Resolving Relativity in Galactic Black Holes

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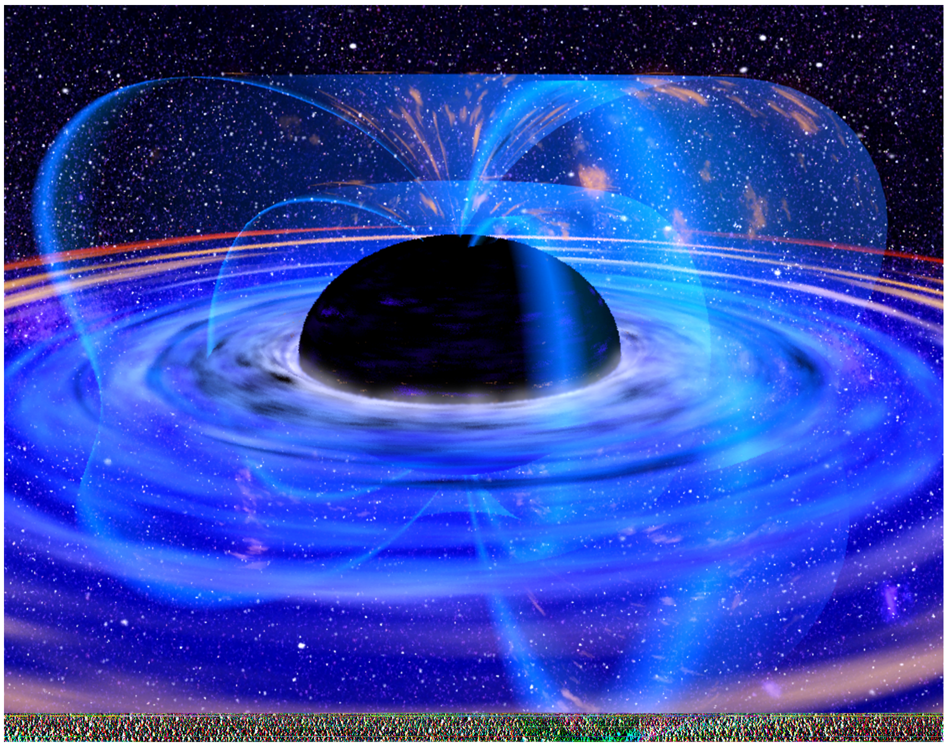
X−ray Binaries in the Chandra and XMM−Newton Era

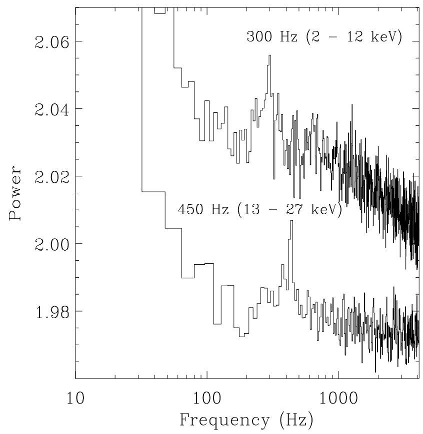
14−15 November 2002



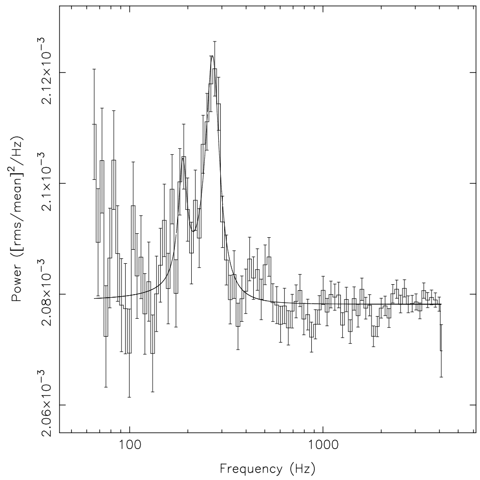
A. C. Fabian
J. Homan
M. van der Klis
W. H. G. Lewin
H. L. Marshall
M. Nowak
D. Pooley
R. Remillard
C. S. Reynolds
N. S. Schulz
R. Wijnands
P. Wojdowski
J. in 't Zand
P. Charles
R. Fender
B. Gaensler
P. Groot

