

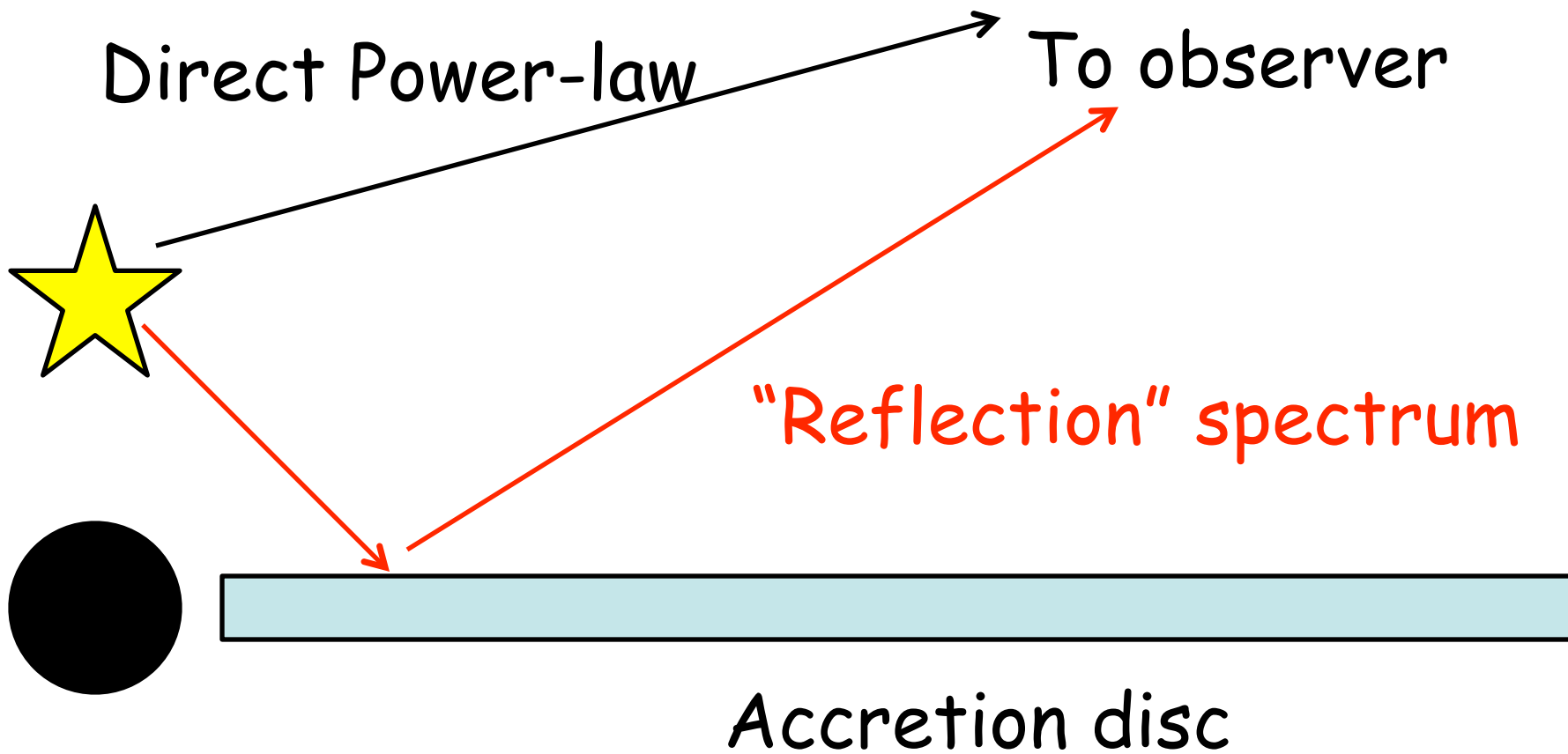
# Reflection and Reverberation

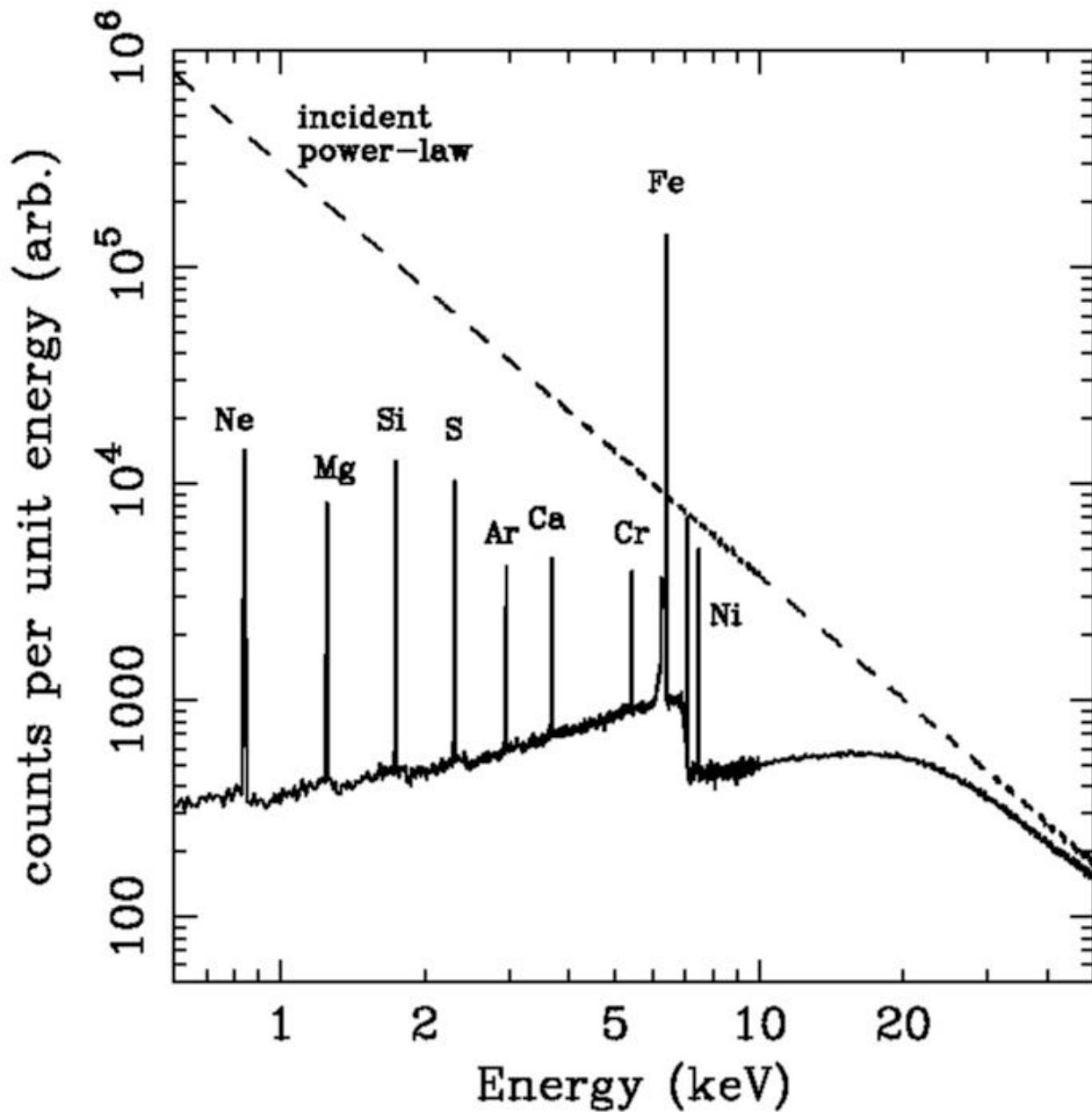
Andy Fabian

IoA, Cambridge, UK

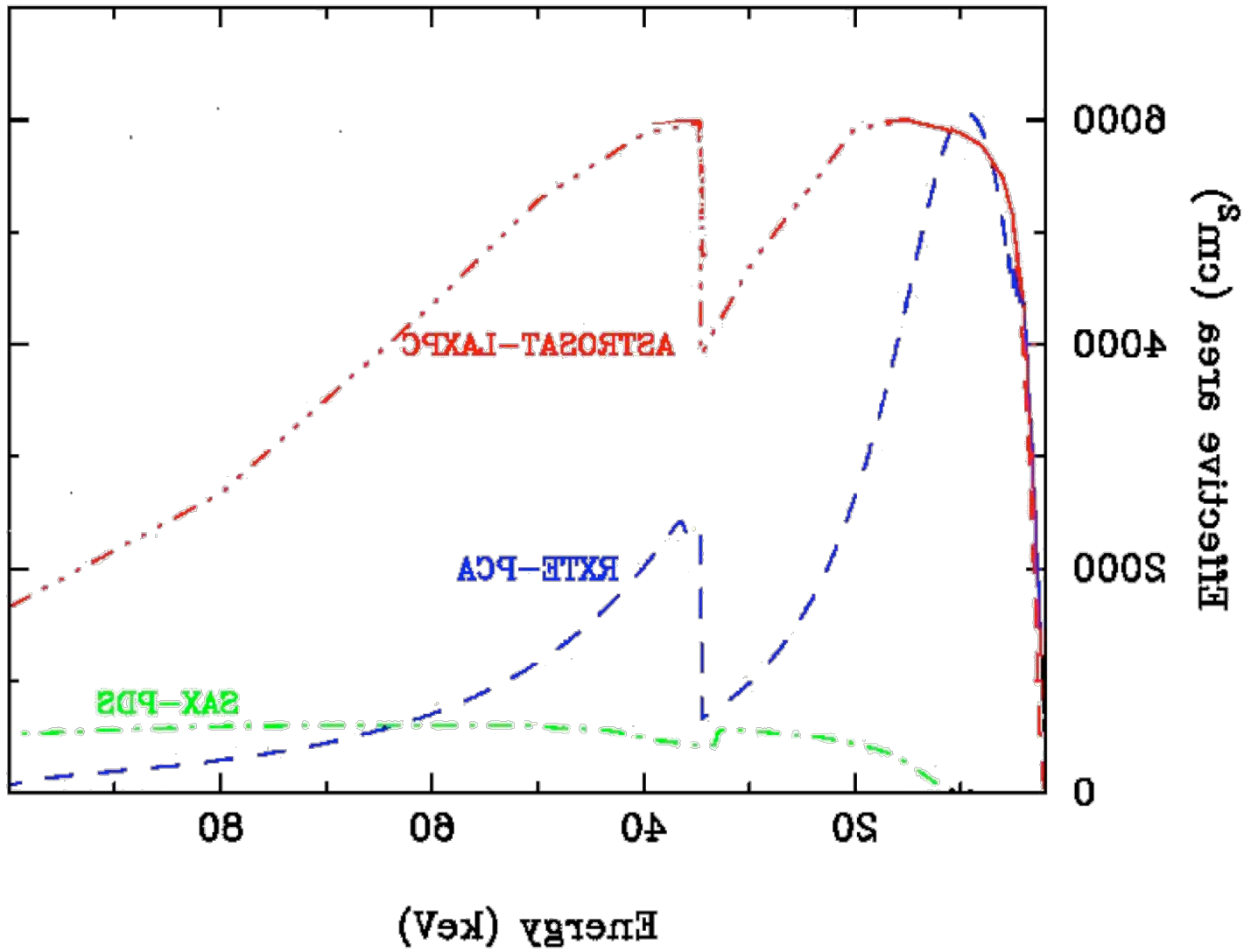
With help from:

Rubens Reis, Ed Cackett, Abdu Zoghbi,  
Randy Ross, Jon Miller, Chris Reynolds...



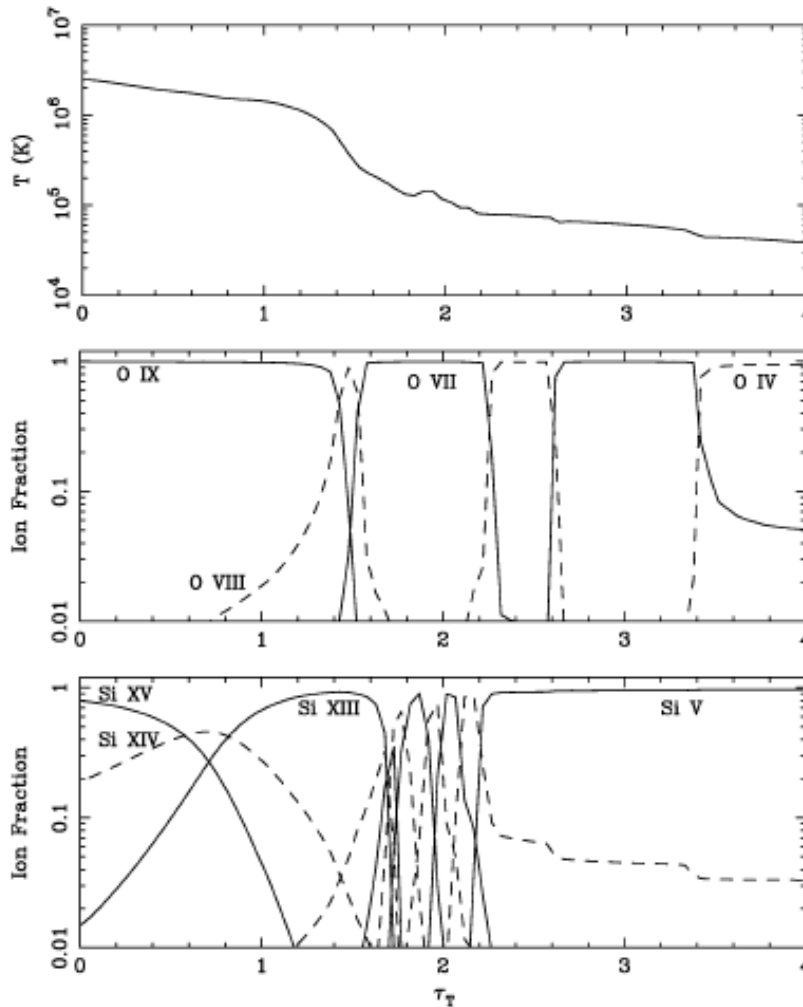


Reflection  
from  
cold matter



# STRONG IRRADIATION

Ross+  
Fabian05

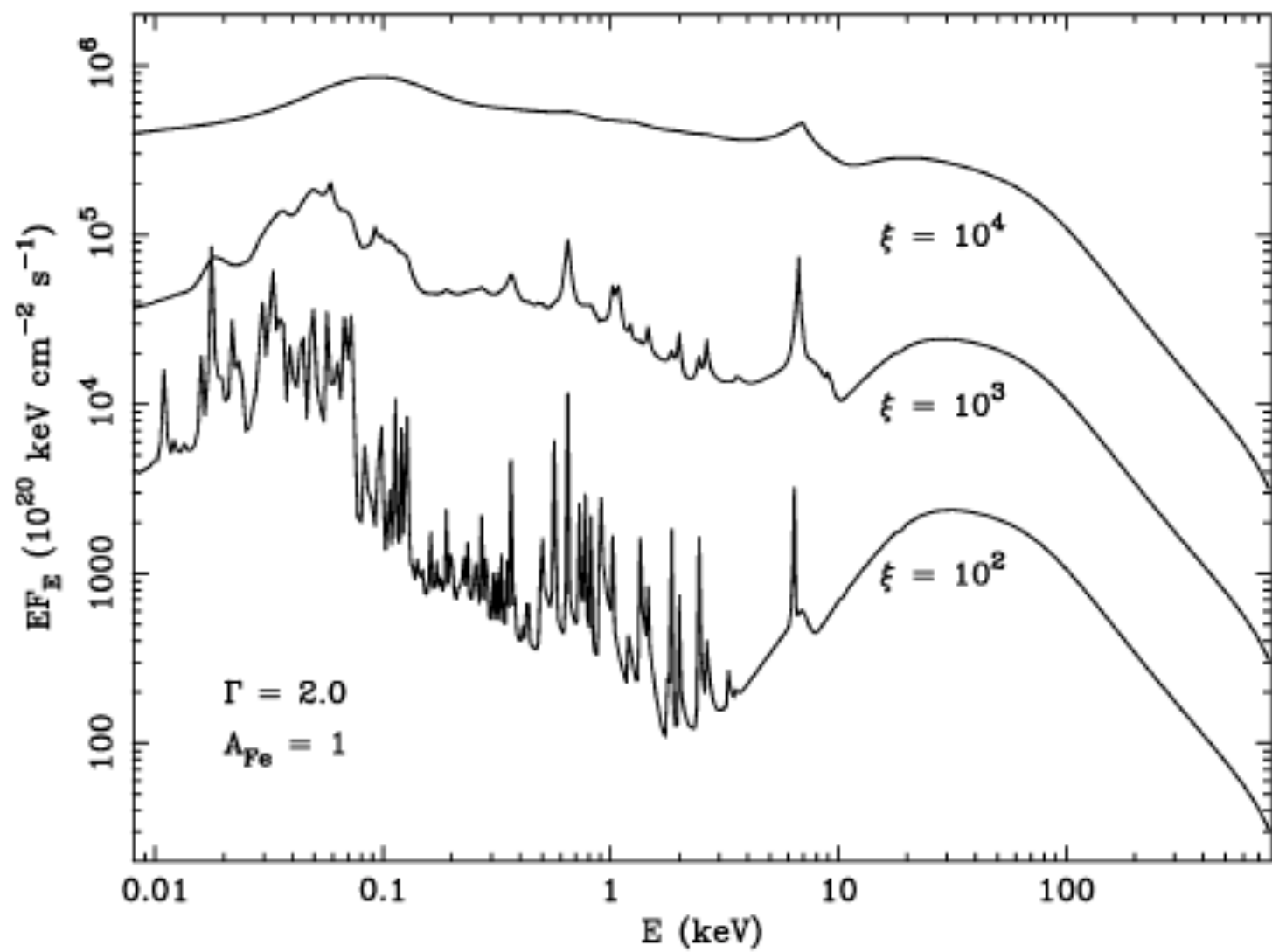


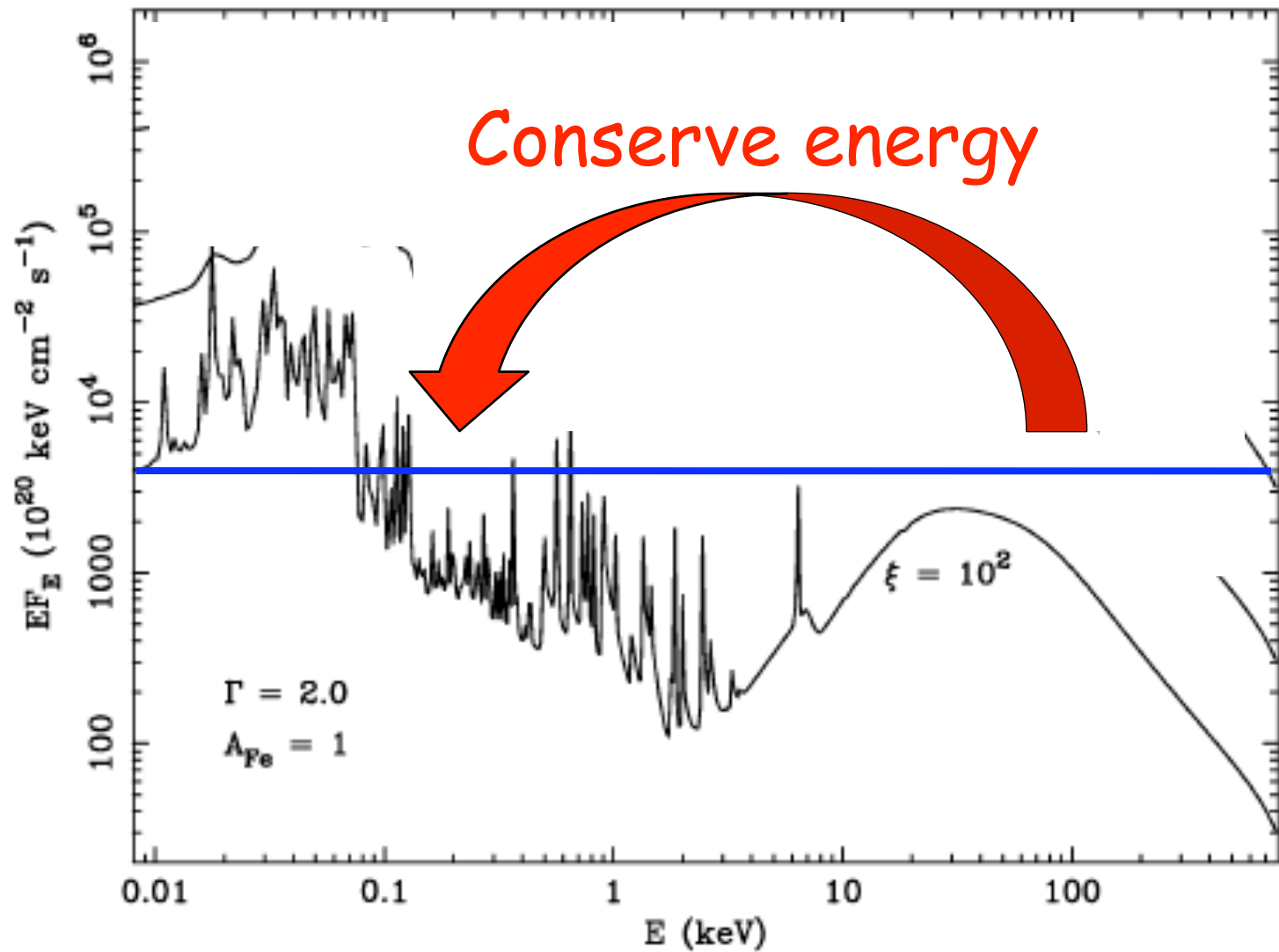
Temp

O ions

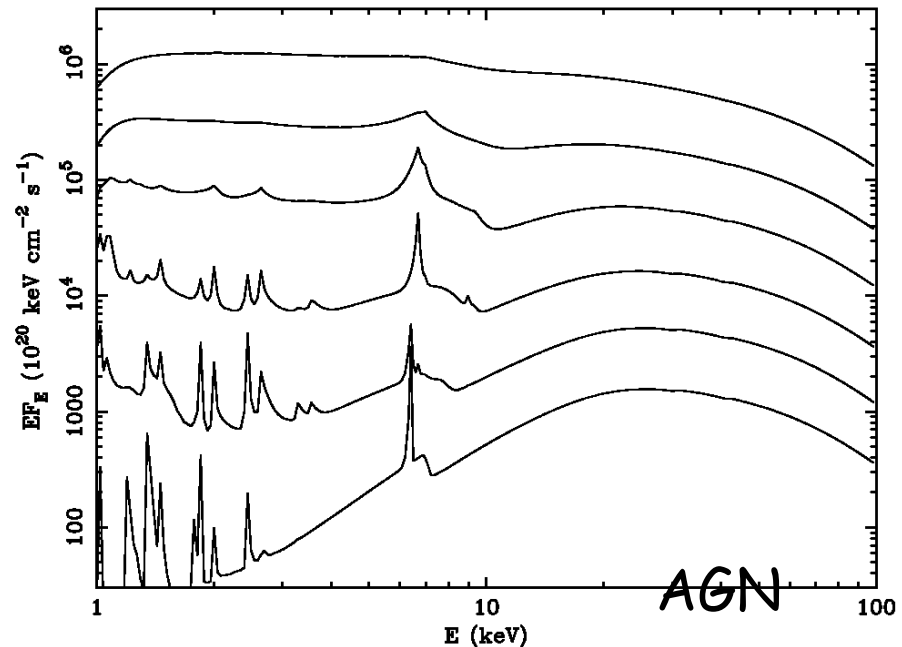
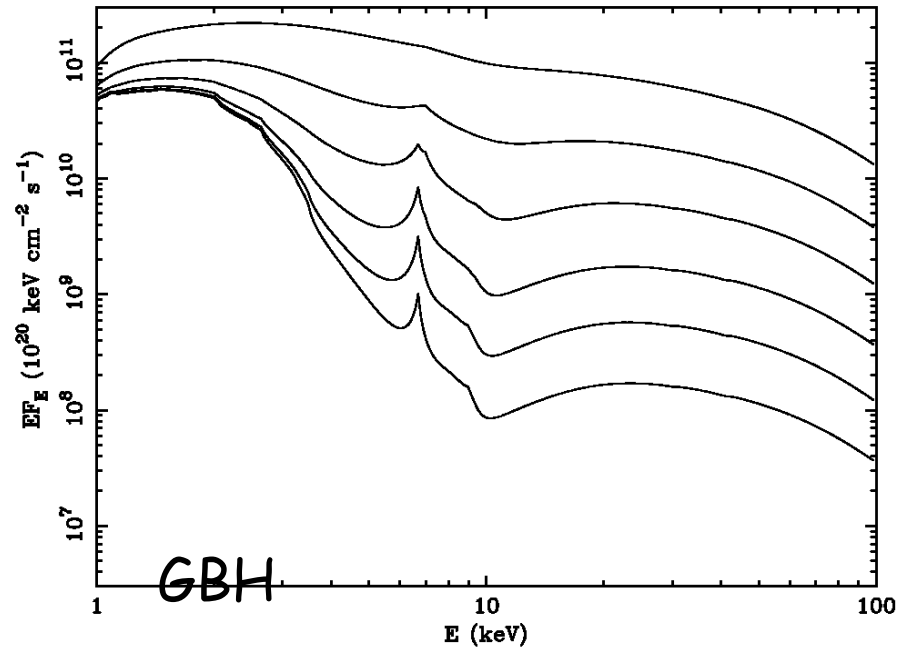
Si ions

