Iron Lines in Stellar-mass Black Holes: Relevance for AGN and Future Directions

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Why use Fe lines to constrain BH spin?

It is the most robust technique available.

"The best current method [of constraining BH spin is] continuum fitting ... the Fe line and HF QPO methods are not well-enough developed to be applied to real systems"

-- Remillard & McClintock 2006

"All of the plausibly reliable estimates of BH spin to date ... depend on fits to the X-ray continuum."

-- McClintock et al. 2006

Disk continua depend critically on the hard component assumed



Fits to RXTE spectra of 4U 1543-475 as per Shafee 06, McClintock 06 The high/soft state chosen because it is "simple".

Statistically equivalent fits require vastly different disk fluxes.

The disk continuum spin constraints



Fits to RXTE spectra of 4U 1543-475 as per Shafee 2006.

Spectra fit with the "kerrbb" model as per Shafee 06, McClintock 06.

a = 0.3 is statistically equivalent to a = 0.9.

Strong Fe lines do not depend on the continuum



XMM-Newton and RXTE spectra of GX 339-4

More examples of the same



Fe lines and BH spin



XMM-Newton reveals the detailed shape of Fe line profiles. GX 339-4 requires a > 0.9, Cygnus X-1 does not require spin.

Relativistic Lines in Galactic BHs



A brief inventory, and the impact of XMM

Broad lines prior to CXO/XMM:

Cygnus X-1 V404, 1543, 1655, 1748, 1915

XMM broad lines, circa 2002: XTE J1650-500 GX 339-4 SAX J1711.6-3808 Lines recently seen with XMM: Cygnus X-1 GRO J1655-40 GRS 1915+105

Before XMM: 1 Since XMM: 9

Lines found in archival data: XTE J1550-564 GRO J1655-40 V4641 Sgr 4U 1543-475 Including all SAX, RXTE, ASCA: Nearly 20 systems with broad Fe.

BHC – Seyfert Connections



- Both lines require $R_{in} \sim 2 R_{q}$, high spin (a/M > 0.8-0.9 or so).
- Centrally concentrated emission, $J(r) \sim r^{-q}$, q =4-5 (q=3 expected).
- Inner accretion flows must be *remarkably* similar.

A few things AGN observers should know about Fe lines in stellar-mass black holes.

Overlapping additive continuum components do not create false Fe lines



Winds/absorbers do not affect Fe line profiles.



Partial Covering Fails



Partial covering also fails for Sy 1s.



- BUT such fits require Γ = 2.3, incompatible with high energy data (Γ =1.7).
- Moreover, continuum above 7 keV is flat; for MCG-6, tau < 0.03.
- Look forward to Suzaku: simultaneous data up to 200 keV for FREE.

QPO Phase-resolved spectroscopy



(Miller & Homan 05)

Difference Spectra: High – Low QPO Phase

The iron line is relatively more important at the top of the QPO than at the bottom – the line does not merely trace the overall flux.



Probing orbits is a critical next step

Modulation of the Iron line flux in NGC 3516 (M ~ 10 Million Msun)





Modulation of the Iron line flux in GRS 1915+105 (M = 14 Msun)



Observational questions for the next 5 years

- Time variability: Using difference spectra, can we see differences between flare spectra and non-flare spectra?
- Can we detect multiple relativistic lines? If L/nr^2 is really lower in the low/hard state, can we find relativistic O VII or O VIII ?
- Do Fe lines react to radio blob ejections? Radio jet properties? the "jet line"?
- Systematic fits with new variable spin line models needed for better spin constraints.
- Can we use the emissivity index to constrain the nature of the corona?

(Simultaneous XMM & Suzaku observations will be very important.)

Some theoretical issues, in random order

- Do jet models and quasi-spherical coronal models predict the same emissivity index?
- Are we sensitive to inner disk torques via lines and reflection?
- Do we miss something by averaging over angle in reflection models?
- What might reflection from a "slim disk" look like? Can we argue in favor of, or against slim disks, based on Fe lines and reflection?
- Multi-wavelength lightcurves seem to indicate that optical & IR light are not primarily due to reprocessing in the outer disk ... how can we achieve inner disk reprocessing in the absence of outer disk reprocessing? a beamed hard X-ray component?
- Is the issue of the plunging region settled? for all disk torques and spins?

Extra slides beyond this point.

Iron Lines in AGN





More Lines in AGN



Iron Lines in Galactic Black Holes





Inner disk signatures



Broad-band spectra well fitted by the same reflection models.

- Both lines require R_{in} ~ 2 R_g, high spin (a/M > 0.8-0.9 or so).
- Sy1s: moderately ionized disks; stellar-mass BHs: highly ionized disks.
- Inner accretion flows must be remarkably similar.

Cygnus X-1 in a soft state as observed with ASCA



Cygnus X-1 in a soft state as observed with ASCA