(with thanks to F. Jansen, J. Swank, H. Tananbaum)

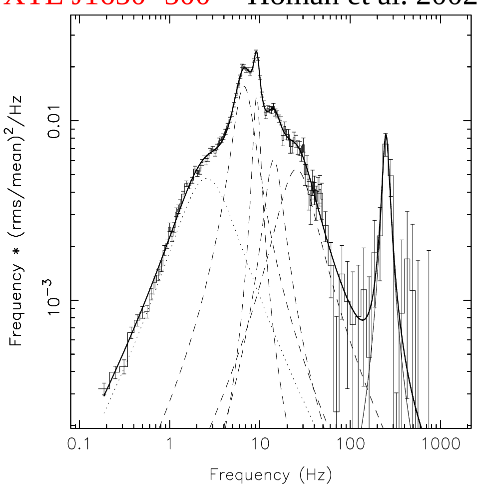
GRO J1655−40 Strohmayer 2001



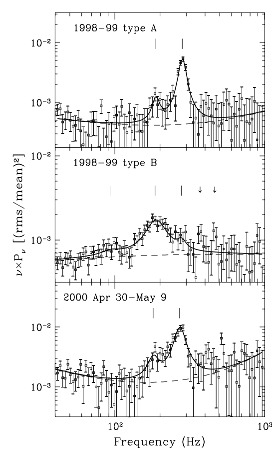
XTE J1550−564 Miller et al. 2001



XTE J1650−500 Homan et al. 2002



XTE J1550−564 Remillard et al. 2002



Keplerian Frequency at ISCO (a=0) −−> 220 Hz (10 M_sun/ M_BH)

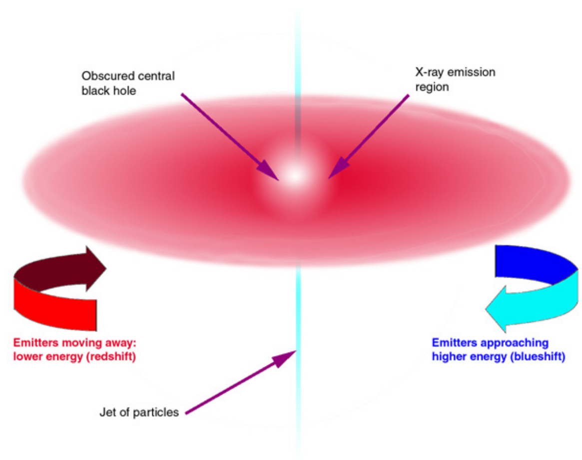
a = cJ/GM^2

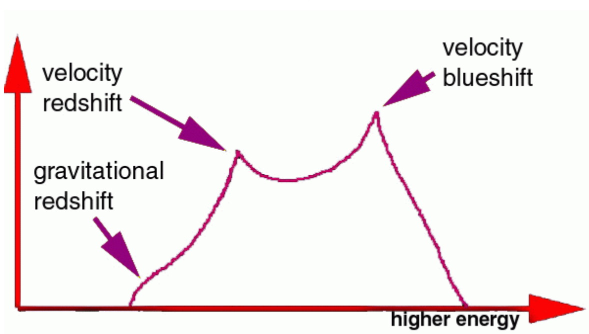
Relativistic precession frequency model (Stella, Vietri, Morsink 1999)

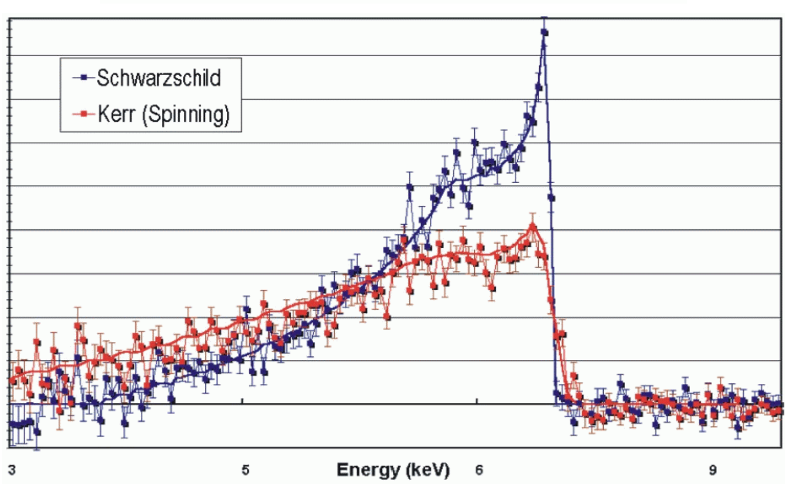
Parametric epicyc. resonance freq model (Kluzniak & Abramowicz 2002)

