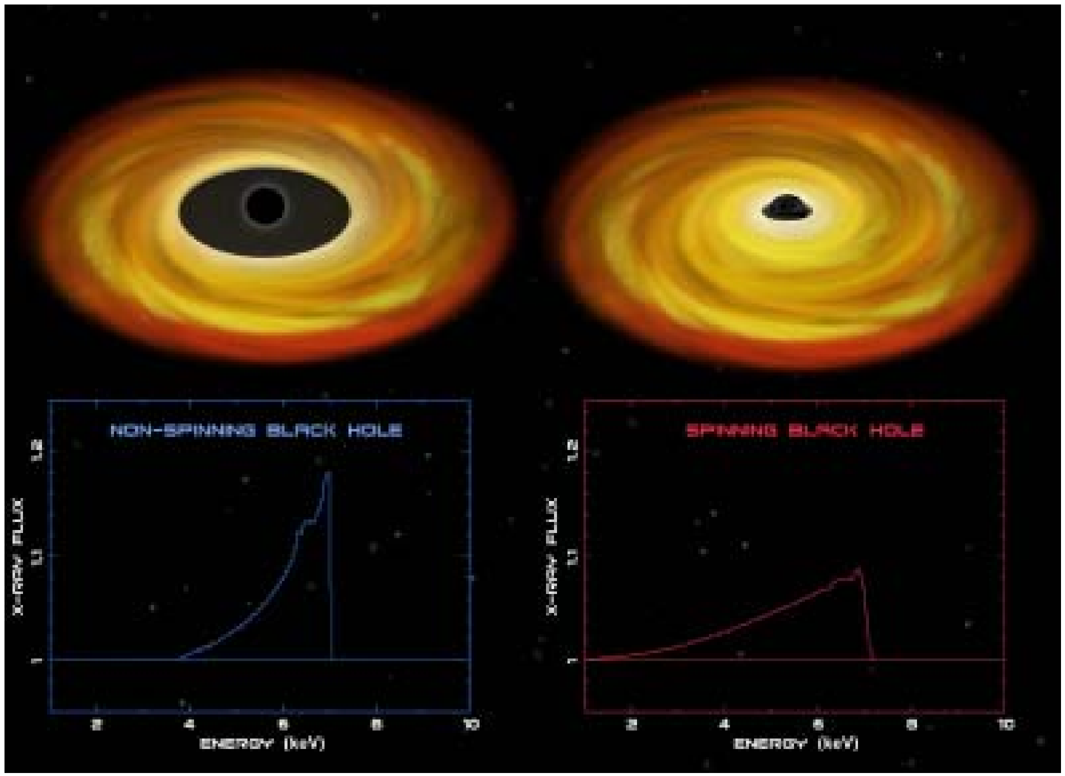
Broad Iron Lines in Galactic Black Holes



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X-ray

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Optical, IR, X-rays

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Rob Fender

Michael Rupen

Danny Steeghs

Also:

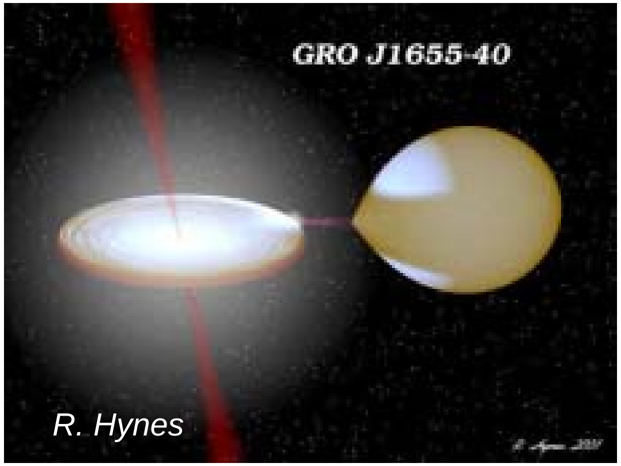
Claude Canizares

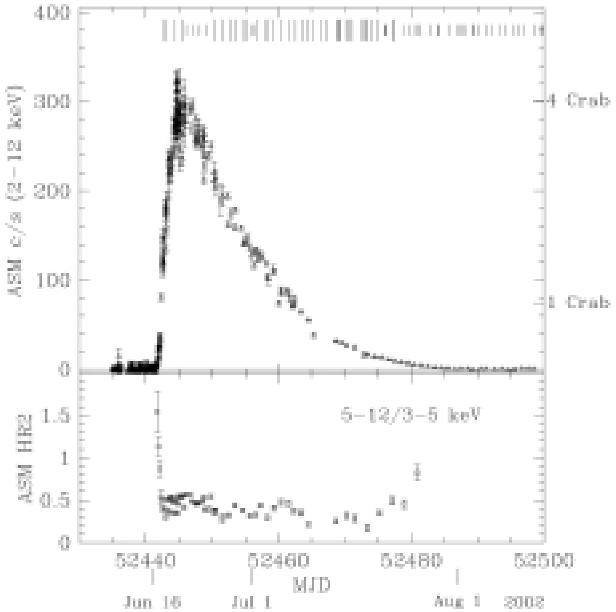
Fred Jansen

Jean Swank

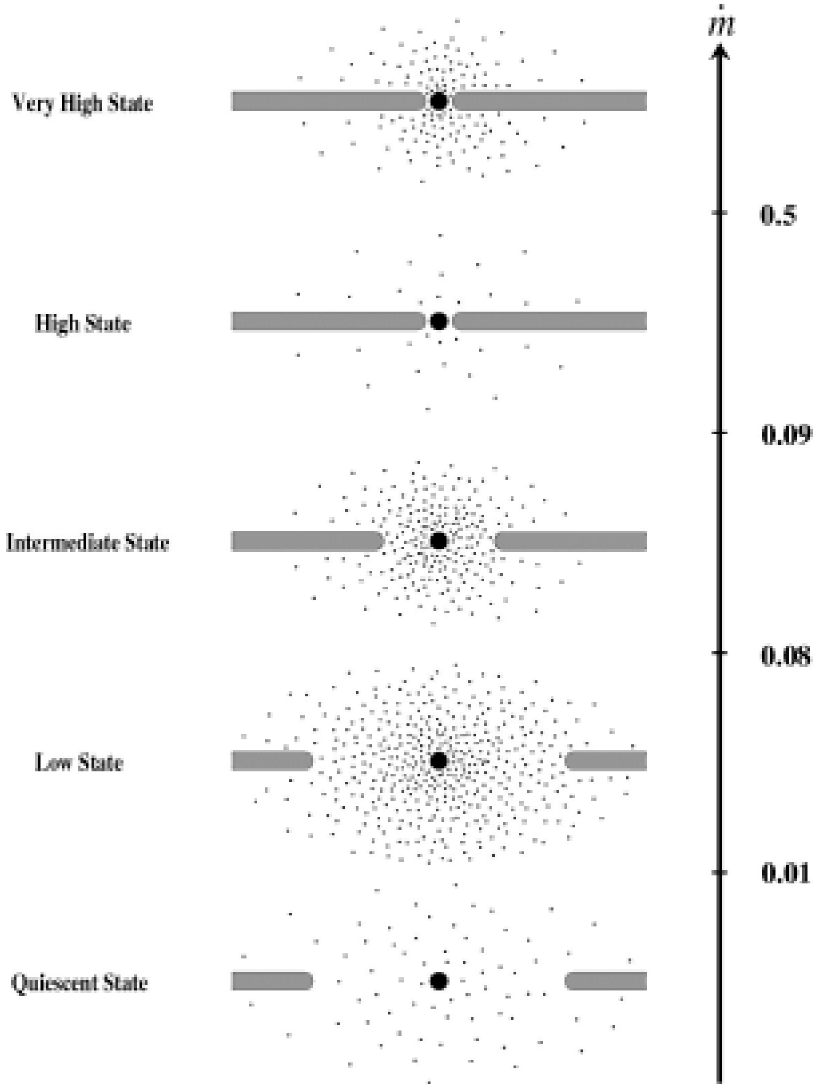
Harvey Tananbaum

Black Hole (Candidate) X-ray Binaries





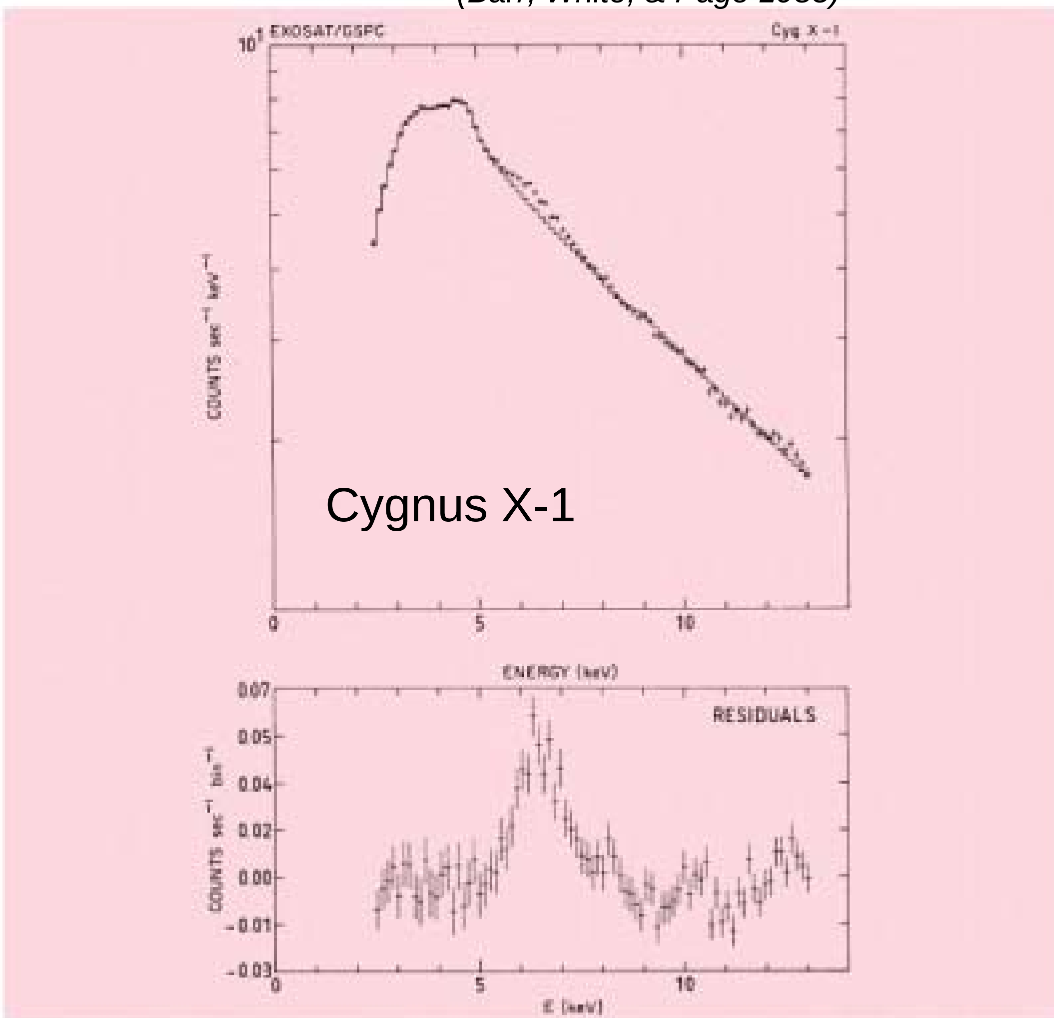
(Park et al. 2003)



(Esin, McClintock, & Narayan 1997)

In the beginning ….

(Barr, White, & Page 1985)



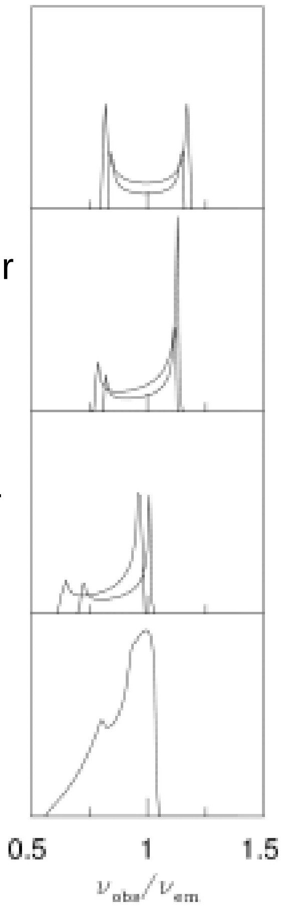
Relativistic Fe K line theory

Newtonian

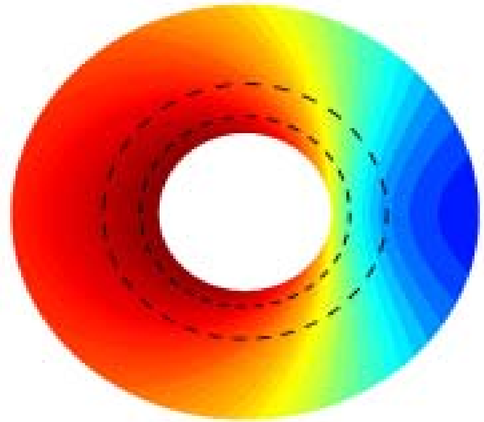
Special Relativity
Tranverse Doppler
Shifts, Beaming

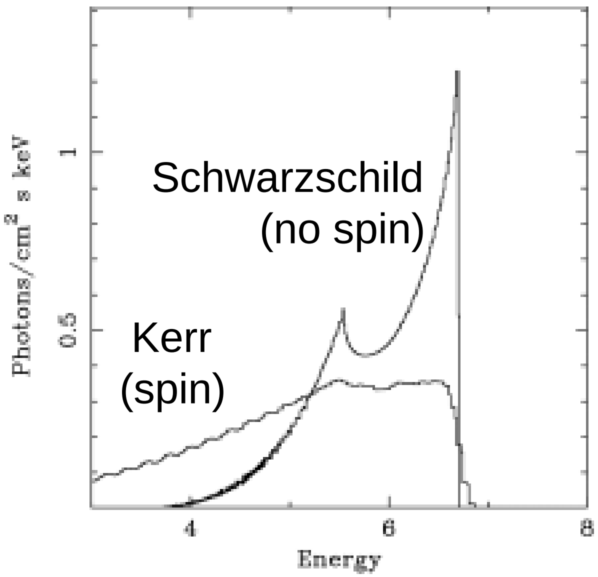
General Relativity
Gravitational Red-
shifts

