XMM and Broad Iron Lines

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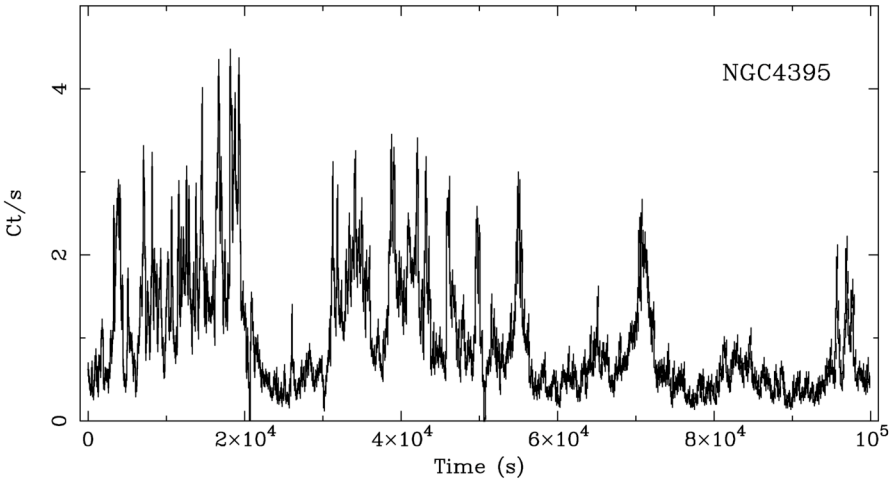
With help from Giovanni Miniutti

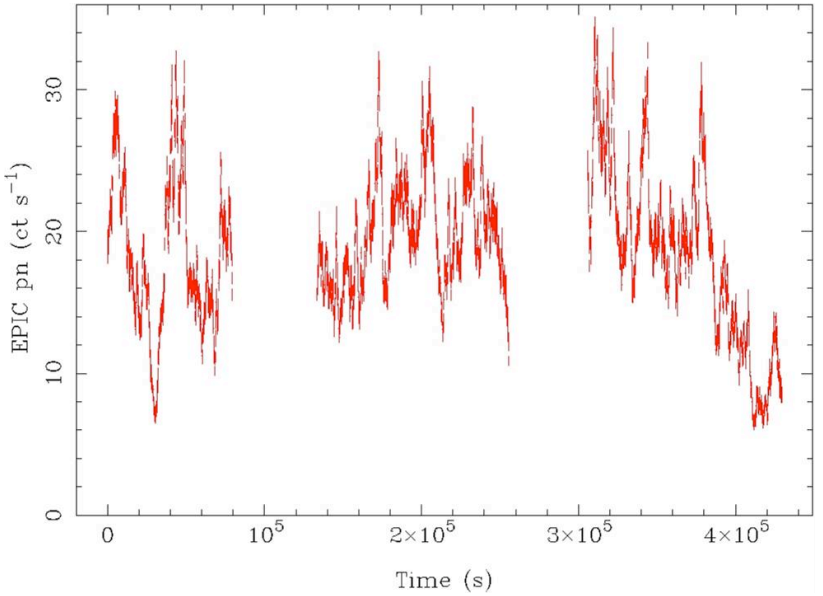
Strong Gravity Effects

- Gravitational redshift
- Gravitational light bending
- Dragging of inertial frames in Kerr metric (ISCO depends on BH spin)

