# Systematic Errors on Black Hole Spin

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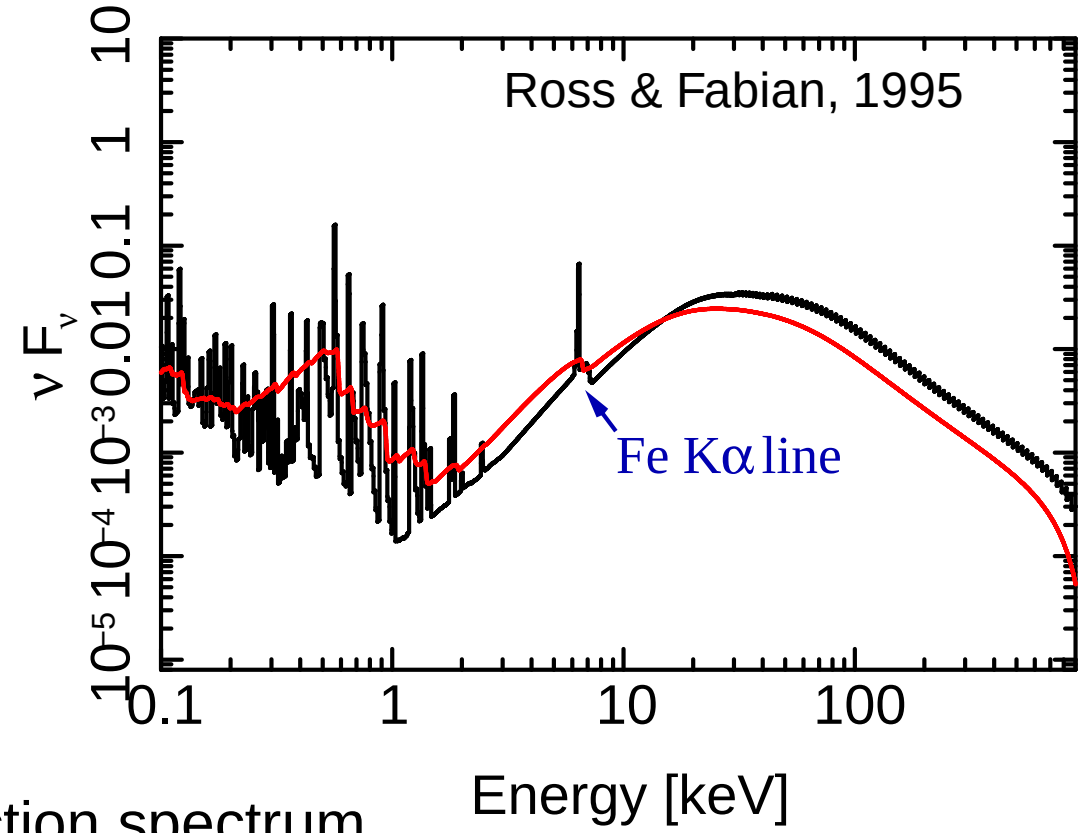
## Measuring Black Hole Spin?

$\Rightarrow$ Measurement from relativistic Fe K$\alpha$ 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 ($\sim$ 10)
(e.g. Dabrowski et al. 1997, Nandra et al. 1997, 2007, Brenneman & Reynolds 2006, Gallo et al. 2010)

$\Rightarrow$ 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)

$\rightarrow$ There must be many more!

