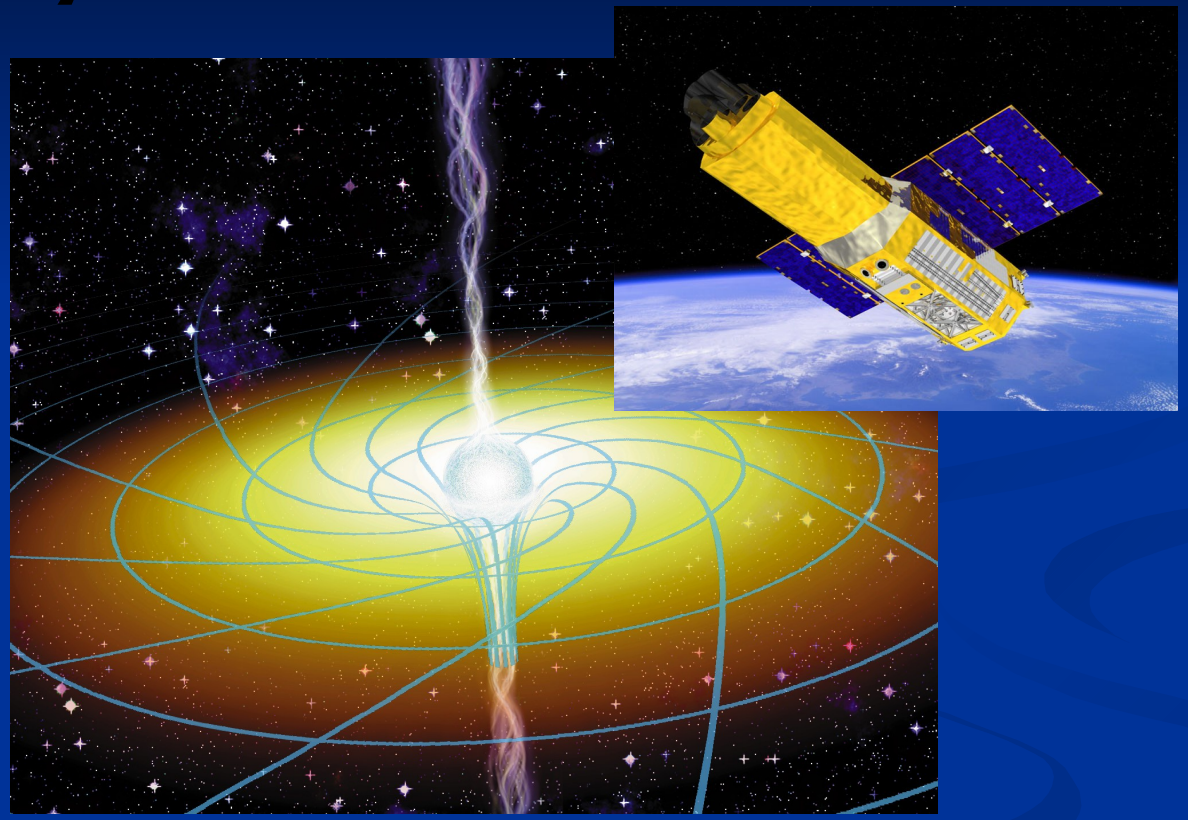
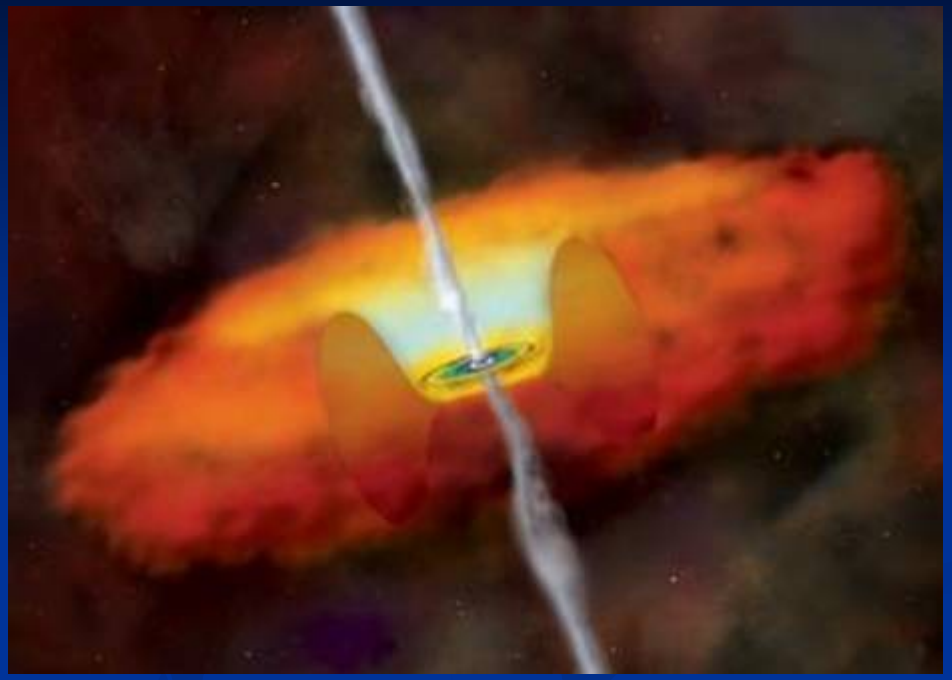
Constraining Black Hole Spin in Seyfert 1 AGN with Suzaku



Laura Brenneman
NASA Postdoctoral Fellow (GSFC)
Three Years of Science with Suzaku
September 10, 2008