Rapid variability



Implies much of radiation from innermost radii



MCG-6-30-15

Accretion makes massive black holes

$$\varepsilon(1+z) = \eta\rho_{\bullet}c^2$$

Soltan 82

Mean redshift

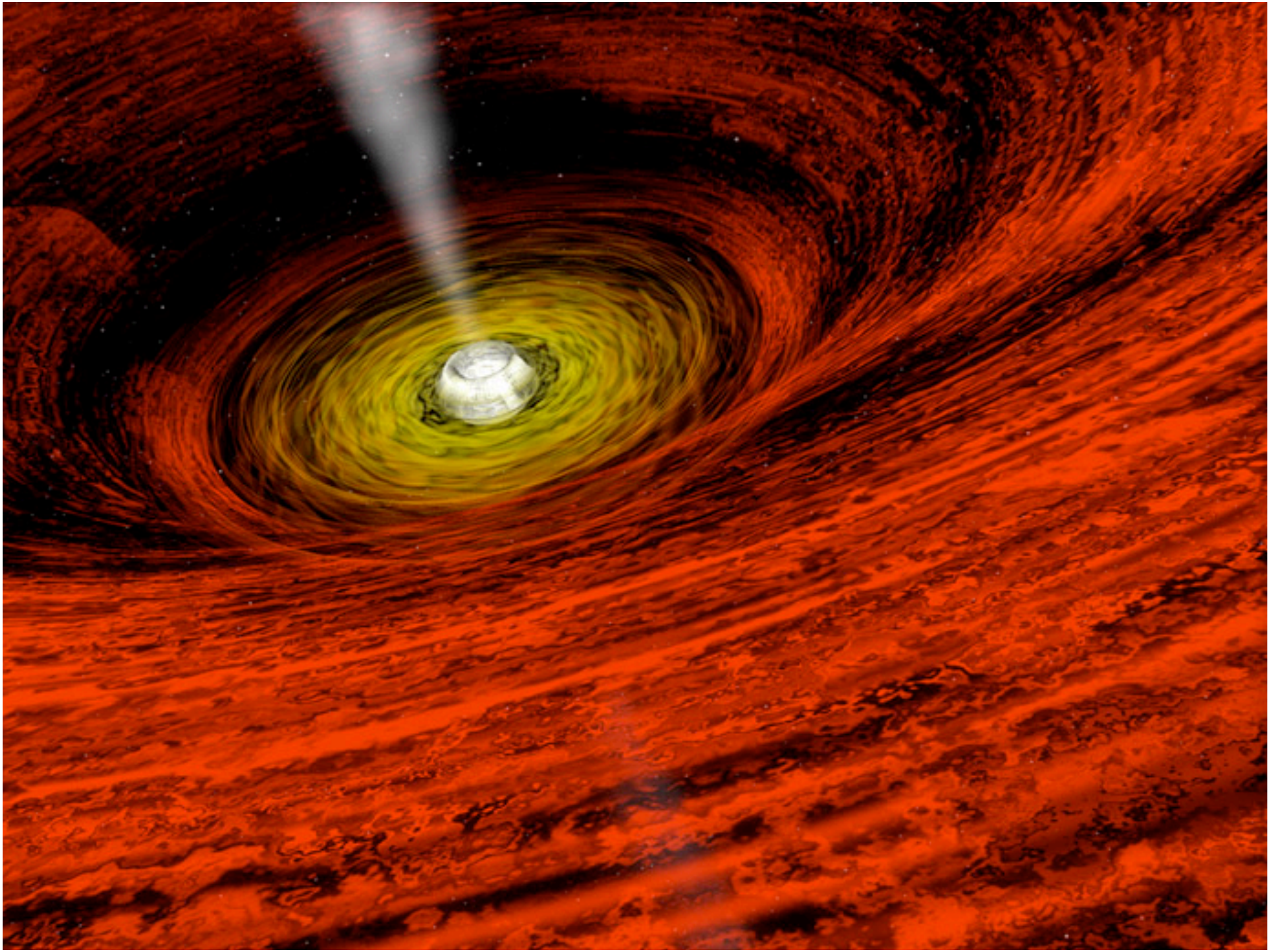
Radiative efficiency

Light

Mass density in BH

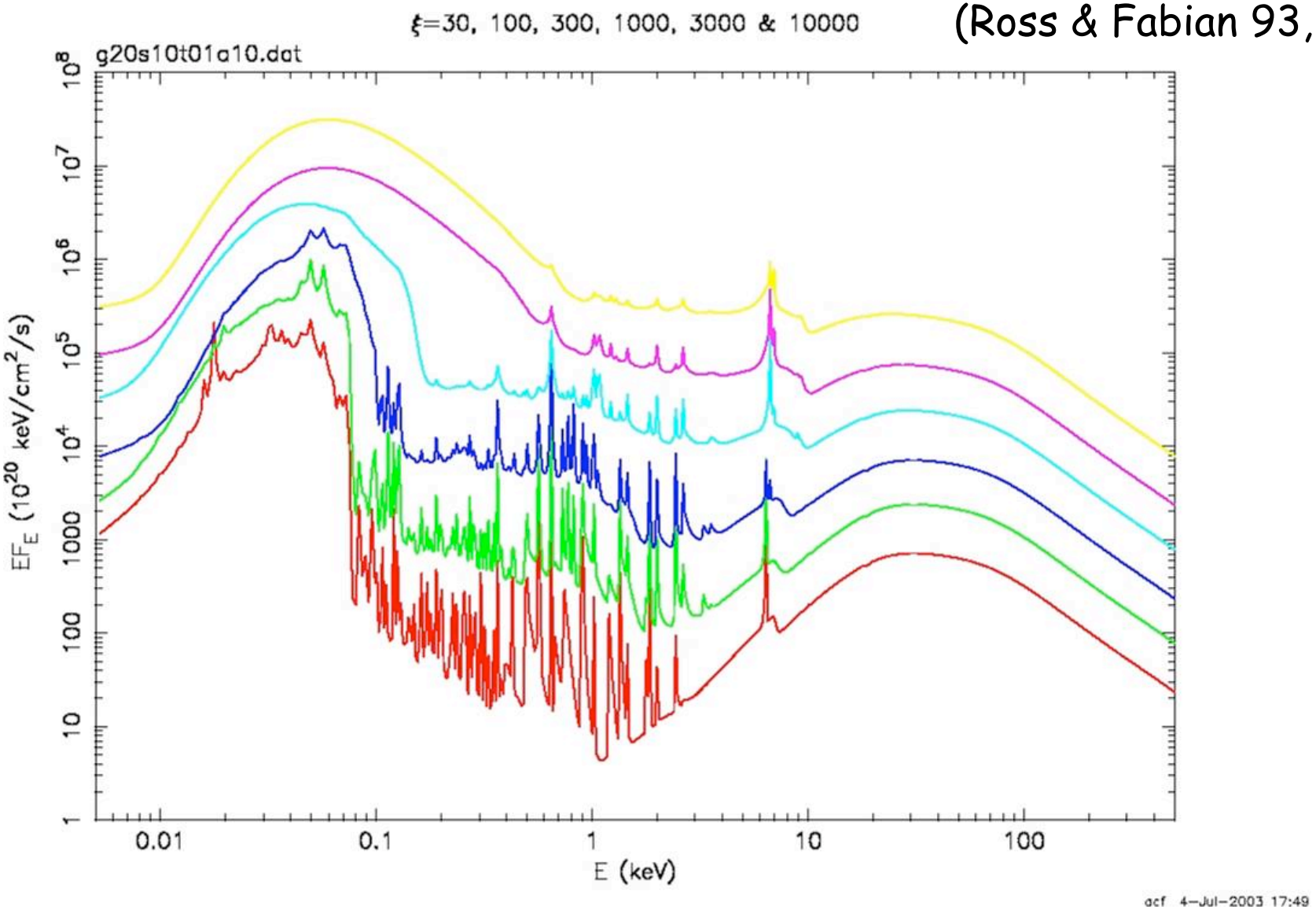
Observations ⟶ $\eta > 0.1$