Thomson depth in slab



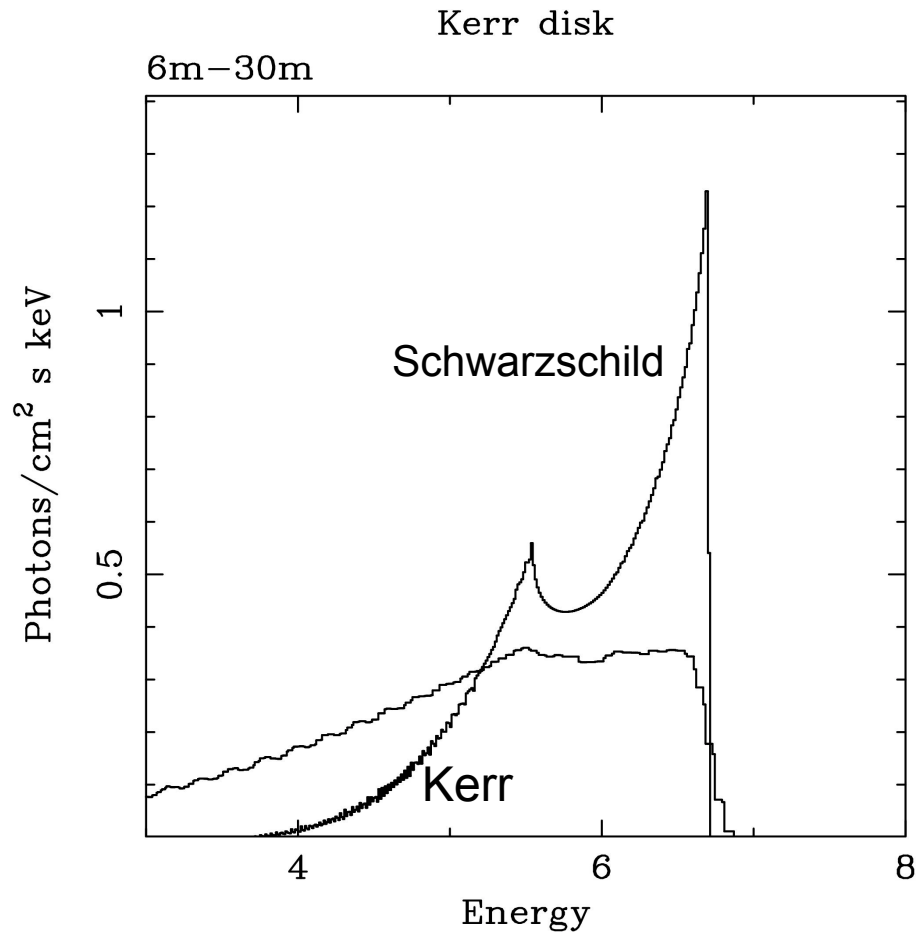
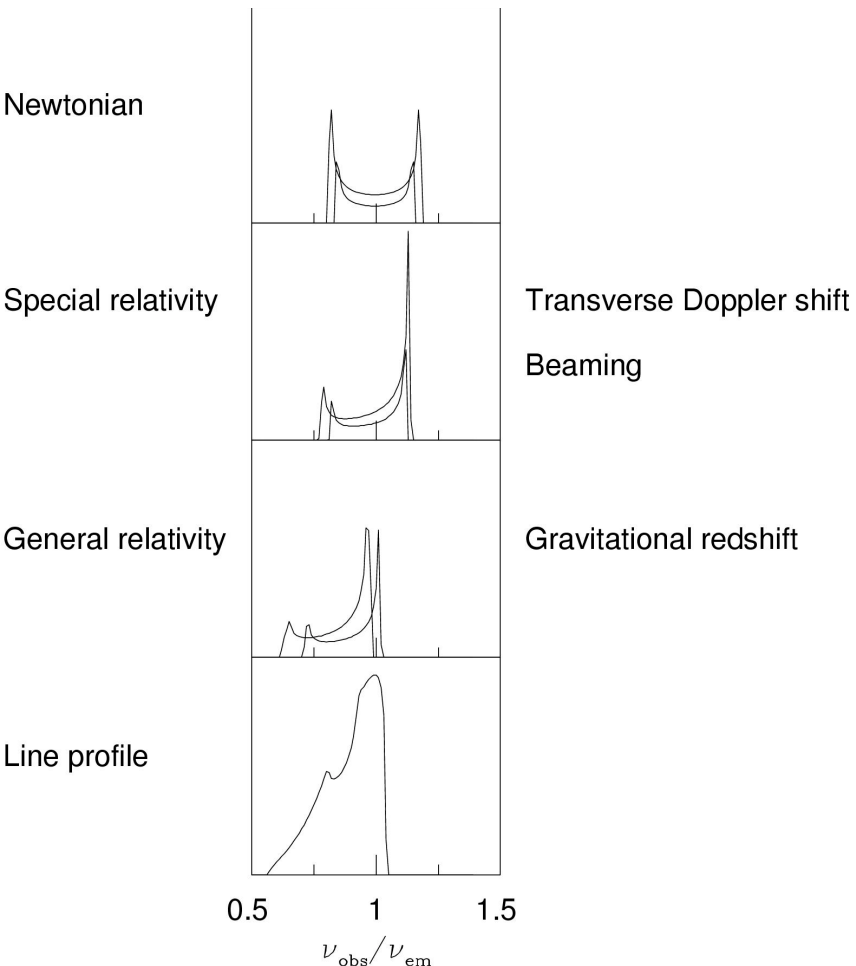
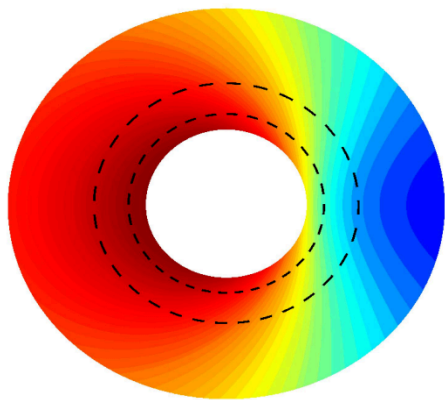


Galactic BH:  
Disk hot, so line  
Comptonized

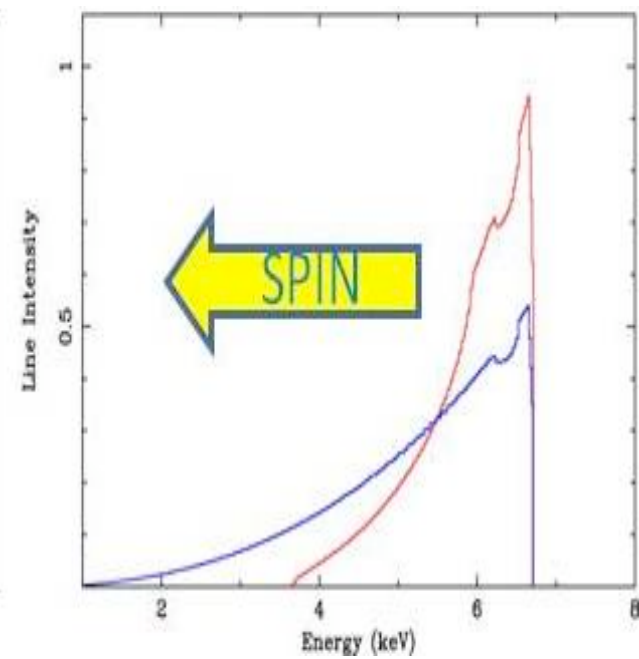
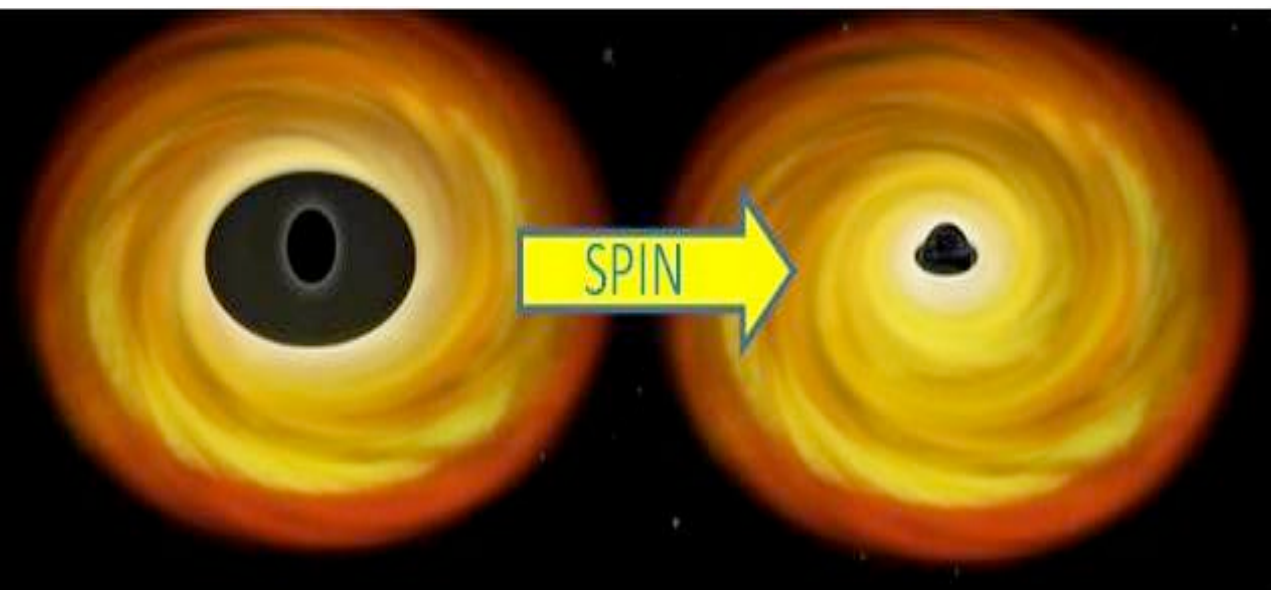


# Strong Gravity Effects

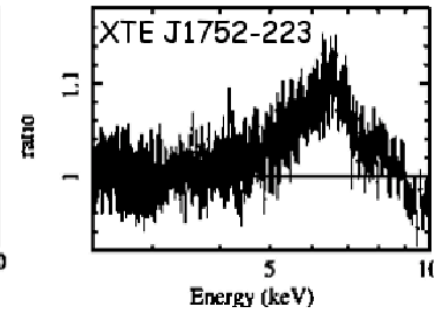
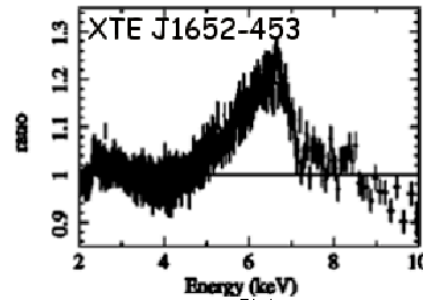
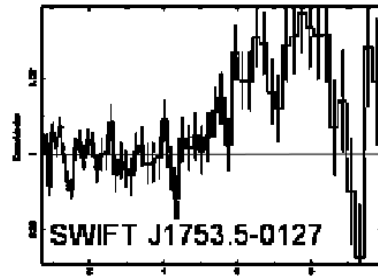
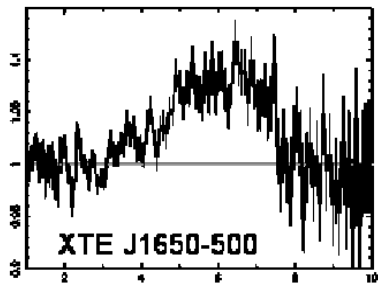
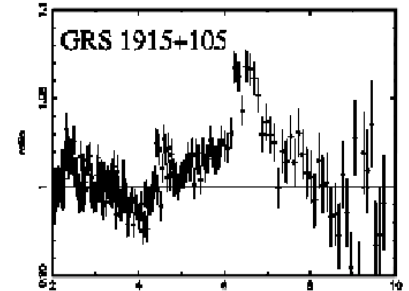
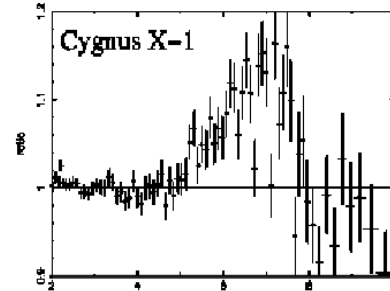
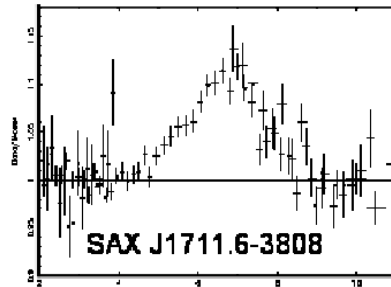
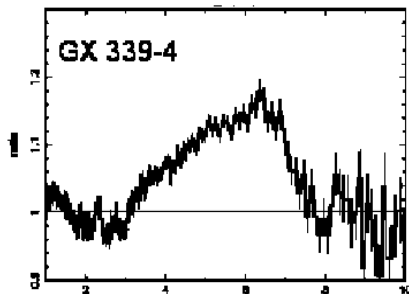
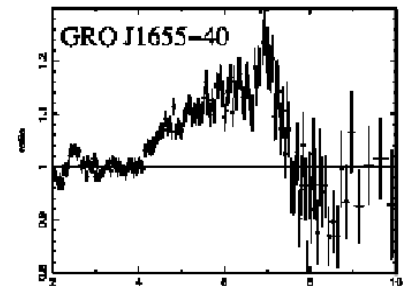
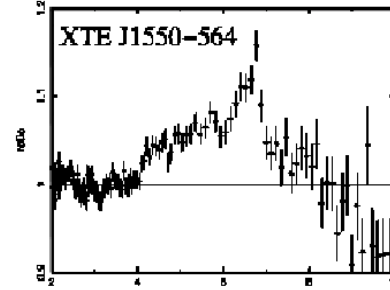
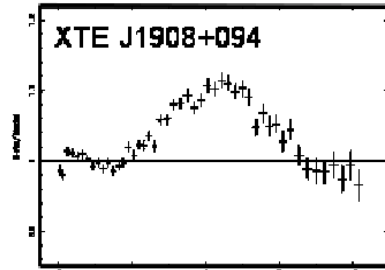
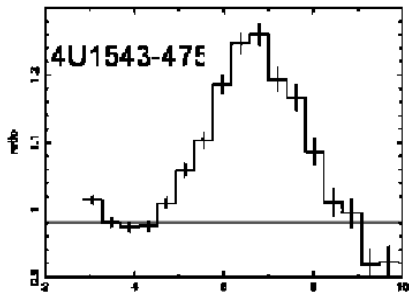
- Gravitational redshift
- Gravitational light bending
- Dragging of inertial frames in Kerr metric (ISCO depends on BH spin)  
NB In rapid spin objects most of power emerges from a few  $r_g$



Fabian+89, Laor 90...

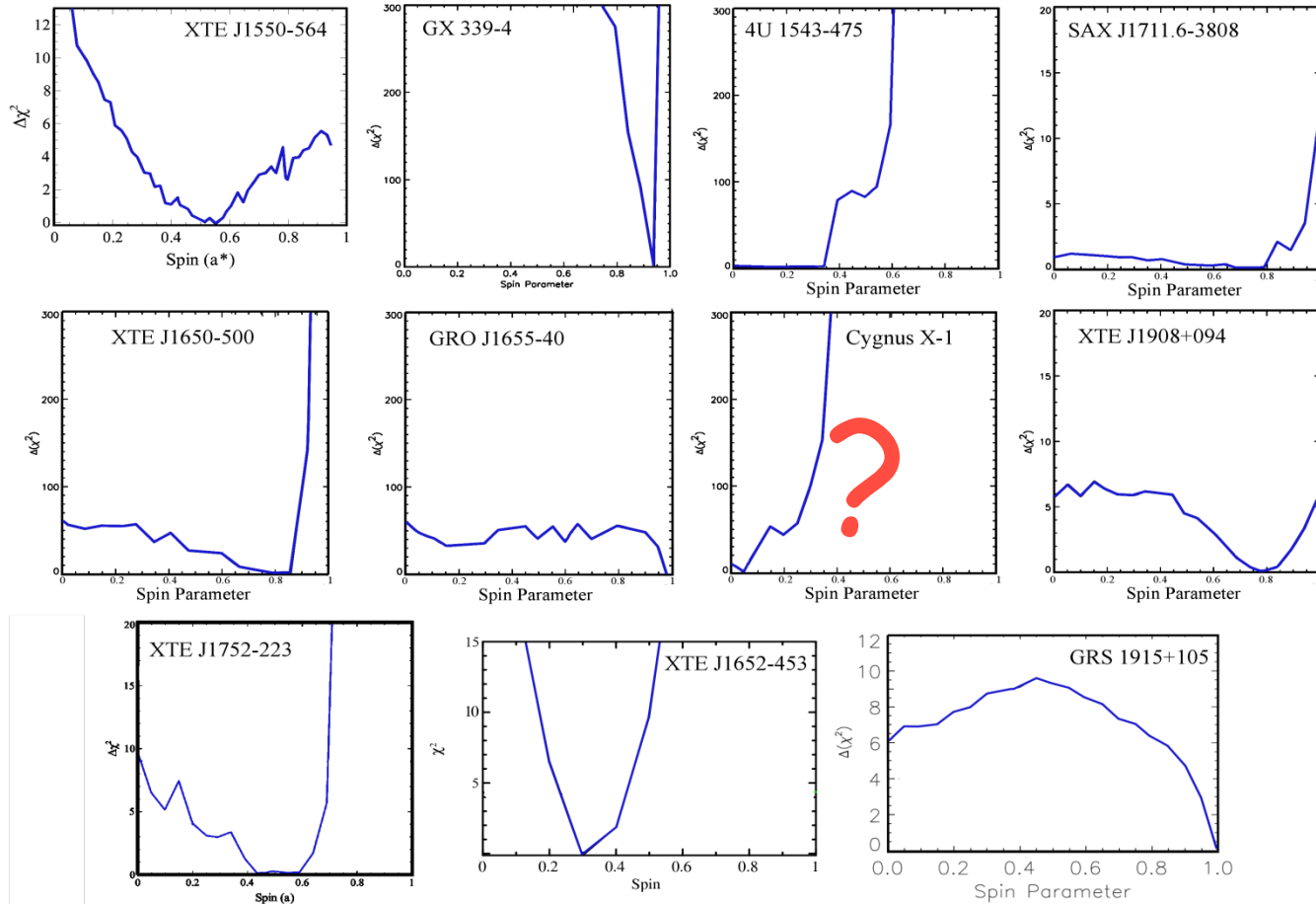


# Broad Fe Lines in BHB



Originally compiled by J. M. Miller

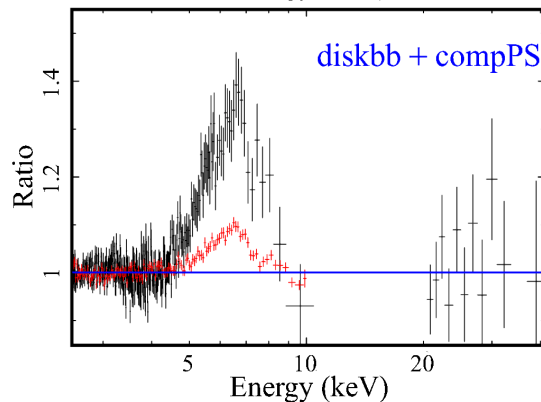
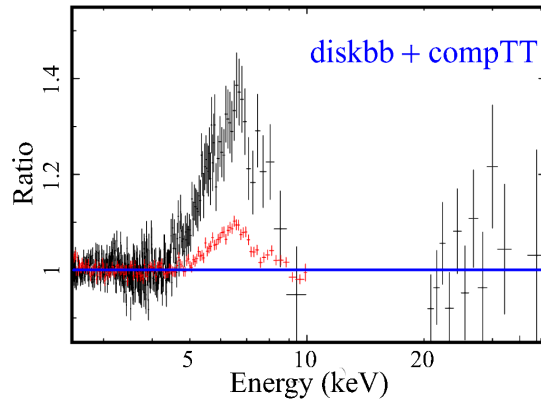
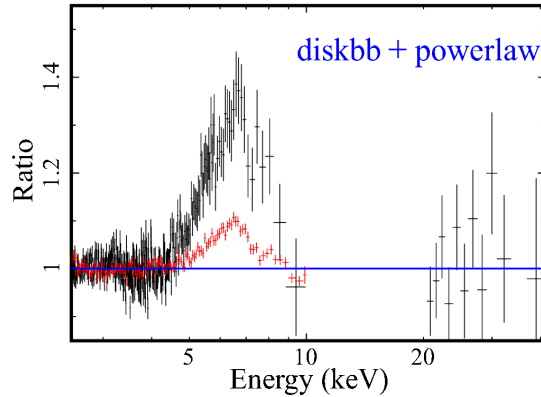
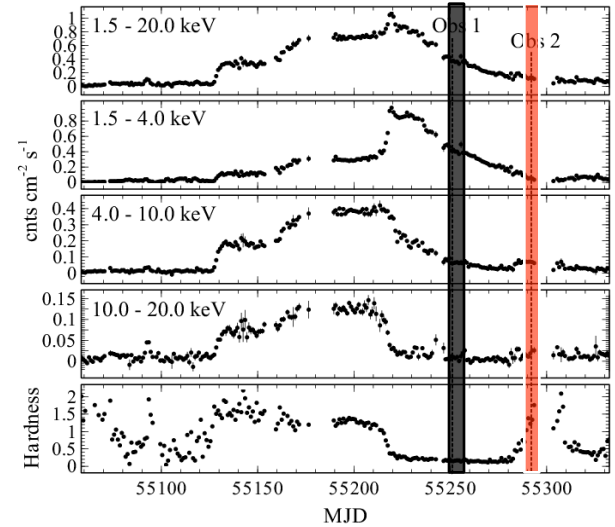
# Spin Population (by Rubens Reis)



