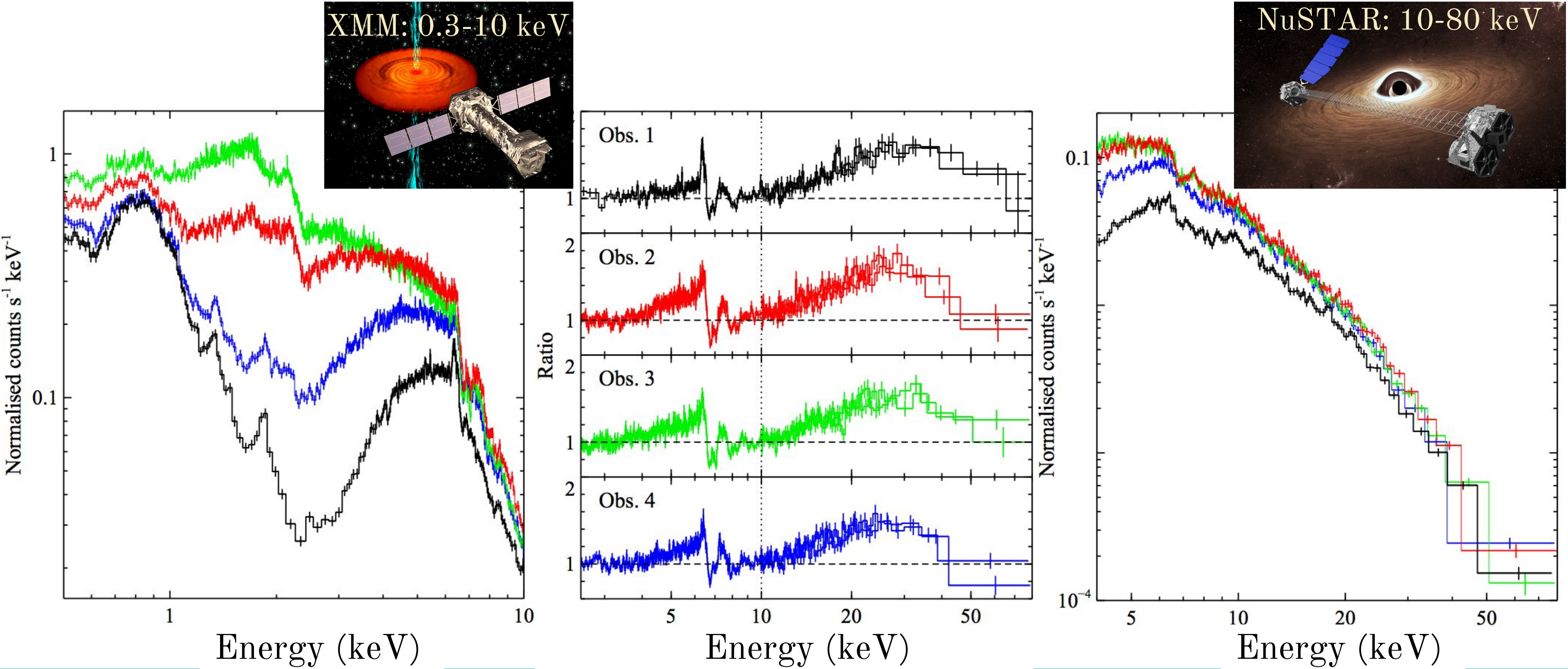
Ricci 2011



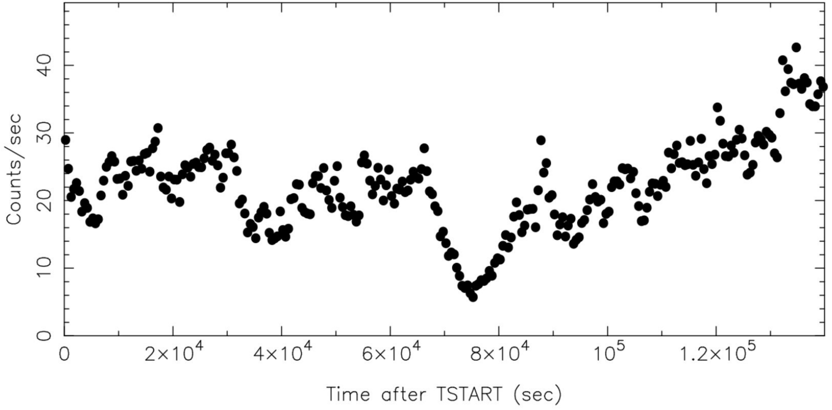
Fabian 2006

Absorption & intrinsic variability interplay

Example: NGC 1365 (Walton 2014)