Much of the radiation originates within $6R_g$

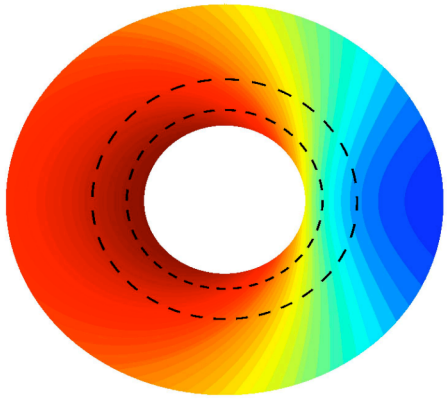


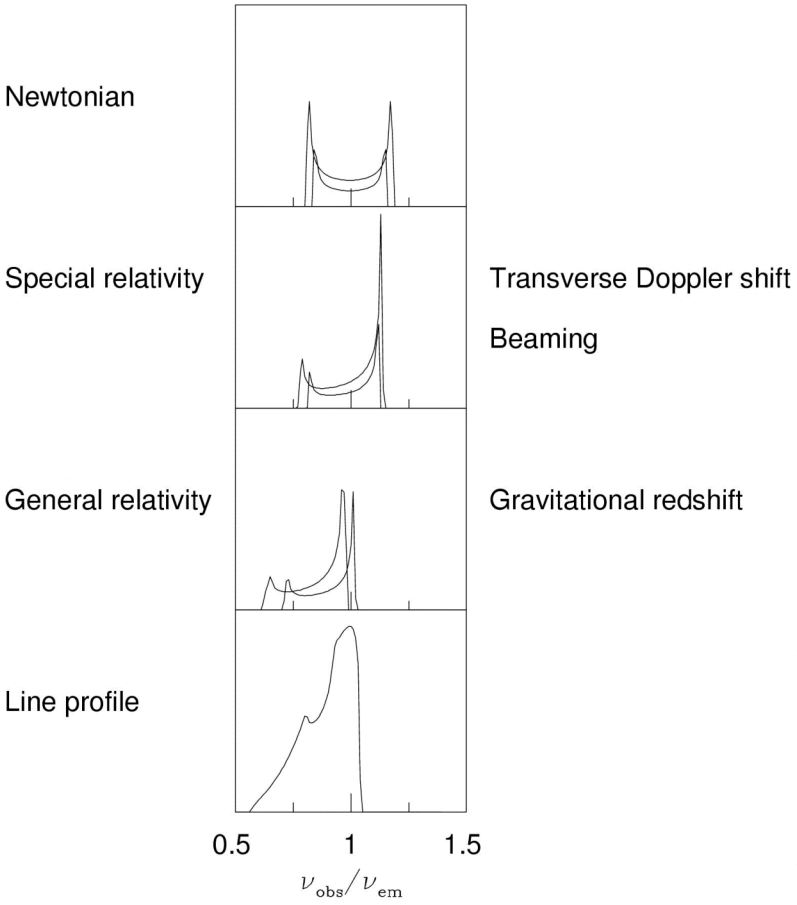
Reflection from photoionized matter

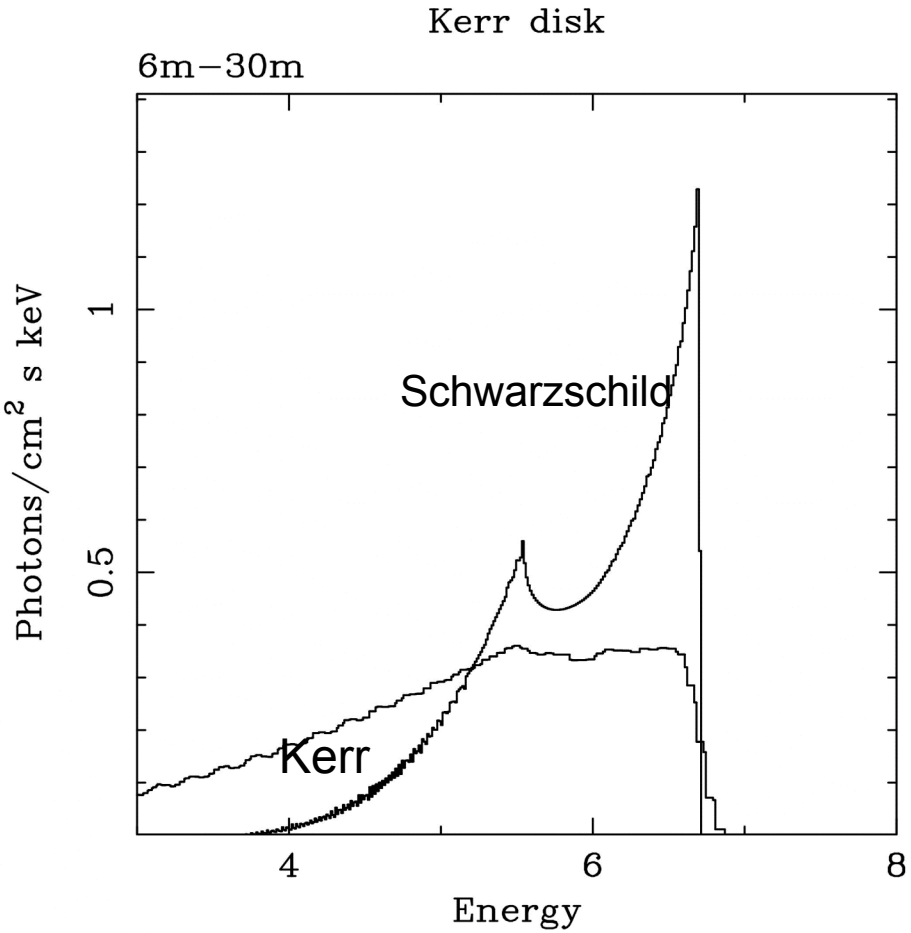
(Ross & Fabian 93, 05)



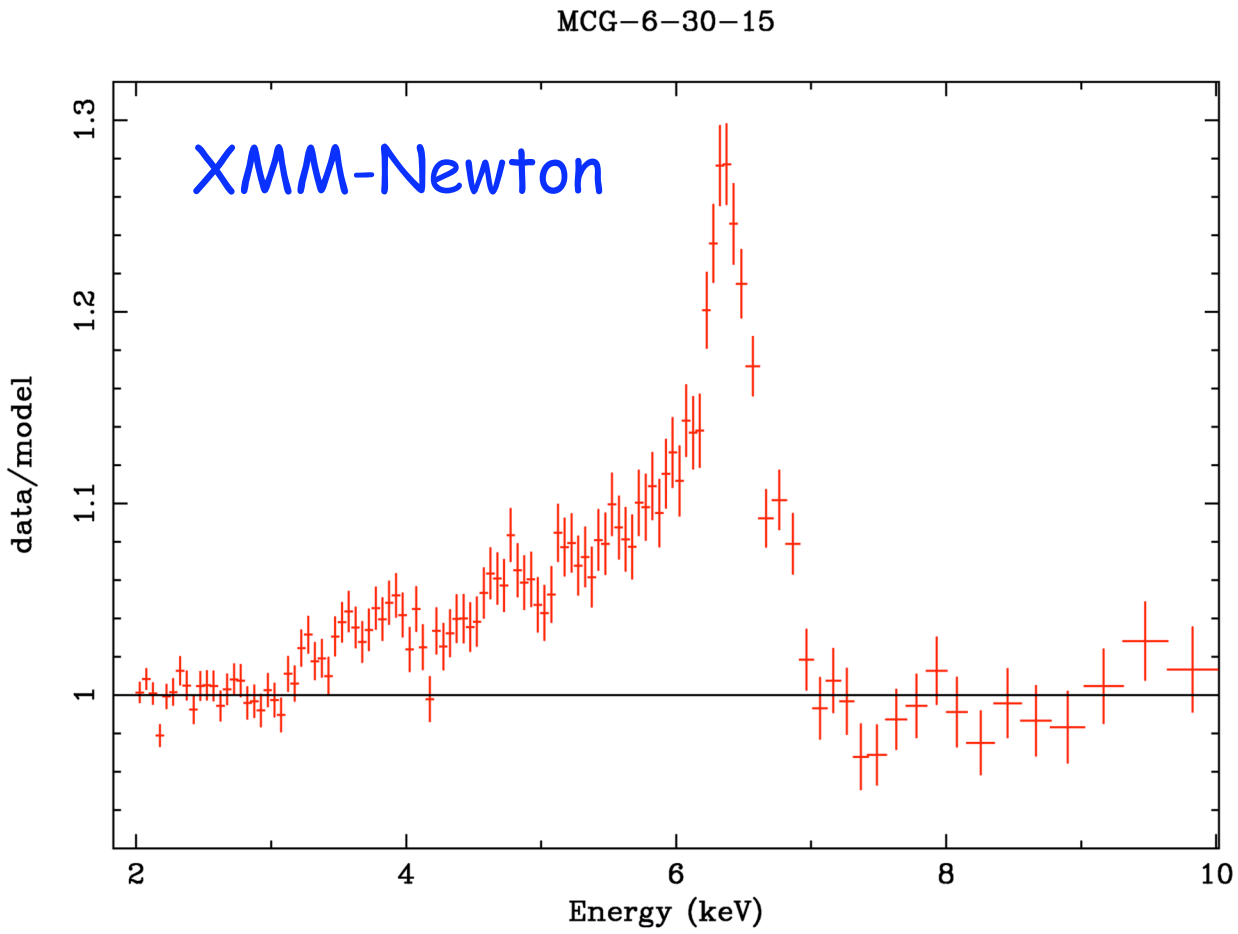
Also see Young+, Nayakshin+, Ballantyne+, Rozanska+, Dumont+