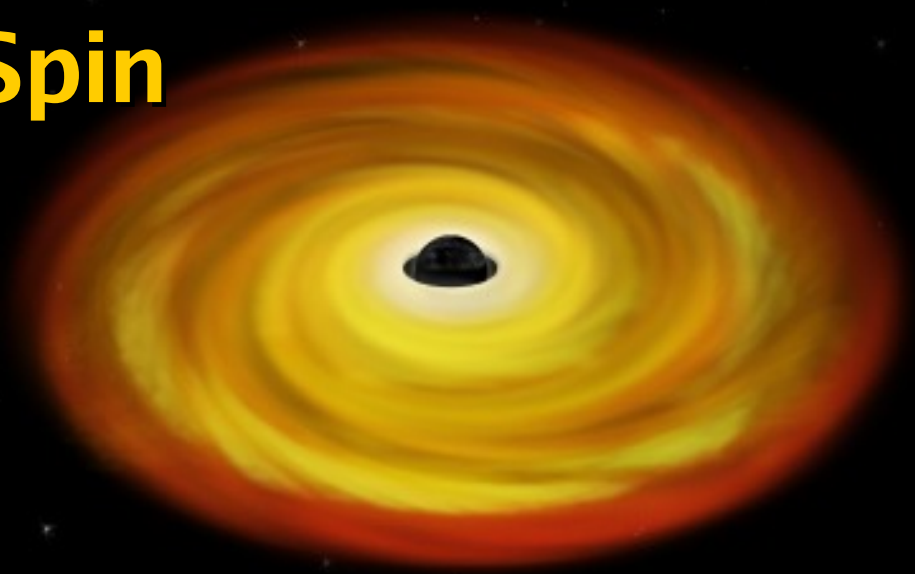
Why is Spin Interesting?

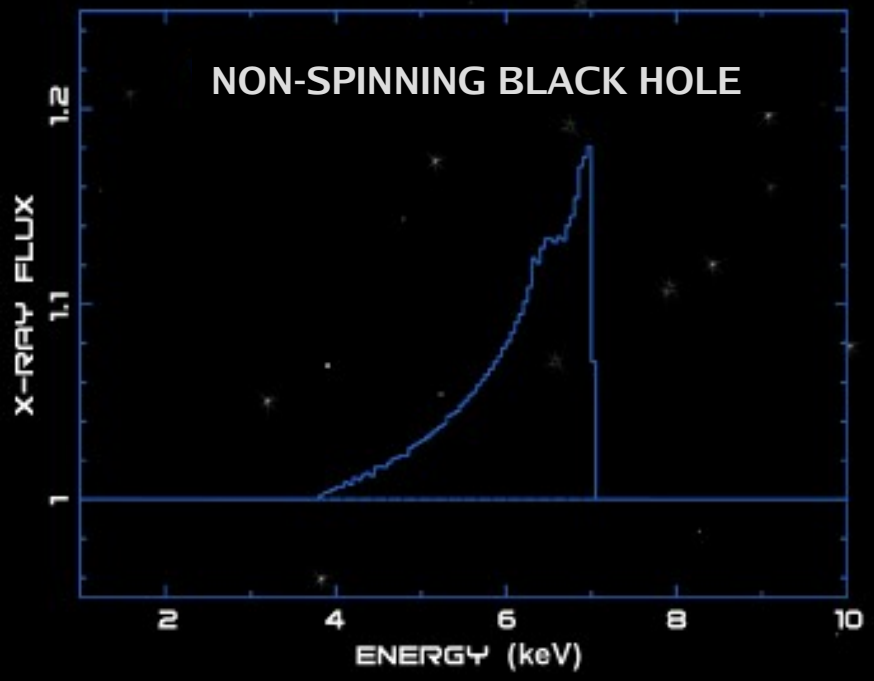
- One of only two quantities that completely defines an astrophysical black hole.
- Useful as a measure of accuracy of GR predictions (e.g., frame-dragging).
- Natal spins in stellar-mass BHs can probe formation event; spins in AGN can probe accretion/merger history.