Miller et al. 2009; Reis et al. 2009, 2010; Blum et al. 2009

# How Robust are These Lines?

XTE J1752-223

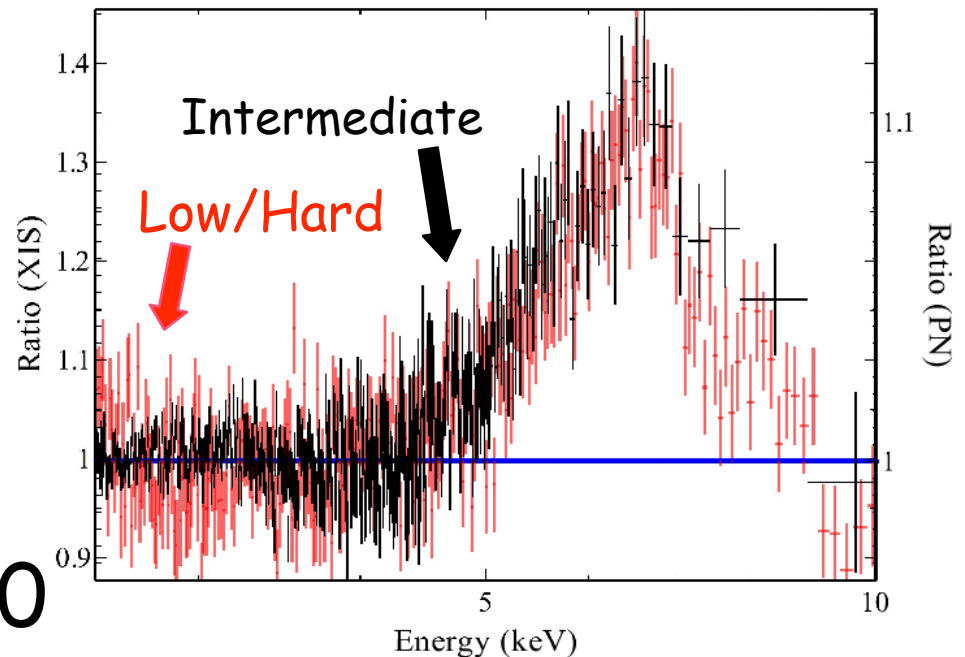


Independent  
of  
Continuum

and

States

Reis+10

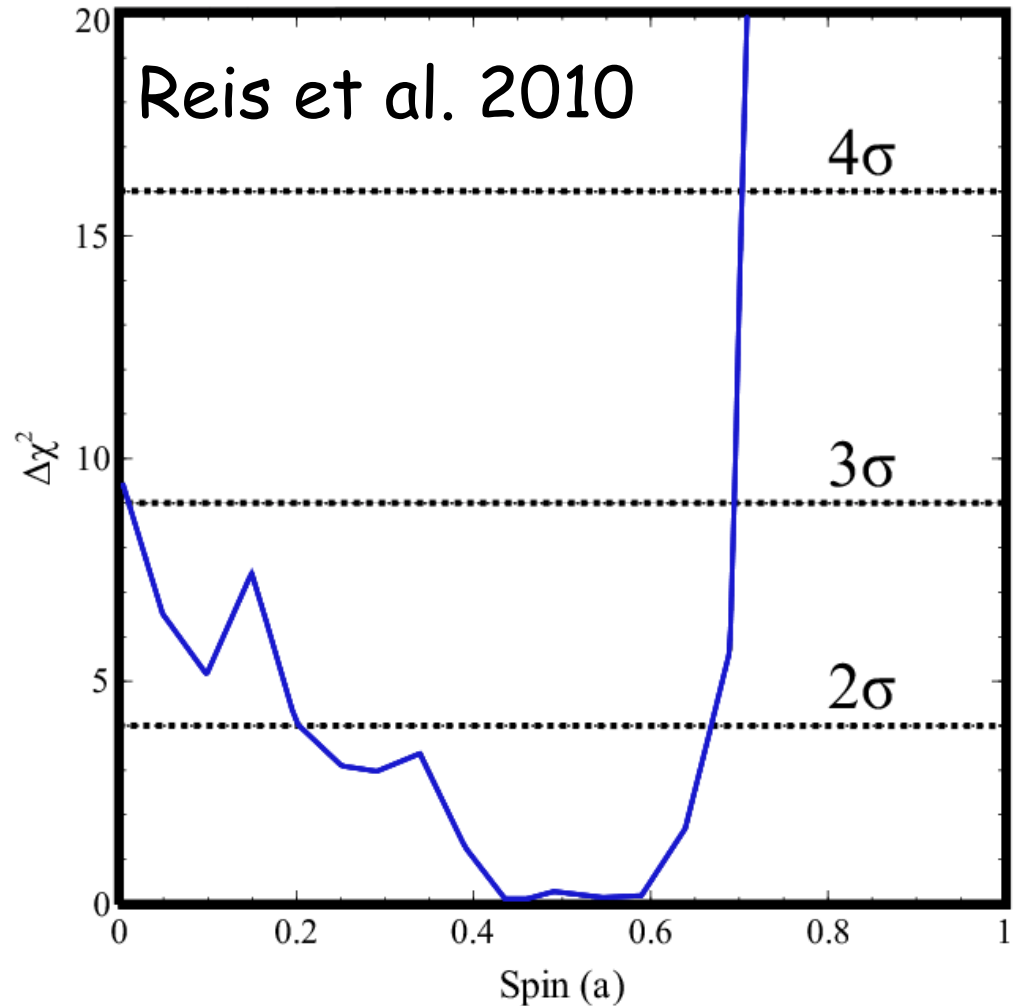


# An Intermediate BH Spin in J1752-223

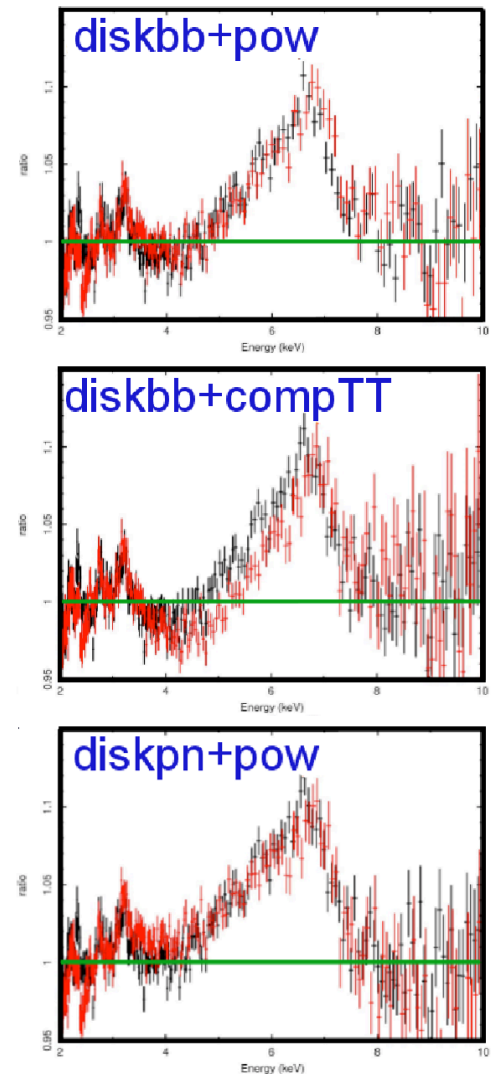
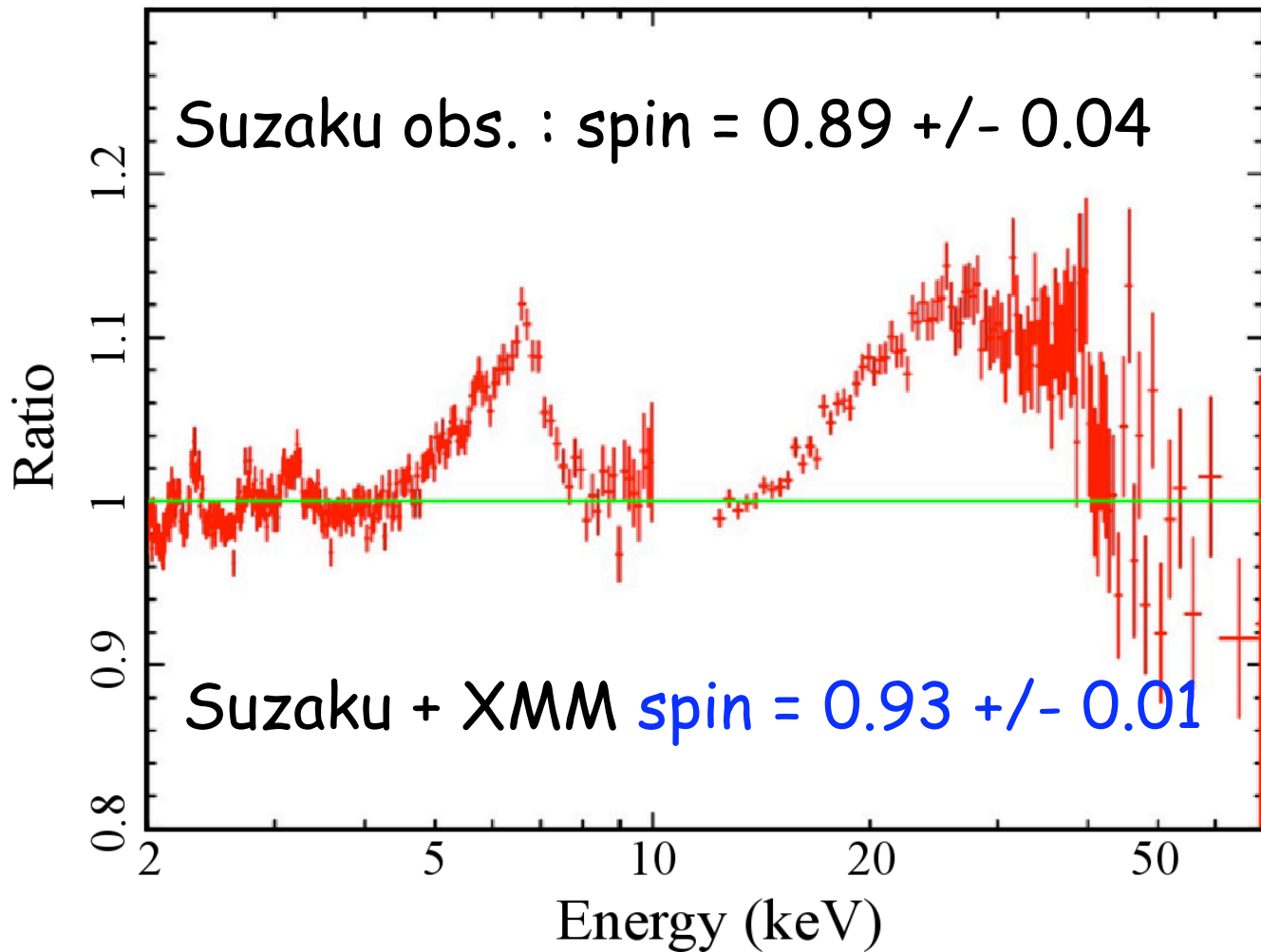
Self-Consistent  
Reflection Models  
(e.g. reflionX)

+

Relativistic  
blurring  
(e.g. Kerrconv)