Fabian, Rees, Stella & White 89,
Laor 90... Dovciak+04;
Beckwith+Done05

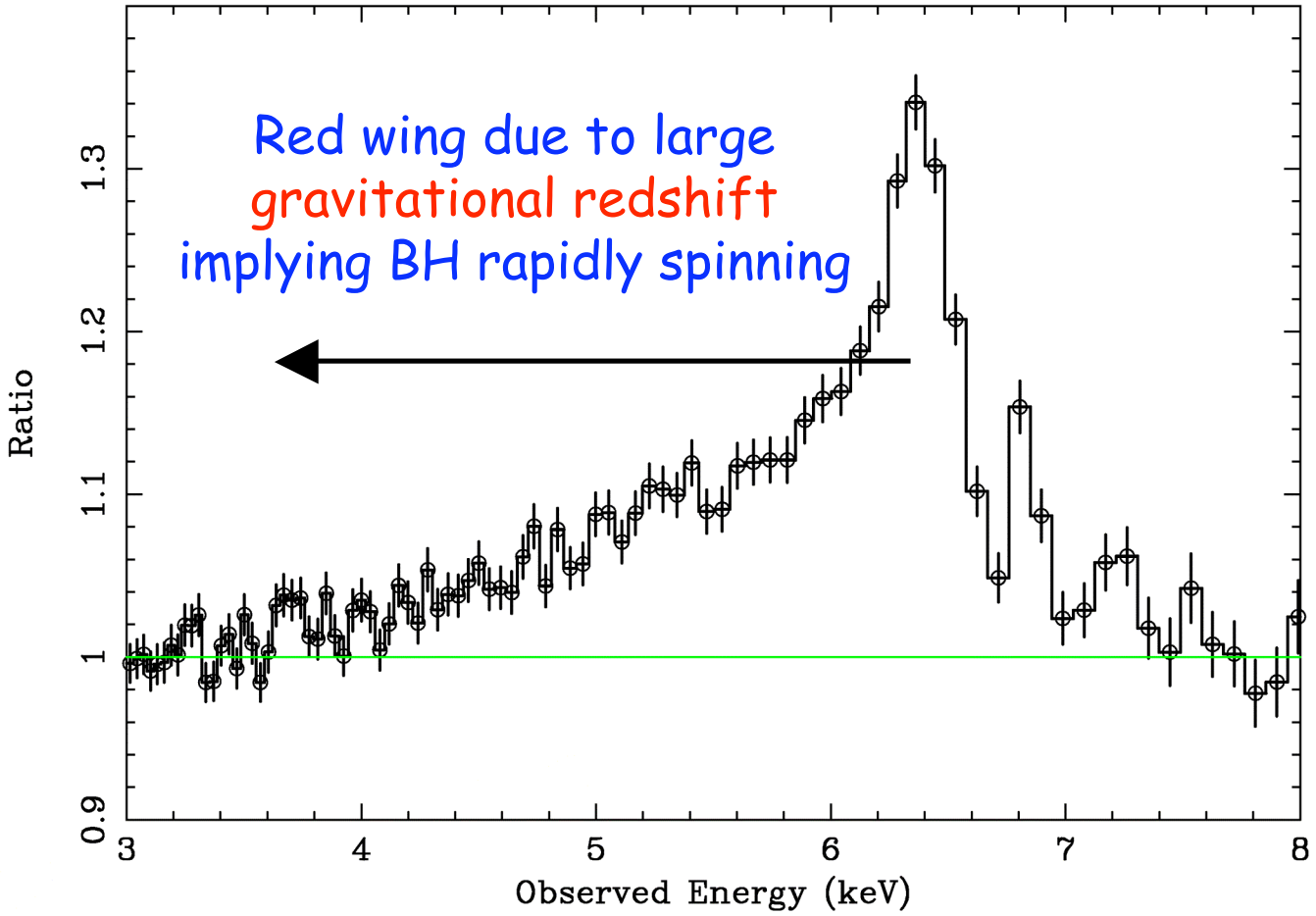


Very Broad Line ⇒ Spinning BH

Tanaka+ Iwasawa+ Wilms+ Fabian+ Brenneman+Reynolds