Case Study: 1H1934-063



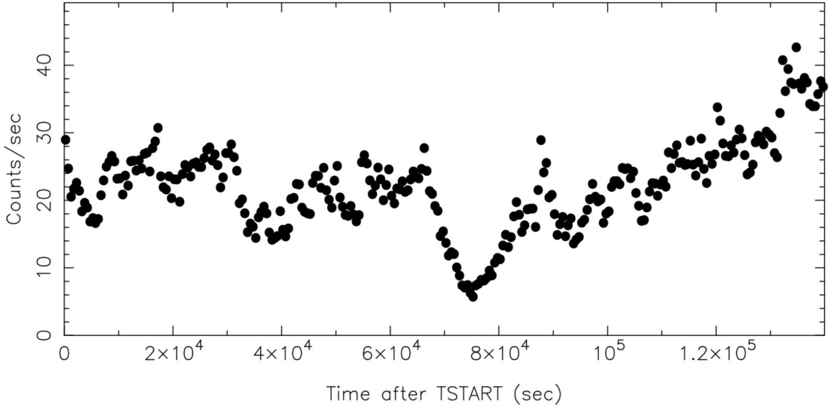
- Bright and highly variable AGN (CAIXA, Ponti 2015)
- Radio-quiet (Condon 1998)
- NLS1 (Nagao 2001)
- $z=0.0102$ (Rodriguez 2007)
- $M_{BH}=3\times10^6\ M_{\odot}$ (Malizia 2008)

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

Case Study: 1H1934-063

- Bright and highly variable AGN

  (CAIXA, Ponti 2015)

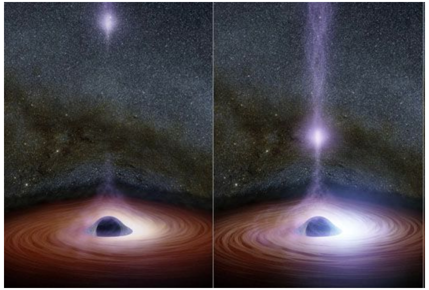


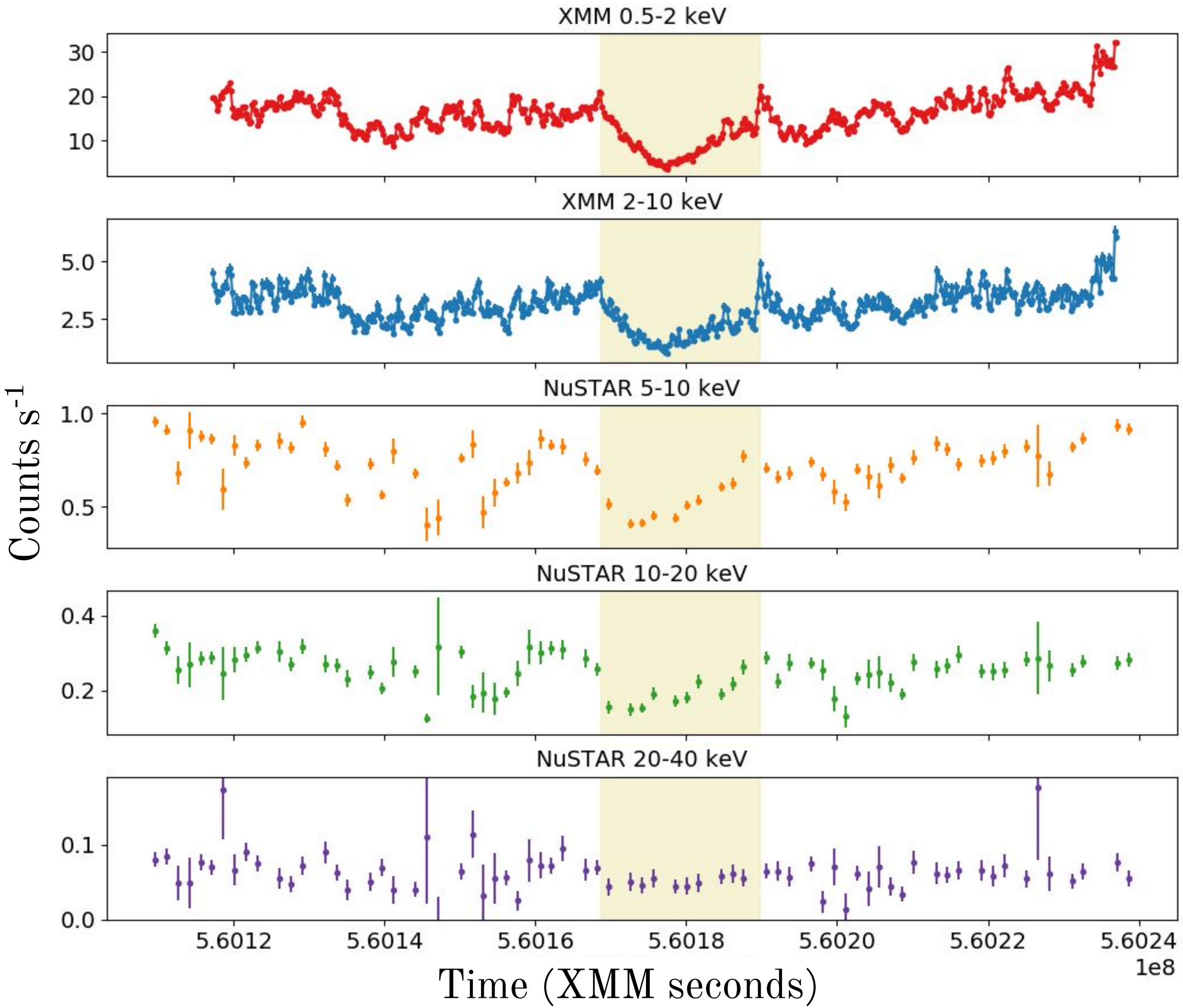
What causes extreme variability in this source?