−−> *No consensus on a physical mechanism for QPOs.*

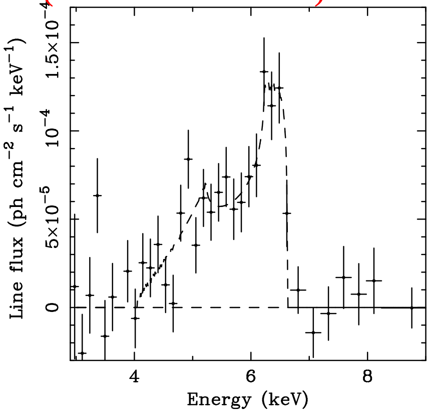
1st Broad Fe K line: Barr, White, & Page 1995 (Cygnus X−1, EXOSAT)
Schwarzschild Line: Fabian et al. 1989, Kerr Line: Laor 1991



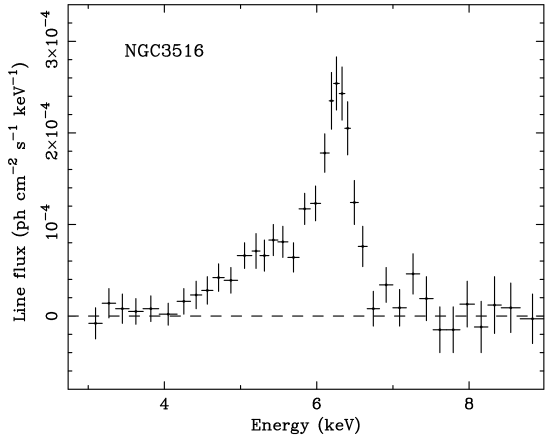




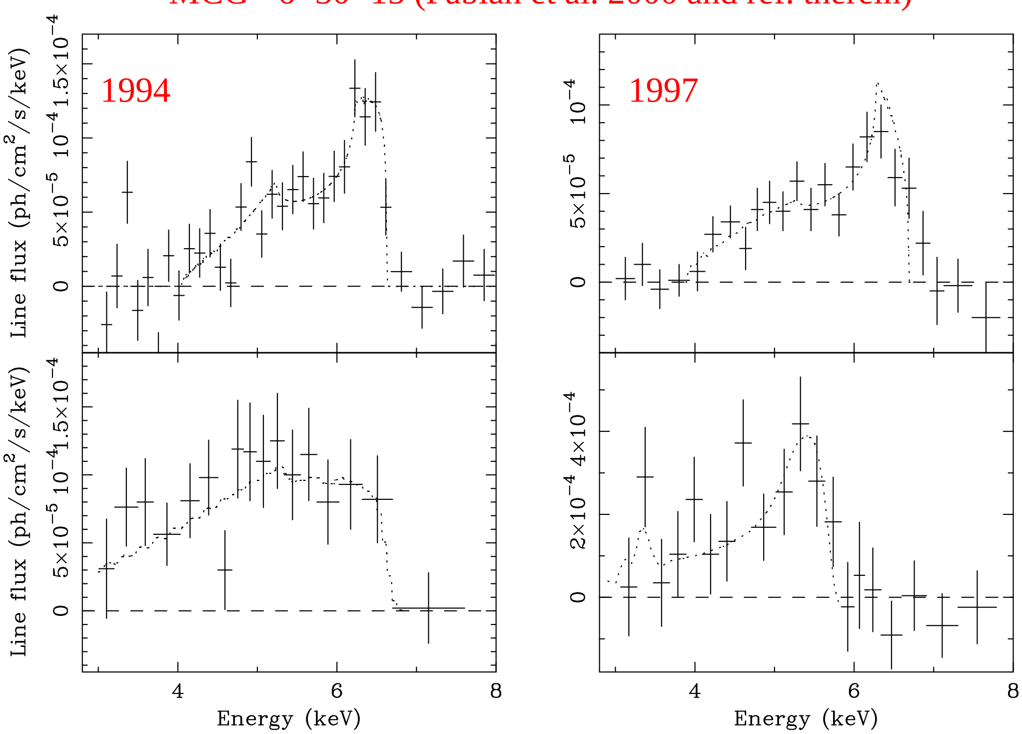
MCG −6−30−15 (Tanaka et al. 1995)