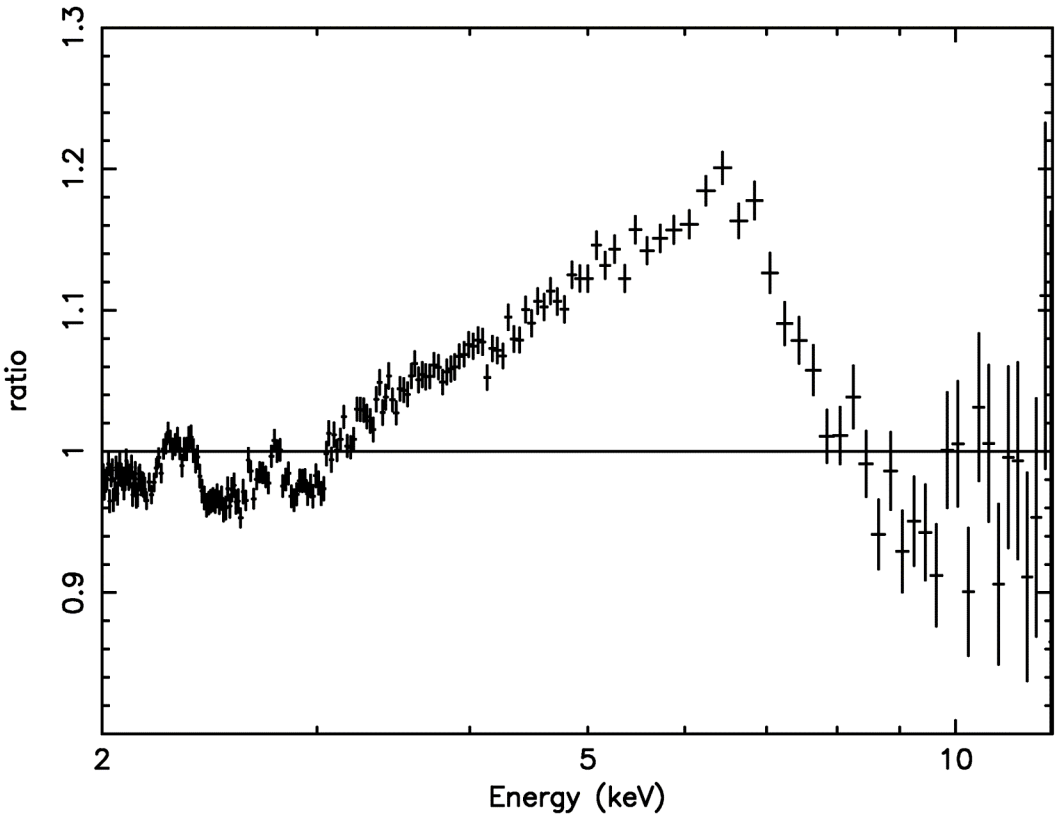
MCG-6-30-15

Suzaku



Strength and behaviour of line implies
GRAVITATIONAL LIGHT BENDING

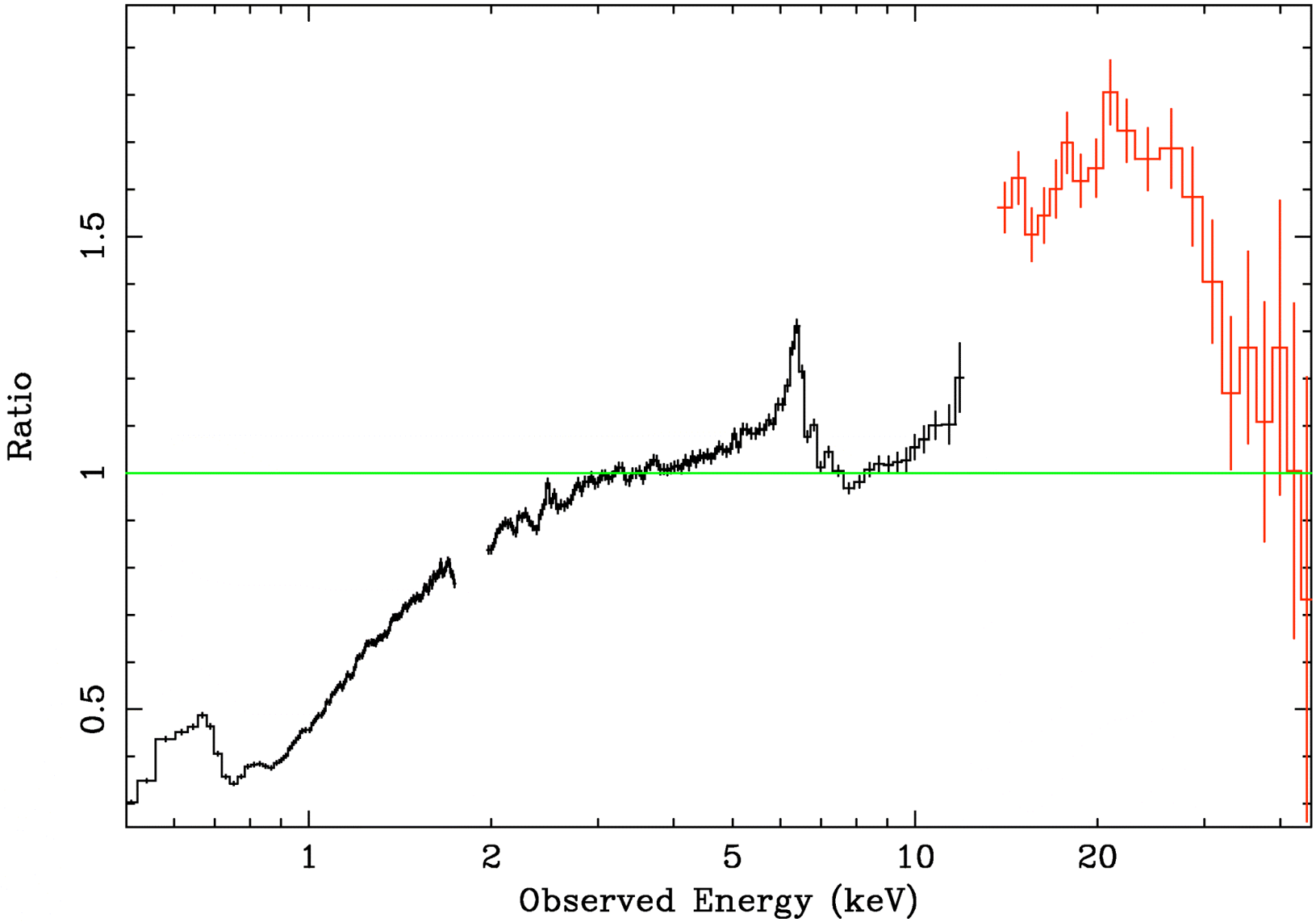
Galactic Black Hole GX339-4



Very Broad Line ⇒ spinning BH