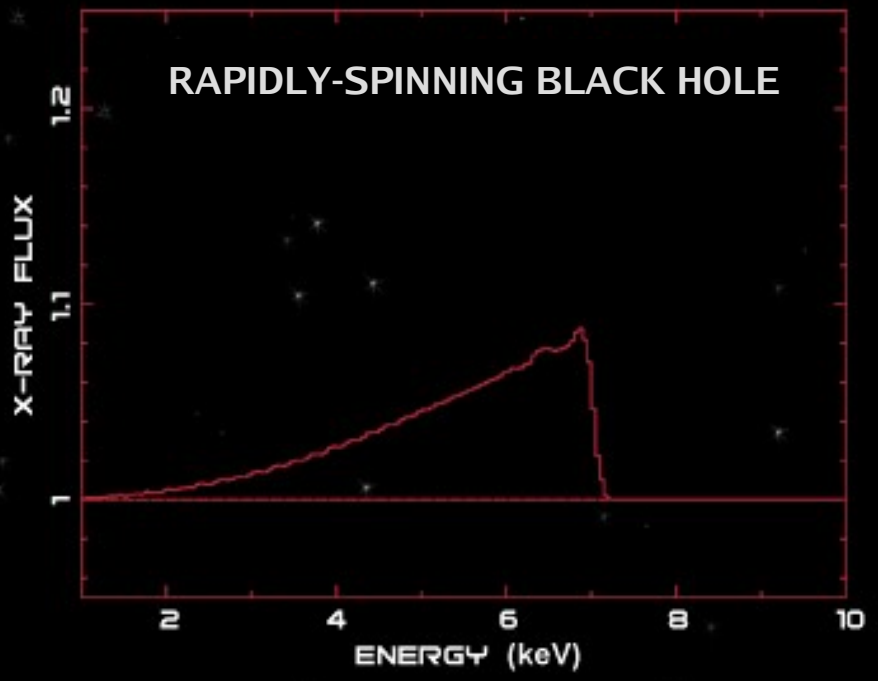


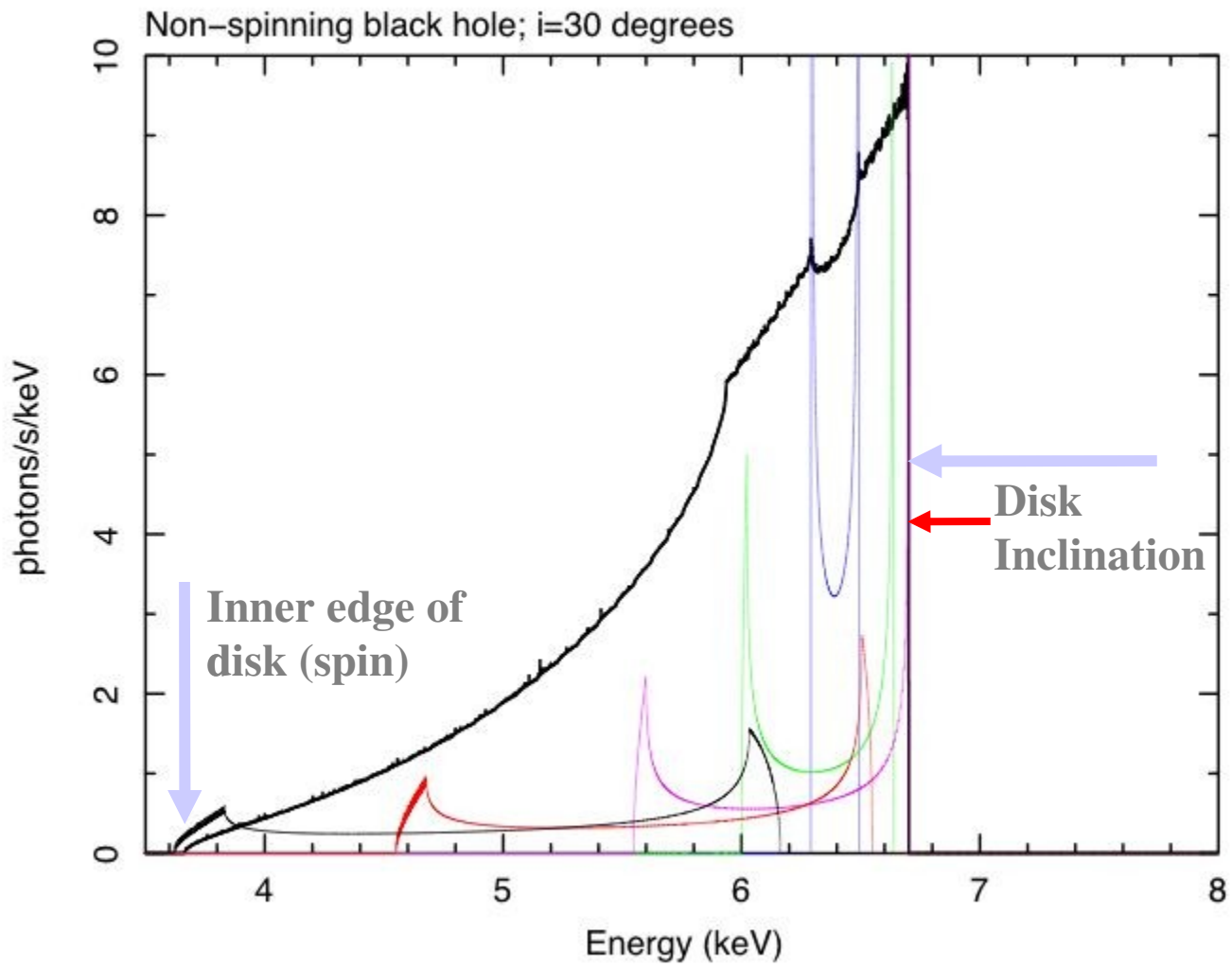
- May enable extraction of rotational energy by magnetic torquing between the BH and accretion disk.
- May power other AGN phenomena (e.g., jets, relativistic outflows via Blandford-Znajek process).