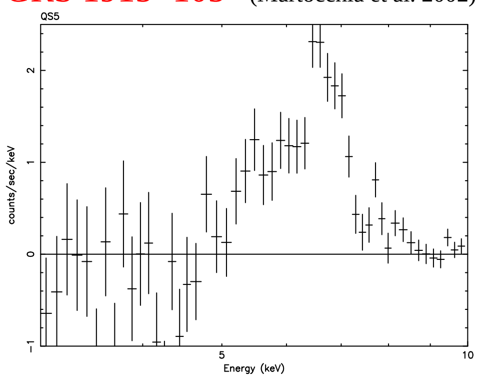
NGC 3516 (Nandra et al. 1999)



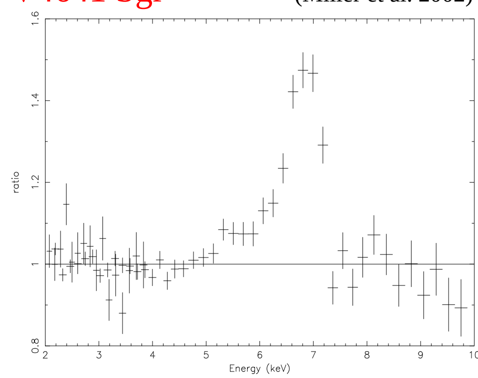
MCG −6−30−15 (Fabian et al. 2000 and ref. therein)



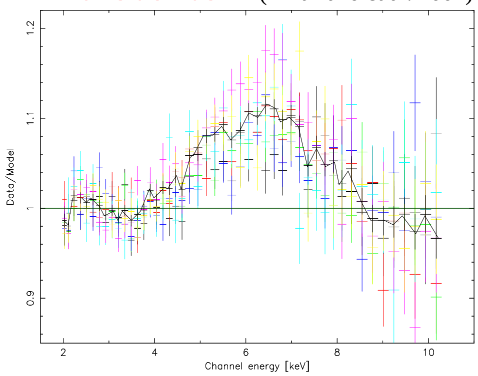
GRS 1915+105 (Martocchia et al. 2002)



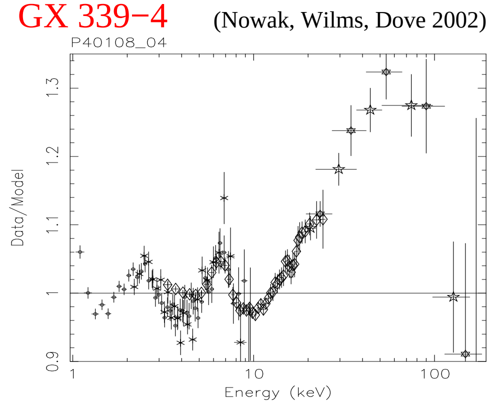
V4641 Sgr (Miller et al. 2002)



XTE J1908+094 (In 't Zand et al. 2002)