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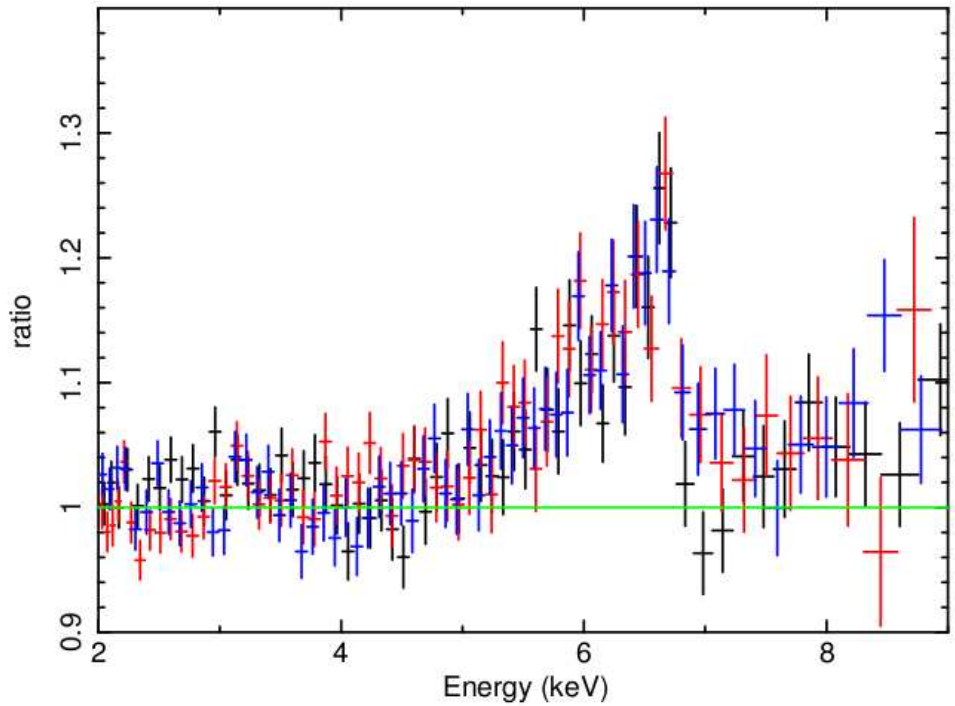
Goals for this project:

1) Identify errors
2) Determine their impact
3) Try to improve measurements

## Previous Spin Studies on Fairall 9 ($z = 0.047$):

| | Soft Excess | Spin |
|---|---|---|
| Schmoll et al. 2009 | Blurred Reflection | $0.60 \pm 0.07$ |
| Emmanoulopoulos et al., 2011 | Blurred Reflection | $0.39^{+0.49}_{-0.30}$ |
| Patrick et al., 2011 | Comptonization | $0.67^{+0.10}_{-0.11}$ |

$\Rightarrow$ All previous studies note the absence of warm absorption!