Does it fit with expectations from other well-studied Seyfert 1s?

Possible Causes

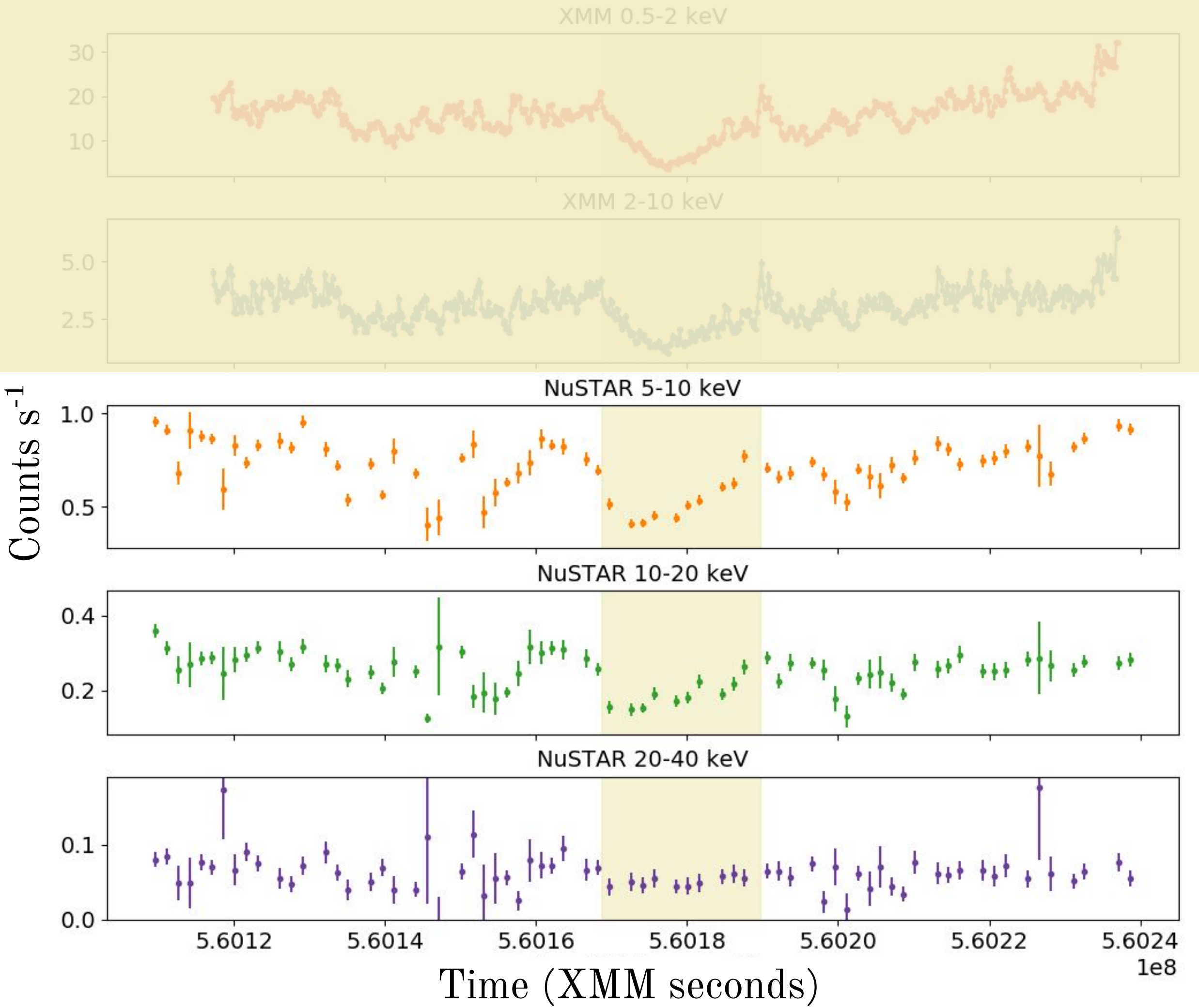
- Line of sight obscuration
  - Clumpy torus
  - BLR clouds
- Intrinsic variability
  - Weak radio jet activity
  - “Crashing” X-ray corona