Miller+

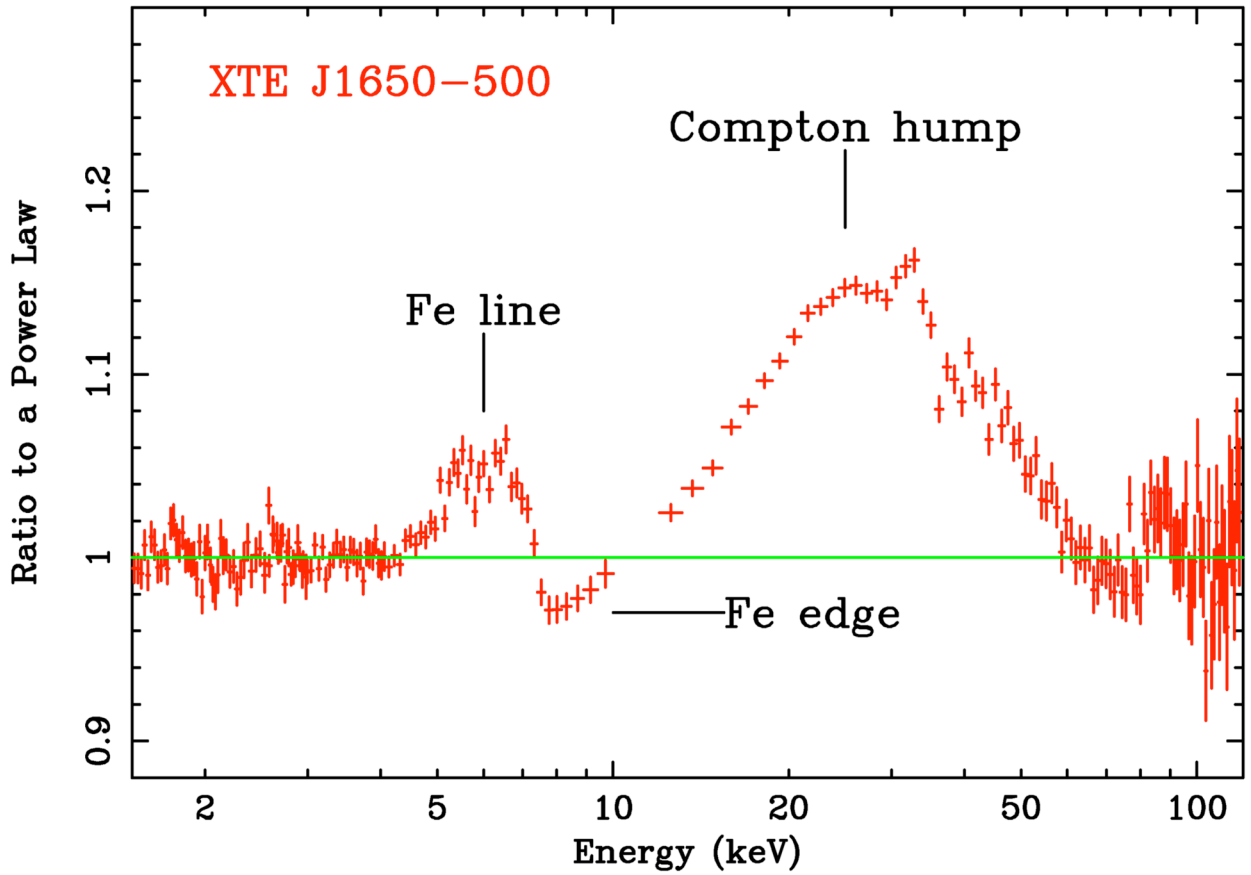
MCG-6 Suzaku: Miniutti+06



Observed reflection requires strong iron emission line

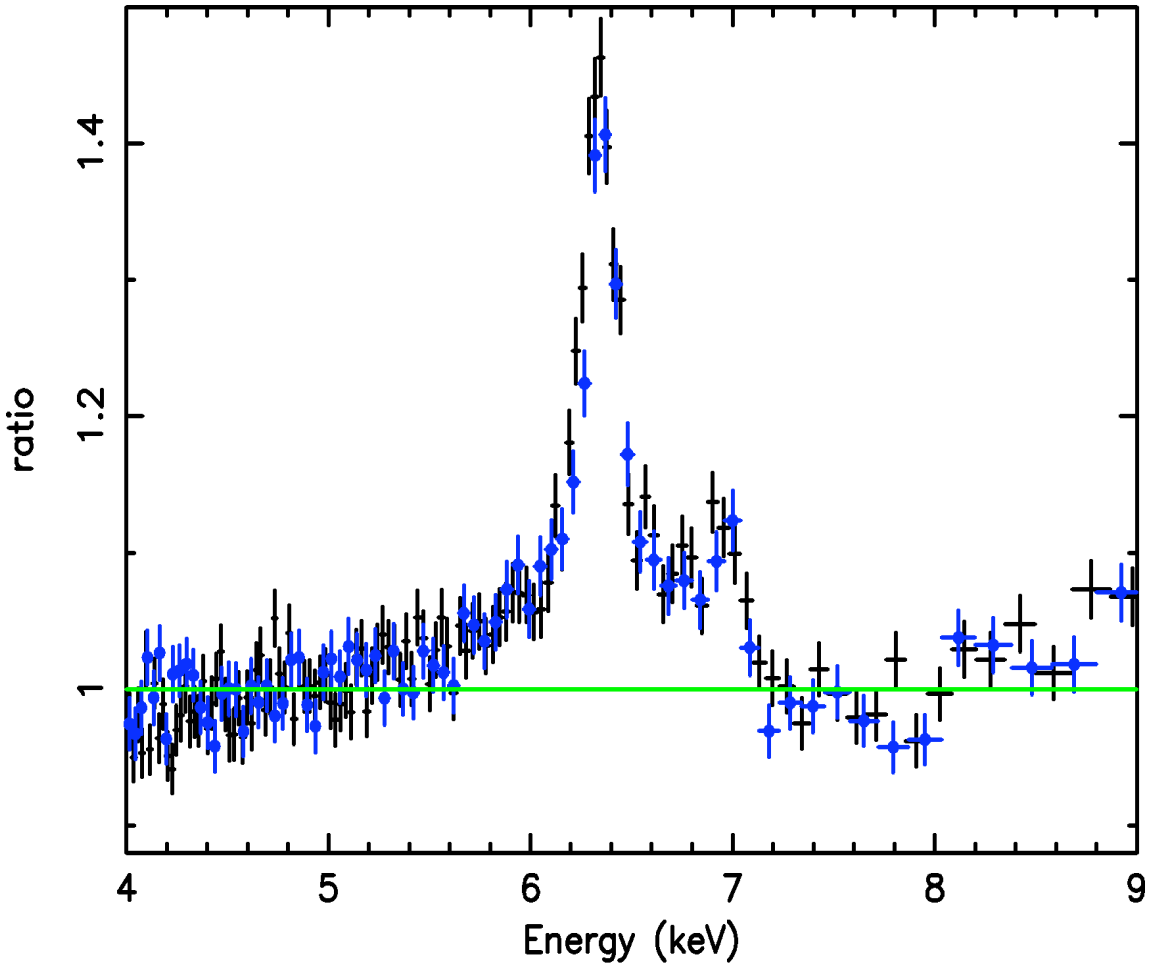
XTE J1650-500 from BeppoSAX

(G. Miniutti+)