Iron Line Spectra as a Probe of BH Spin

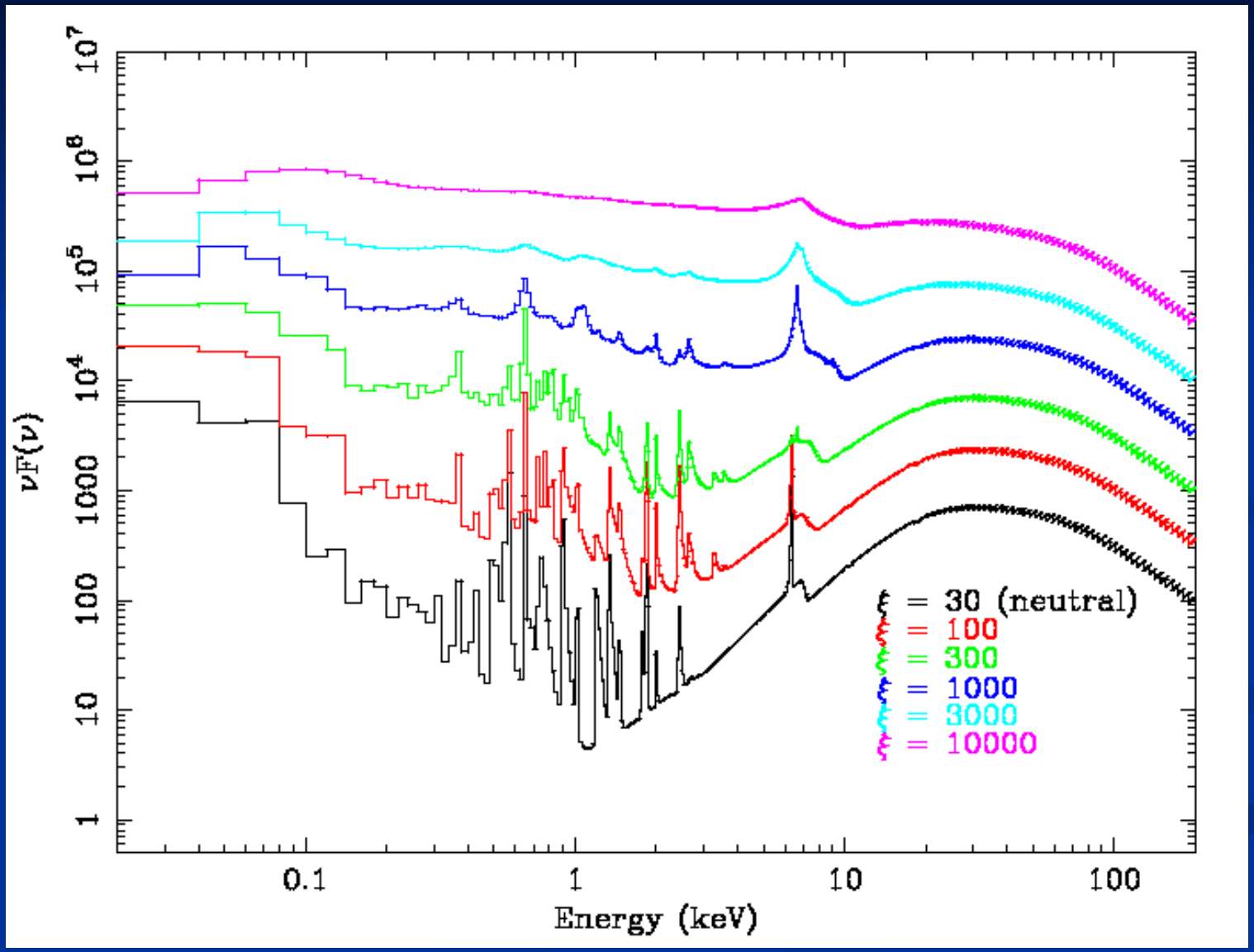






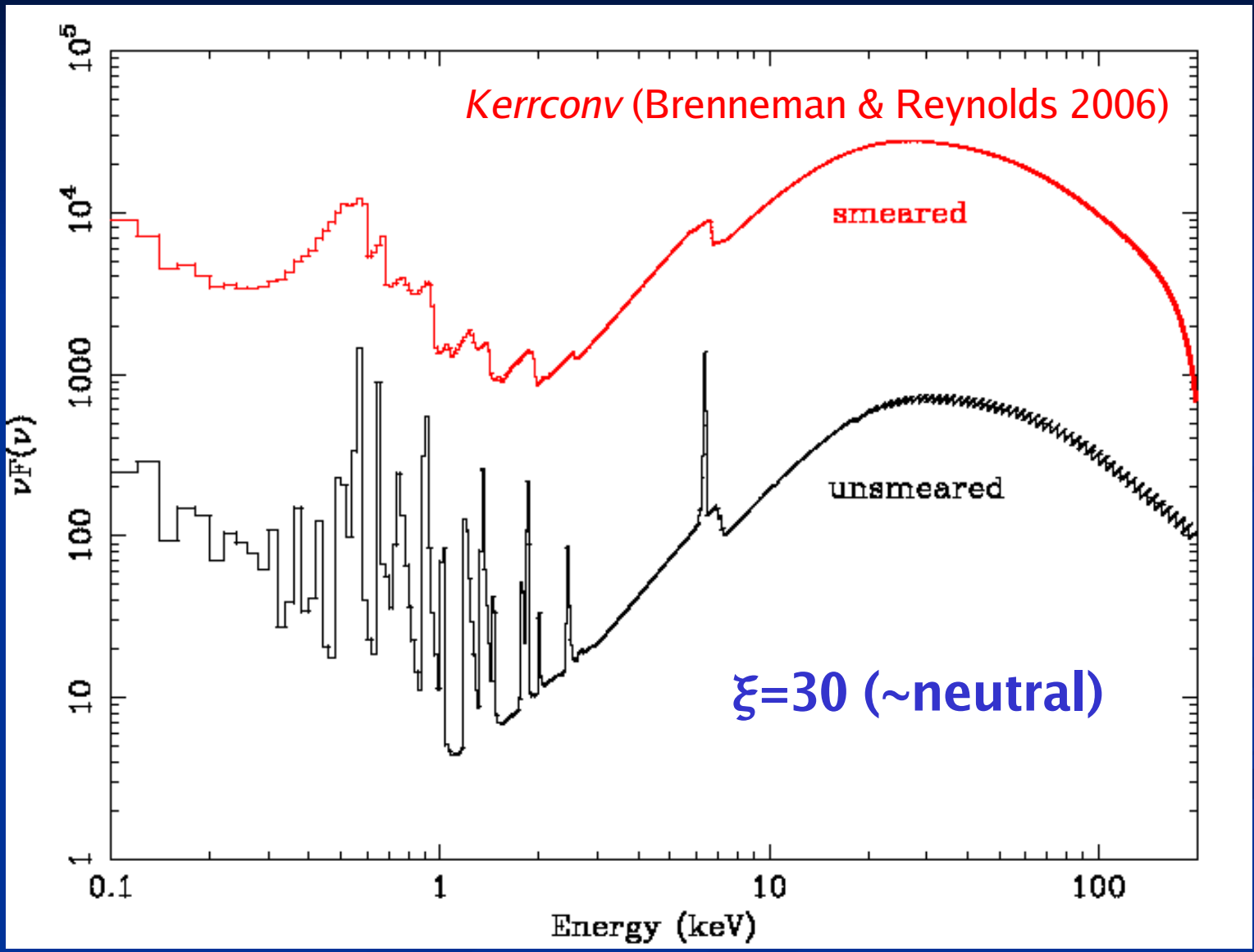

Non−spinning black hole; i=30 degrees
photons/s/keV