Line Profile



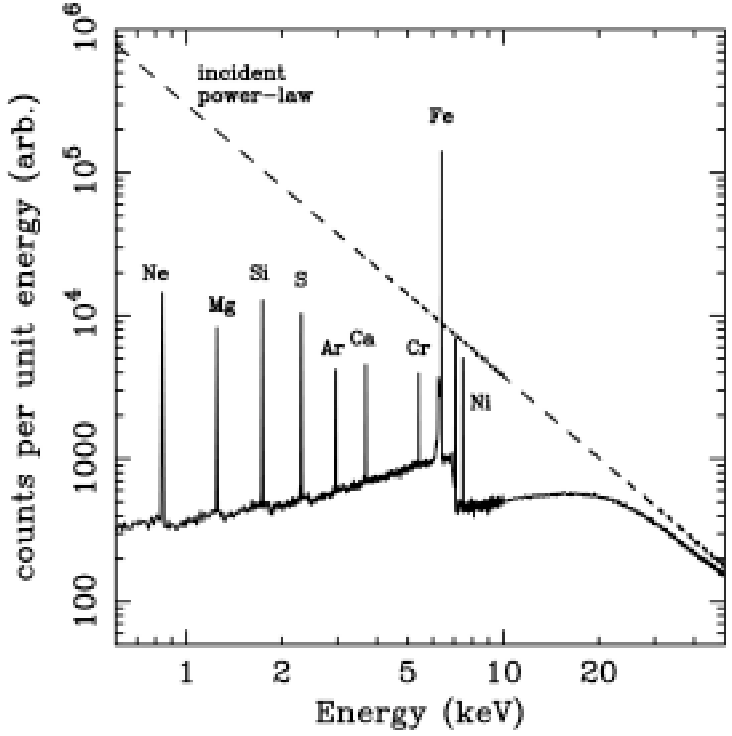
(see Fabian et al. 2000, ref therein)



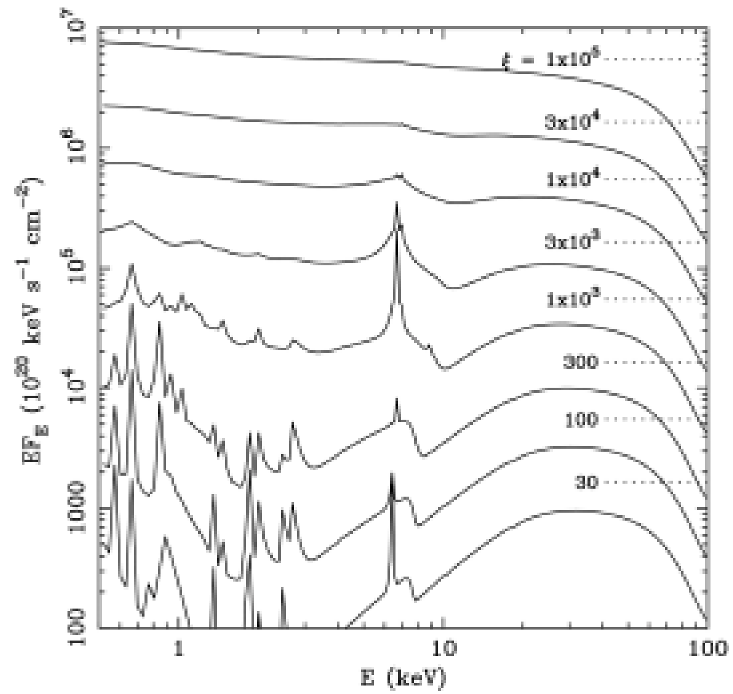


Disk Reflection

(George & Fabian 1991)

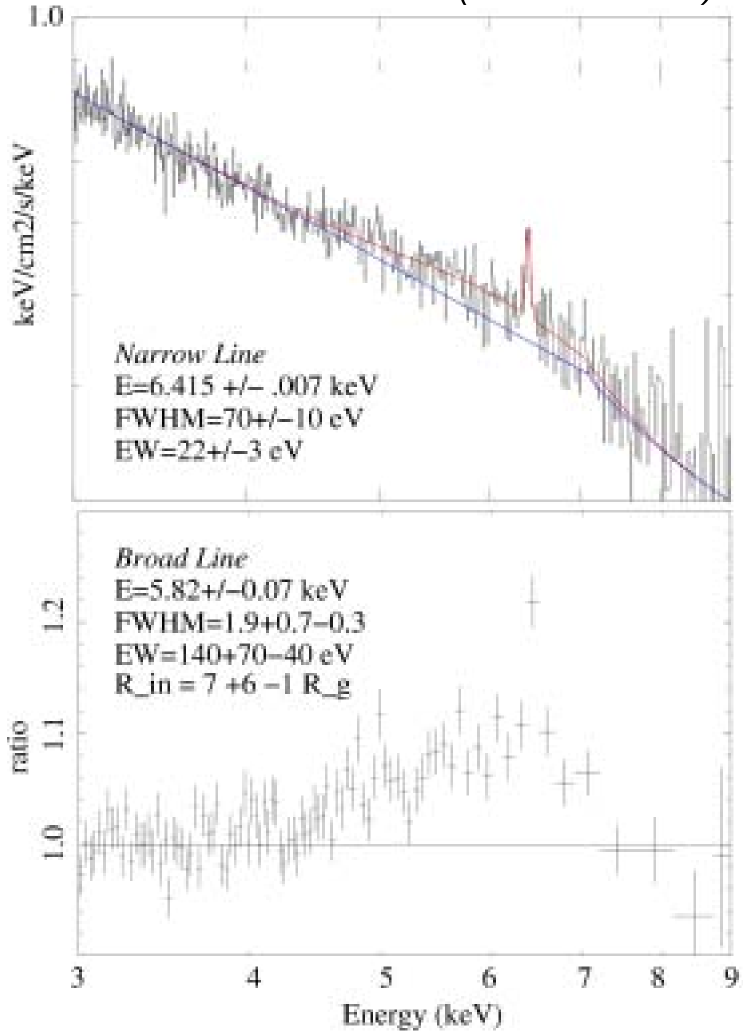


(Ross, Fabian, Young 1999)



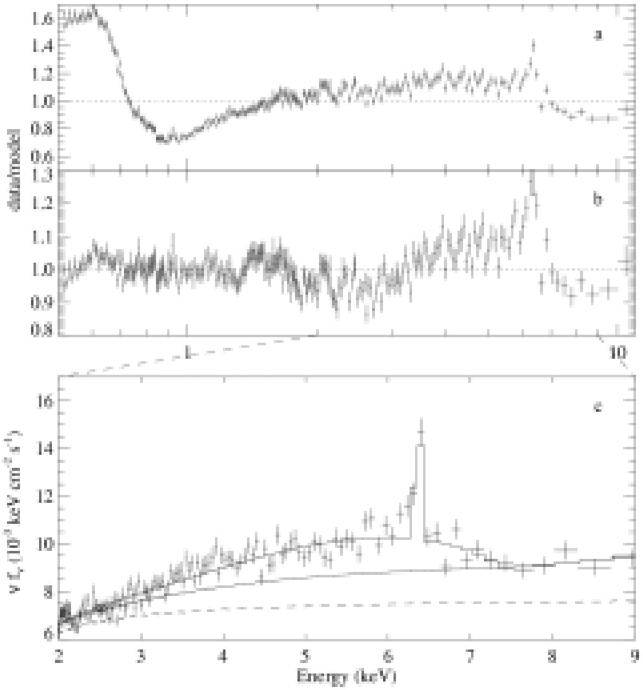
Cygnus X-1 with the Chandra HETGS

(Miller et al. 2002)