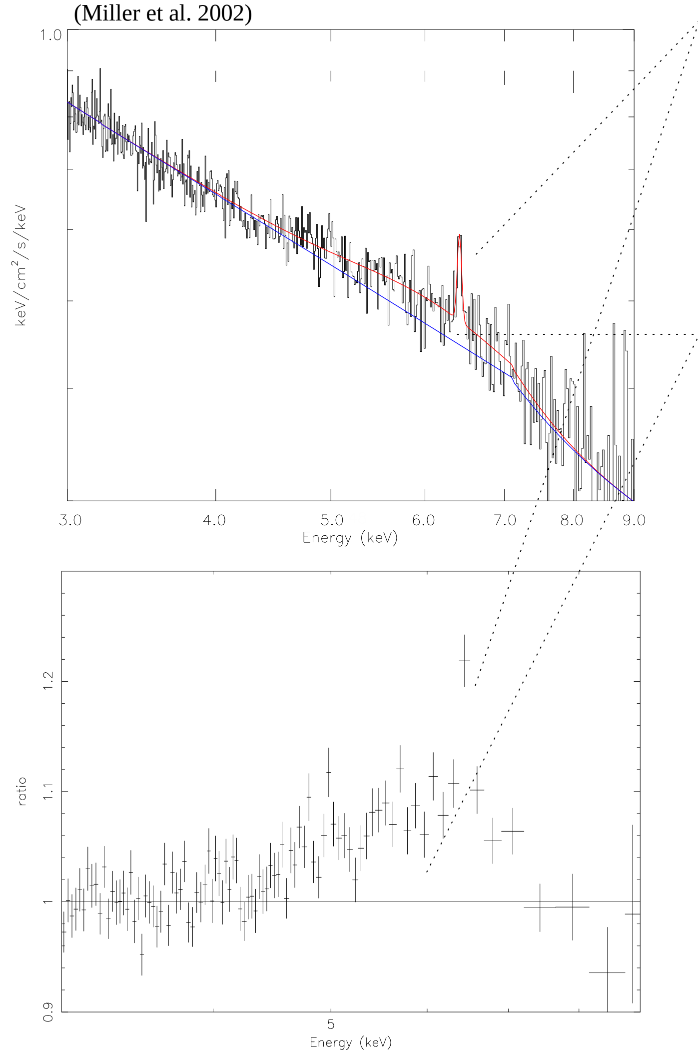
GX 339−4 (Nowak, Wilms, Dove 2002)



→ BeppoSAX, ASCA had resolutions adequate to see red & blue wings.

→ These line profiles do not strongly require spin.

(Miller et al. 2002)



Narrow Fe K line

E = 6.415 +/− 0.007 keV

FWHM = 70 +/− 10 eV

EW = 22 +/− 3 eV

Broad Fe K line

E = 5.82 +/− 0.07 keV

FWHM = 1.9 (+0.7,−0.3) keV

EW = 140 (+70,−40) eV

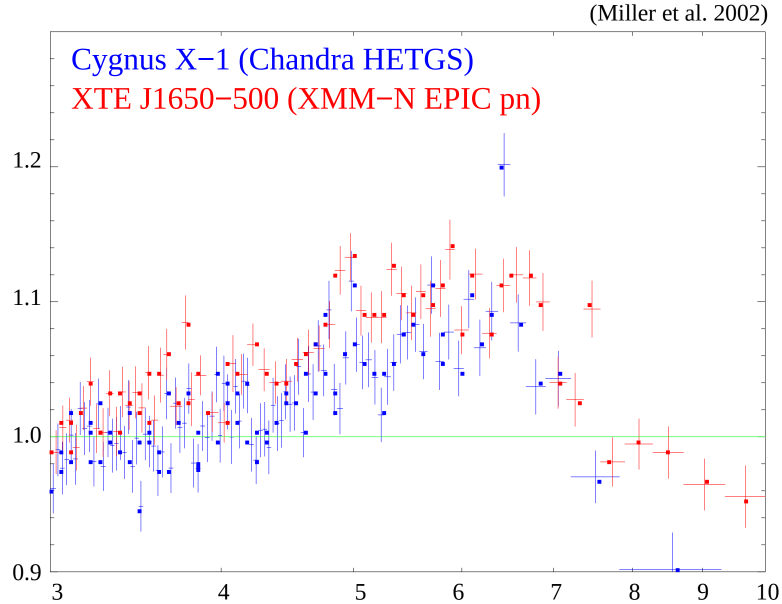
R_in = 7 (+6,−1) R_g

Components required at
8 sigma.

Components are resolved.

Broad line confirmed with
dispersive spectrometer.