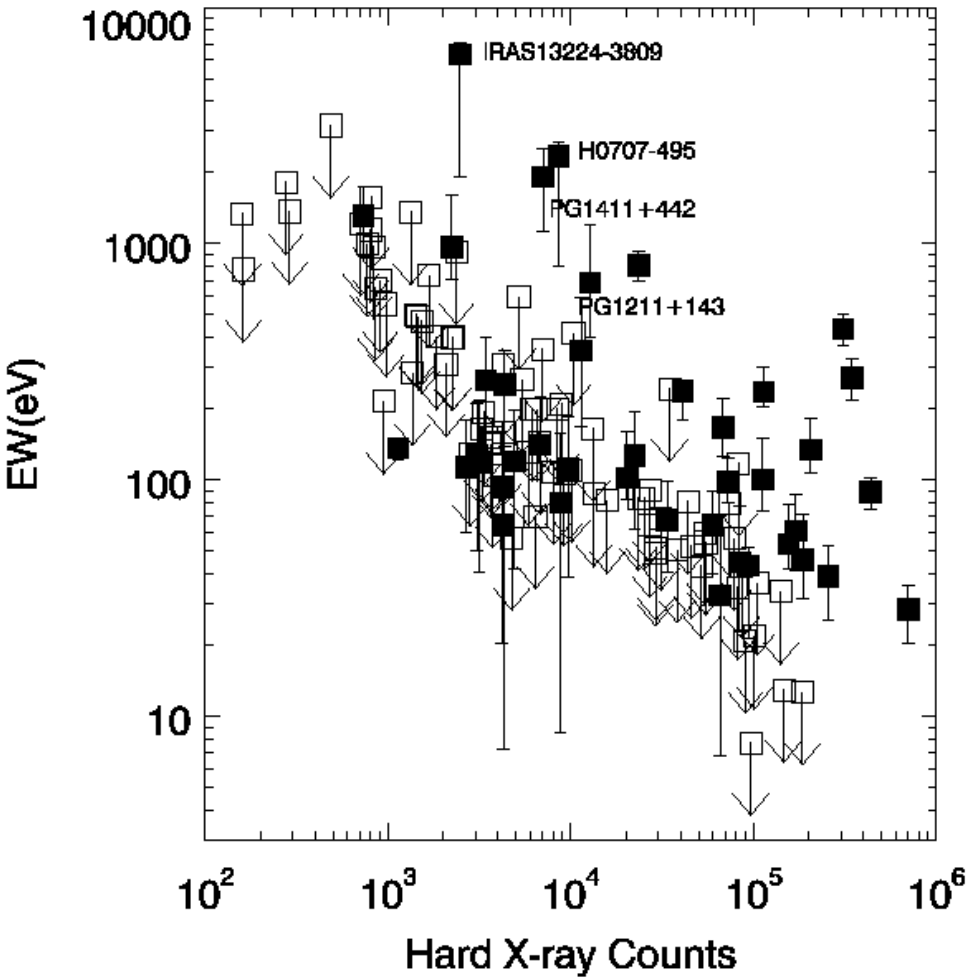
MCG-5-23-16

Suzaku: Reeves+06



Incidence of broad lines in XMM database

Guainazzi+06 (see also Nandra+06)



Broad lines found in >50% of spectra with >150,000 counts

Emphasises need for good data

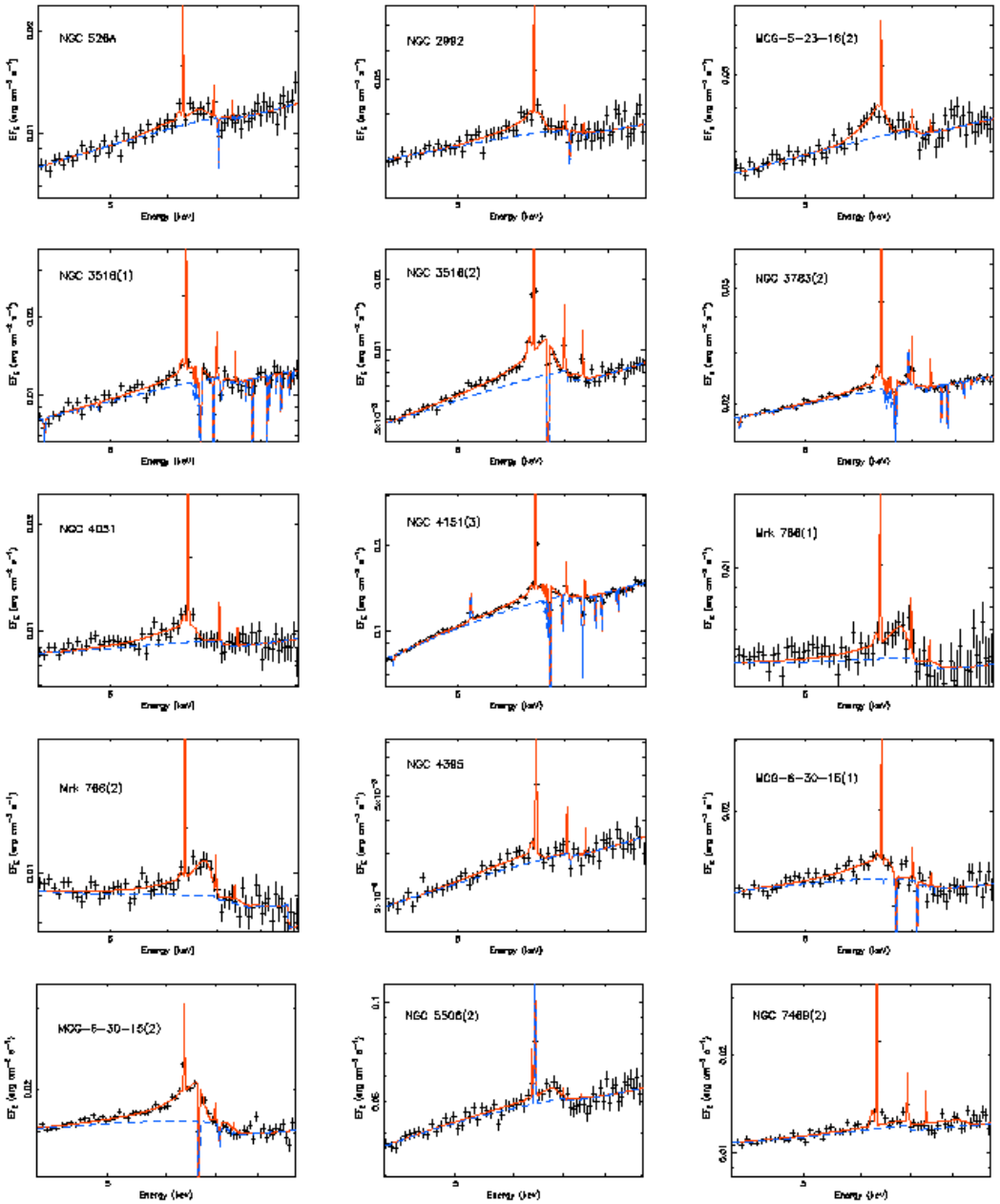


Figure 6. Relativistic disk lines. The unfolded spectra centered around the iron band are shown for observations in which the additional of the blurred reflection component improves the fit at > 99 per cent confidence and for which the best-fit characteristic emission radius is $< 50\ R_g$. The solid line shows our best-fit model. The dashed line shows the model excluding the pexmon line components (distant and blurred).