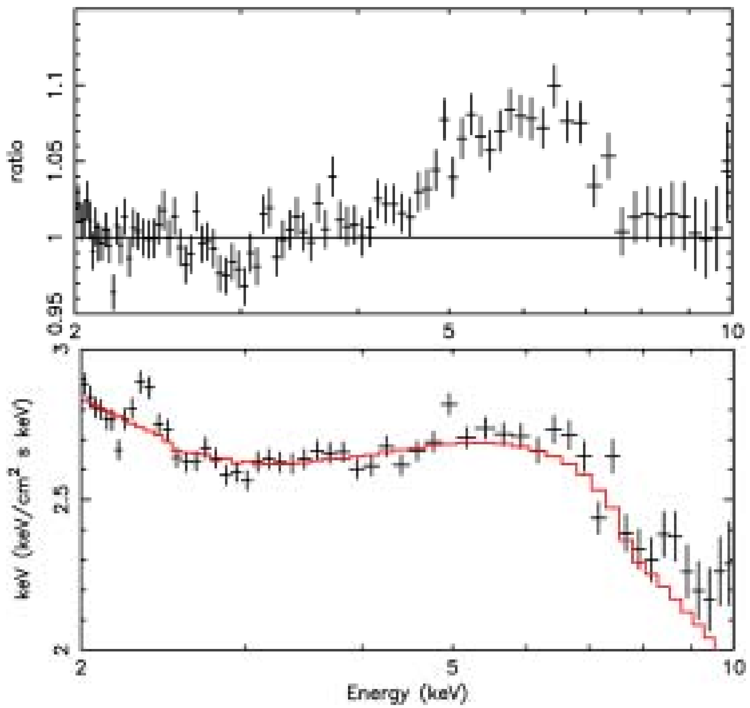


MCG -6-30-15 and XTE J1650-500

MCG -6-30-15 *(Wilms et al. 2001)*



XTE J1650-500 *(Miller et al. 2002)*



E = 6.97 (-0.1) keV, EW = 300-400 eV

R_in = 1.2 R_g, q=4.3-5.0

f = 1.5-2.0

E = 6.8 (+0.2,-0.1) keV, EW = 350 (50) eV

R_in = 1.2 R_g, q=5.0 (0.5)

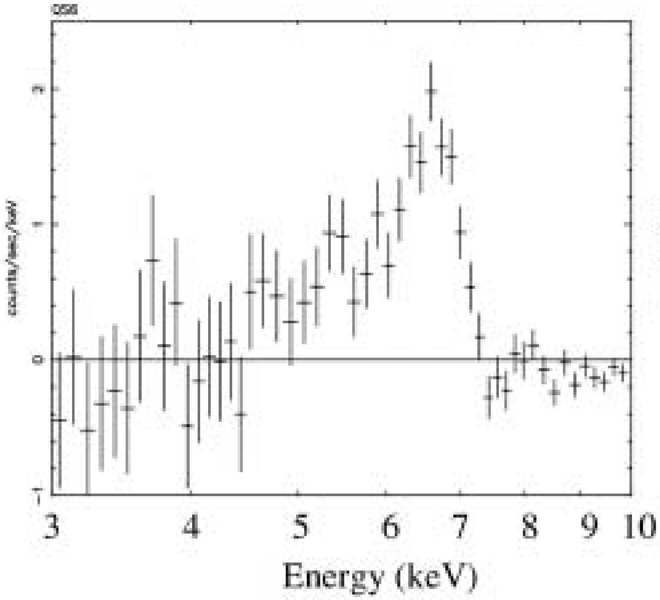
f = 0.6 (+0.3,-0.1)

R_in > 6 R_g, q = 3, ruled out at 6 sigma

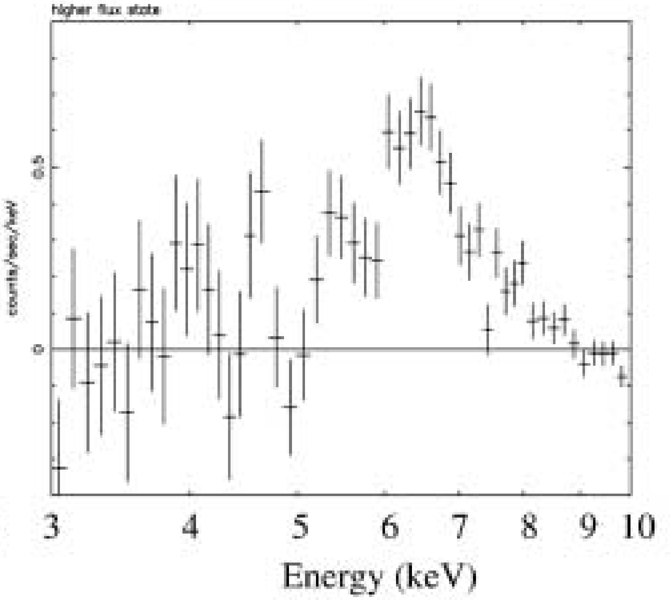
Broad Fe K lines are fairly common

GRS 1915+105 with BeppoSAX

(Martocchia et al. 2003)



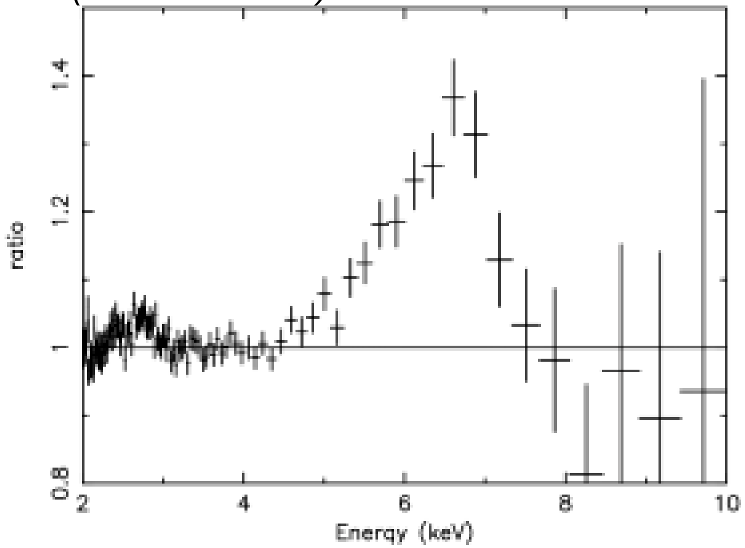
1998 observation, does not require spin.



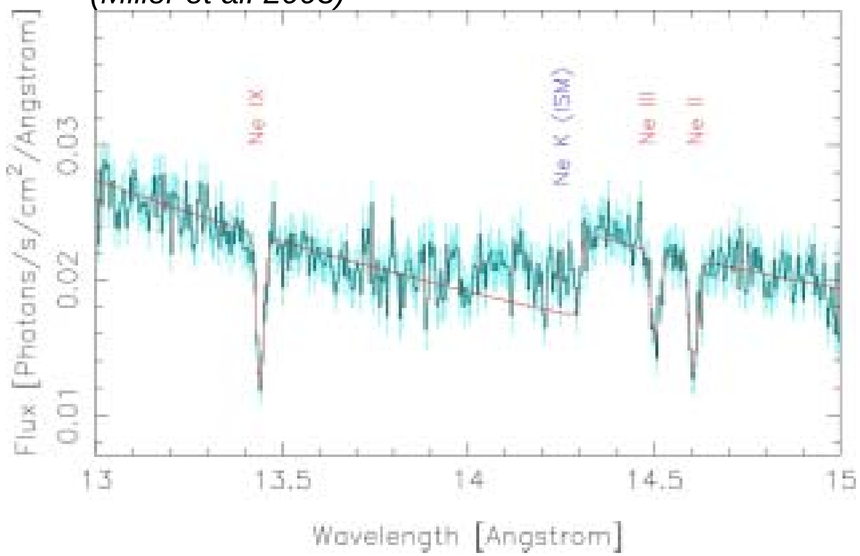
2000 observation, may require spin.