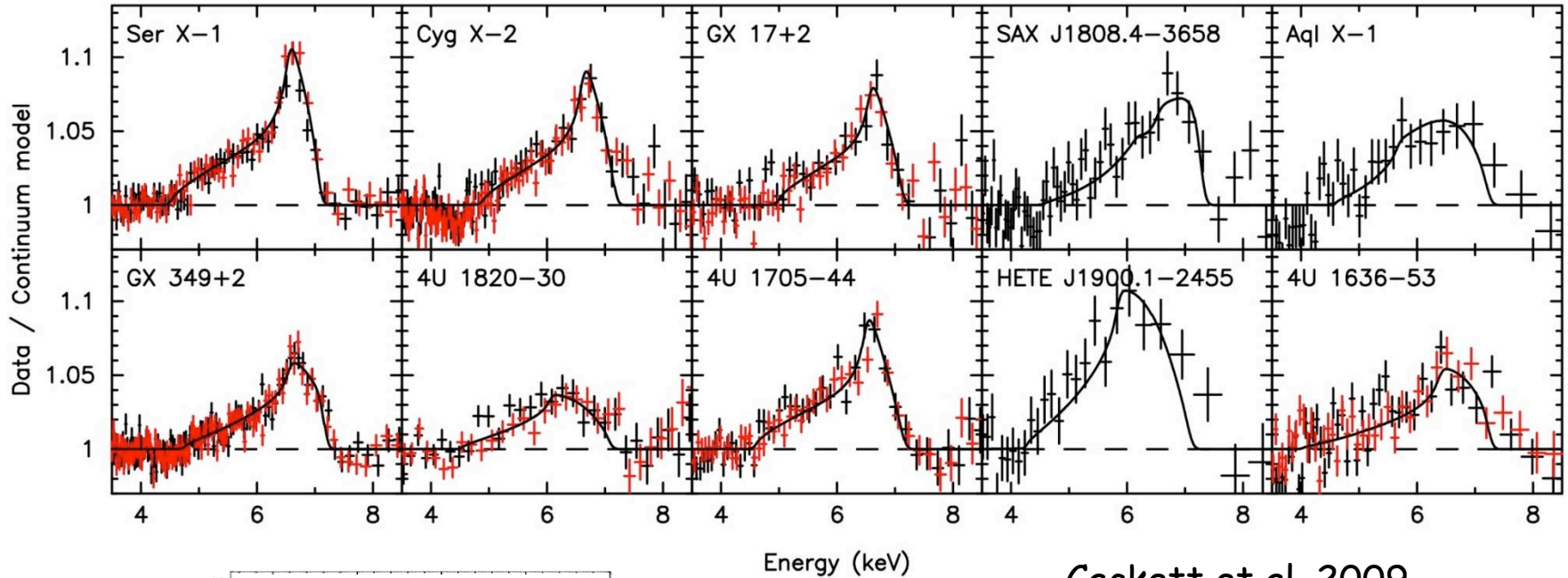
# GX339-4: A Highly Spinning BH



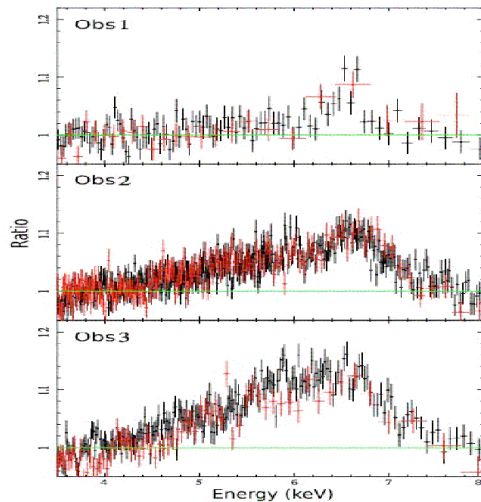
Miller et al. 2008; Reis et al. 2008

Miller et al. 2006

# Neutron Star Binaries



Cackett et al. 2009

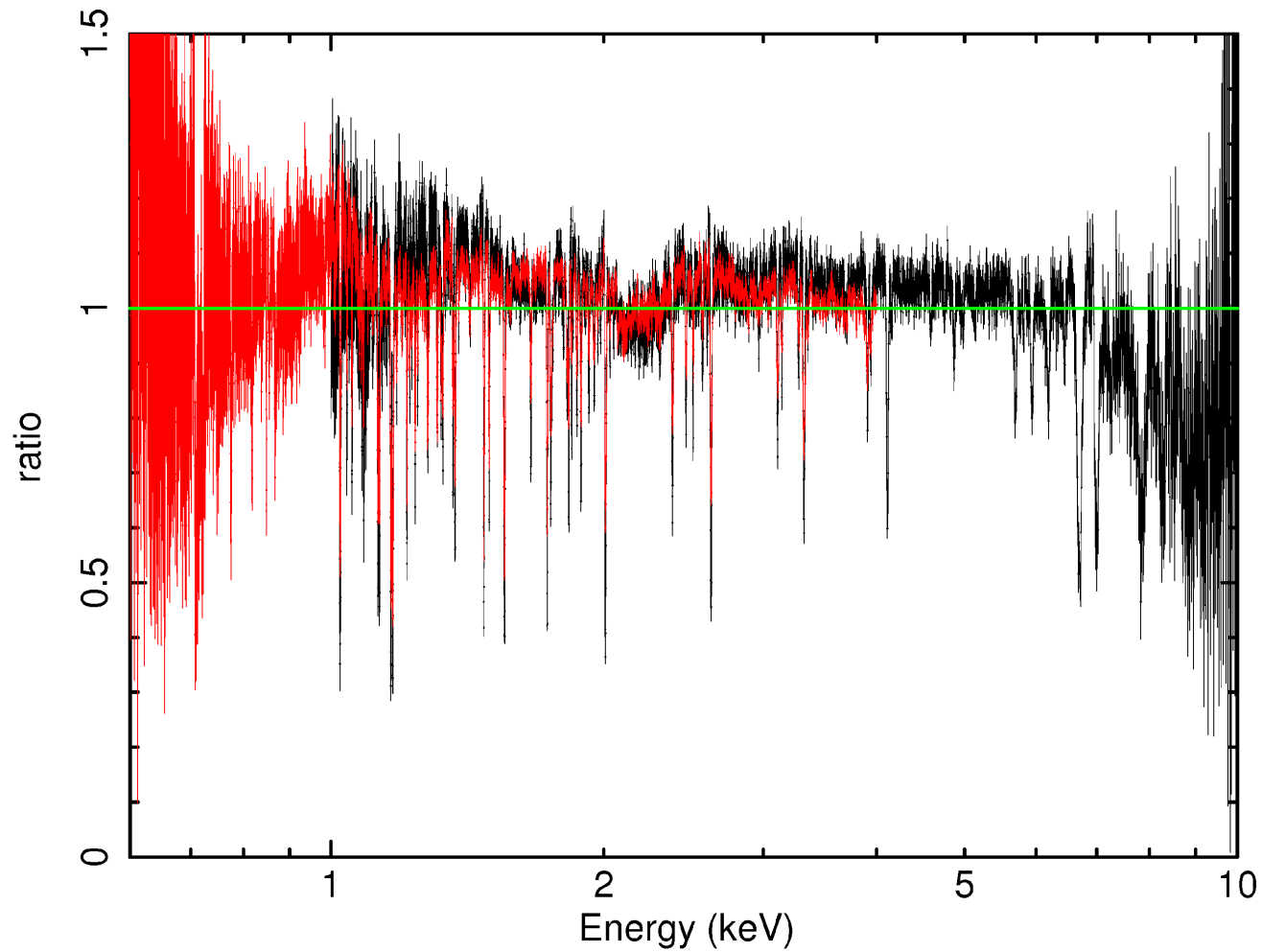


4U1705-44

Reis+09

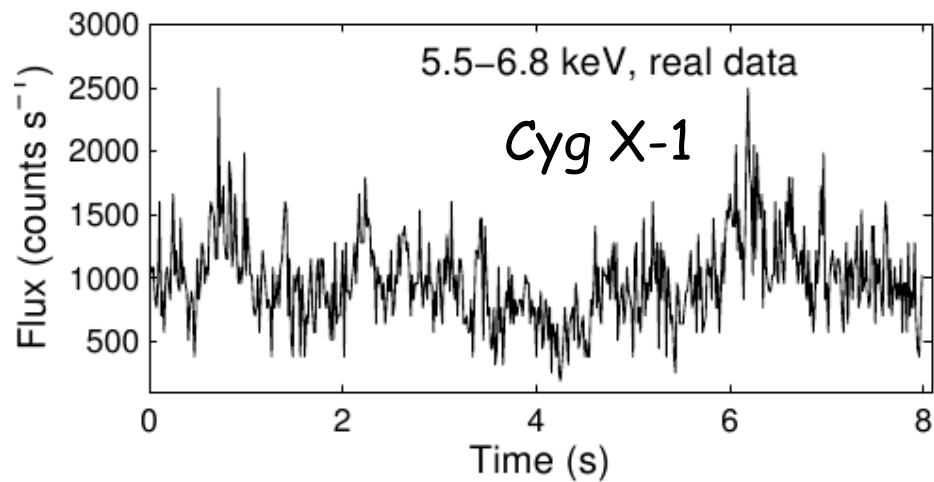
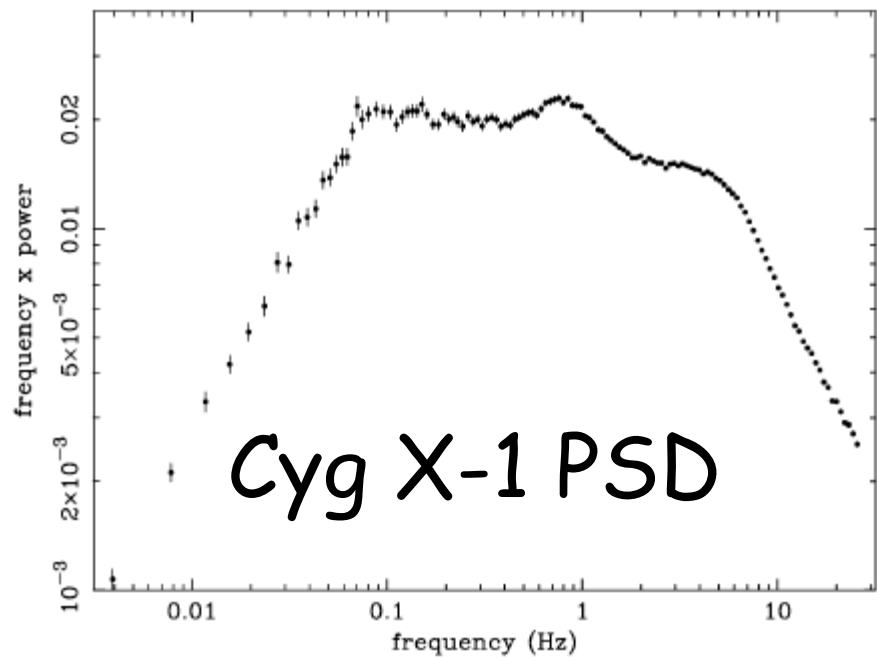
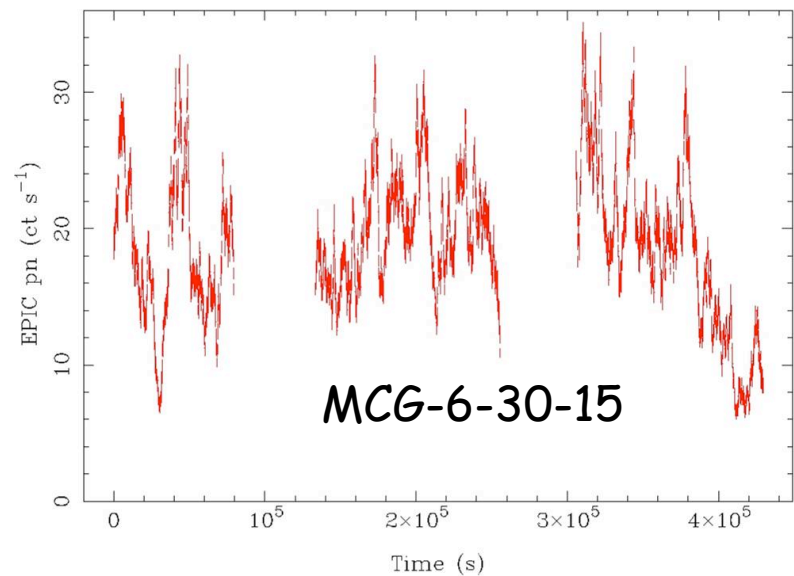
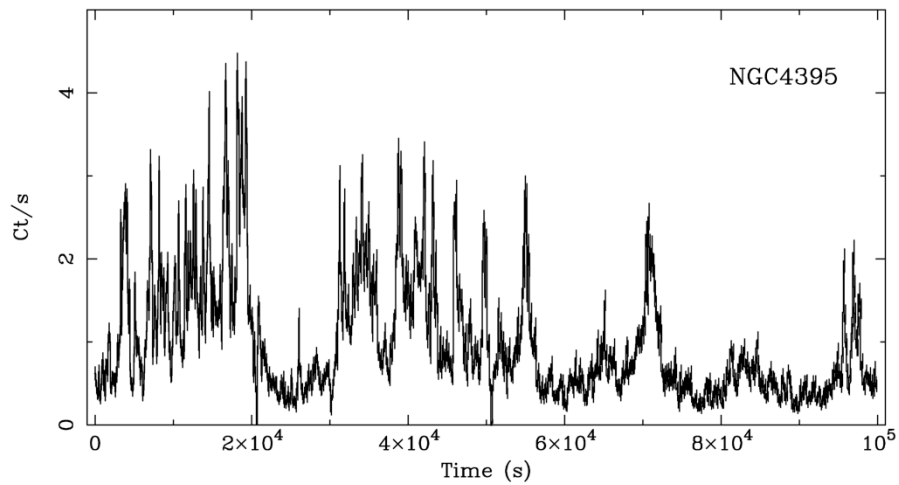
$$R_{in} = 10.5 r_g$$

# Absorption in 1655

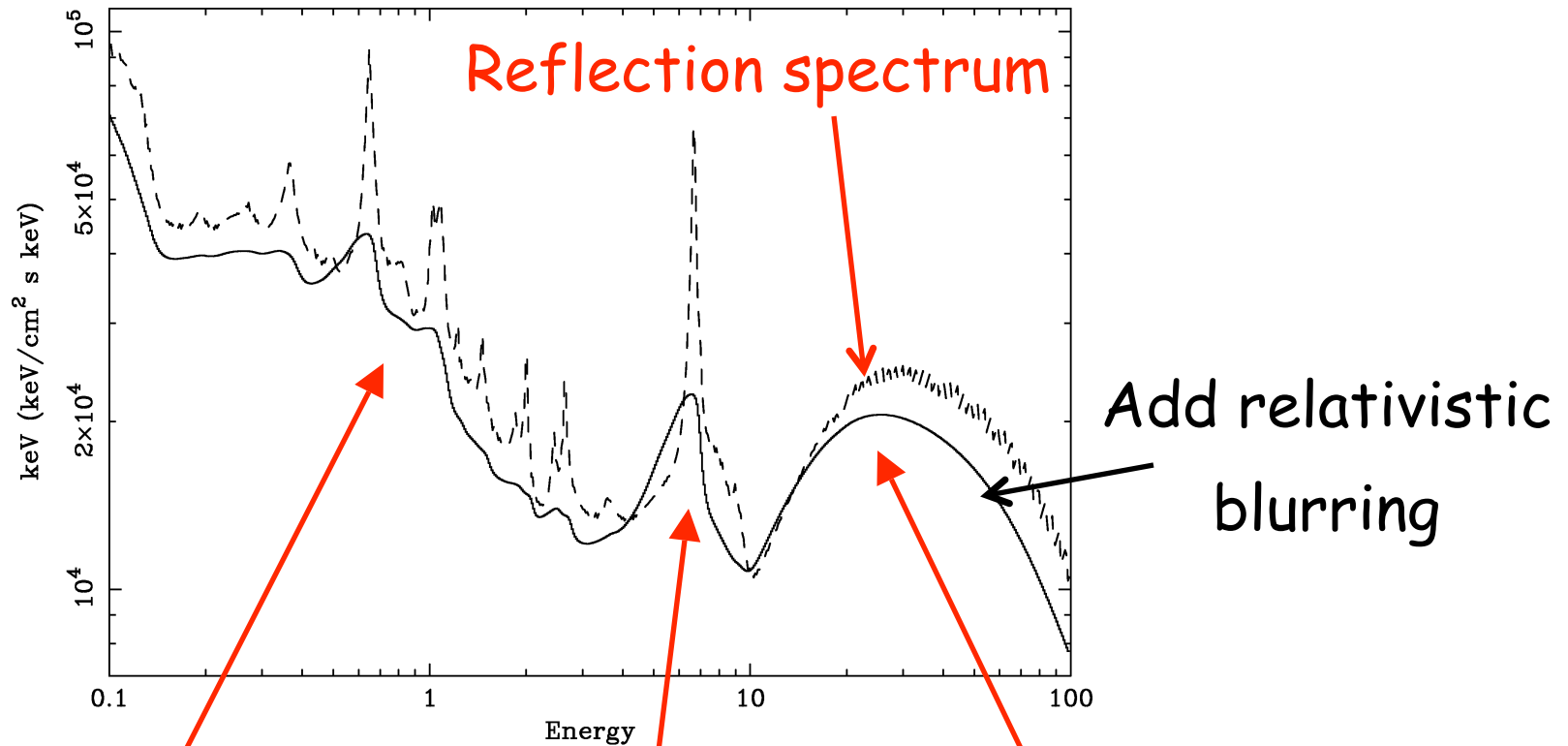


# Implication

- Relativistically-blurred reflection is common in luminous accreting black holes and should be expected there



# Reflection in accreting BH

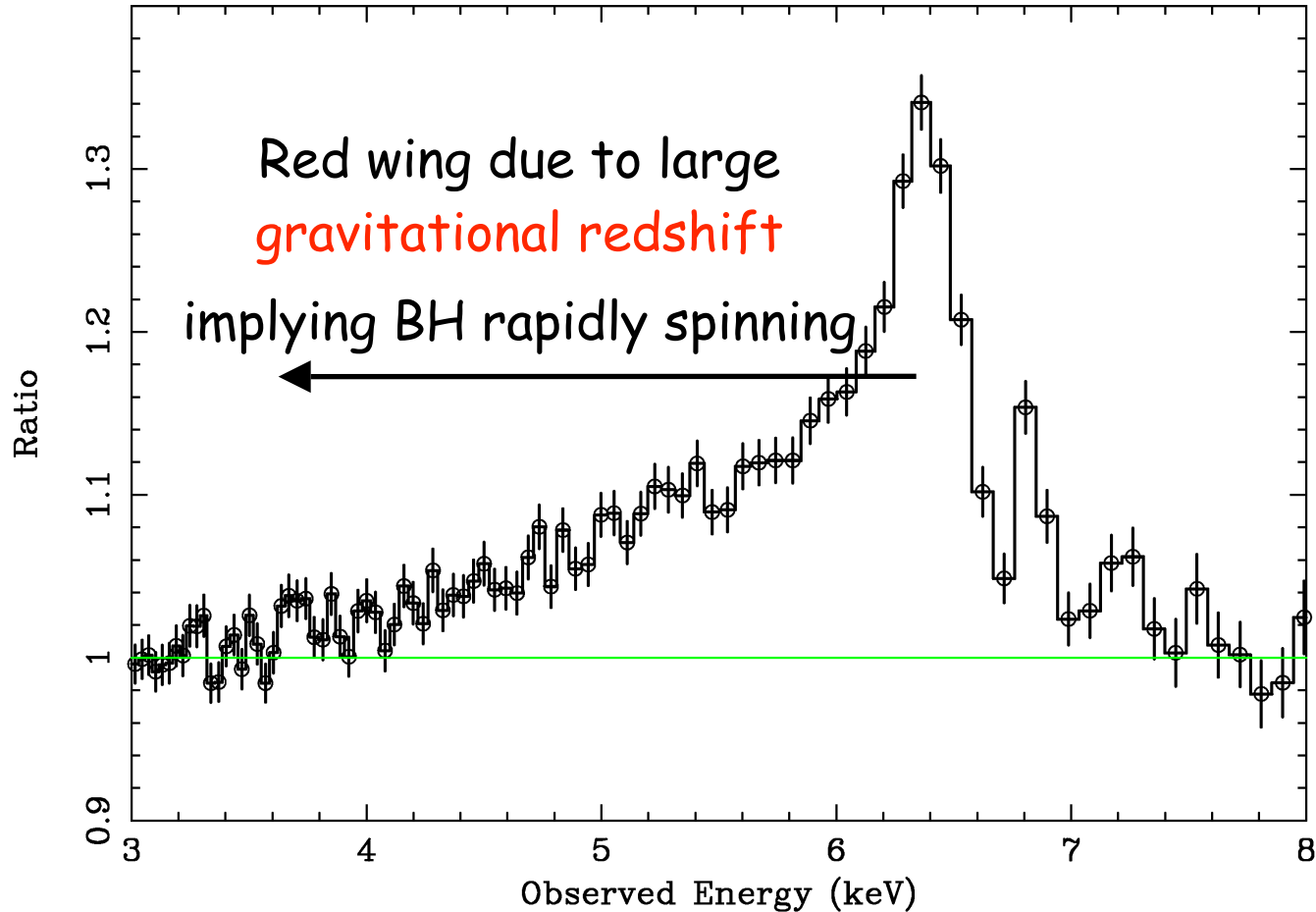


Soft excess - broad iron line - Compton hump

MCG-6-30-15

Miniutti+07

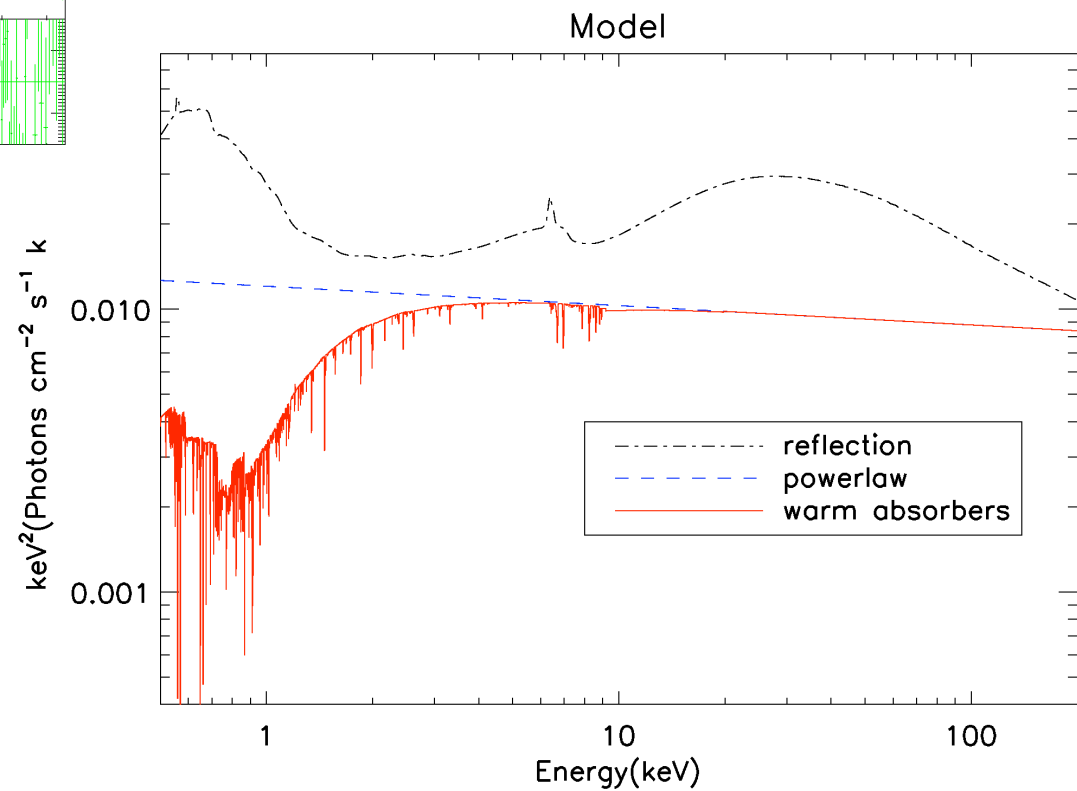
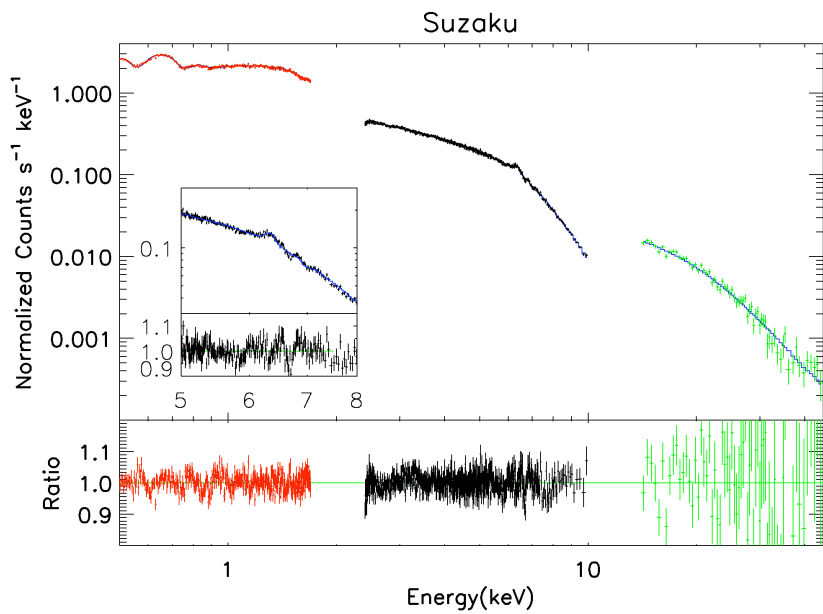
# Suzaku



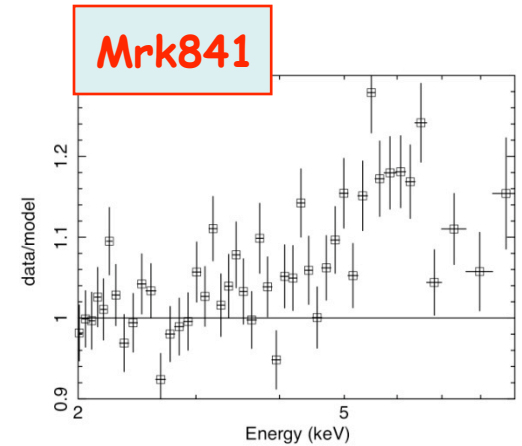
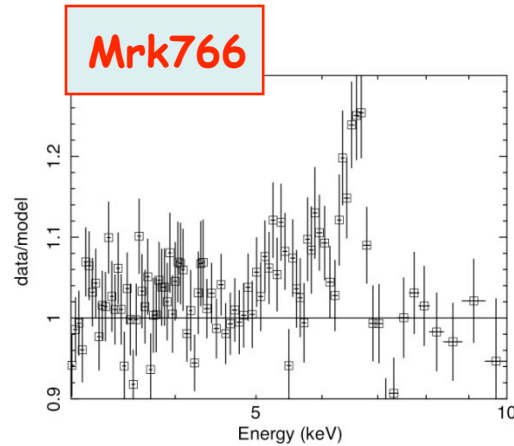
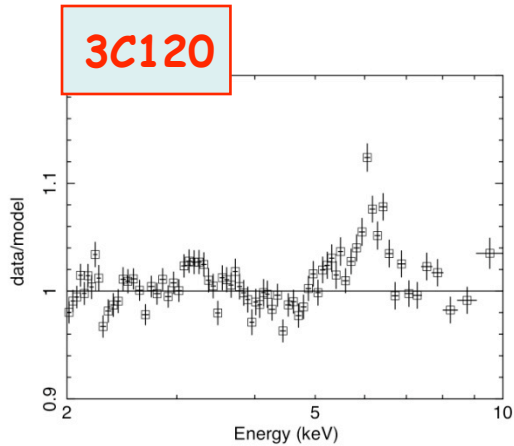
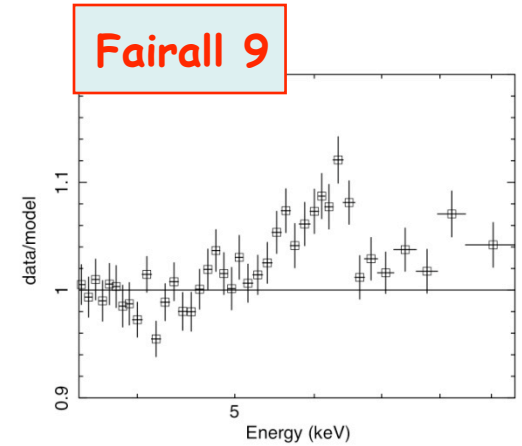
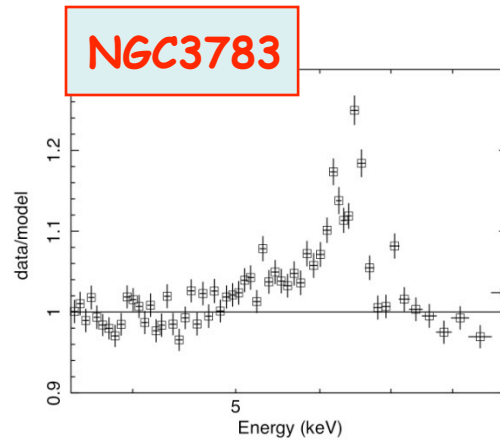
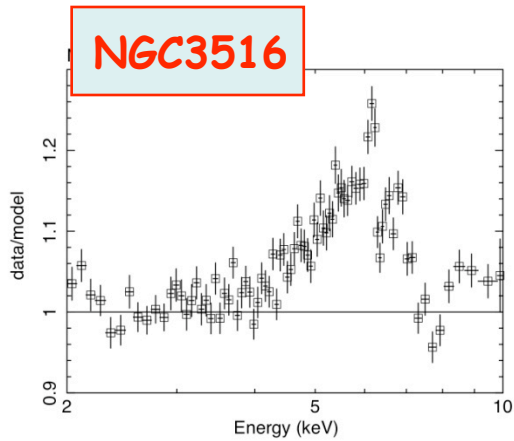
Strength and behaviour of line implies  
**GRAVITATIONAL LIGHT BENDING**

# MCG-6-30-15

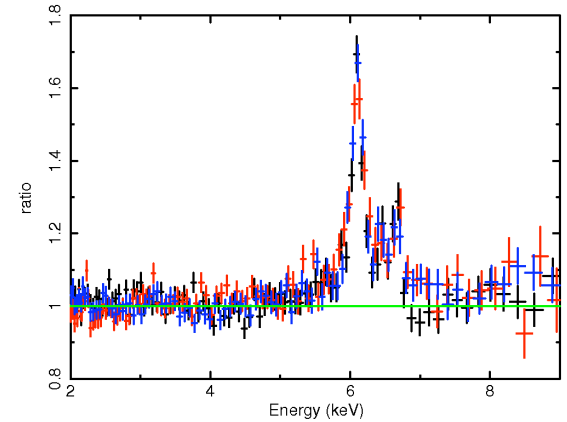
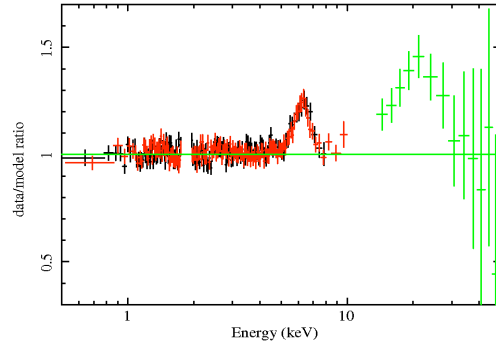
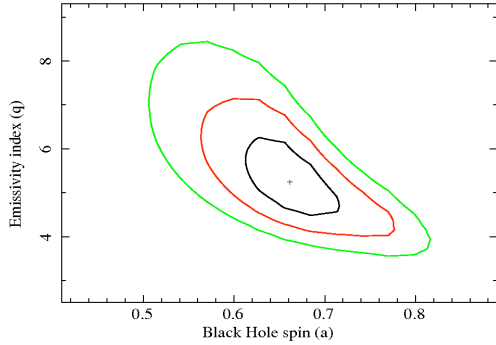
Chiang+Fabian10