(Miller et al. 2002)

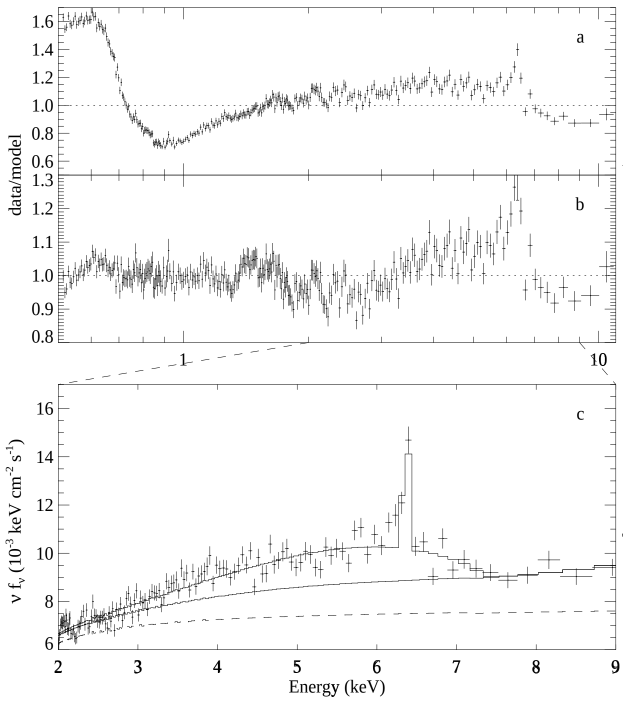


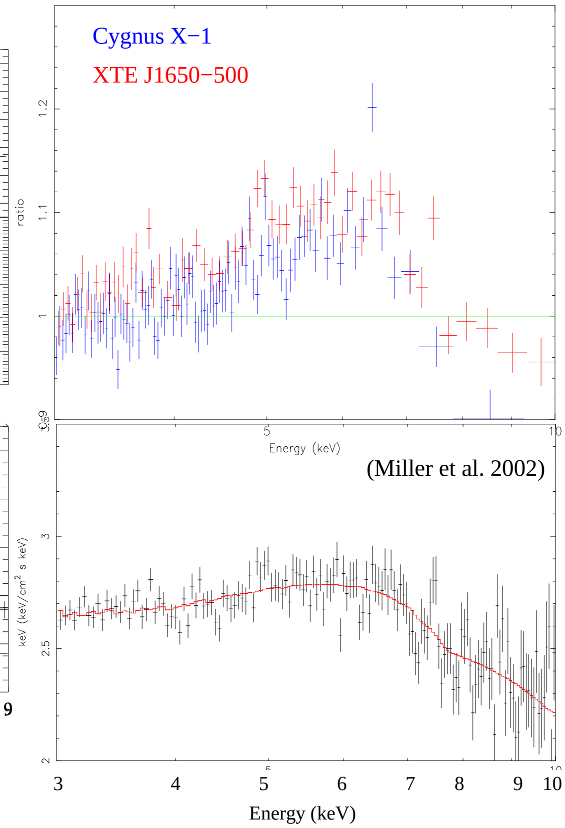
Multicolor disk	Power−law	Gaussian	Smeared Edge
kT=0.322(4) keV	2.09(5)	E=5.3(2) keV	tau=0.5

Pexriv (Ionized Reflection)	Laor (Kerr BH Line Model)
Index = 2.04(3)	E = 6.8 +0.2 −0.1 keV
log(xi) = 4.3 (fixed)	EW = 350 +60 −40 eV
R = 0.6 +0.3 −0.1	R_in = 1.24 R_g (6 R_g @ 6 sigma)
	$J(r) \sim r^{-q}$
	q = 5.4(5) (q=3 @ 5.6 sigma)

A Connection to MCG −6−30−15 ?