GX 339-4 with the Chandra HETGS

(Miller et al. 2003)



(Miller et al. 2003)



<u>Relativistic Iron Line</u>

E = 6.9 (0.1) keV

R_in = 2.0 (+2.0,-1.0) R_g
R_in > 6 R_g ruled out at ~4 sigma

f = 1.0 (0.4)

<u>Warm Absorber</u>

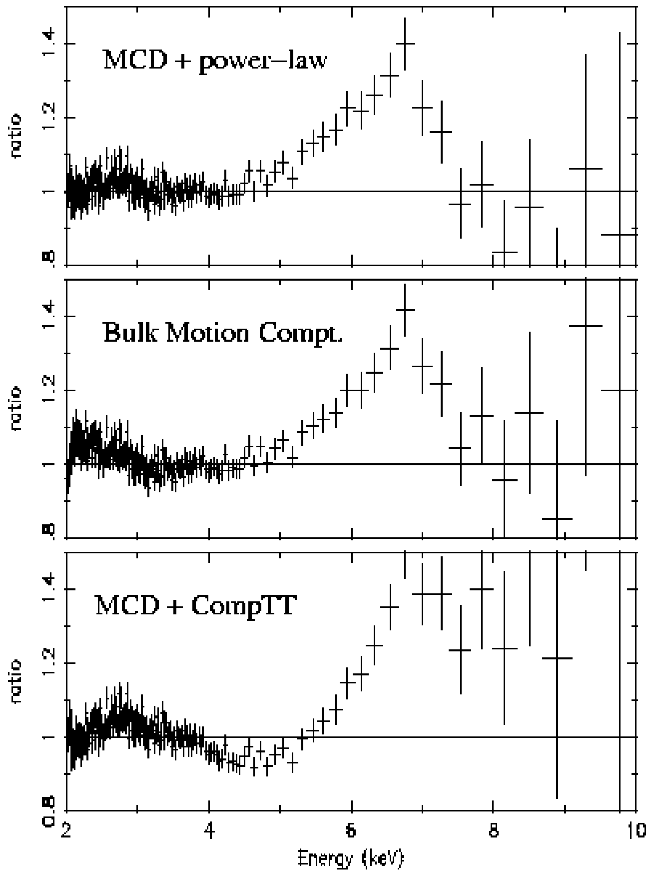
He-like and/or H-like Ne, Mg, O
Ne II, Ne III

Vel. Width: 150-250 km/s
Outflow: 150 km/s, 400-500 km/s

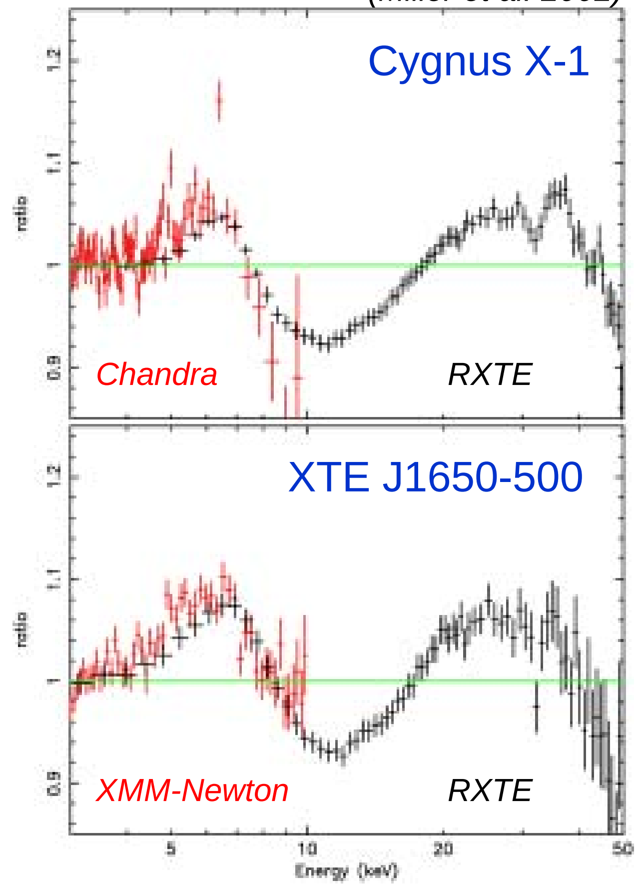
10^6 cm shell at 10^{11} cm, xi ~ 70

On the robustness of Fe K lines

GX 339-4



(Miller et al. 2002)



Relativistic profile is model-indp.

Lines agree with reflection, RXTE.

Alternative explanations

- Lines are model-dependent

  Statistically significant lines are largely model-independent, e.g. the example of GX339-4 shown here.

- Comptonization

  (e.g., Misra & Kembhavi 1998, & Sutaria 1999)

  To get enough scatters, an optically-thick geometry would be required, and only blackbody emission would be seen (Reynolds & Wilms 2000).

- Optically-thick outflows

  (e.g., King & Page 2003, Titarchuk, Kazanas, & Becker 2003)

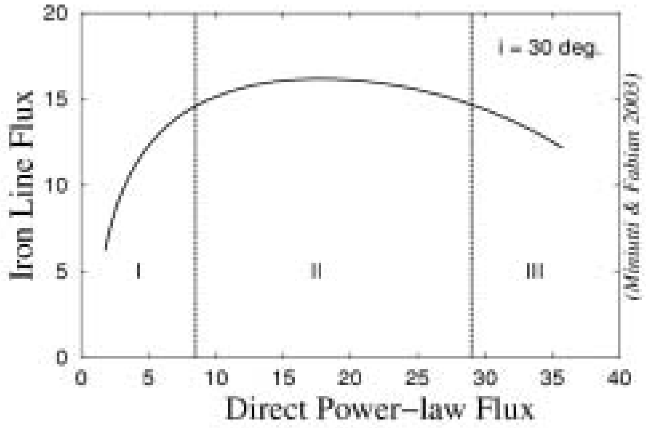
  Hot disk component, HF QPOs should not be observable.

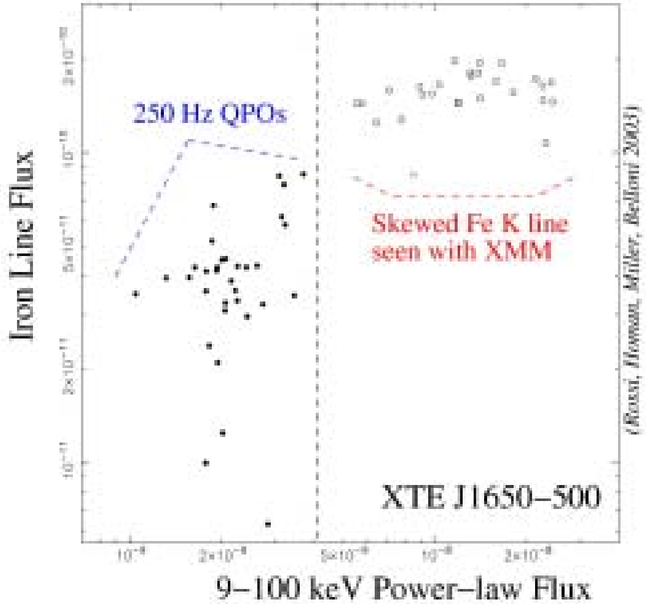
  Requires mass_outflow_rate = 10 mass_inflow_rate.

  Broad lines seen across nearly 10^4 in L_X.