# Broad Fe lines in AGN

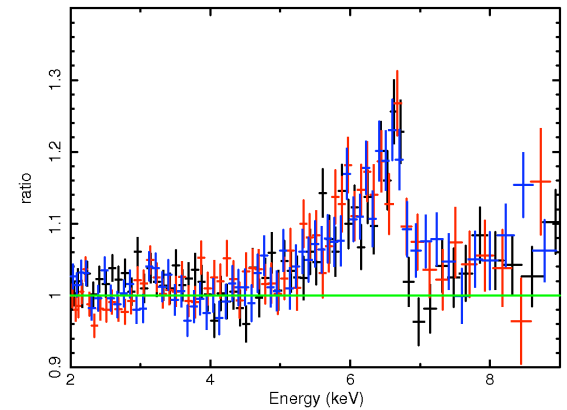
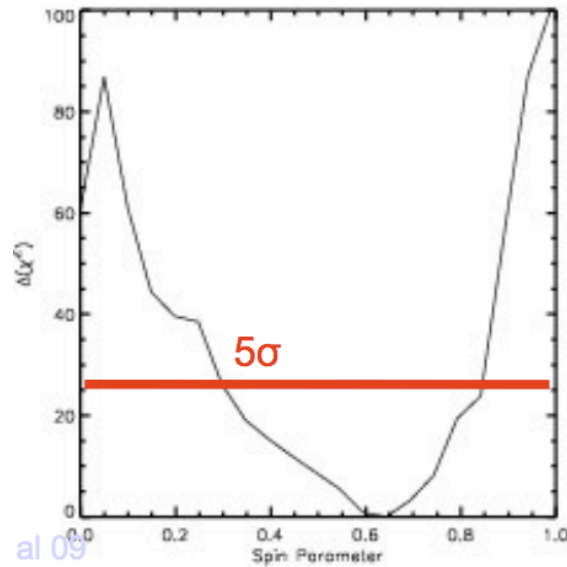


# SWIFT J2127 Miniutti+09



# Fairall 9 Schmoll+09

AGN



# Even with XMM-Newton and Suzaku, need long observations...

- MCG-6-30-15       $\alpha > 0.98$       (Brenneman & CSR 2006)
- Fairall 9       $\alpha = 0.60 \pm 0.07$       (Schmoll et al. 2009)
- SWIFTJ2127.4       $\alpha = 0.6 \pm 0.2$       (Miniutti et al. 2009)
- 1H0707-495       $\alpha > 0.97$       (Zoghbi et al. 2009)
- Mrk79       $\alpha = 0.7 \pm 0.1$       (Gallo et al. 2010)

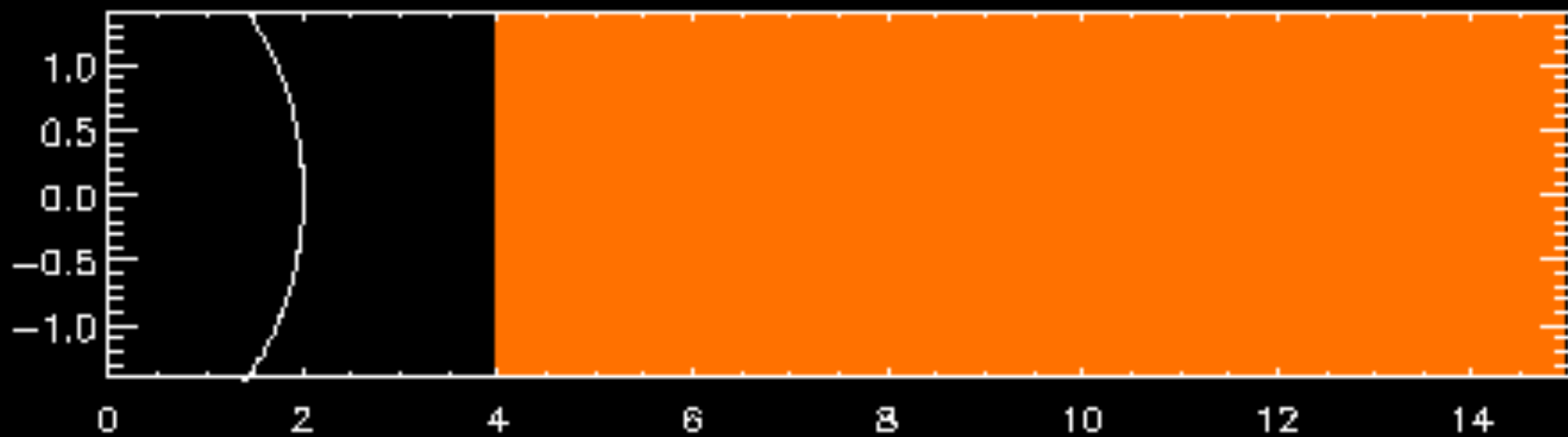
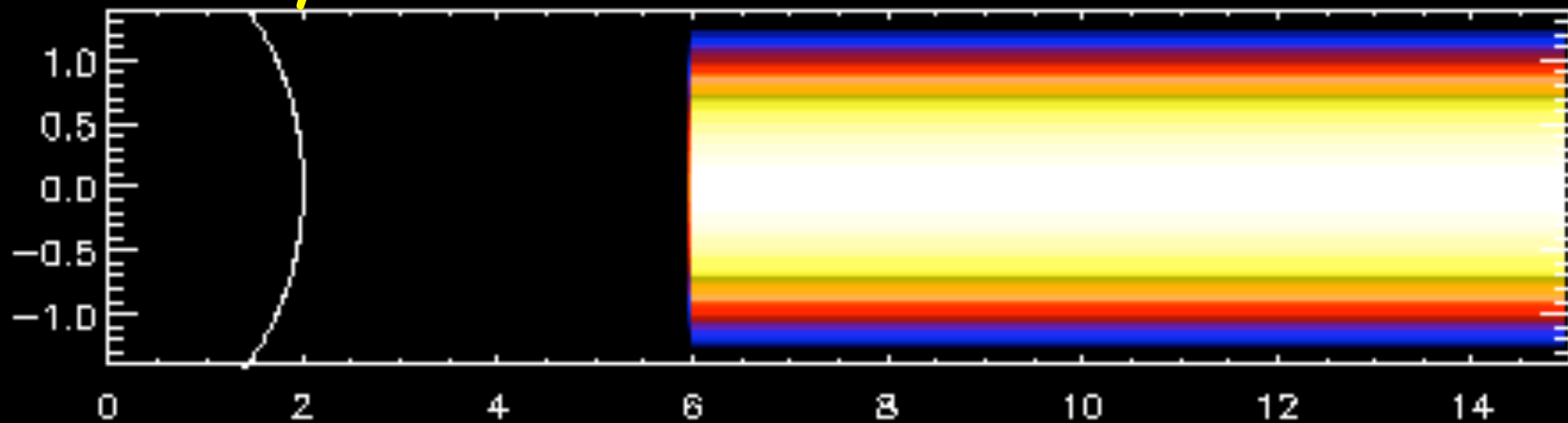
For a robust decomposition of a complex spectrum  
+ spin constraint, need  $\sim 10^6$  photons in 2-10keV

# ISCO issue

- Measure  $R_{in}$  from spectra  $\Rightarrow R_{ISCO} \Rightarrow$  spin?
- $B$  decreases  $R_{in}$  (Gammie, Krolik)??
- BUT **low ionization**  $\Rightarrow$  thin, slowly accretion disc, which is **not** plunging, so  $R_{in} \sim R_{ISCO}$

Computations show that  $R_{in}$  measured from iron line is within  $\sim 0.5r_g$  of  $R_{isco}$  (Reynolds & Fabian 08)

Density

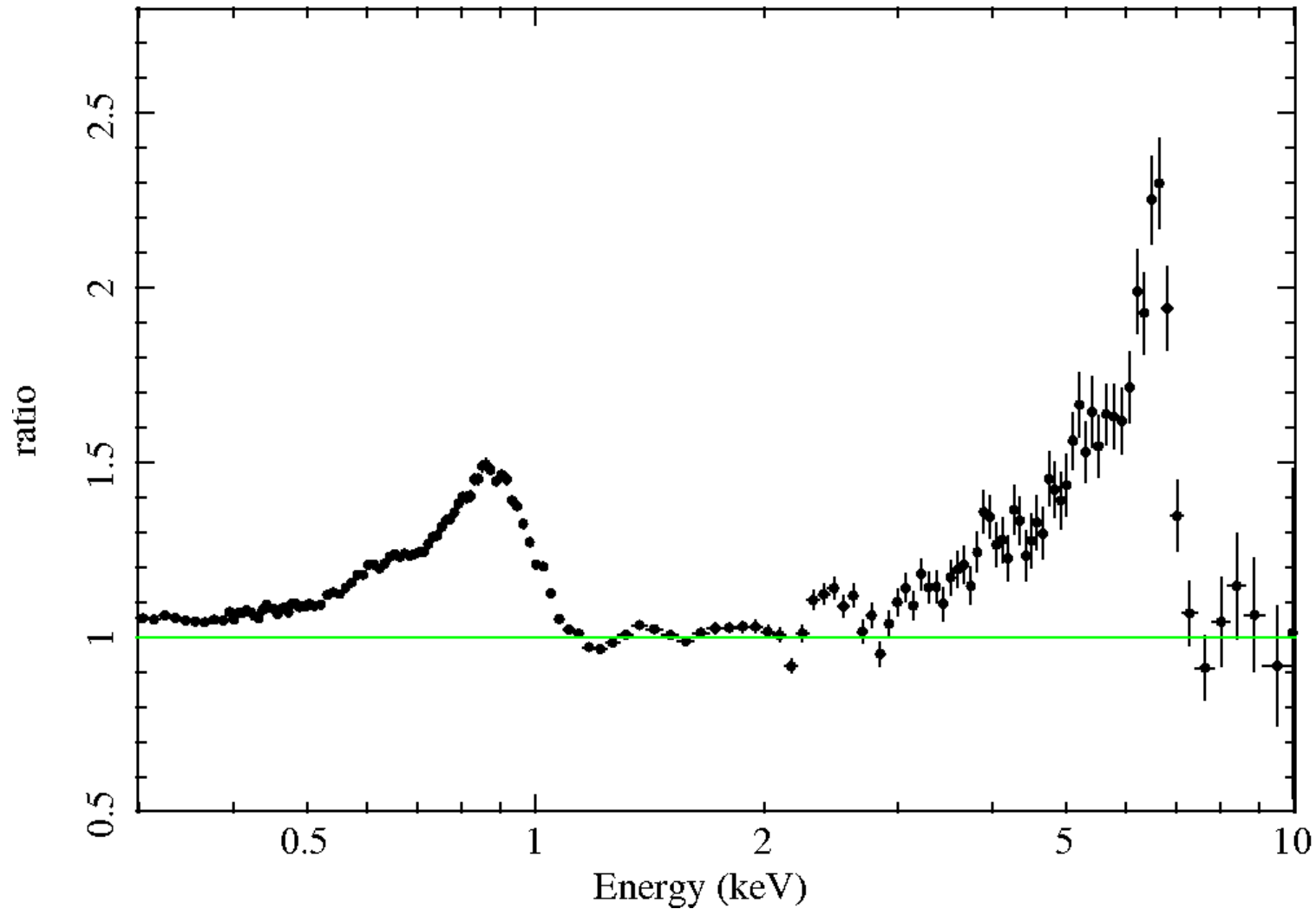


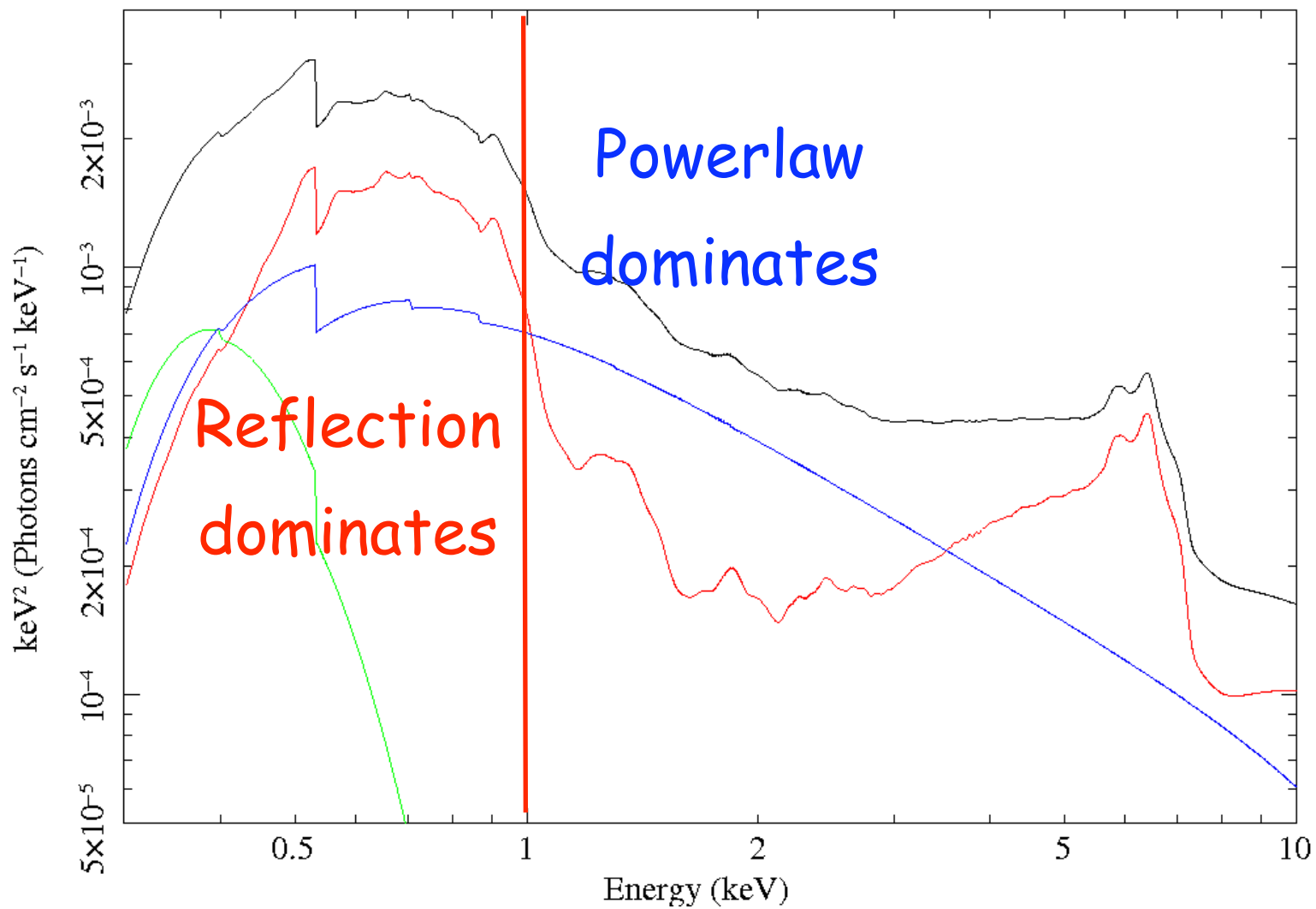
Azimuthal field

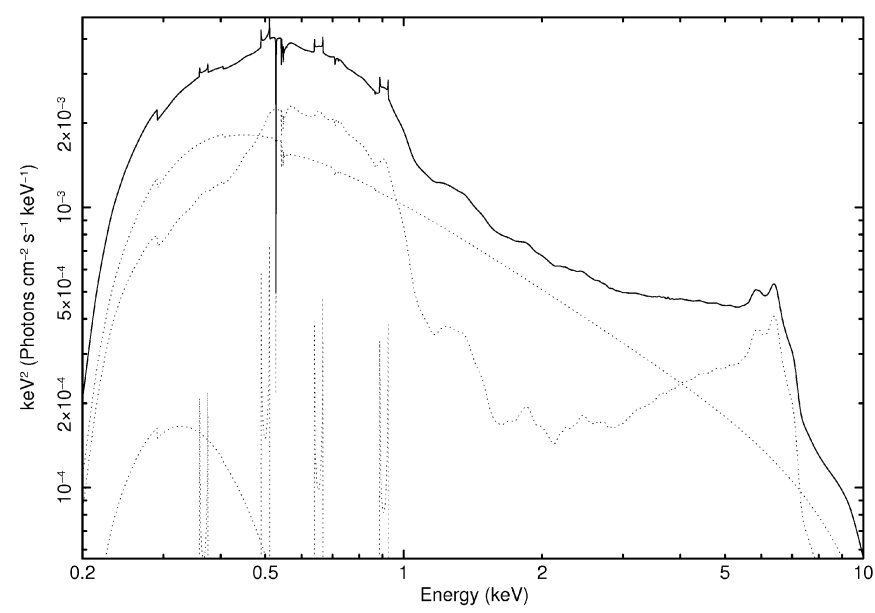
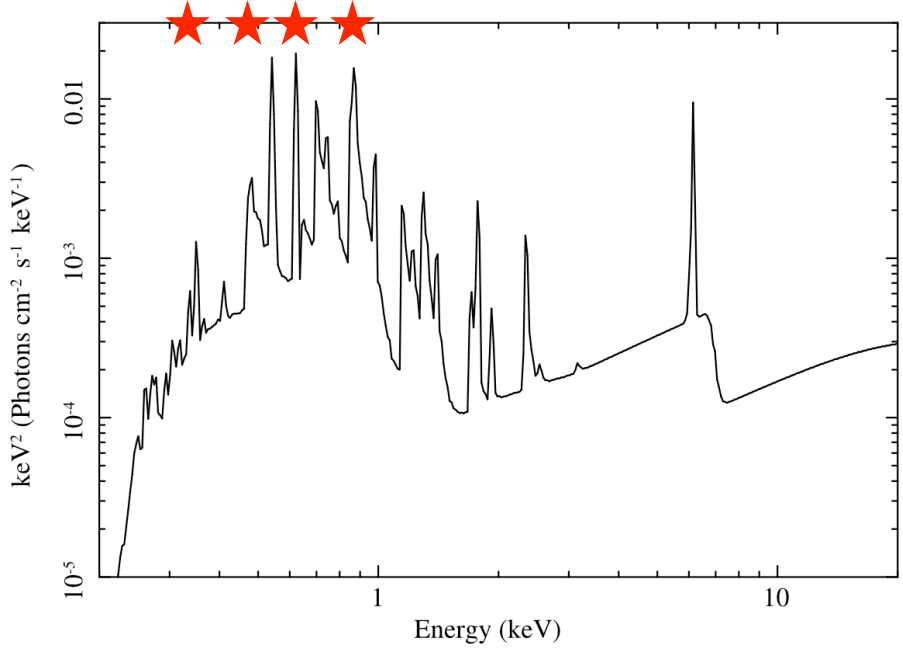
Reynolds & Fabian 08

X-ray Reverberation discovered in the  
NLS1 1H0707-495 , Fabian+09

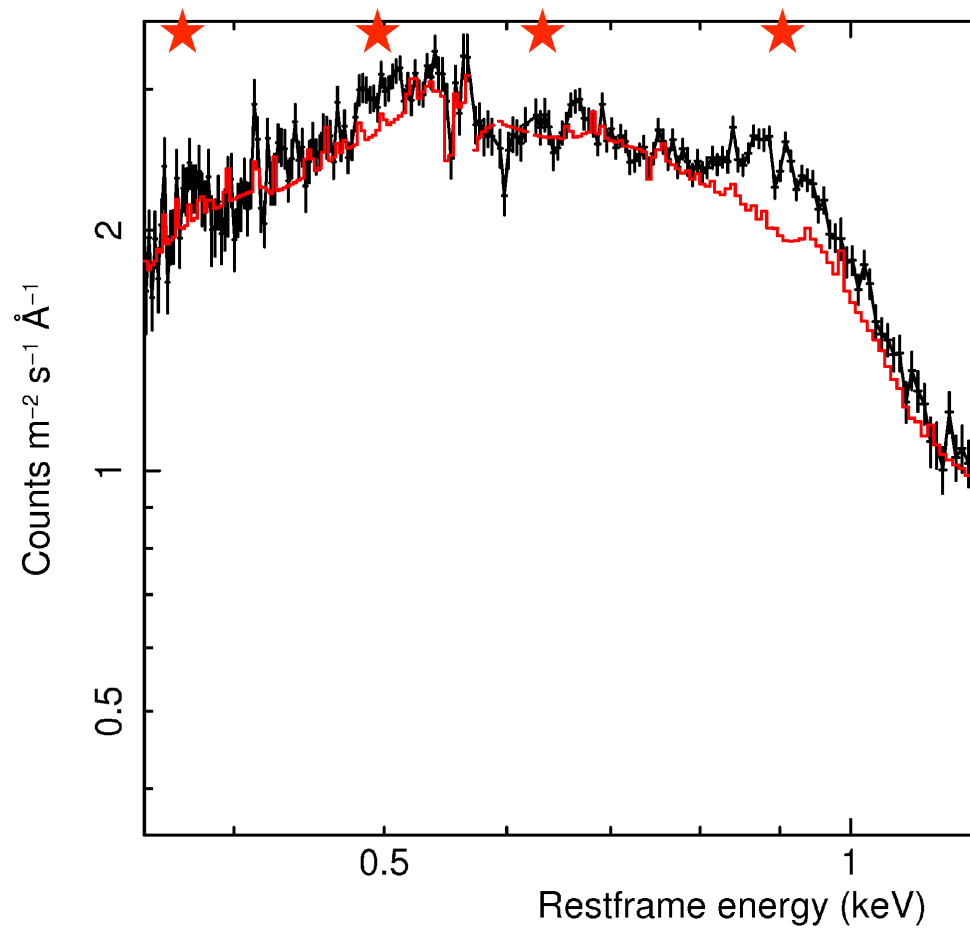
# Broad iron-L and iron-K emission lines