MCG −6−30−15 (Wilms et al. 2001)





E = 6.97 (−0.1) keV ------------- E = 6.8 (+0.2, −0.1) keV

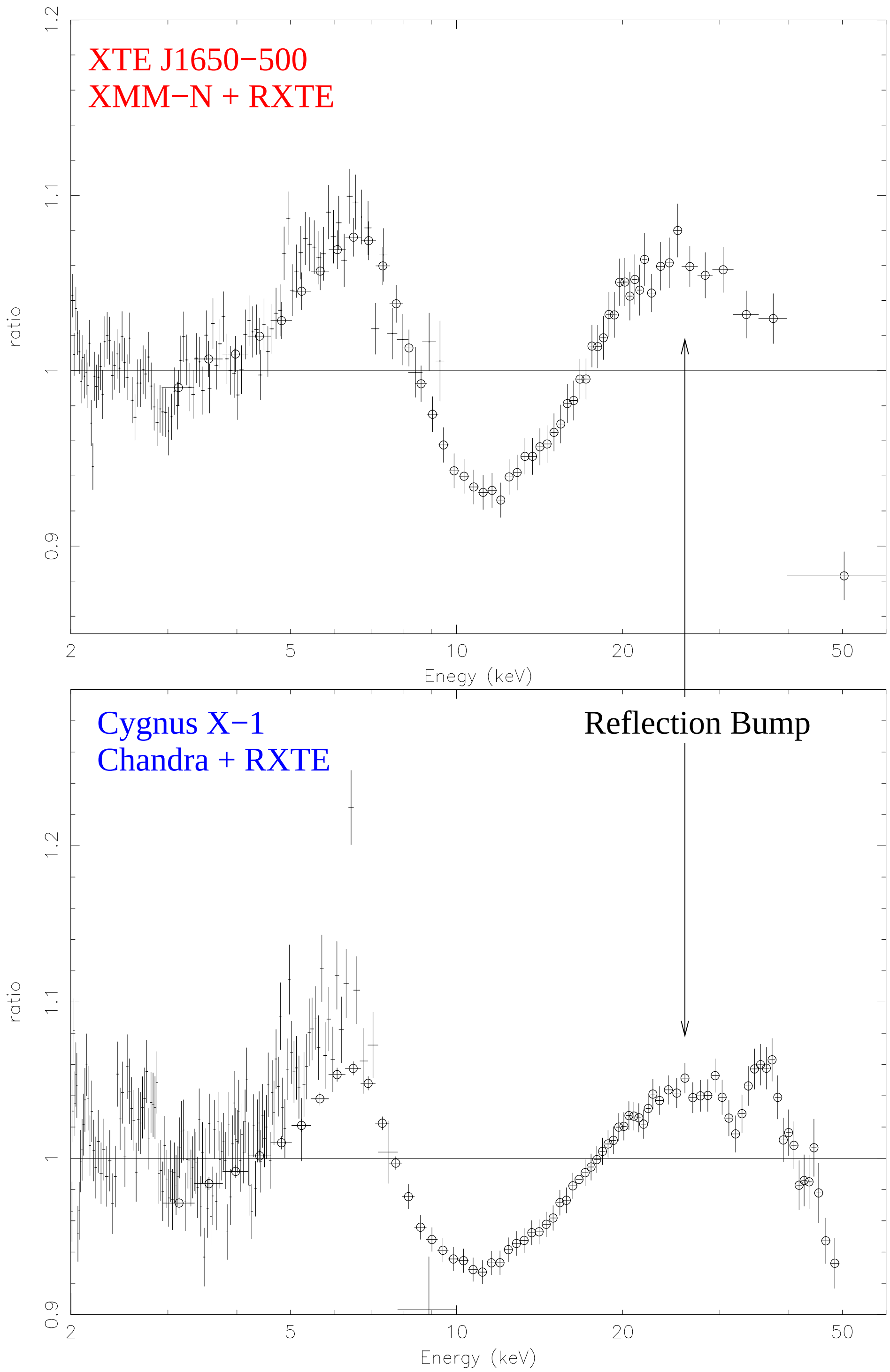
R_in −> 1 R_g ------------- R_in −> 1 R_g

EW = 300−400 eV ------------- EW = 350 (+60, −40) eV

f = 1.5−2.0 ------------------ f = 0.6 (+0.3, −0.1)