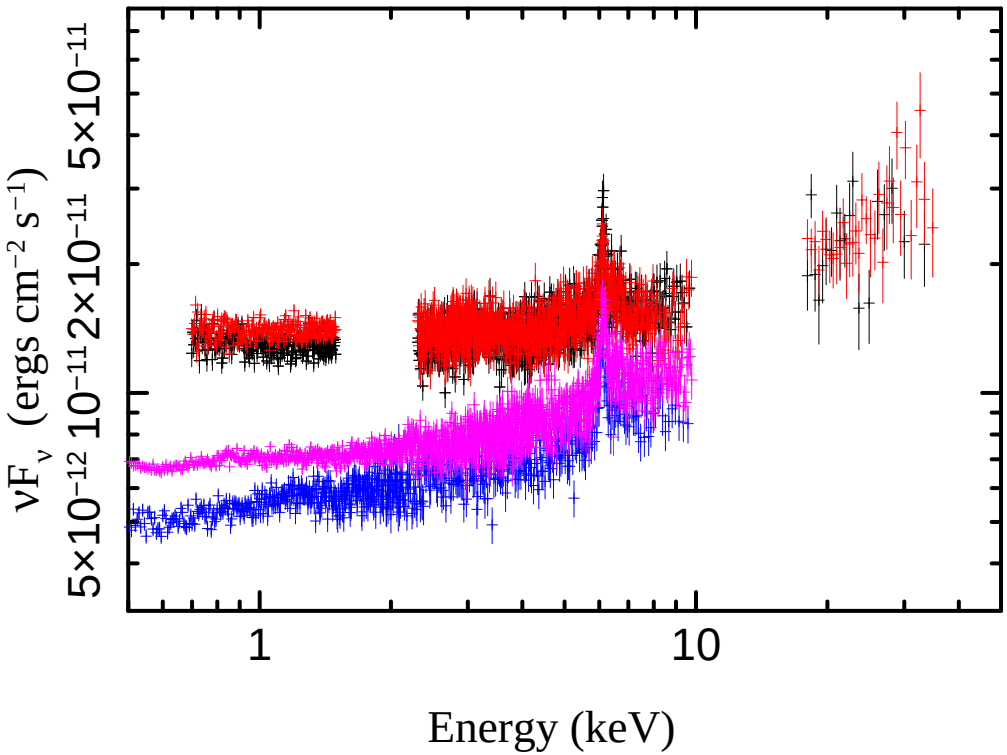

(Schmoll et al., 2009)

$\Rightarrow$

Study **Typical** AGN!

Available Data:

- 2× *Suzaku*
  (140 ks & 190 ks)
  (2007 & 2010)
- 2× *XMM*
  (15 ks & 90 ks)
  (2000 & 2009)




⇒ There is some spectral variability on timescales of years!

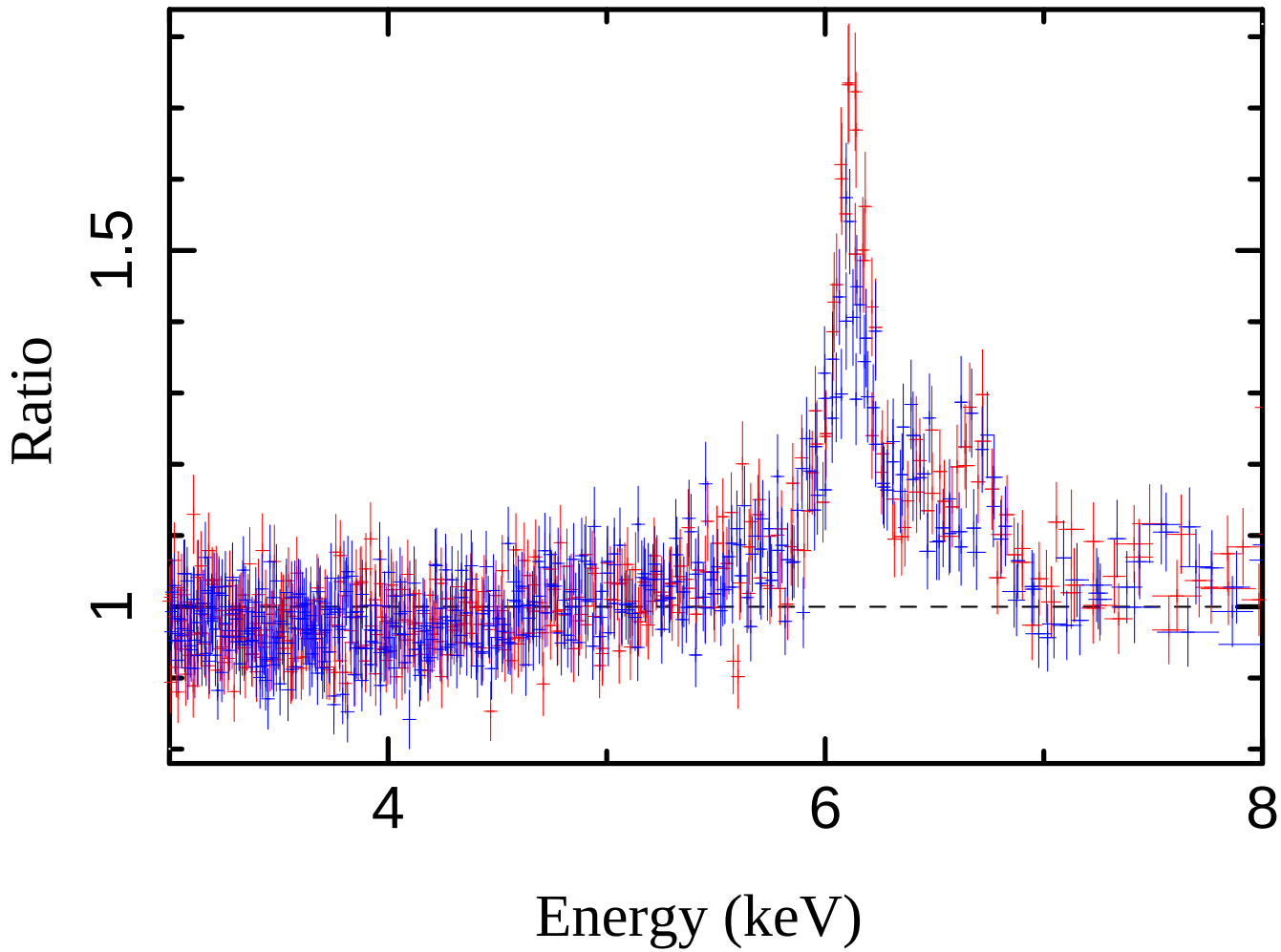
From light curves:

overall source flux changes over time

no (very little) variability within pointings

⇒ use pointing averaged spectra

# The iron line




$\Rightarrow$ Relativistic Line is present in spectra!

$\Rightarrow$ Line required in <u>all</u> fits!

## 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

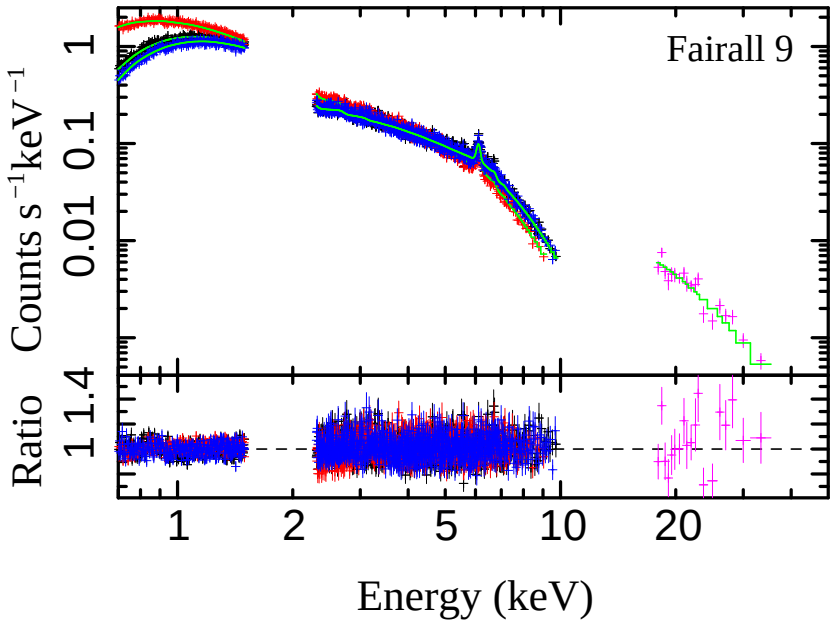
photoelectric absorption: `TBnew` (Wilms et al. 2001)

General results from fits to individual pointings:

very good fit to the data, but: scattered results

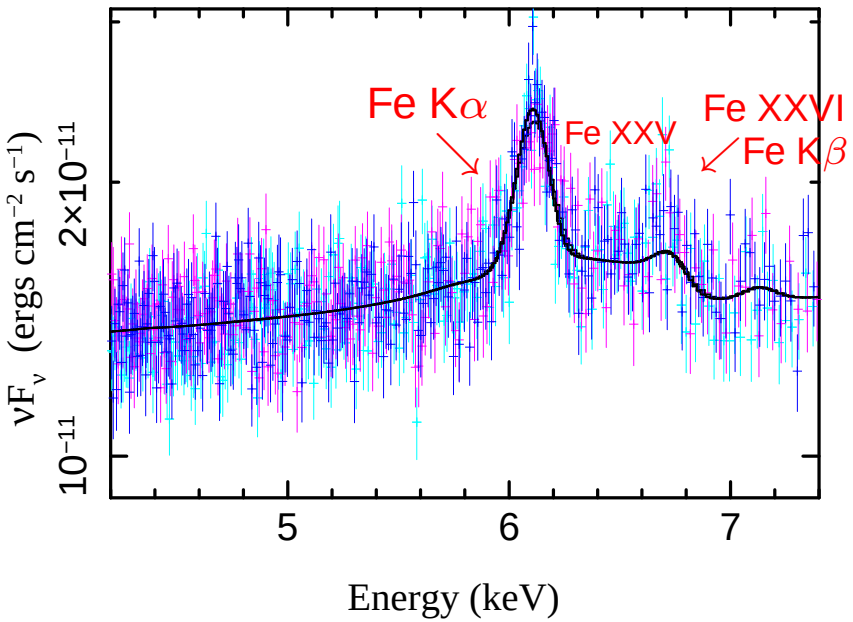
- sub-solar abundances
- disagreements in between pointings,
  *XMM – Suzaku*
  (e.g. inclination: $\sim$5 deg vs. $\sim$45 deg)
- emissivity indexes: first one $\gg$ 3 & second one $<$3
- spin parameter: mostly very high

$\Rightarrow$ Why is the spin so high?

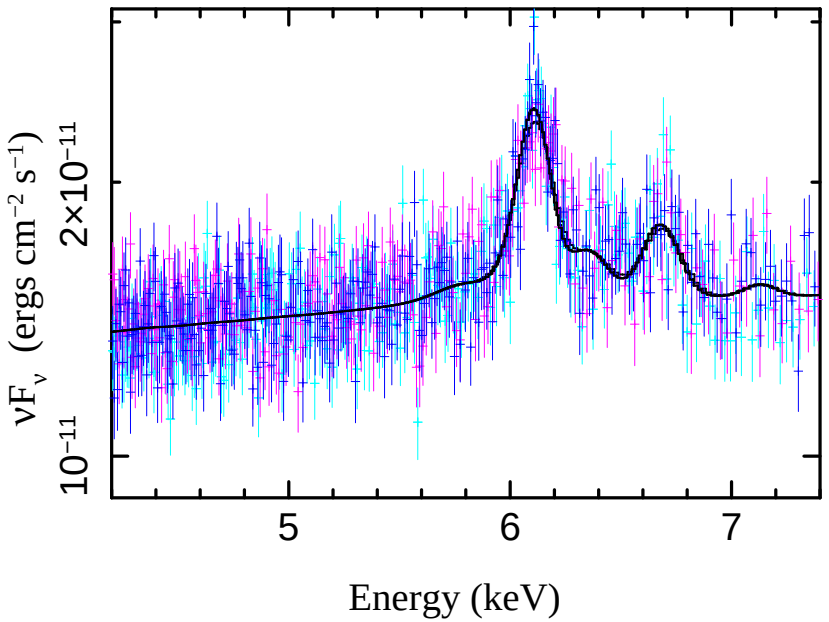


# Narrow lines?!?

without lines




with lines




Two possibilities: Collisionally Excited Plasma OR Photoionization

$\Rightarrow$ We cannot differentiate...but lines improve fit!

$\Rightarrow$ Ionization state is high!

$\Rightarrow$ Spectral Parameters are still scattered and spin is still rather high!

# Possible Errors – An Incomplete List

- blue wing of relativistic line $\Leftrightarrow$ 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

$\Rightarrow$ Try Multi-Epoch Fitting!