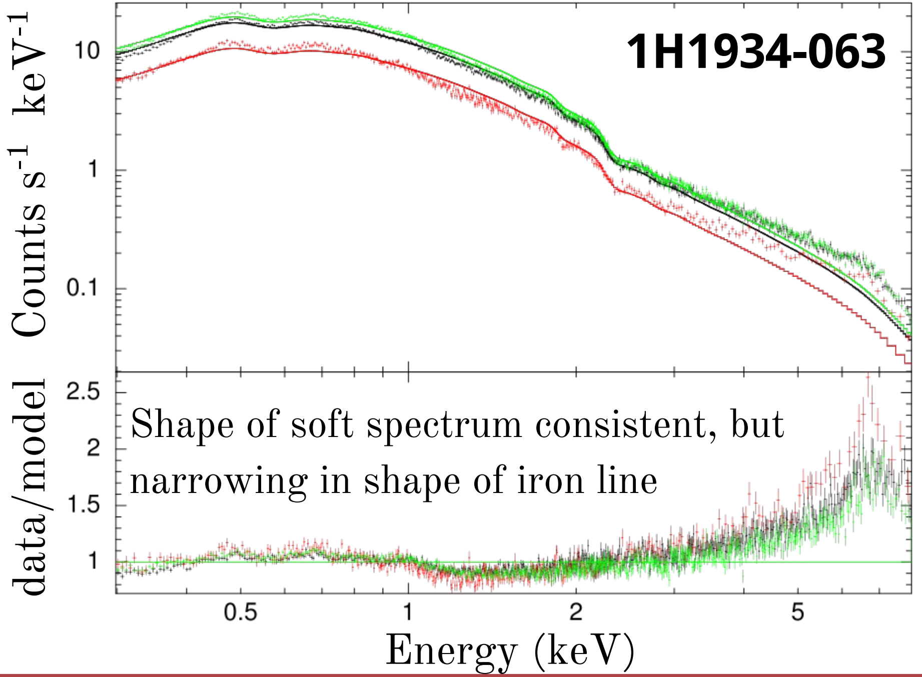
Compton-thick absorption is disfavored

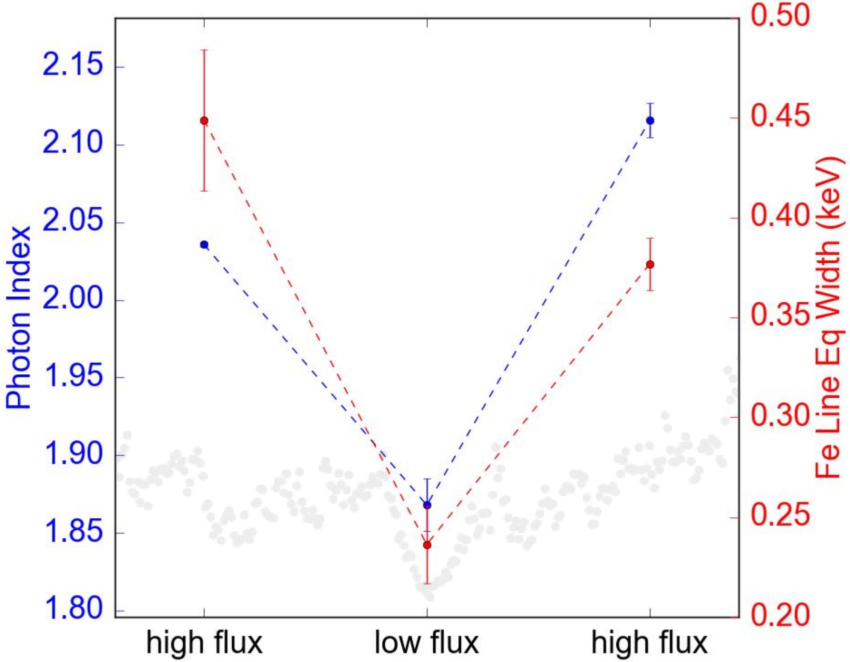
➤Change is intrinsic to X-ray emitter



Spectral Analysis

Time-resolved XMM-Newton Spectra



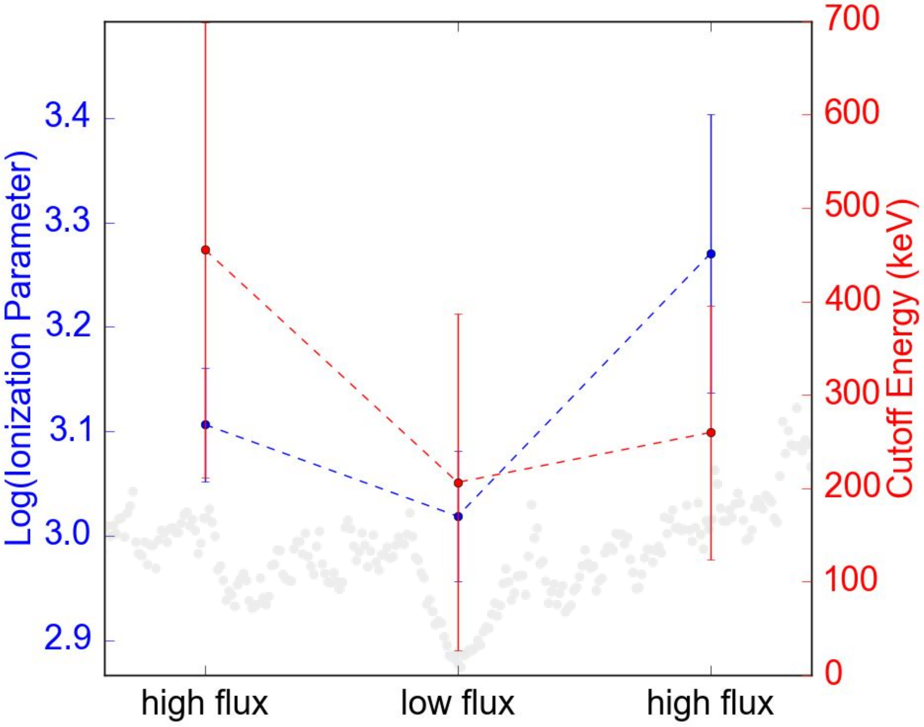


Pivoting of power law continuum, confirmed with spectral fitting

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 ~ 40°
- $a < 0.4$
- h_{corona} ~ 2.5 - 4.5 r_G