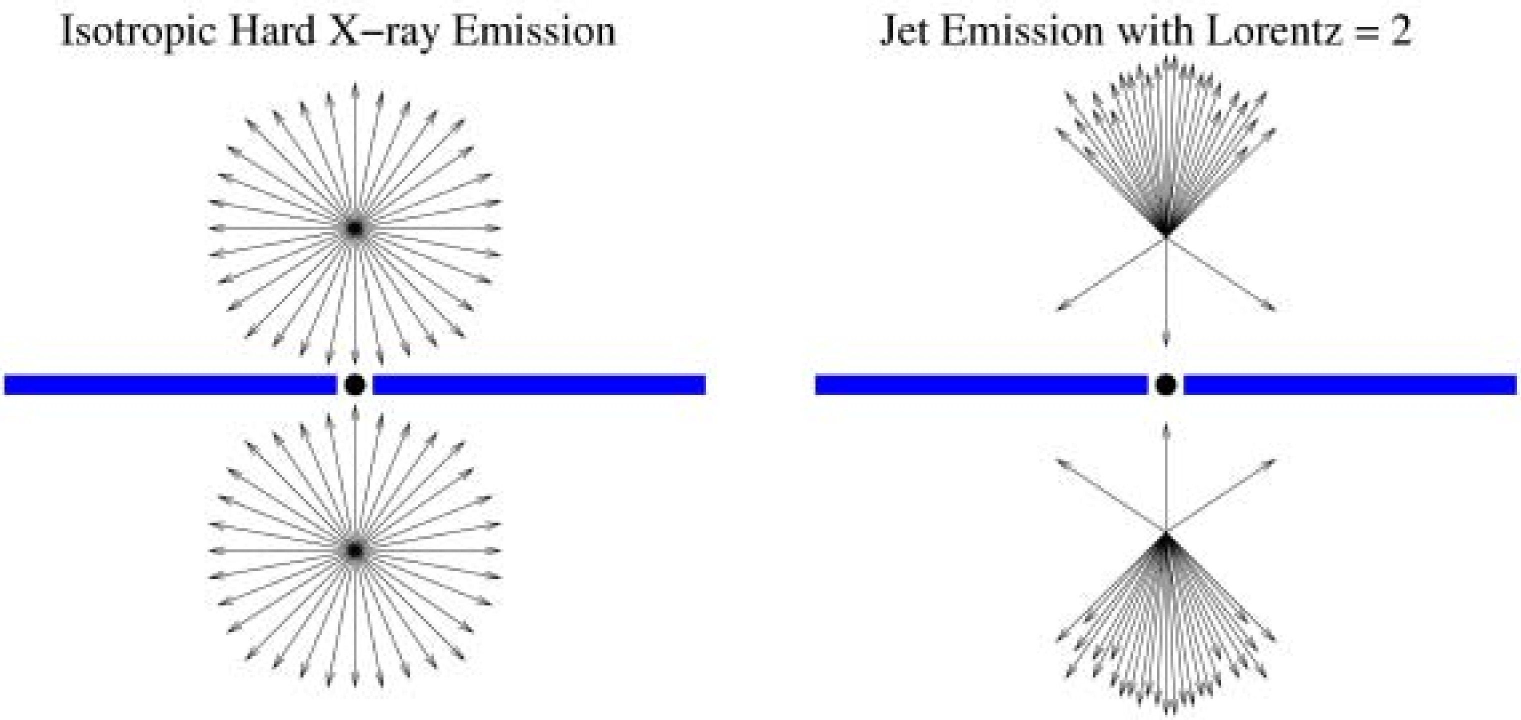
  Requires hard X-rays to be produced very far from BH.

Evidence for Other GR Effects?