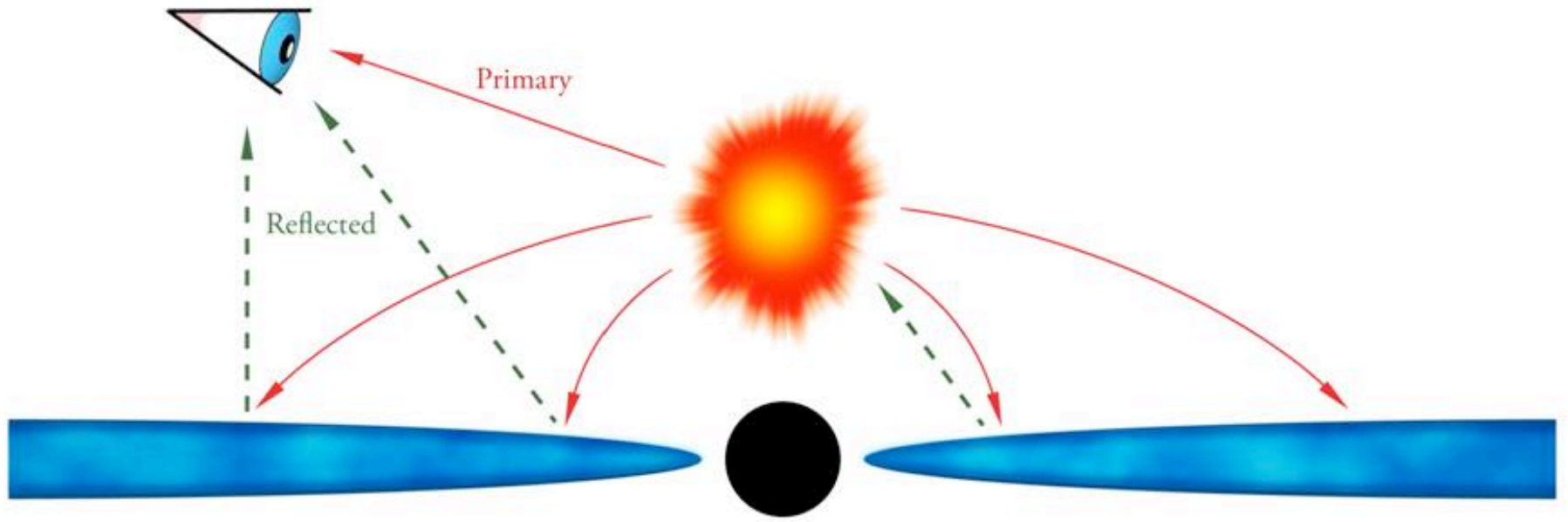




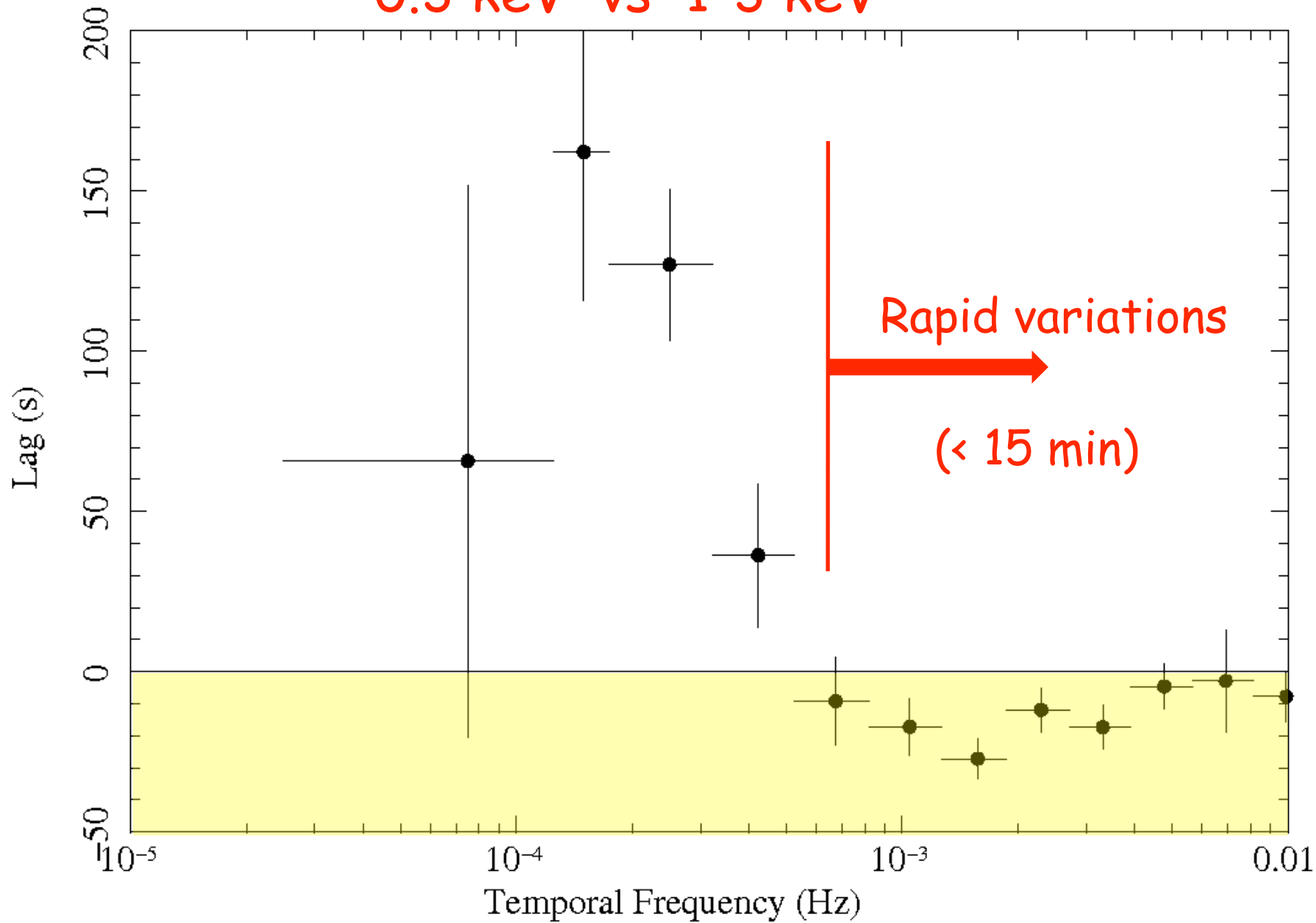
RGS

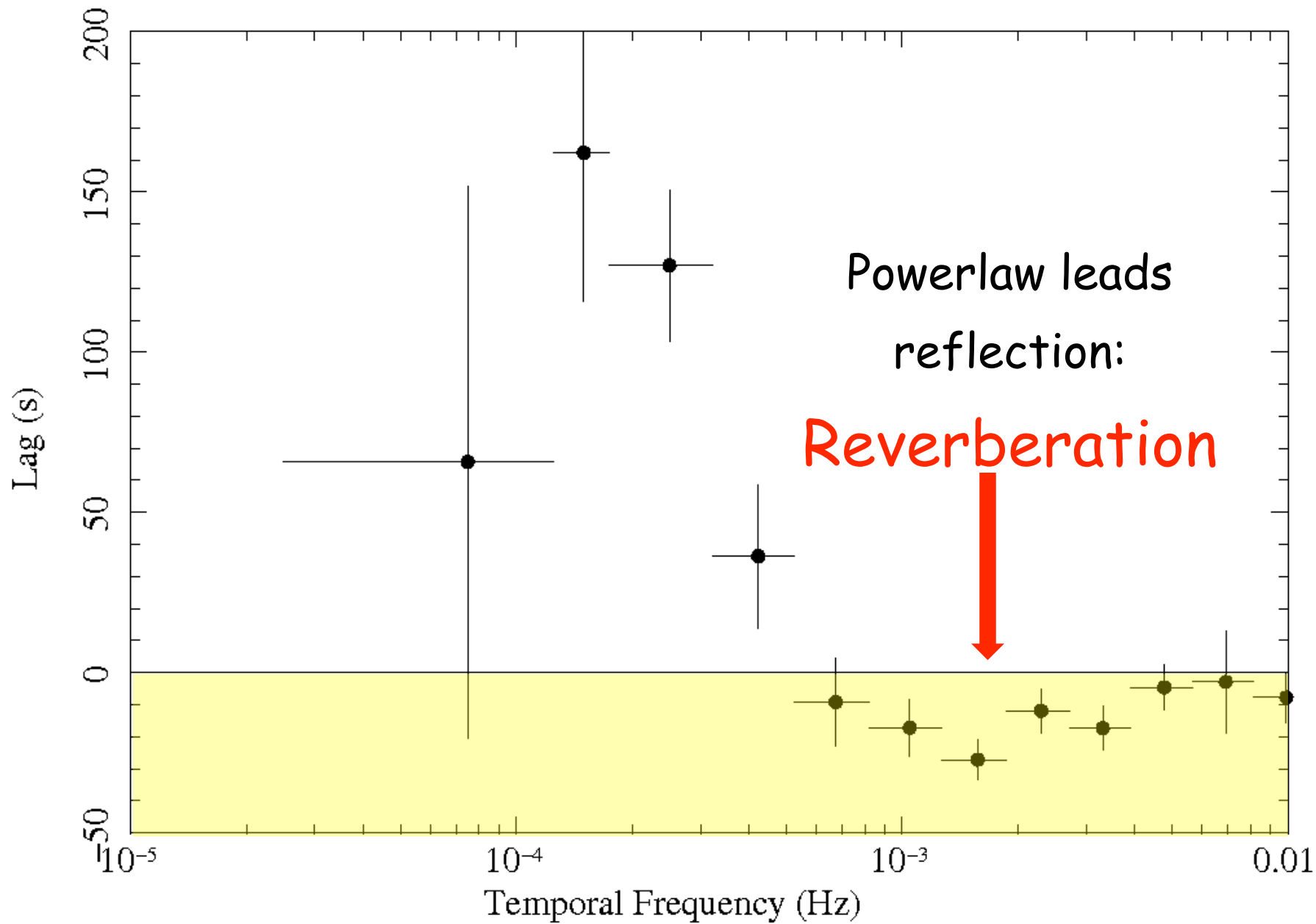


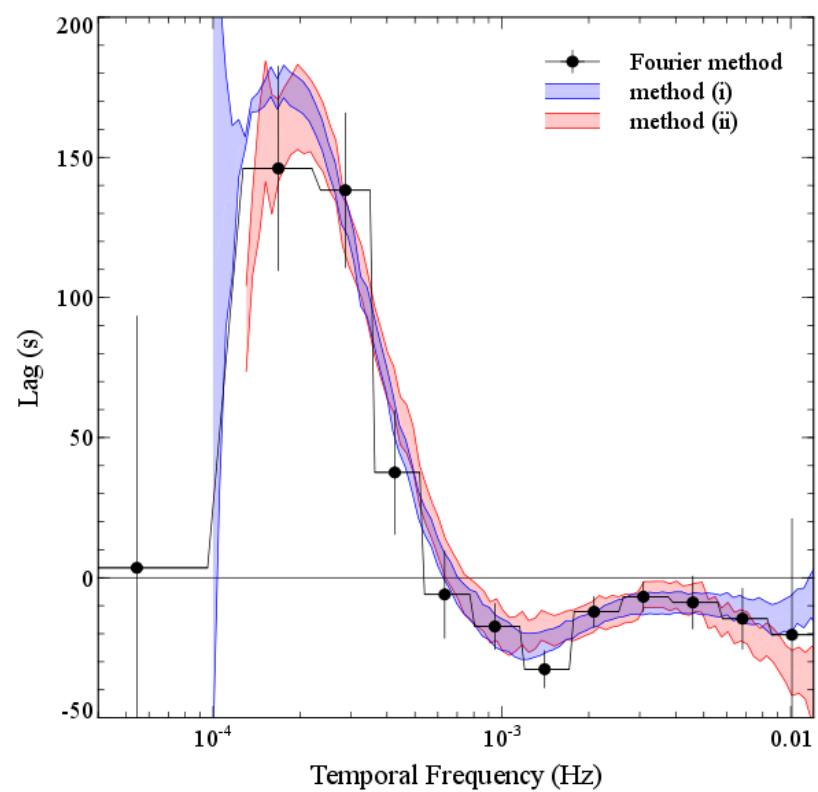
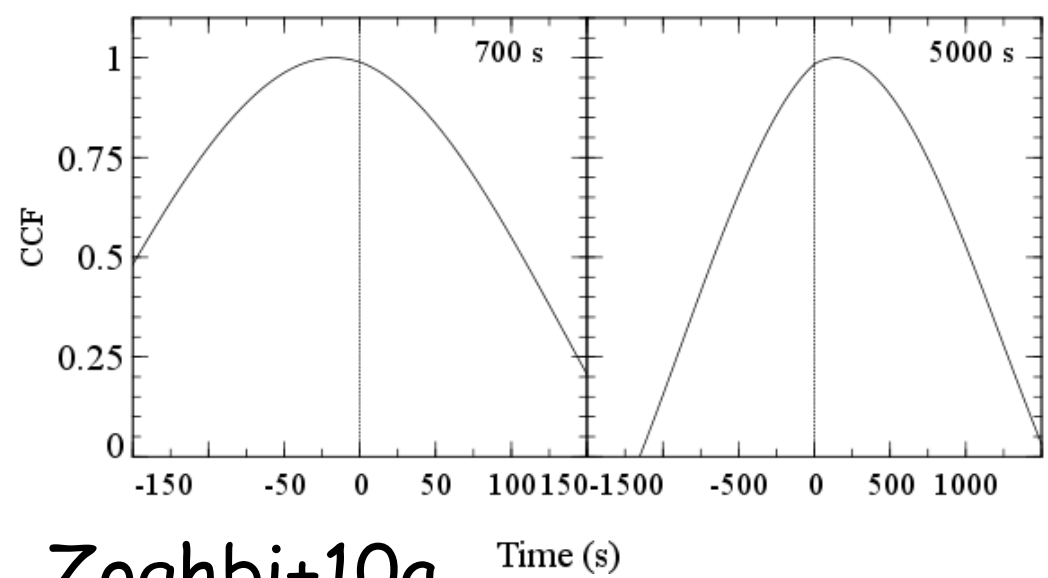
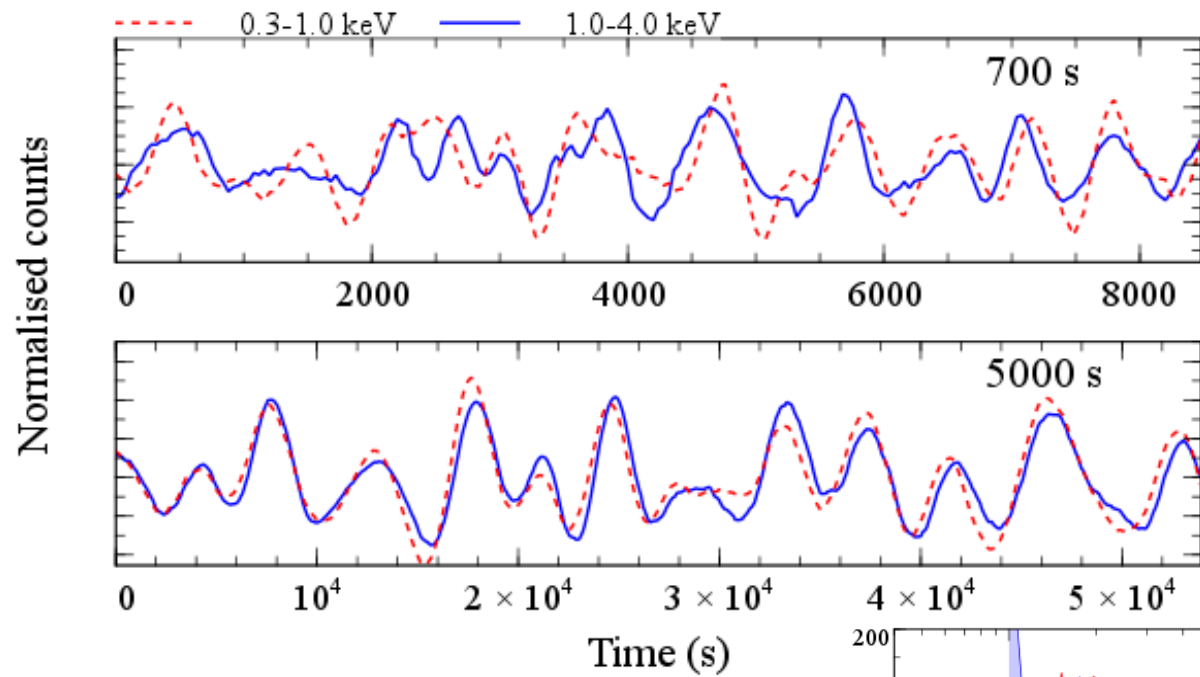
Blustin&Fabian09