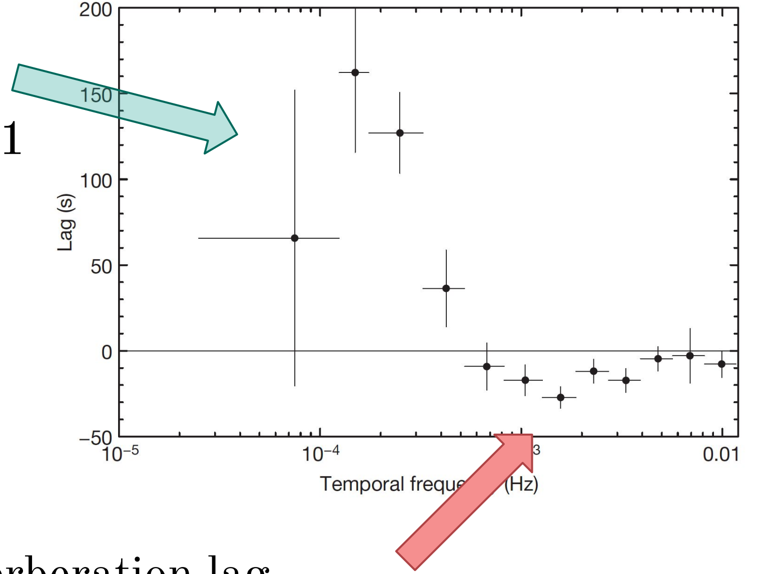


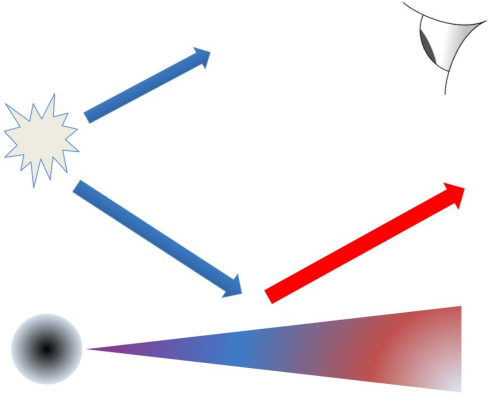
Timing Analysis

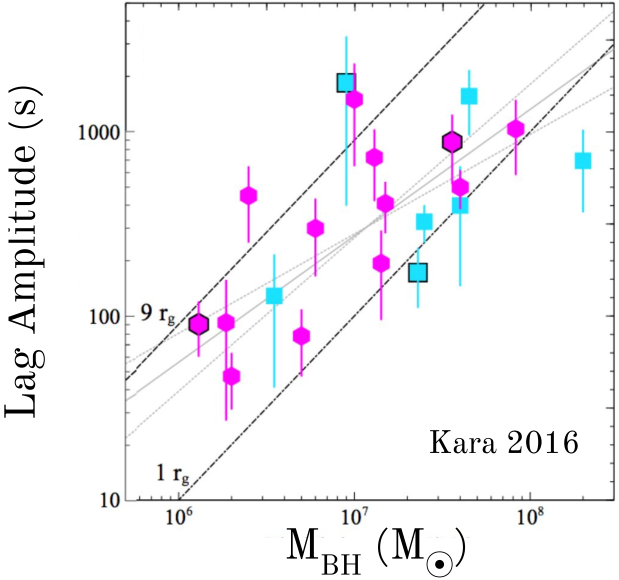
X-ray Reverberation Studies

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

