Measuring Black Hole Spin?

⇒ Measurement from relativistic Fe Kα line
BUT: Line is only a part of reflection spectrum!

We need to ...

• ... model the entire reflection spectrum
• ... understand the entire continuum
Current Status: some measurements made for AGN (~ 10)
(e.g. Dabrowski et al. 1997, Nandra et al. 1997, 2007, Brenneman &
Reynolds 2006, Gallo et al. 2010)

⇒ What about systematic errors?

Most cited possible error sources:
  - narrow components in iron K-band
  - unknown emissivity profile
  - no line emission from within ISCO (Reynolds & Fabian 2008)

→ There must be many more!
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Goals for this project:

1) Identify errors
2) Determine their impact
3) Try to improve measurements
Previous Spin Studies on Fairall 9 ($z = 0.047$):

<table>
<thead>
<tr>
<th>Study</th>
<th>Soft Excess</th>
<th>Spin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schmoll et al. 2009</td>
<td>Blurred Reflection</td>
<td>$0.60 \pm 0.07$</td>
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<tr>
<td>Emmanoulopoulos et al., 2011</td>
<td>Blurred Reflection</td>
<td>$0.39^{+0.49}_{-0.30}$</td>
</tr>
<tr>
<td>Patrick et al., 2011</td>
<td>Comptonization</td>
<td>$0.67^{+0.10}_{-0.11}$</td>
</tr>
</tbody>
</table>

⇒ All previous studies note the absence of warm absorption!

⇒ Study **Typical AGN**!

(Schmoll et al., 2009)
Available Data:
- $2 \times $ Suzaku 
  (140 ks & 190 ks) 
  (2007 & 2010)
- $2 \times $ XMM 
  (15 ks & 90 ks) 
  (2000 & 2009)

$\Rightarrow$ There is some spectral variability on timescales of years!

From light curves:
- overall source flux changes over time
- no (very little) variability within pointings

$\Rightarrow$ use pointing averaged spectra
Relativistic Line is present in spectra!
⇒ Line required in all fits!
Spectral Analysis

Base model:

continuum + cold reflection + blurred ionized reflection $\rightarrow$ Galactic absorption

Details:
continuum & cold reflection: pexmon (Nandra et al. 2007)
models power law + Fe K$\alpha$, Fe K$\beta$, Ni K$\alpha$ + Compton hump
ionized reflection: reflionx (Ross et al. 2004)
computes reflection spectrum for irradiation by a power law
blurring: relconv (Dauser et al. 2010)
relativistic blurring kernel, that assumes broken power law emissivity profile
photoelectric absorption: TBnew (Wilms et al. 2001)
General results from fits to individual pointings:

very good fit to the data, but: scattered results

• sub-solar abundances
• disagreements in between pointings, \textit{XMM} – \textit{Suzaku} (e.g. inclination: $\sim 5$ deg vs. $\sim 45$ deg)
• emissivity indexes: first one $\gg 3$ & second one $< 3$
• spin parameter: mostly very high

$\Rightarrow$ \textit{Why is the spin so high?}
Two possibilities: Collisionally Excited Plasma OR Photoionization

⇒ We cannot differentiate...but lines improve fit!
⇒ Ionization state is high!
⇒ Spectral Parameters are still scattered and spin is still rather high!
Possible Errors – An Incomplete List

- blue wing of relativistic line ⇔ FeXXV & FeXXVI
- continuum/soft excess
- emissivity profile
- uncertainties in models (reflection models, etc.)
- accretion disk & reflection Physics
- ...

BUT: depends on object and exact line shape

⇒ Try Multi-Epoch Fitting!

Which parameters are tied?
- iron abundance
- spin
- inclination of accretion disk
Possibilities for the soft excess:
blurred reflection + ...

- nothing
- bremsstrahlung
- luke warm Comptonization
- power law

⇒ Soft excess improves fits!

⇒ Soft excess can drive spin constraints!
(because the signal-to-noise is very high at lower energies)
The influence of the emissivity profile
Example: lamp-post model

In plot:
no add. soft excess:
broken power law
lamp-post profile

Comptonization:
broken power law
lamp-post profile

⇒ Emissivity profile determines constraints but not spin value!
For Fairall 9, we can say that...

- a relativistic component is required BUT: accretion disk parameters are inconsistent for fits to individual pointings
- the base model works
- a composite soft excess model is required
- spin constraints are influenced by various systematic errors
- indications for narrow emission features (Fe XXV and Fe XXVI) that can skew the measured accretion disk parameters
- systematic errors on BH spin $\gg$ statistical errors
- multi-epoch fitting is necessary to allow for consistent modeling of spectra

$\Rightarrow$ Preliminary spin measurement: $0.4 \pm 0.2$
(for soft excess modeled by \texttt{comptt} and narrow lines included)

Applies to other bare Seyferts as well!
Back-Up frames
Continuum (In)Dependence?

- soft excess: blurred reflection
- reflection fraction: high
- spin value: very high (0.99)

⇒ Soft excess can drive spin constraints!
⇒ Spin constraints are model dependent!
Need to perform attitude correction!

Contamination issue makes soft energy part of the spectrum unusable for XIS0!