0
2
4
6
8
10
4
5
6
7
8
Energy (keV)
Inner edge of disk (spin)
Disk Inclination

Ionization of the Disk



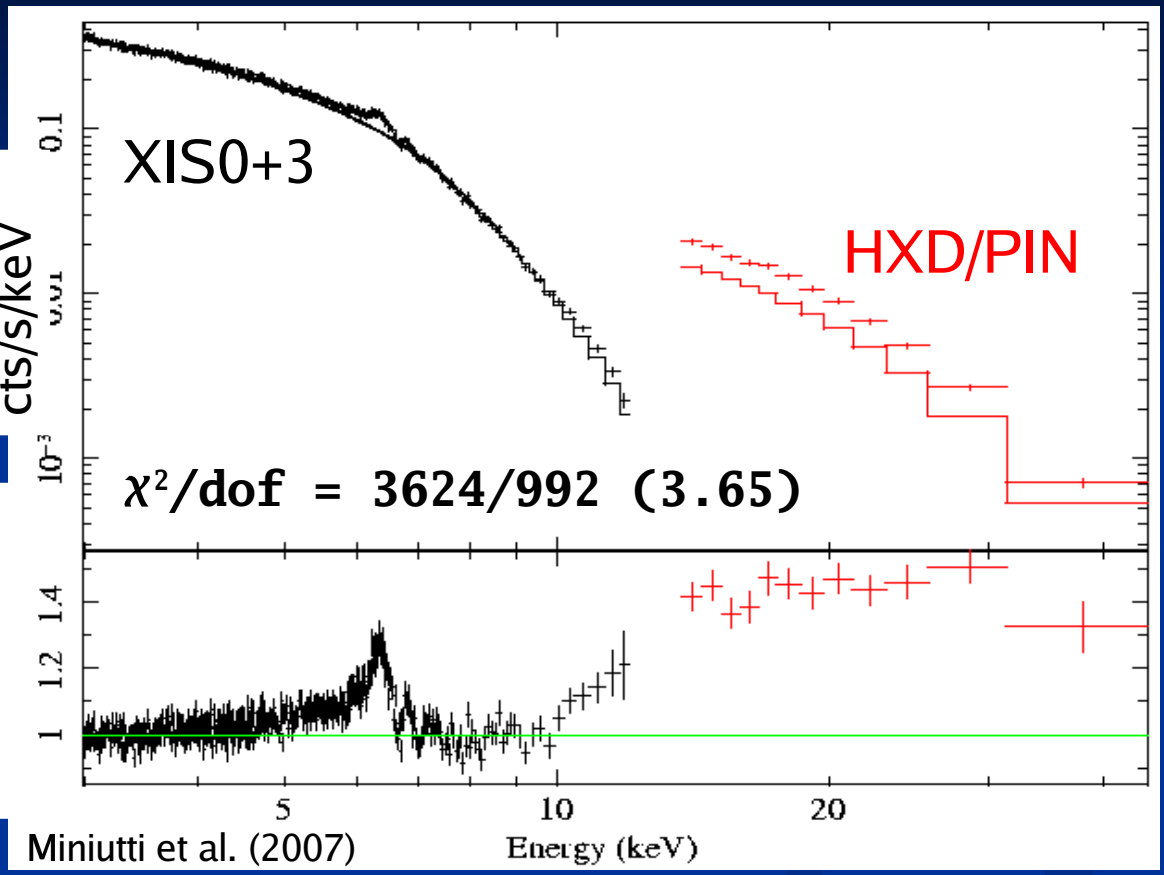
Ross & Fabian (2005)