Lag (s) vs. Temporal Frequency (Hz)



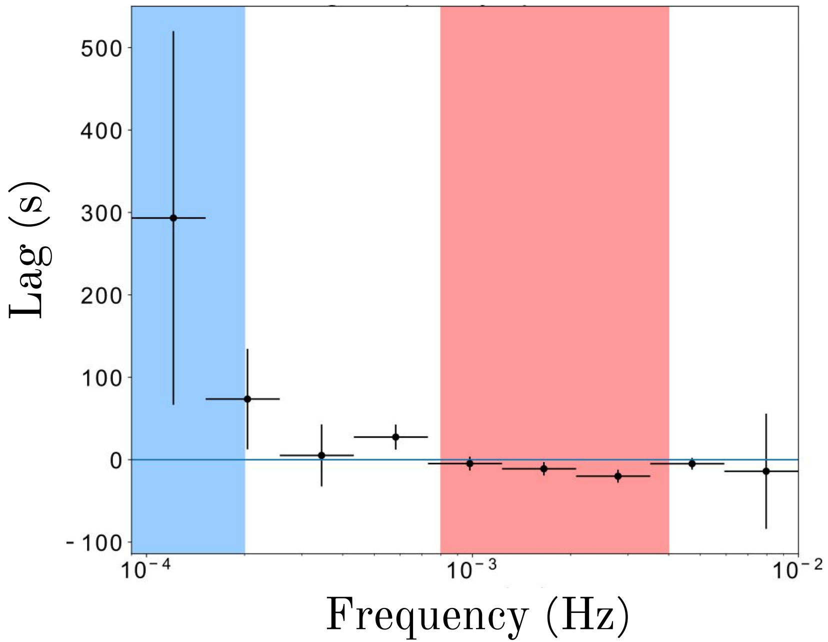




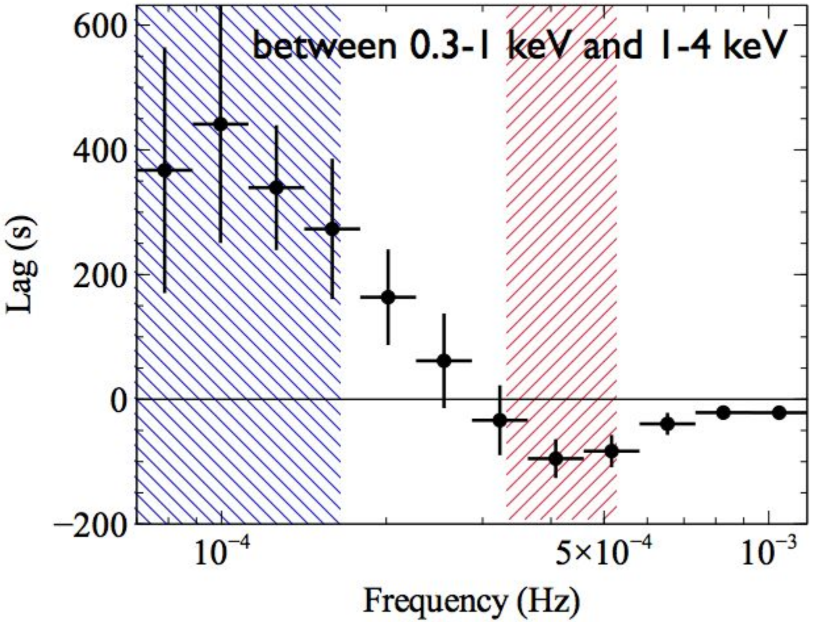
- Short-timescale Reverberation lag
  - First robustly observed in 1H0707-495 (Fabian 2009)
  - Negative by convention