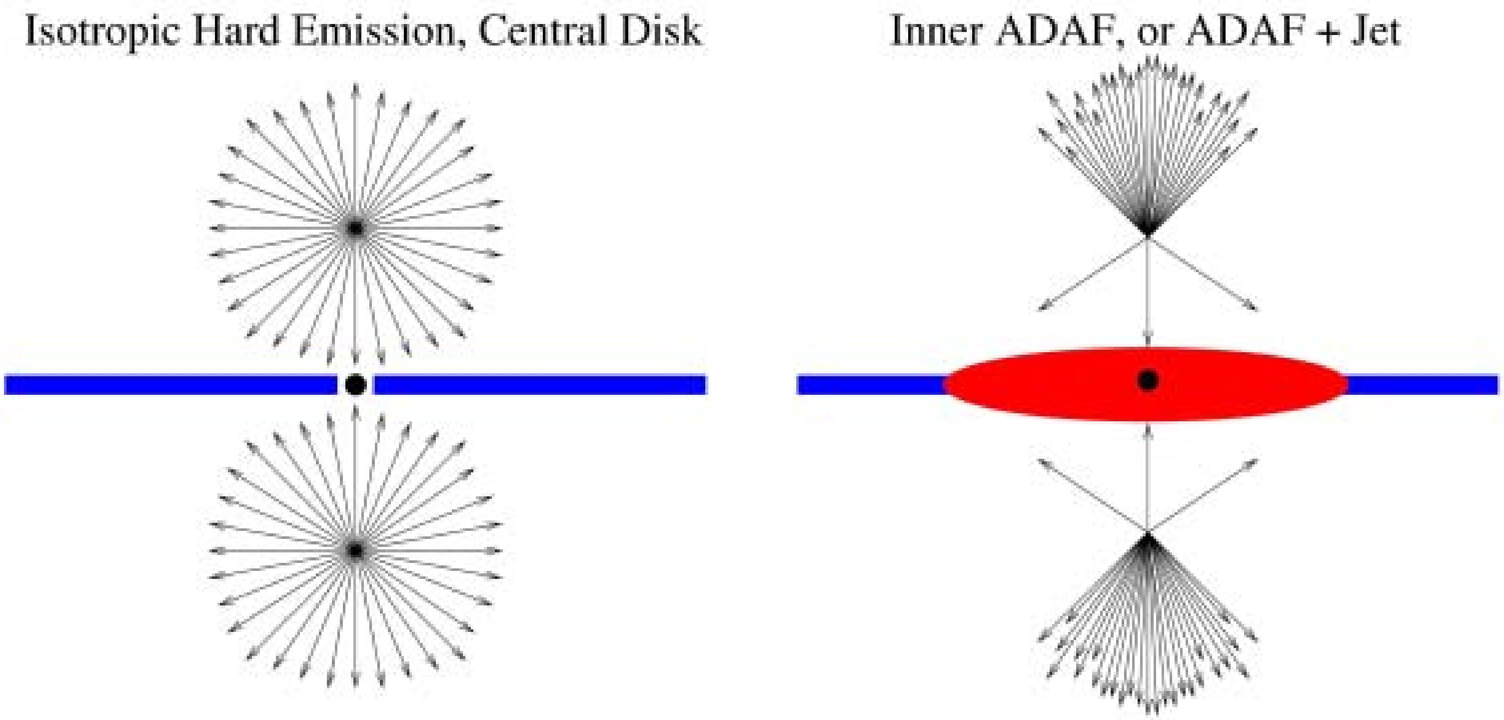


Testing Accretion Models I

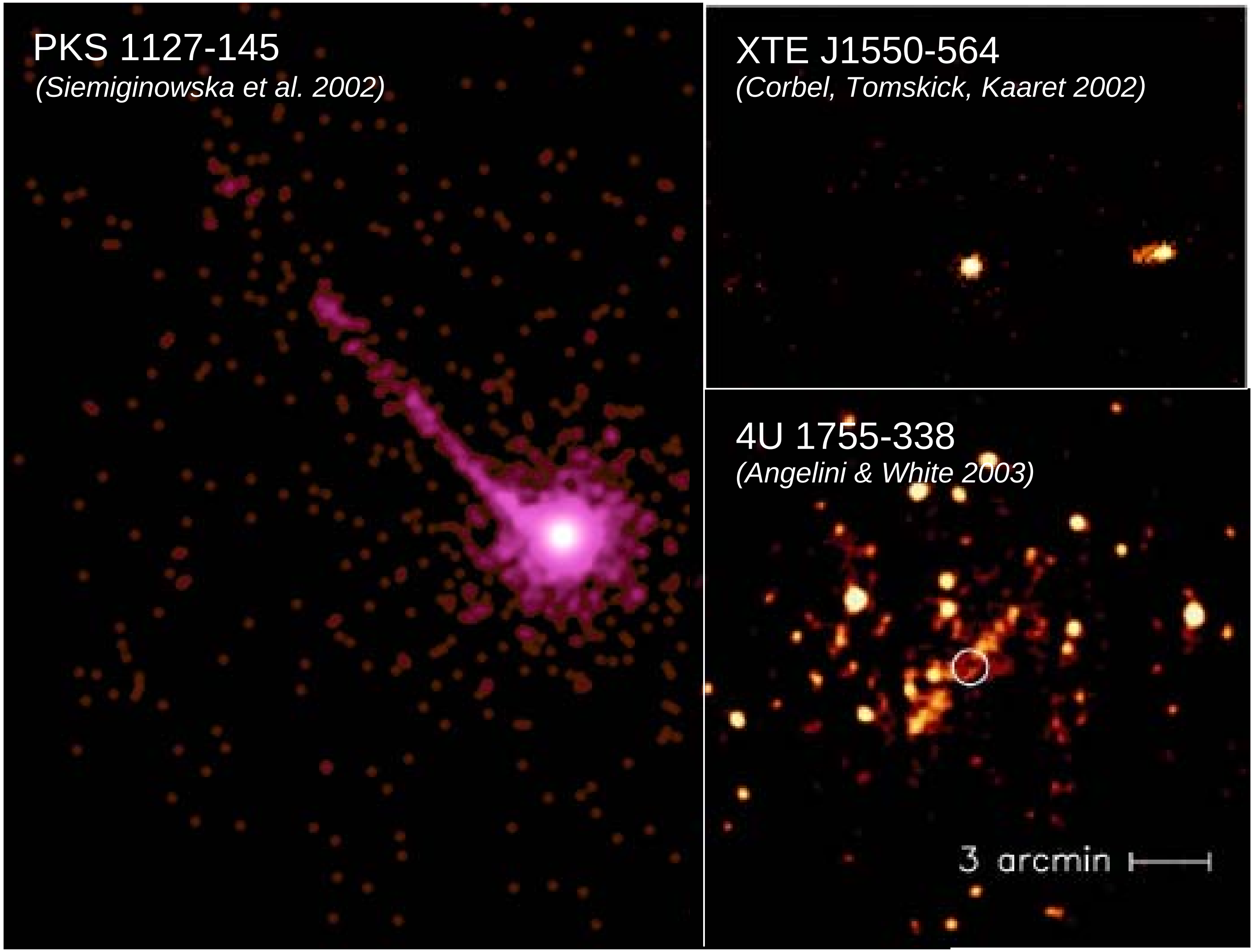


(jet models: e.g. Markoff, Falcke, & Fender 2001; Fender, Gallo, & Jonker 2003, Maccarone 2003)