Profile of the Ionized Disk: Smeared vs. Unsmeared



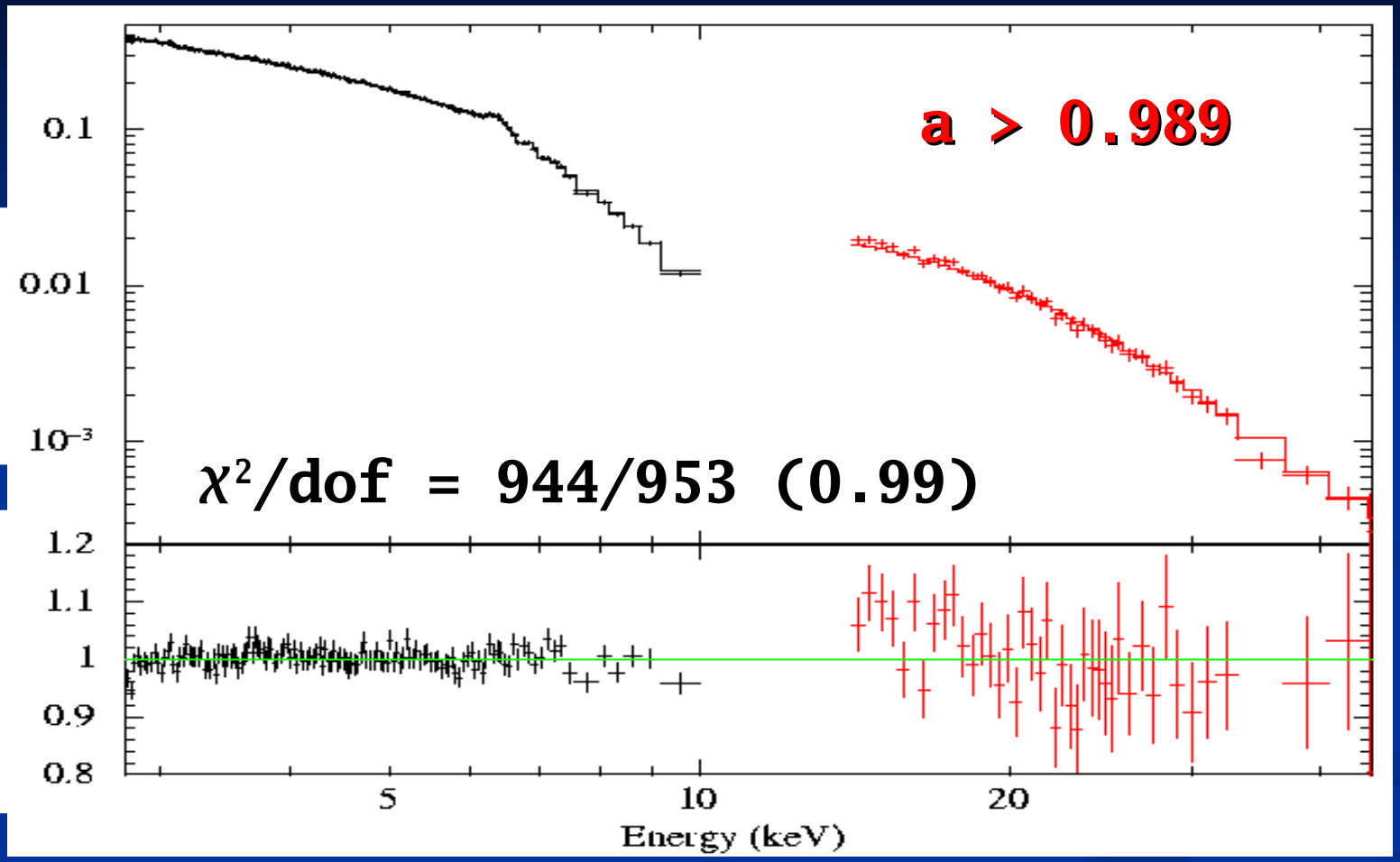
Case Study: the Sy 1 Galaxy MCG–6-30-15

- Fe-K line has extreme red wing… high spin?
- Can fit this line with a non-spinning or low spin BH, but such models need most emission to be deep within the innermost stable circular orbit (Reynolds & Begelman 1997).



- Material within the ISCO falls off very rapidly in ρ and τ while increasing very rapidly in ξ, so its contribution to the overall line emission will be minimal, even for a non-spinning BH (Reynolds & Fabian 2008).