Lag Analysis of XMM-Newton data

1H1934-063

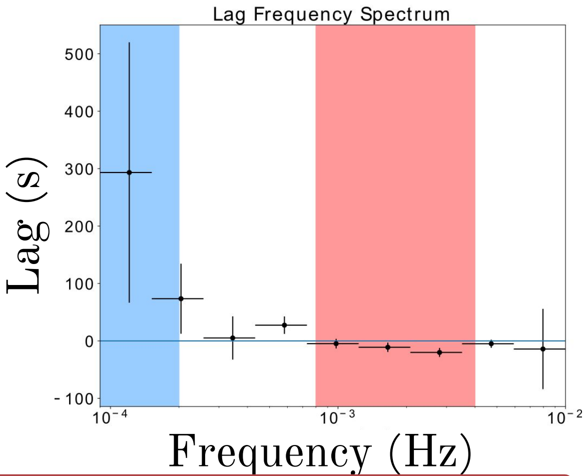


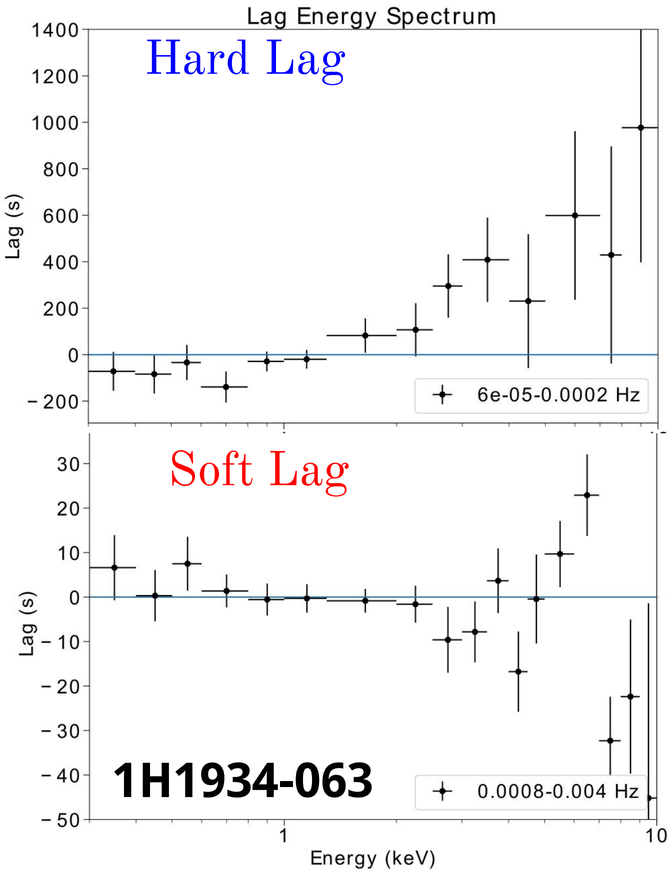
Ark 564

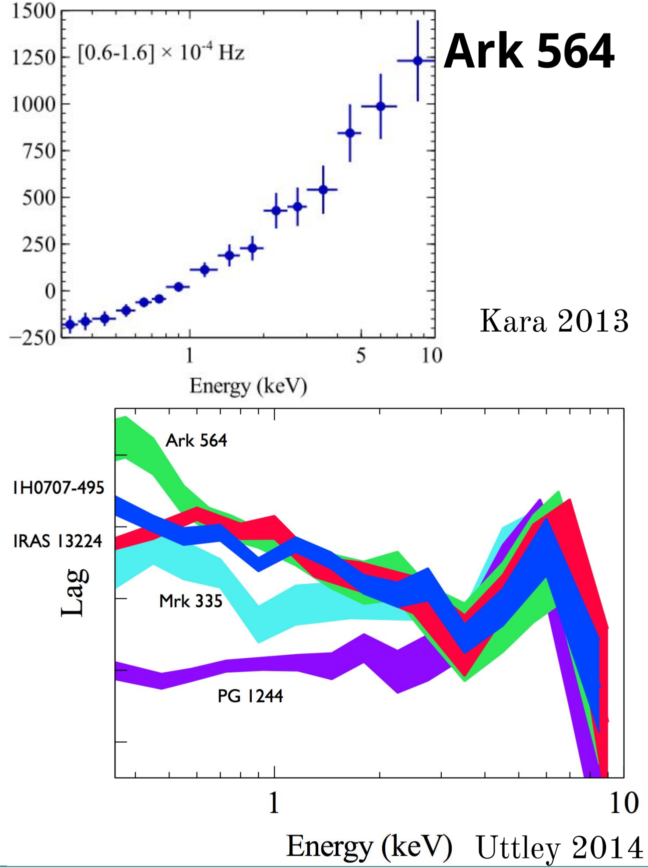


- Soft Lag ~ 20 s $\Rightarrow h_{max} \sim 6.7\ r_G$
- Hard Lag ~ 293 s

Lag Analysis of XMM-Newton data





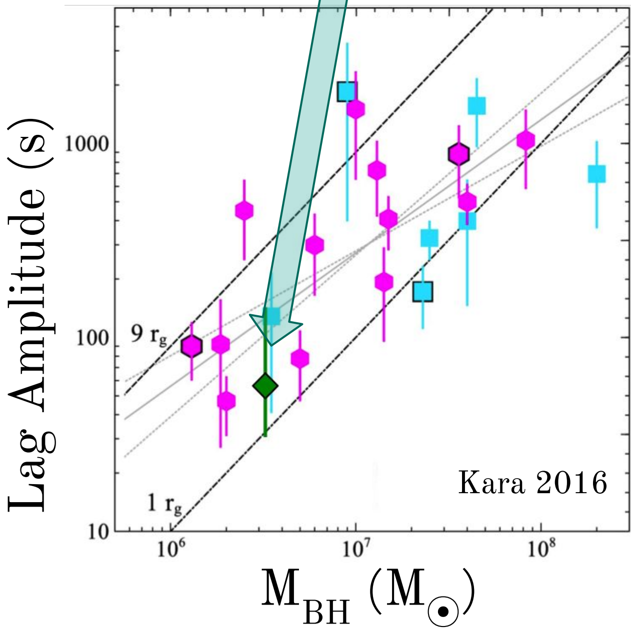


Evidence of Iron $K\alpha$ Line Reverberation

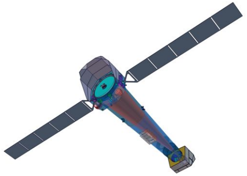
Summary

- 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

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