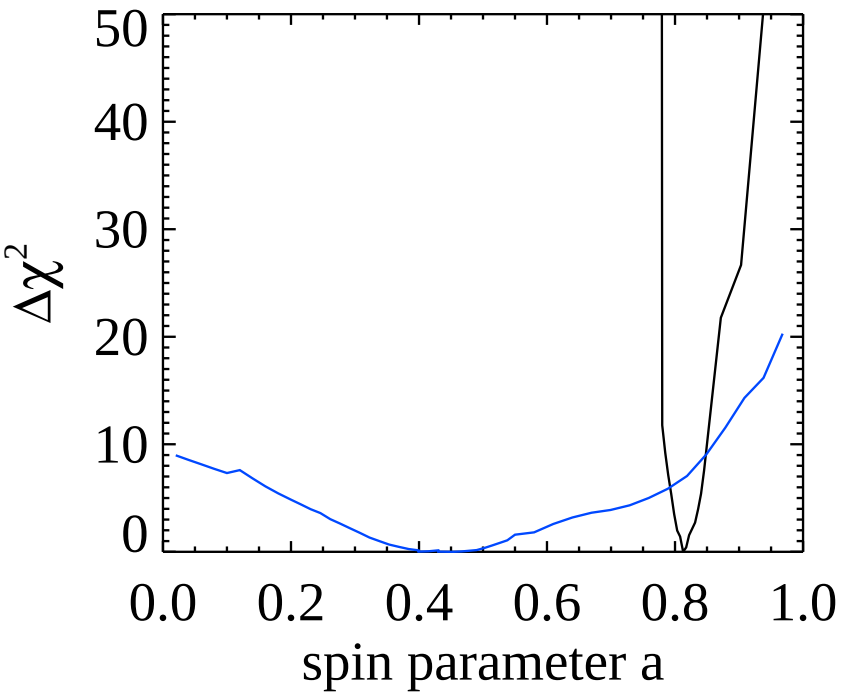
Which parameters are tied?

- iron abundance
- spin
- inclination of accretion disk

Possibilities for the soft excess:
blurred reflection + ...

- ... nothing
- ... bremsstrahlung
- ... luke warm Comptonization
- ... power law

$\Rightarrow$ Soft excess improves fits!



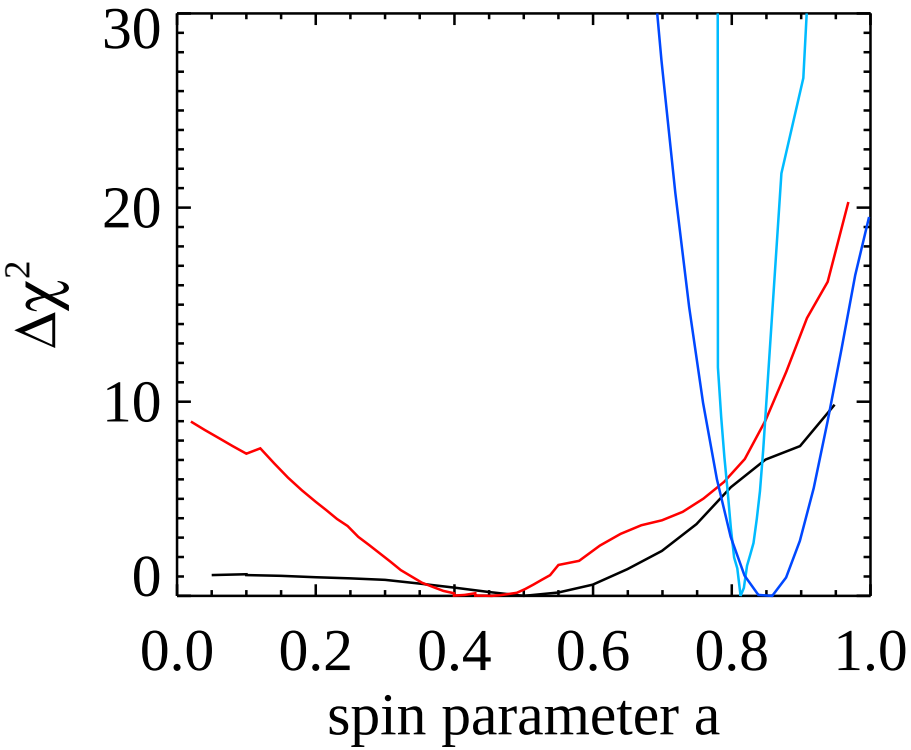

$\Rightarrow$ Soft excess can drive spin constraints!
(because the signal-to-noise is very high at lower energies)

## 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




$\Rightarrow$ Emissivity profile determines constraints but not spin value!