Kerrconv Model –Our Best Fit

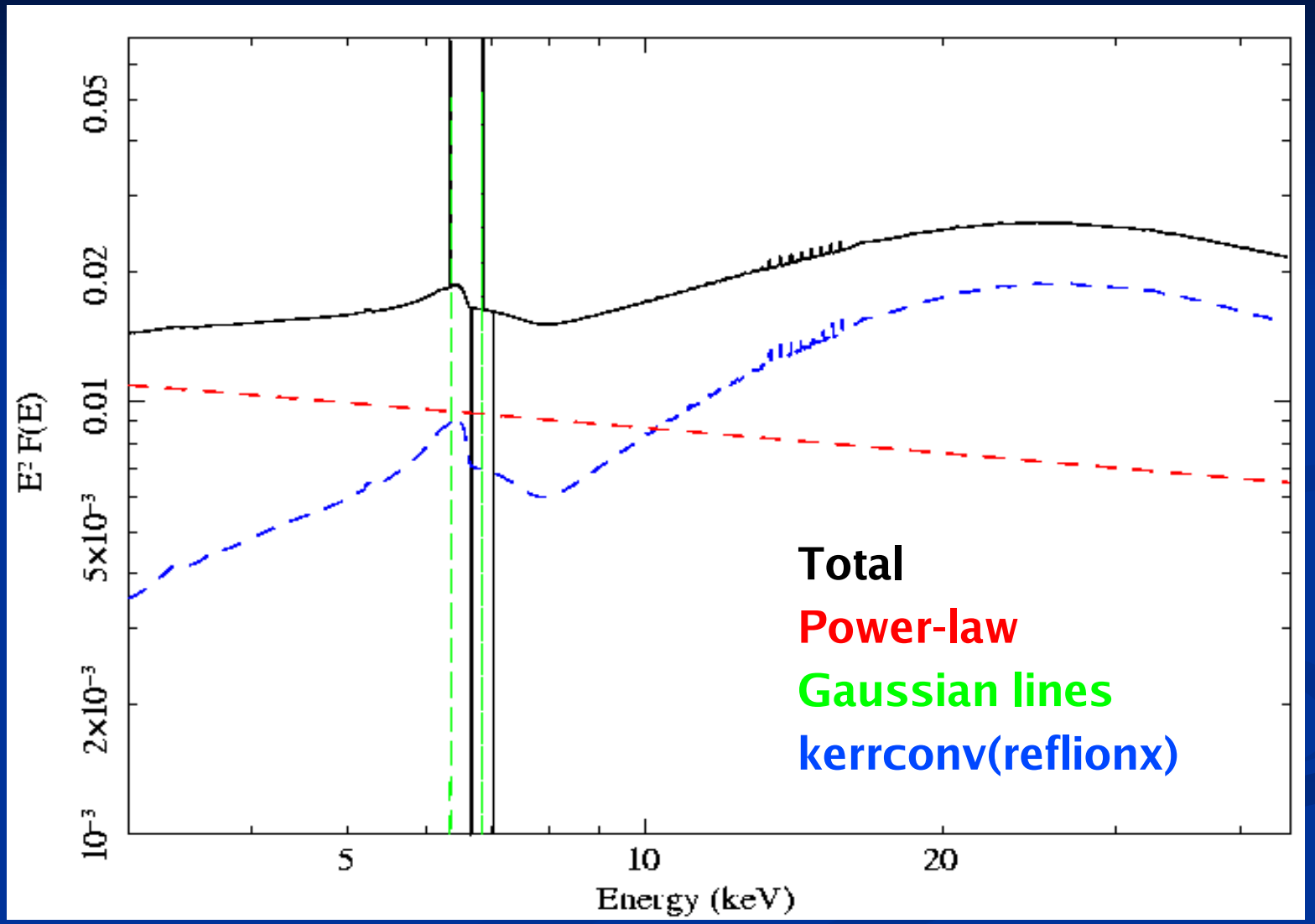


Γ = 2.19, *flux* = 1.36 x 10^{-2} ph/cm²/s

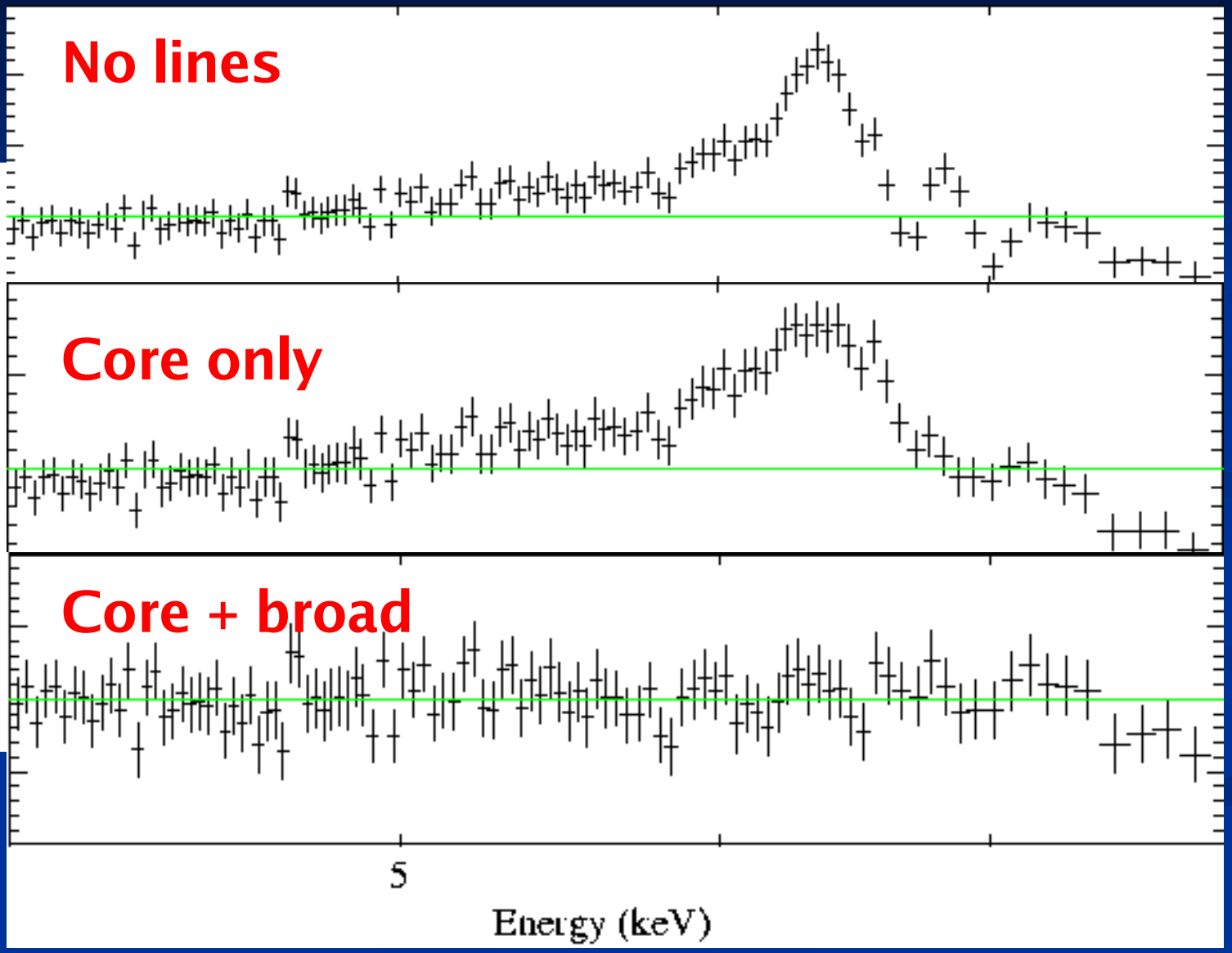
α_1 = 7.31, α_2 = 2.48, r_{br} = 4.43 r_{ms}, r_{min} = 1.17 r_{ms}, i = 28°