Future Work



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

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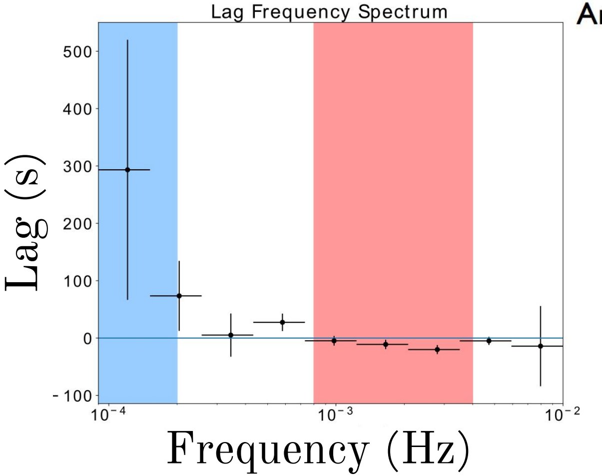
Extra Slides

Lag Analysis of XMM-Newton data



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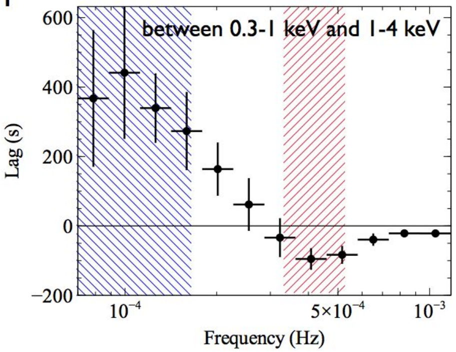
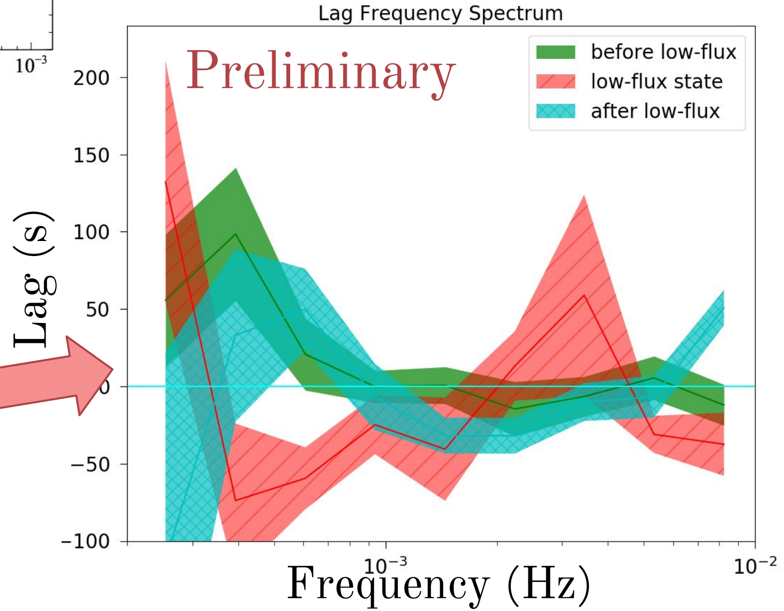


Evidence of Broad Iron Line Reverberation

- Soft Lag ~ 20 s ⇒ h_{max} ~ 6.7 r_G
- Hard Lag ~ 293 s



Lags during low flux state appear to move to lower frequencies