# Summary

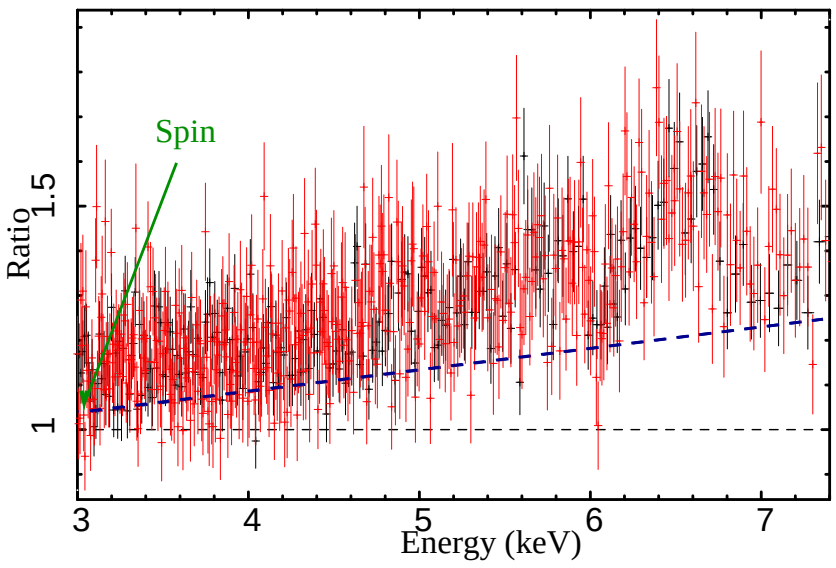
For Fairall 9, we can say that...

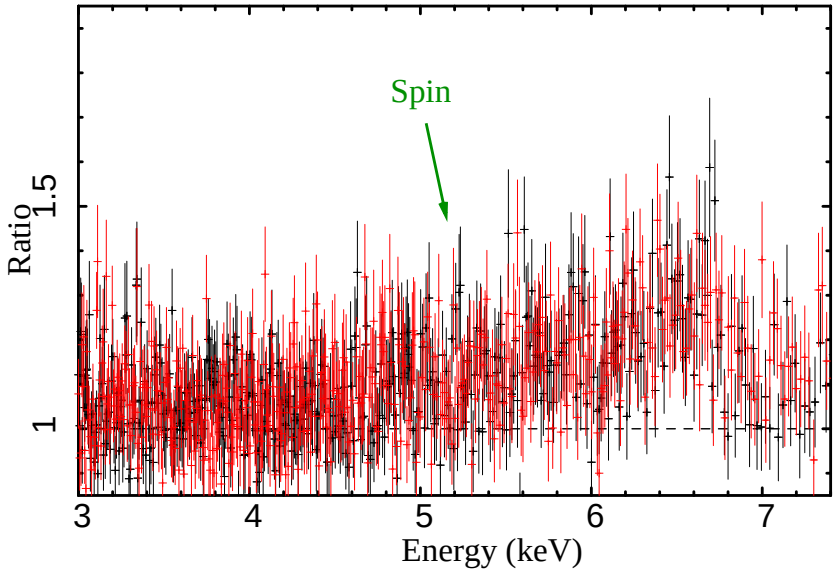
- a relativistic component is required BUT: accretion disk parameters are inconsistent for fits to individual pointings
- the base model works
- a composite soft excess model is required
- spin constraints are influenced by various systematic errors
- indications for narrow emission features (Fe XXV 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 `comptt` and narrow lines included)
Applies to other bare Seyferts as well!