Testing Accretion Models II

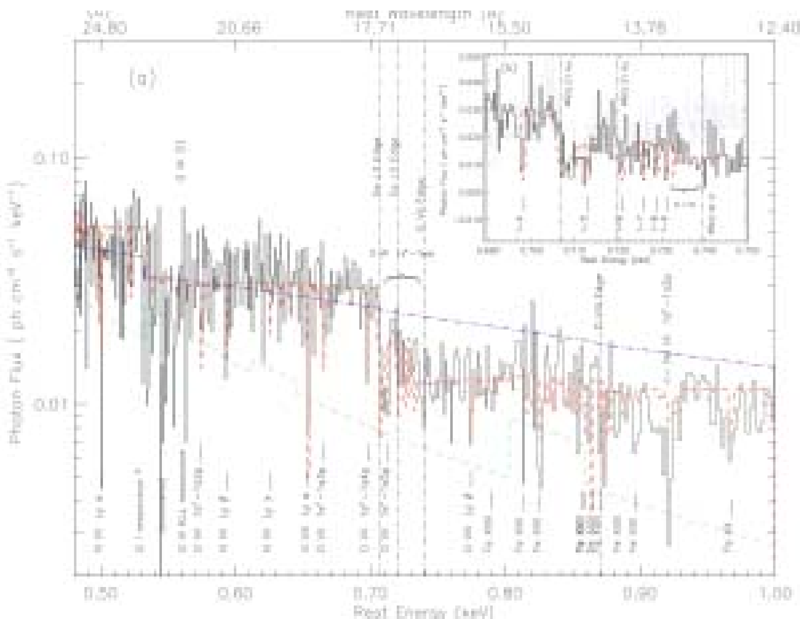


AGN and BHCs: Jets

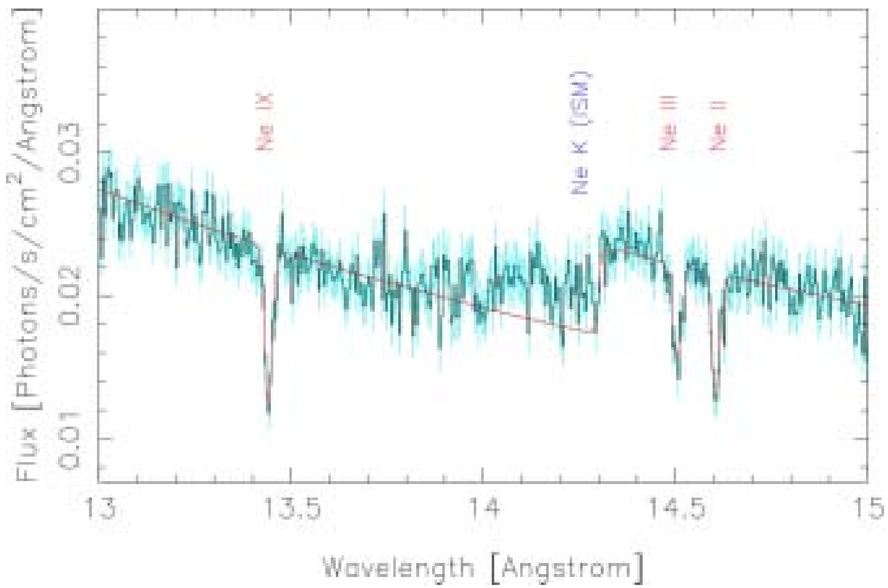


AGN and BHCs: Warm Absorbers

MCG -6-30-15 *(Lee et al. 2001)*

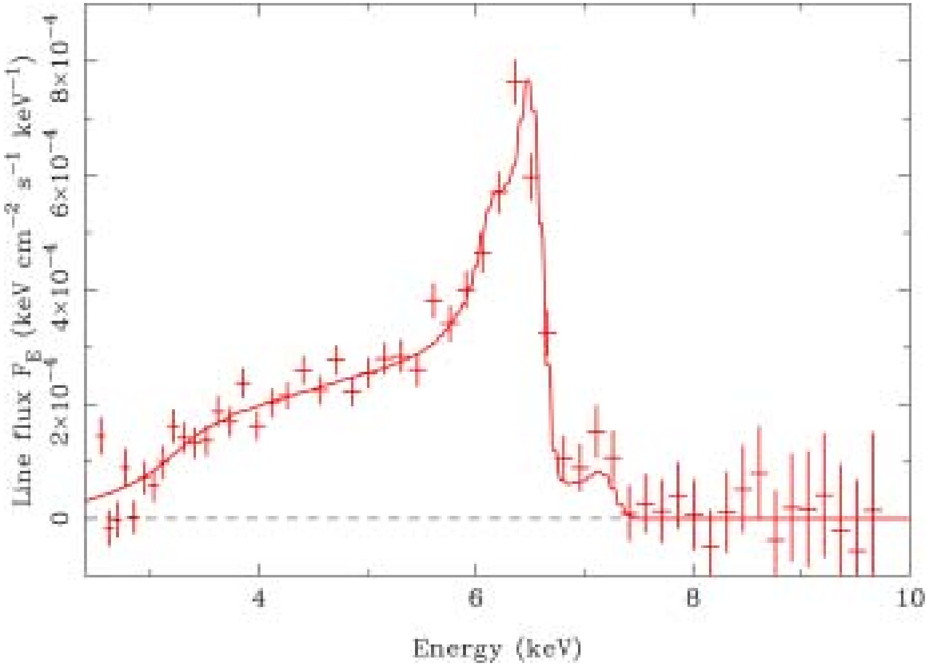


GX 339-4 *(Miller et al. 2003)*

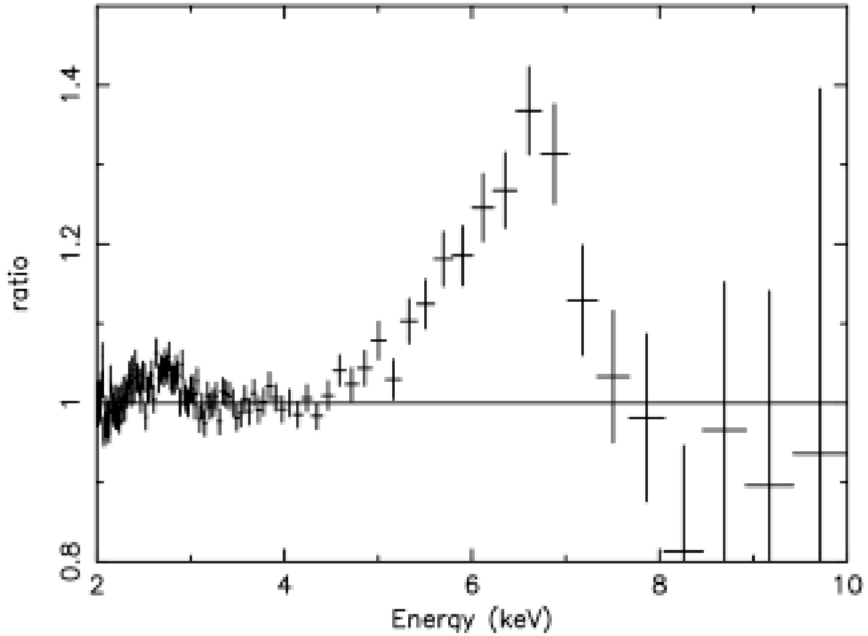


AGN and BHCs: Fe K lines

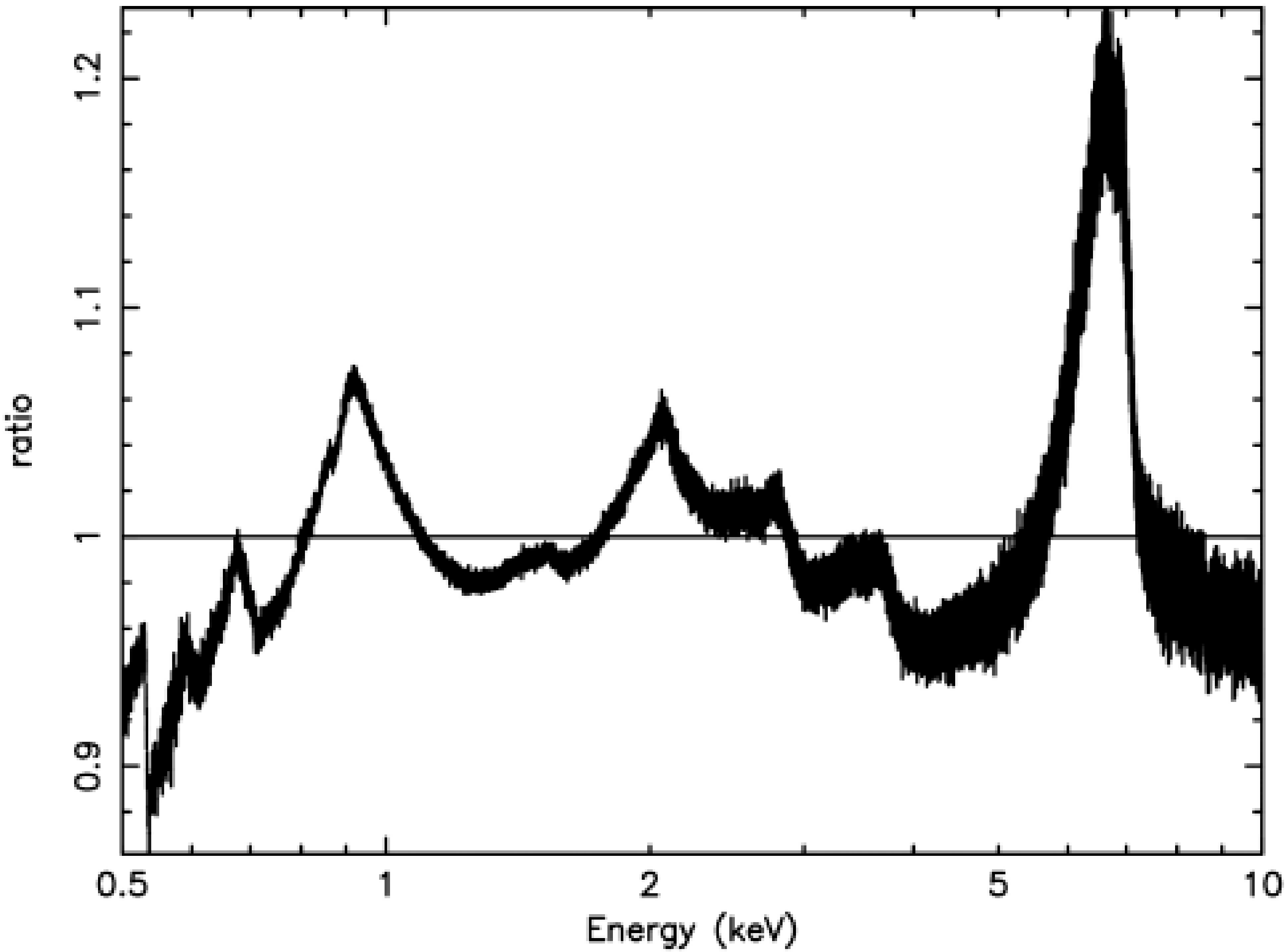
MCG -6-30-15 *(Fabian et al. 2002)*



GX 339-4 *(Miller et al. 2003)*



Relativity in BHCs with Constellation-X



Summary and Conclusions

- Chandra and XMM-N have shown that broad Fe K lines in BHCs are intrinsically broad, and shaped by relativistic effects.
- Sensitive observations can constrain black hole spin parameters.
- Chandra, XMM-N are revealing remarkable similarities between supermassive black holes in AGN, and stellar-mass black holes.
- Fe K lines can probe low-luminosity accretion flows.
- Constellation-X needs to be able to observe F_X ~1 Crab sources.

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