# 0.3 keV vs 1-3 keV

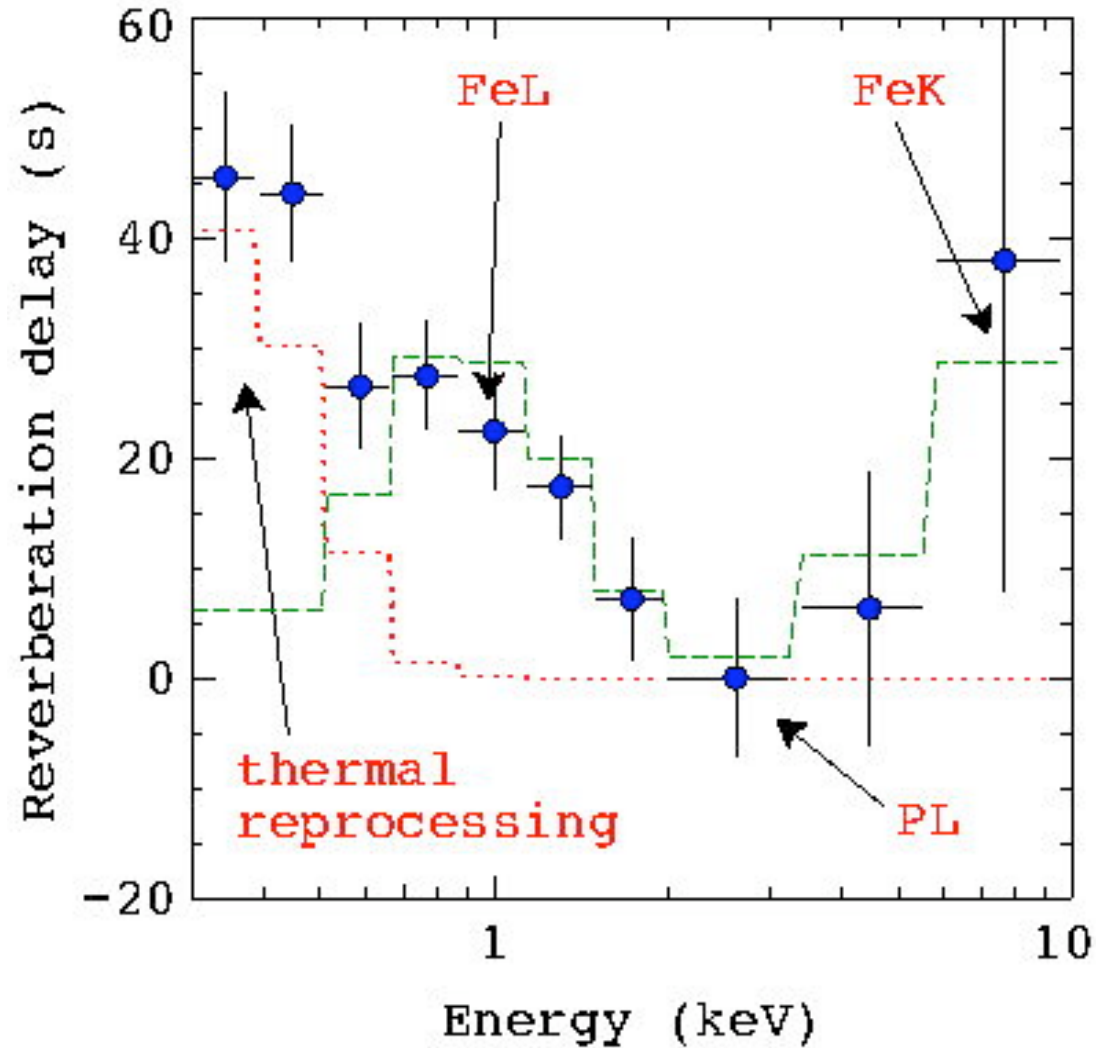




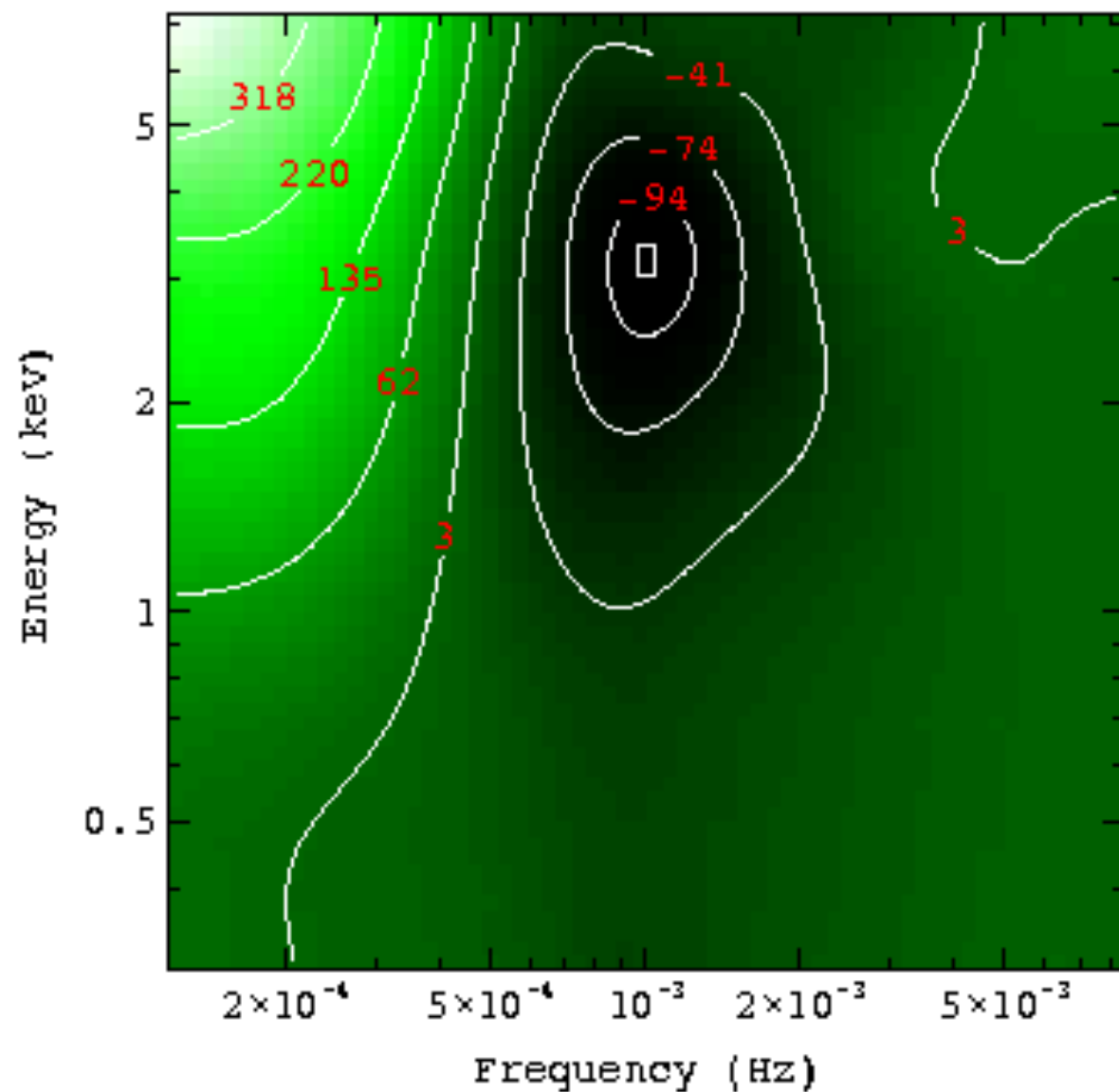


Zoghbi+10a

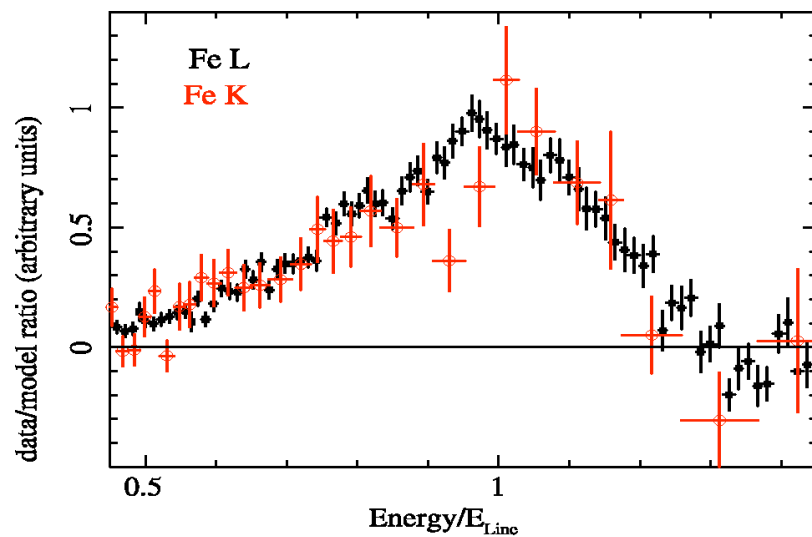
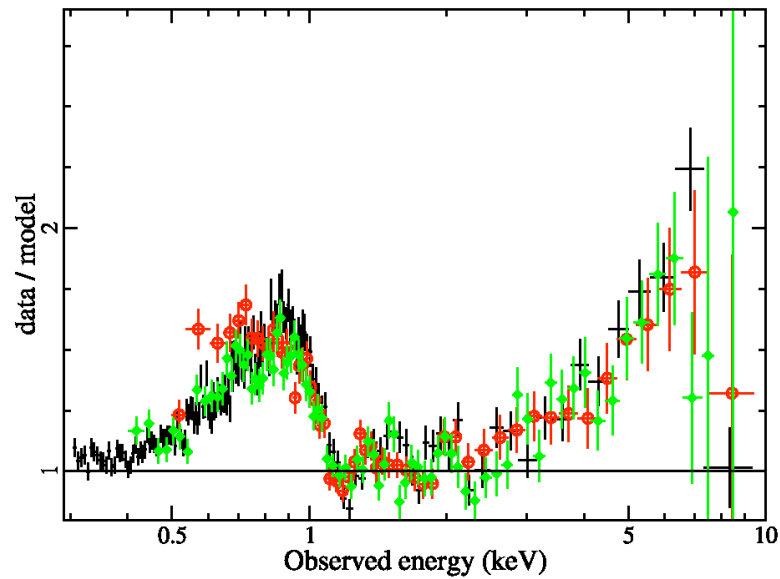
# Zoghbi+10b



- Exploring the frequency-energy axes.



# IRAS13224 Ponti+09



# GRAVITAS

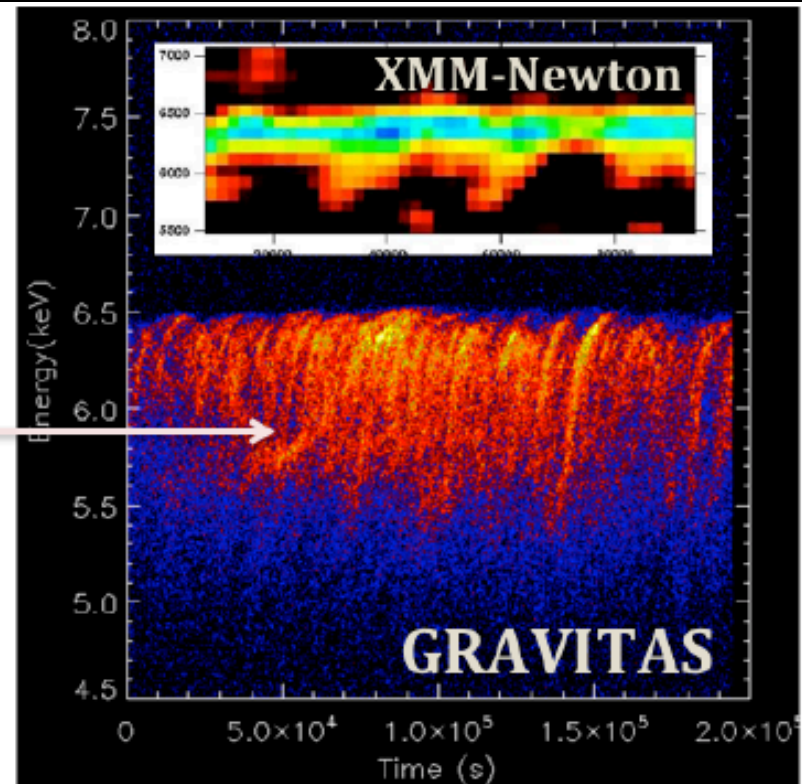
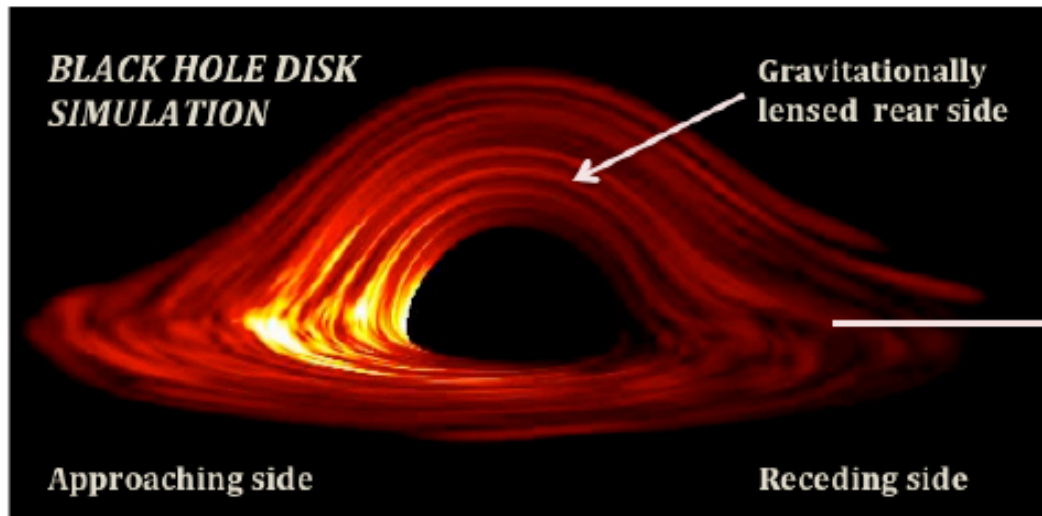
General Relativistic Astrophysics Via  
Timing And Spectroscopy

**An M3 mission proposal to ESA**

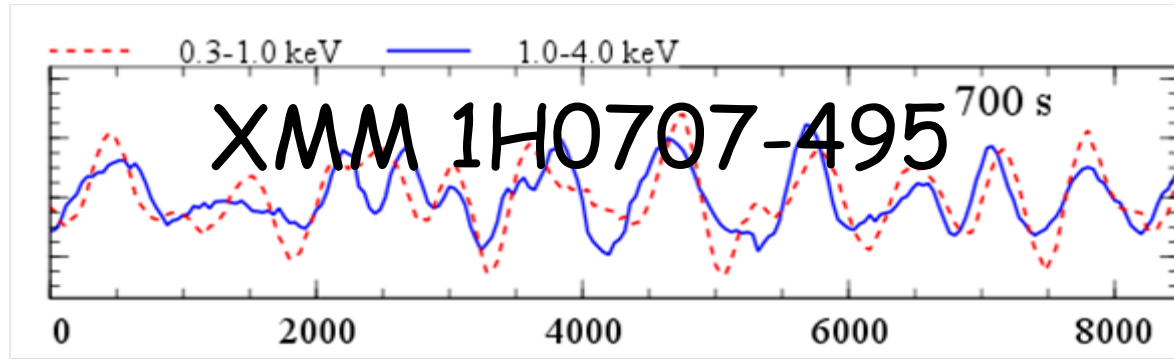
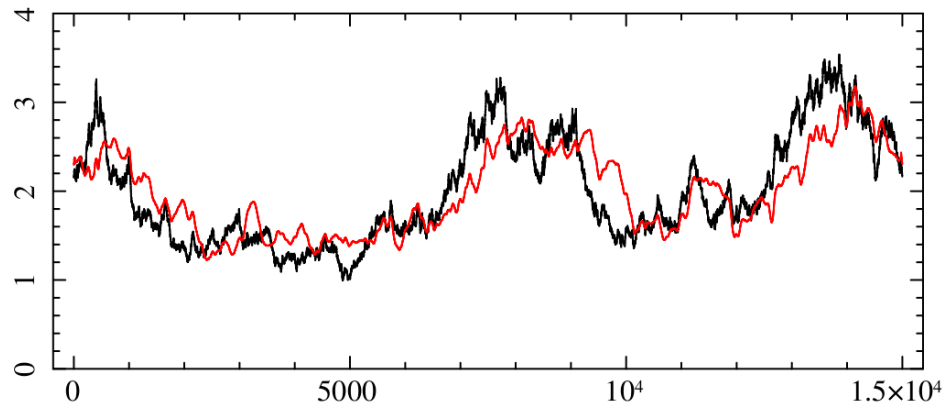
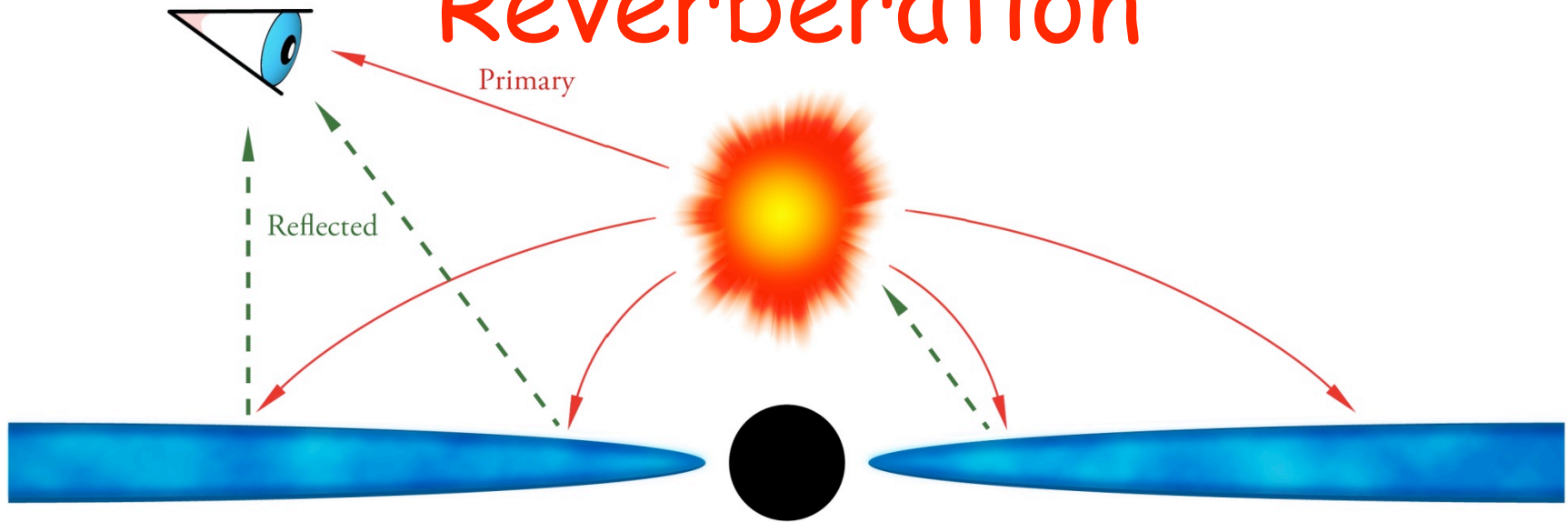
PIs: Paul Nandra (MPE); Didier Barret  
(CESR)

# How do accreting Black Holes

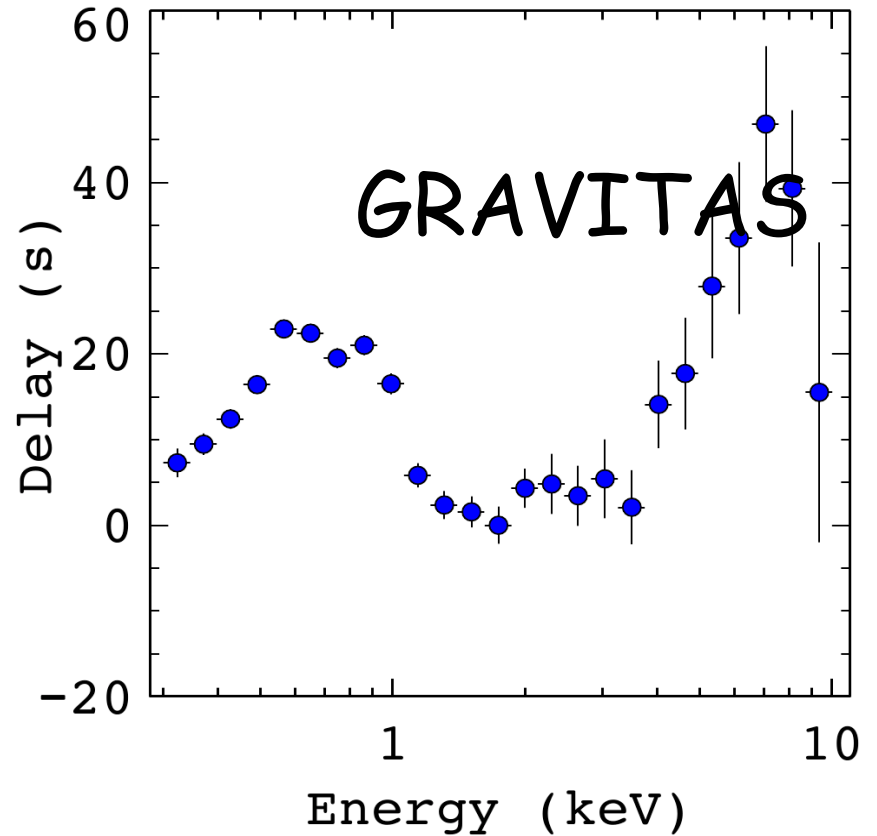
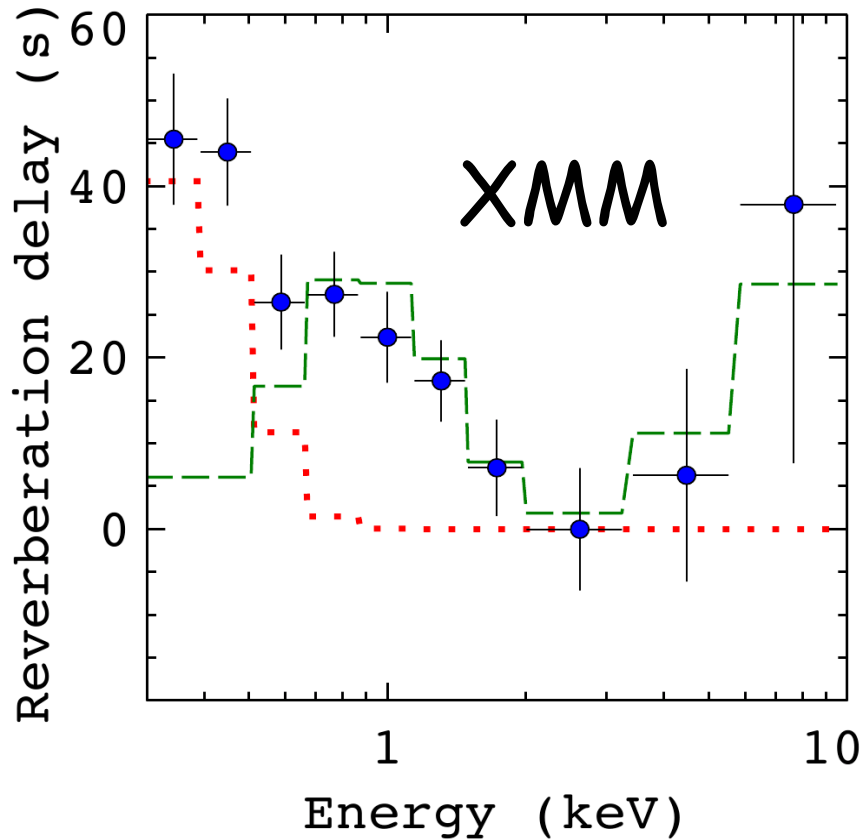