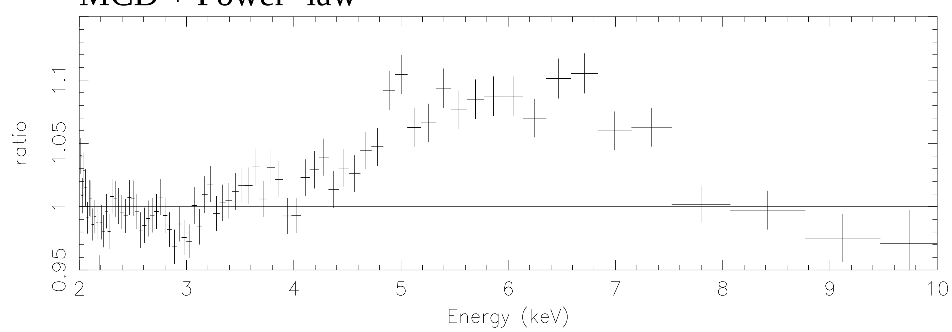
q = 4.3−5.0 ------------- q = 5.4 (0.5)

→ High spin, centrally concentrated hard X−ray sources implied, and perhaps rotational energy extraction via magnetic connections (Blandford & Znajek 1977, Agol & Krolik 2001)

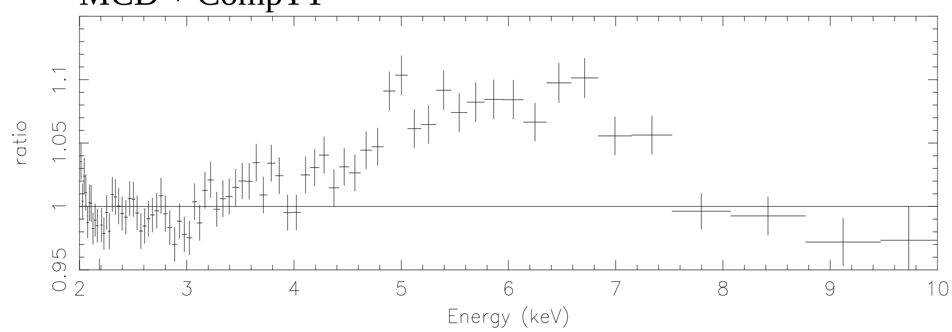

XTE J1650−500
XMM−N + RXTE
ratio
1.2
1.1
1
0.9
2
5
10
20
50
Enegy (keV)
Reflection Bump
Cygnus X−1
Chandra + RXTE
ratio
1.2
1.1
1
0.9
2
5
10
20
50
Energy (keV)

XTE J1650−500

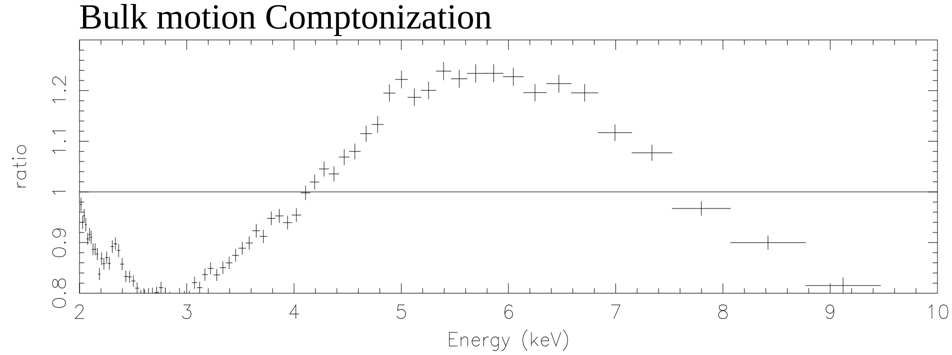
MCD + Power−law



MCD + CompTT



Bulk motion Comptonization



→ RXTE is uniquely able to measure HF QPOs, which provide important spin constraints.

→ Chandra can see strong, broad lines, and can resolve line asymmetries and narrow components within the line profile.

→ XMM−Newton can resolve line asymmetries, effective area at E > 8 keV important.

→ Figure of merit:
(Flux @ 6 keV) * (live fraction) * (eff. area)

→ *Need more examples with HF QPOs, skewed Fe K*

→ *Fe K line profile variability*

→ *Evidence for relativistic effects at low L_X ?*

→ *Do v > 0.9c microquasars spin faster?*