Z_{Fe} = 2.02, ξ_{refl} = 109, Γ_{refl} = 2.19, *flux* = 1.08 x 10^{-5} ph/cm²/s

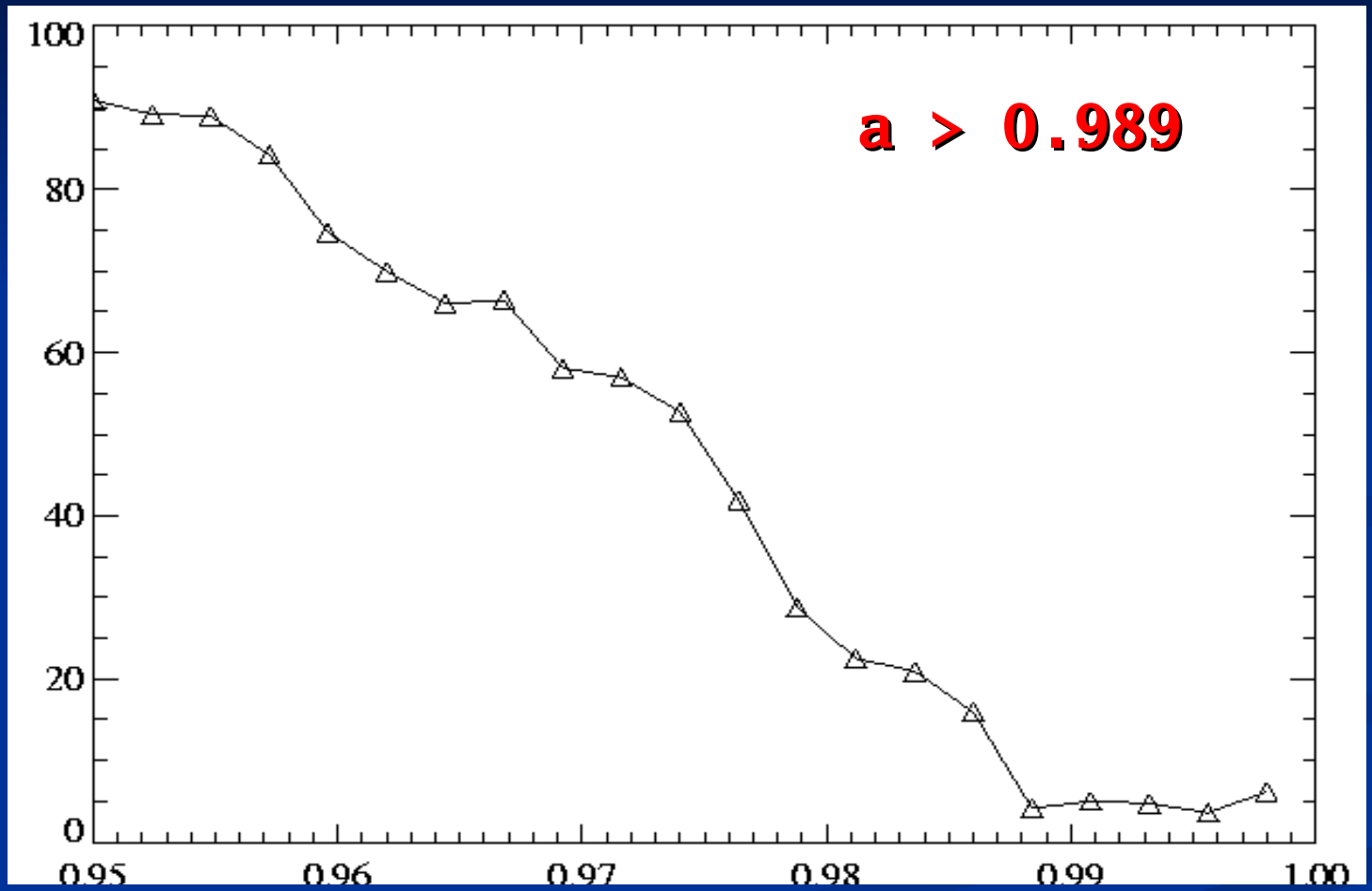
Best-fit Model for MCG-6



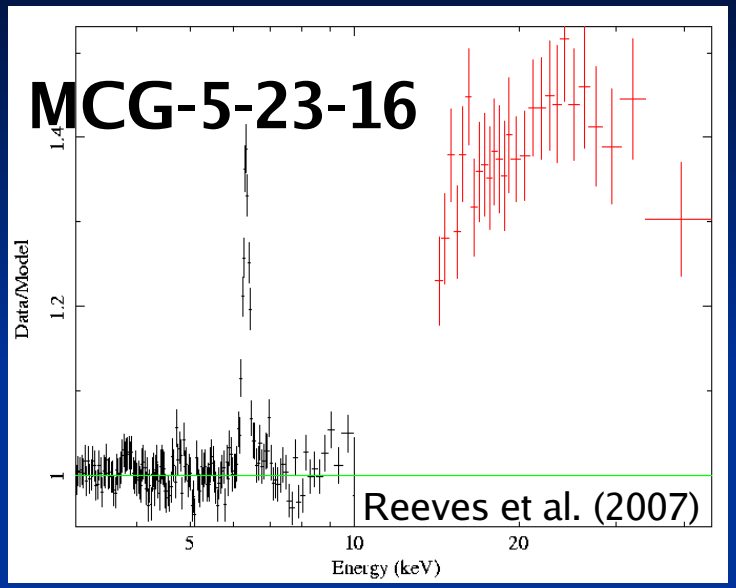
Fe-K Line Structure

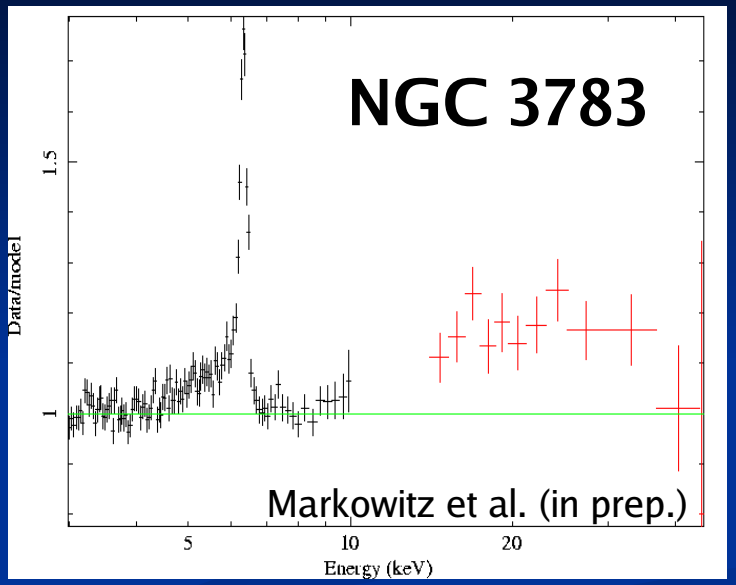


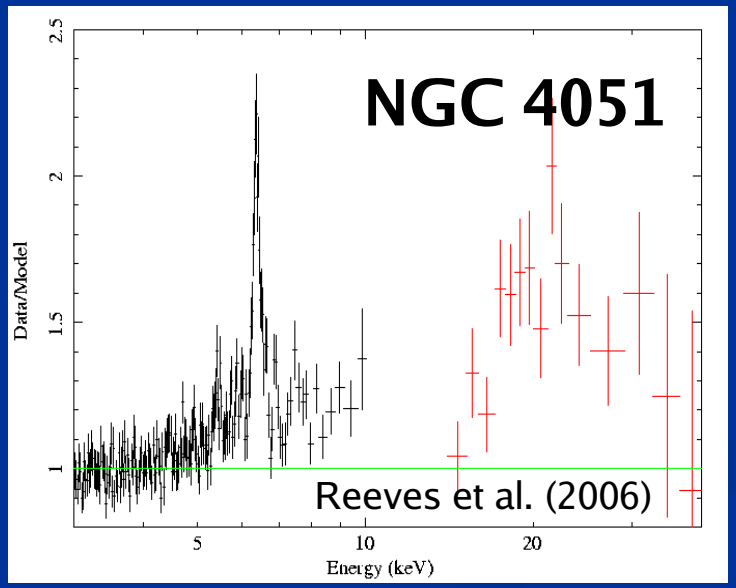
Error Curve for Black Hole Spin

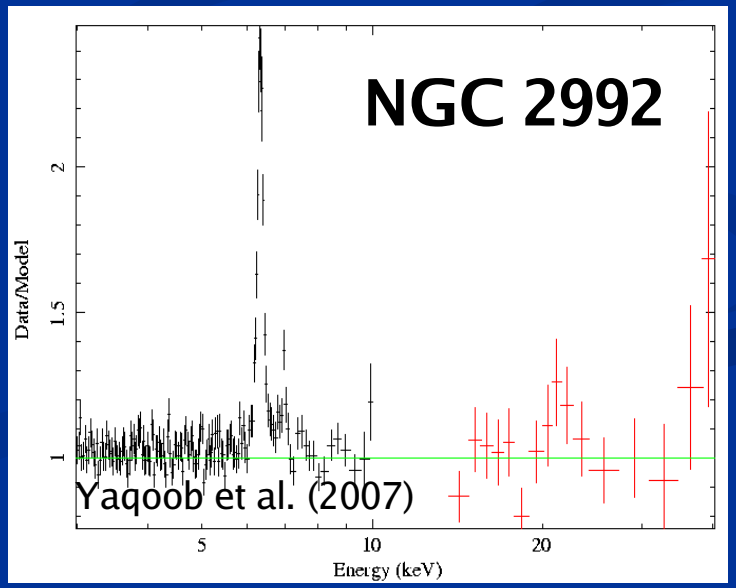


Other Sy 1 Candidates









Kerrconv Fit Results

AGN	a (cJ/GM^2)	r_{min} (r_g)	Incl (°)	$\Delta\chi^2/\Delta$d.o.f. (with smearing)
MCG–6-30-15	> 0.989	< 1.70	26-29	-1026/-6
MCG–5-23-16	0.45-0.75	4.14-4.21	42-43	-159/-5
NGC 3783	0.40-0.80	4.05-4.20	21-24	-115/-4
NGC 4051	> 0.82	< 5.49	25-35	-15/-4
NGC 2992	0.56-0.86	3.92-4.99	38-52	-20/-4

Conclusions

- Roughly 10^{5-6} photons and a strong, broad Fe-K line are needed in order to use Fe-K fitting to constrain BH spin. Simultaneous data > 10 keV with *Suzaku* enables reflection to be modeled properly, allowing for better spin constraints.

- 4 out of our sample of 5 Sy 1 AGN showed a statistically significant improvement in fit when relativistic effects were convolved with an ionized disk reflection spectrum model. This demonstrates the importance of relativistic effects and enables us to constrain BH spin in these sources.

- In our radio-quiet sample, we see a wide range of spin constraints, but none are consistent with non-rotating BHs. This shows that radio-loudness is not dependent on spin alone.