# Reverberation

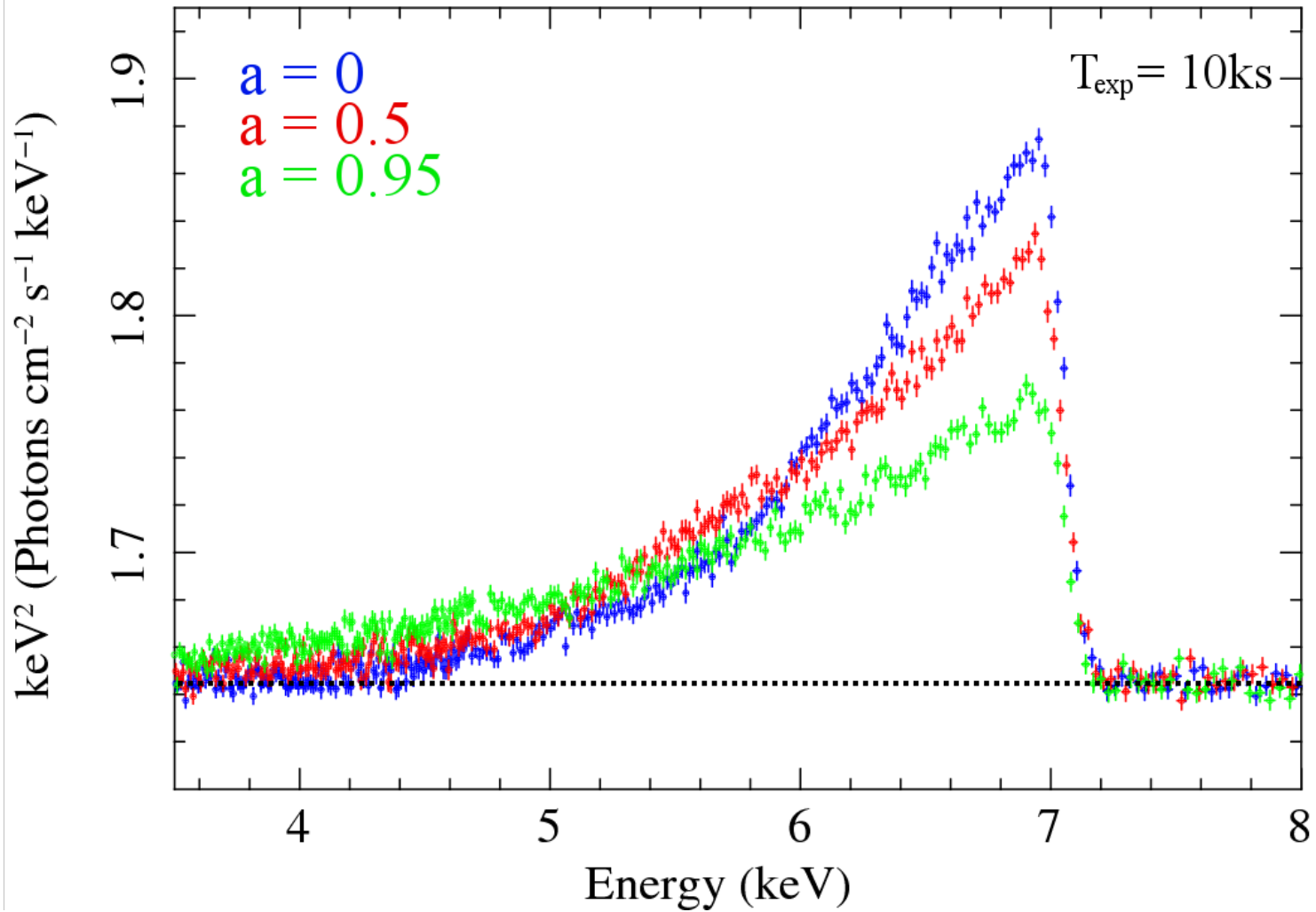


# 1H0707-495

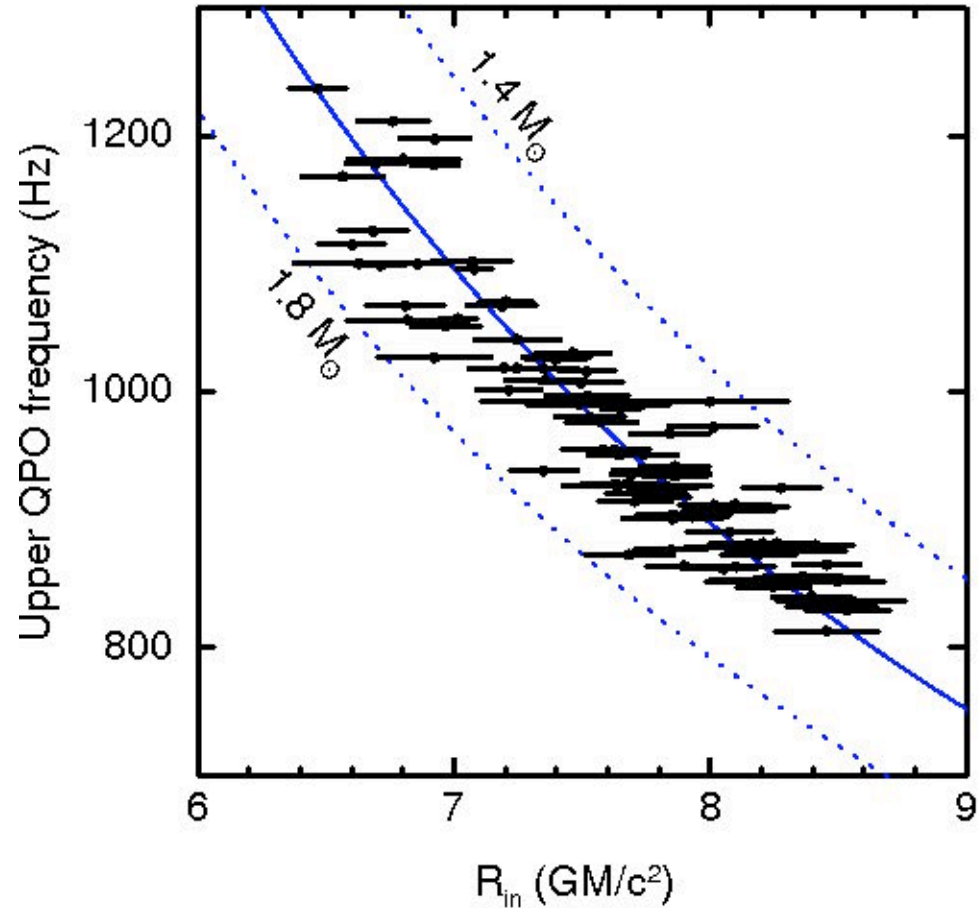
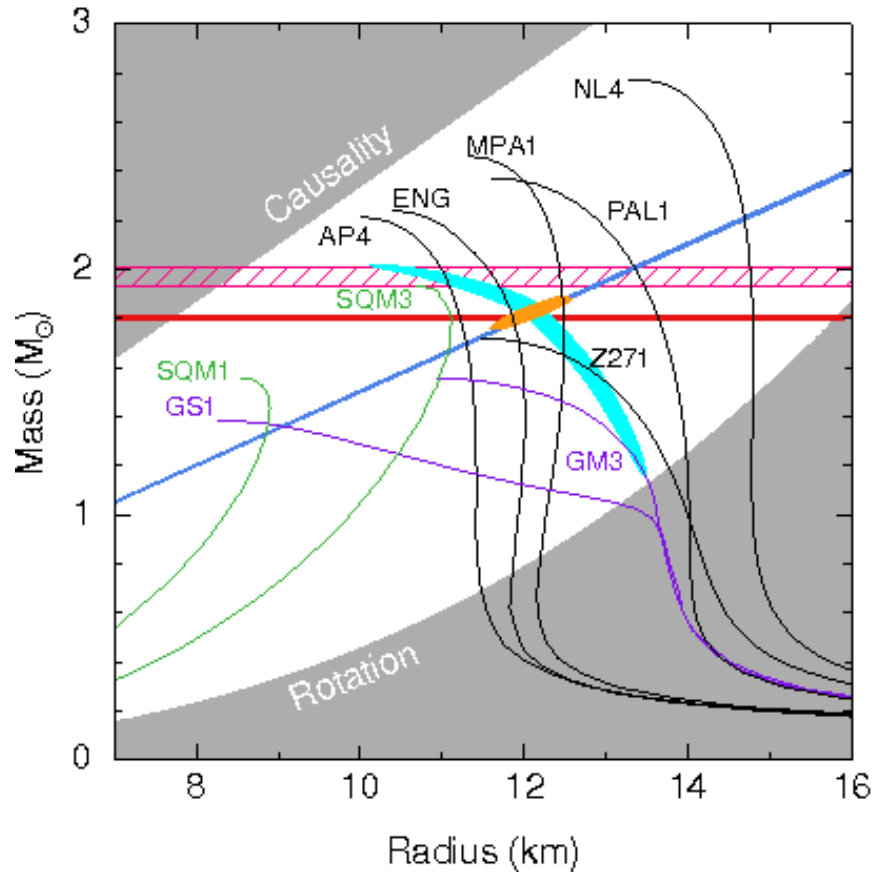


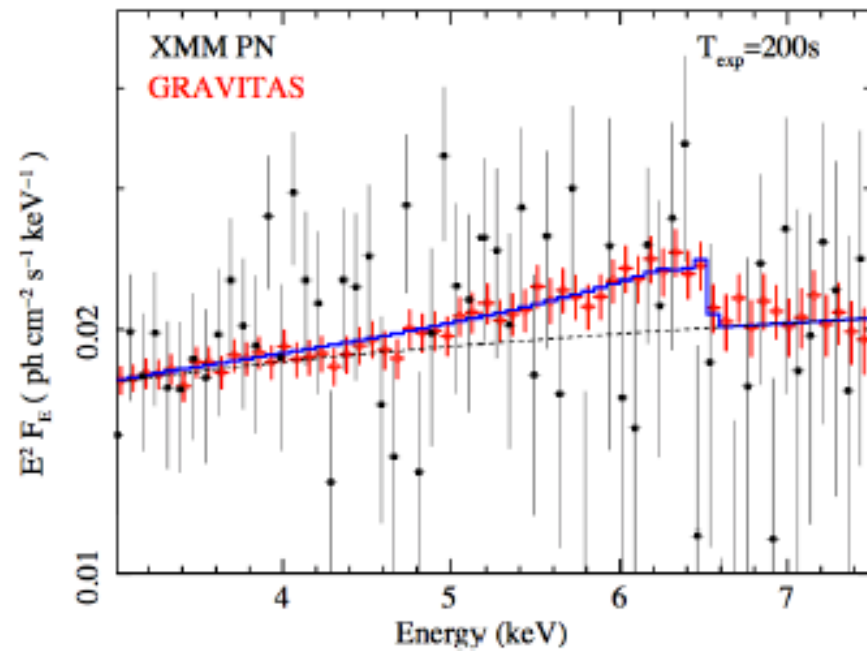
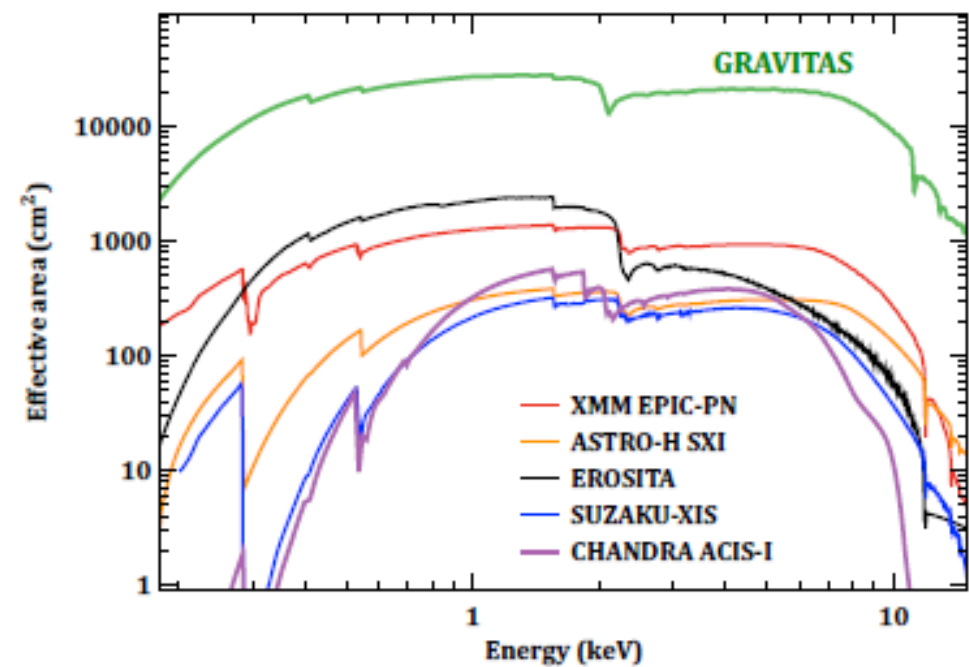
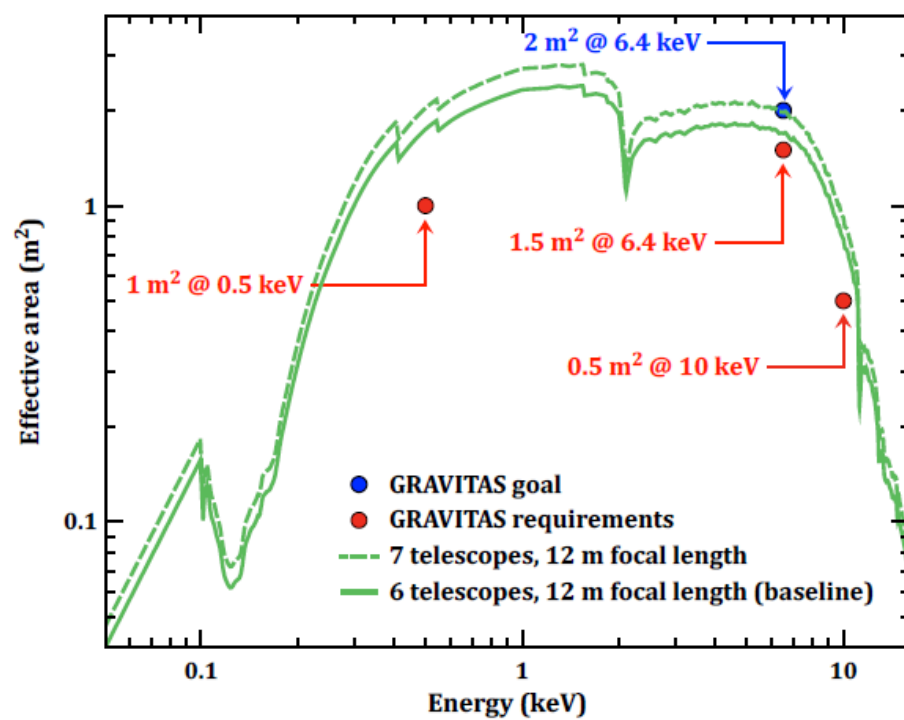
Zoghbi+10a,b

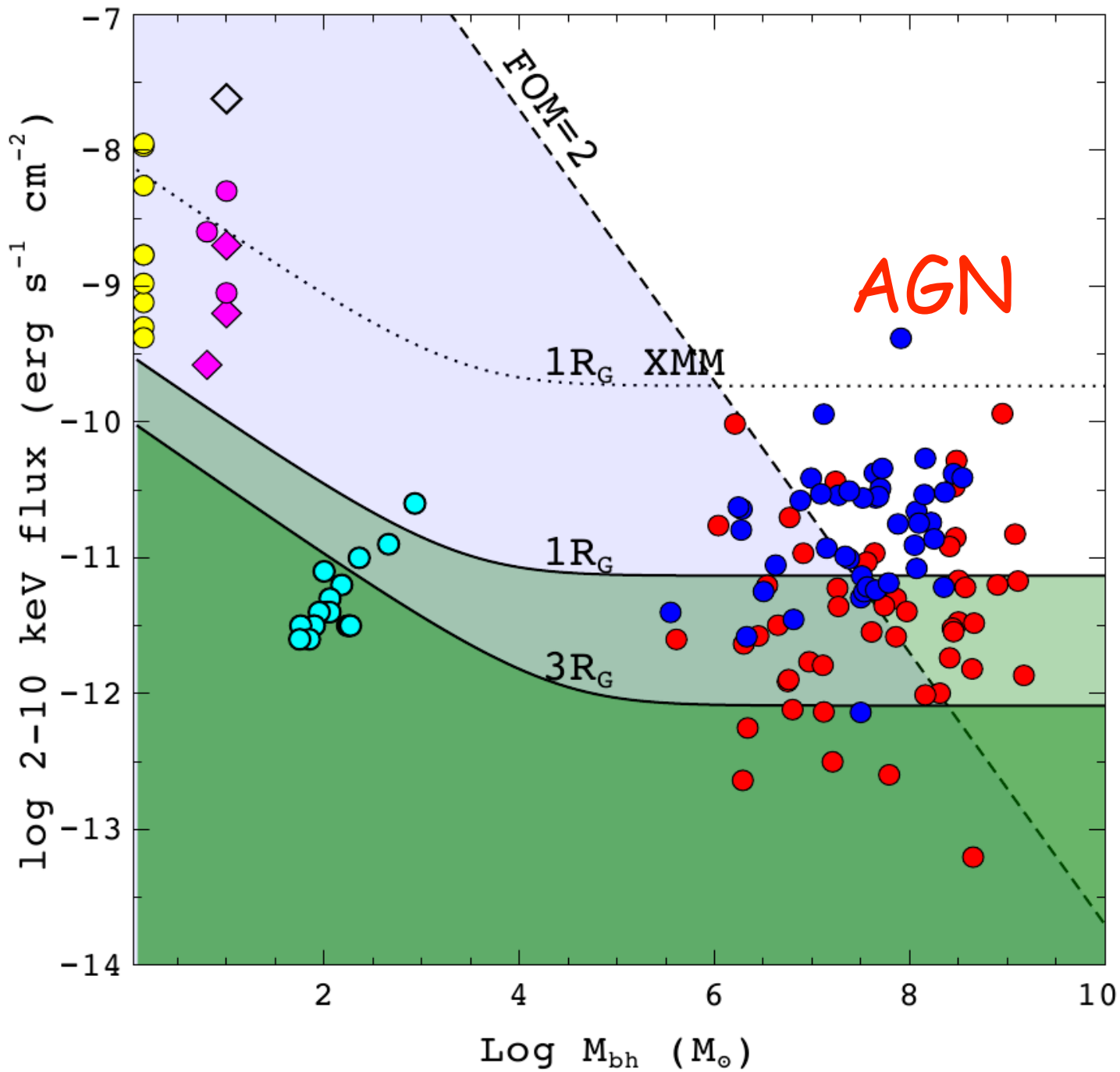
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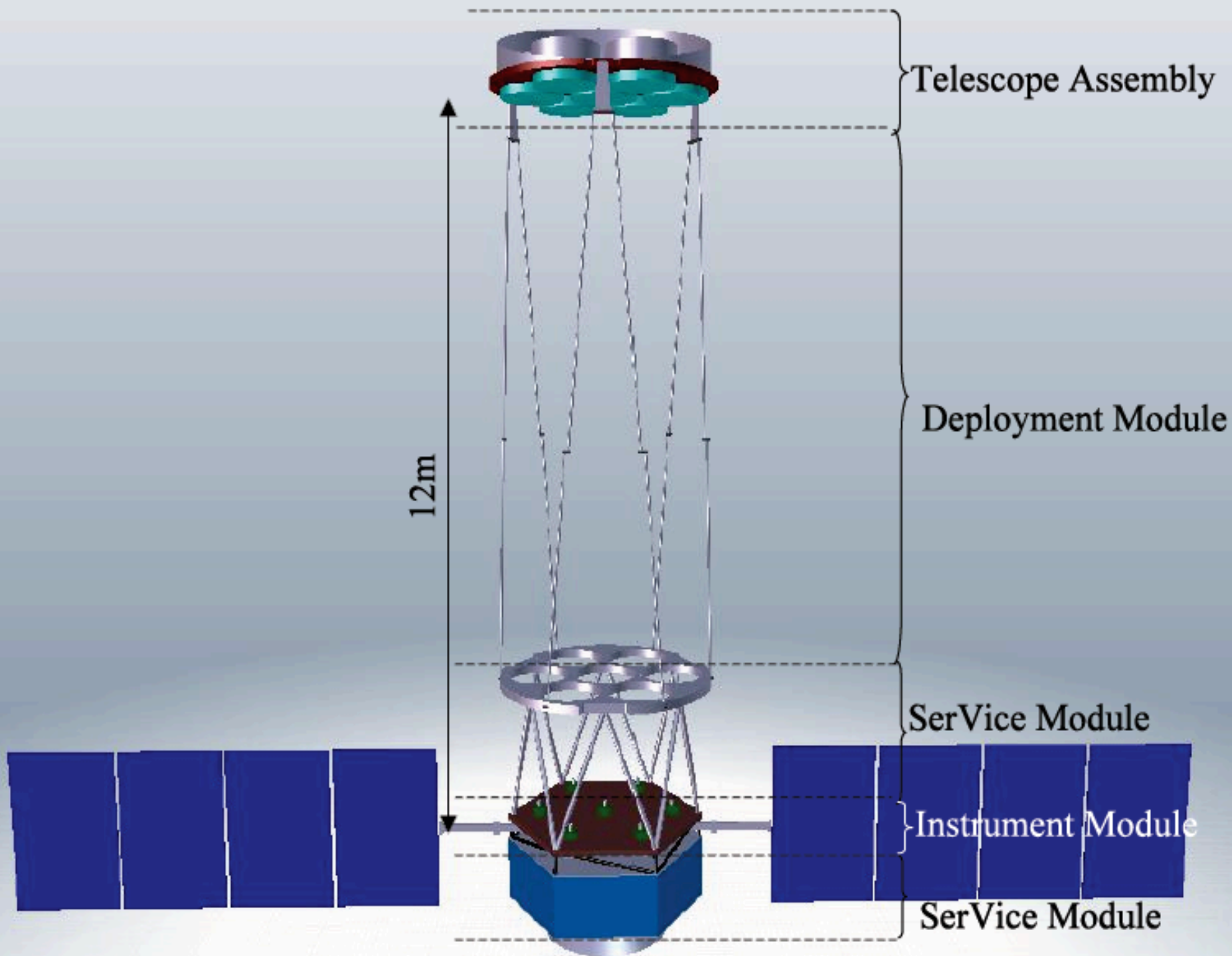


# Neutron Star Equation of State





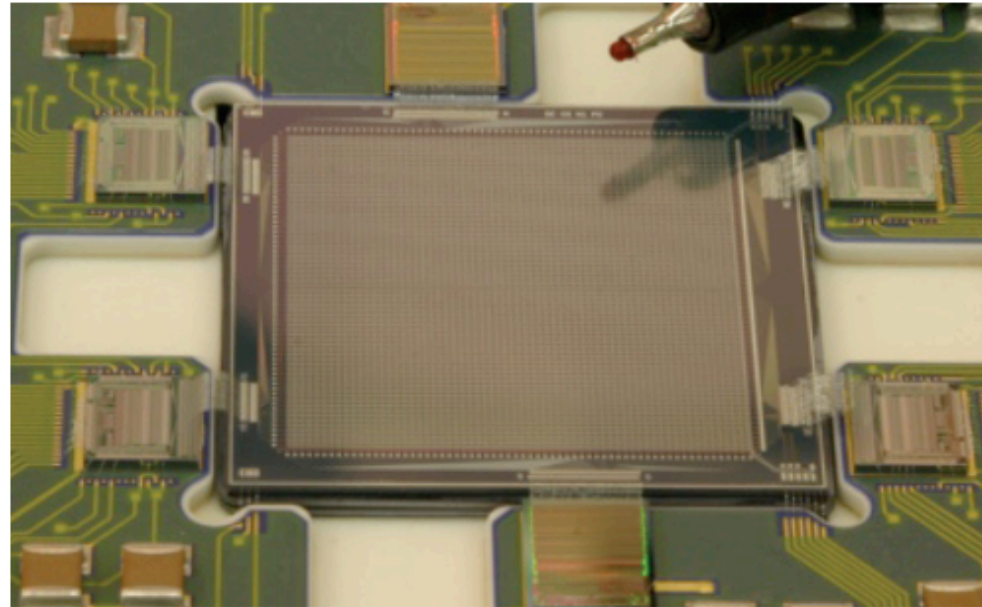
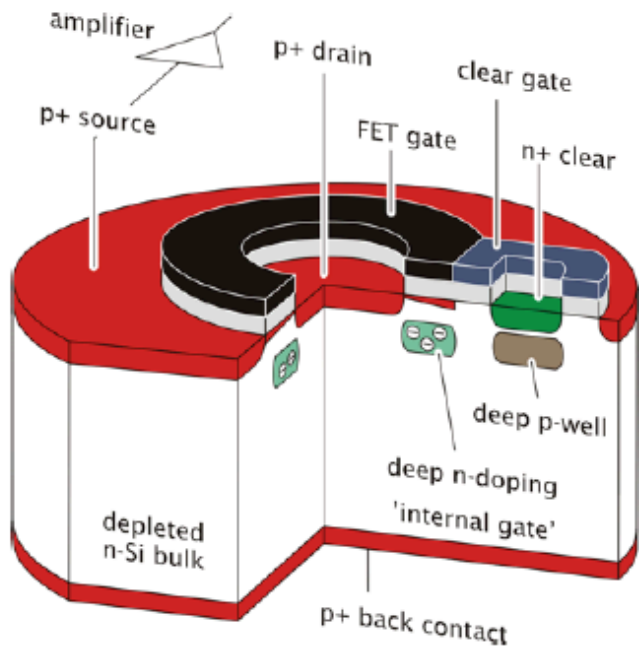




# X-ray Optics

- 6 identical telescope modules (cf e-ROSITA)
- 12m focal length (via EOB, cf ASTRO-H)
- Slumped glass (or SPO) 0.4mm thick (NuSTAR)
- Modest angular resolution ( $< 1$  arcmin)
- Iridium coating (Chandra)

# High Framerate Imager HIFI



64x64 pixels over 7 arcmin FOV

Prospects for studying the innermost regions around accreting black holes - understanding how accreting black holes work - are bright and within our grasp