# Back-Up frames

# Continuum (In)Dependence?

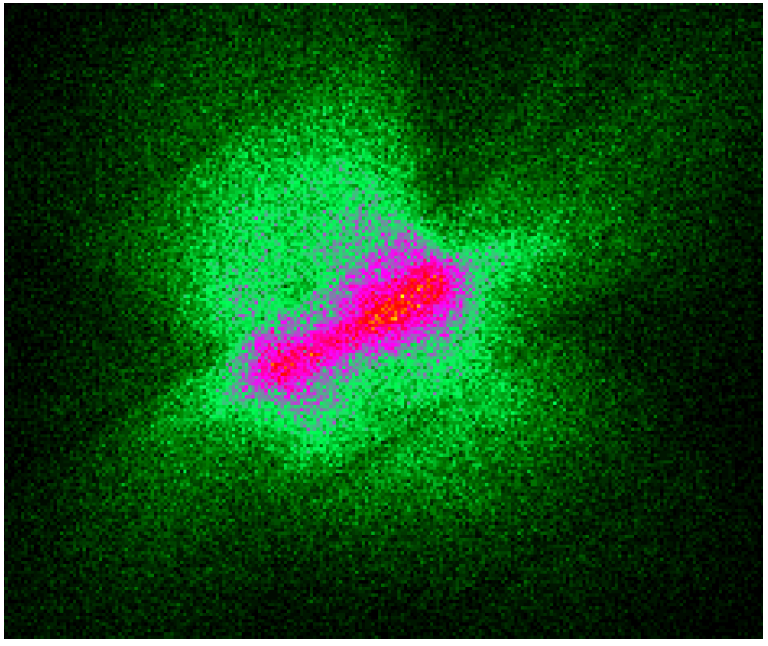


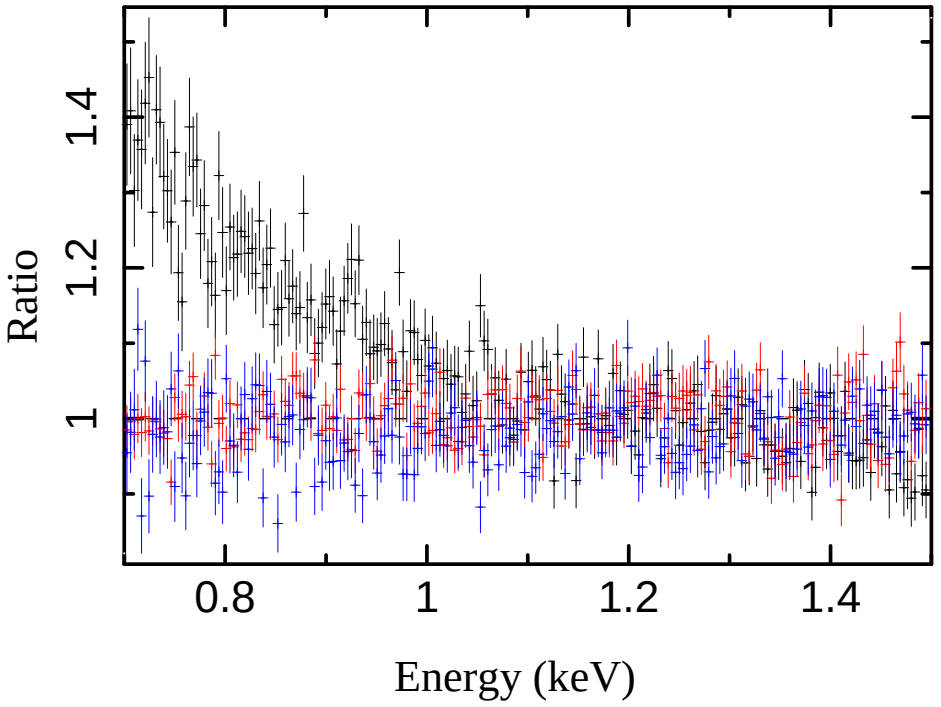

| | | |
|---|---|---|
| soft excess: | blurred reflection | optically thick Comptonizatio |
| reflection fraction: | high | low |
| spin value: | very high (0.99) | low/medium ($\sim$ 0.21) |

$\Rightarrow$ Soft excess can drive spin constraints!

$\Rightarrow$ Spin constraints are model dependent!



Need to perform attitude correction!




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