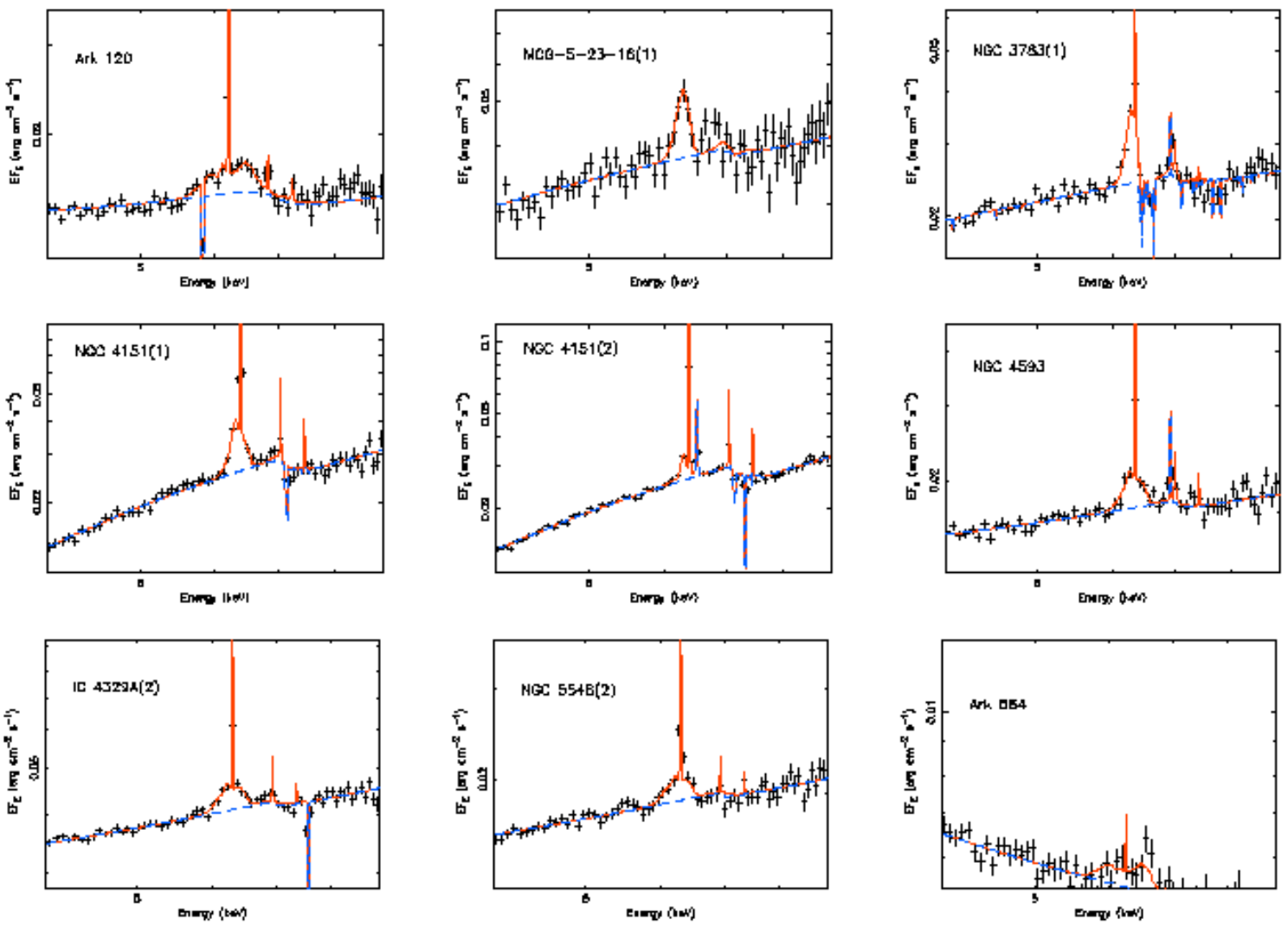
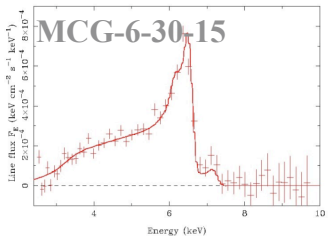
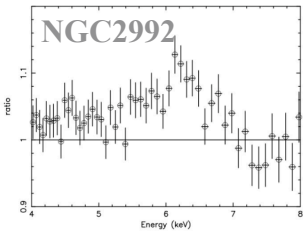


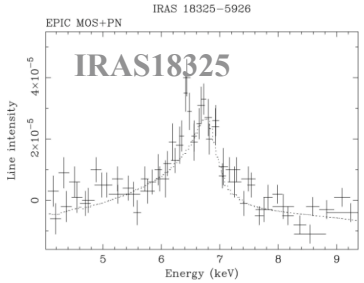
Figure 7. Broad, but non-relativistic lines. Unfolded spectra and models for observations in which a velocity-broadened neutral reflection component improved the fits significantly, but that had a characteristic emission radius outside $50\,R_g$. Model lines are as in Fig. 6.

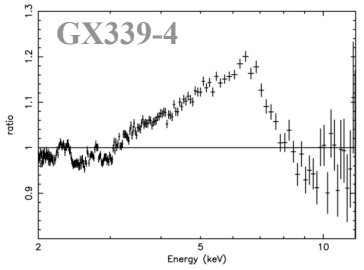
K Nandra

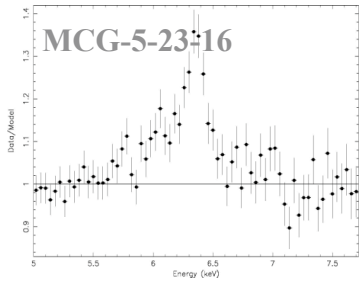
Re-affirmed importance of broad iron lines

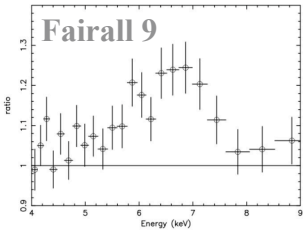


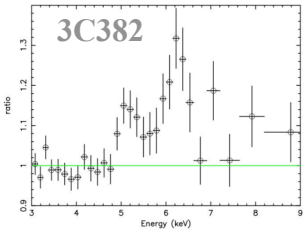


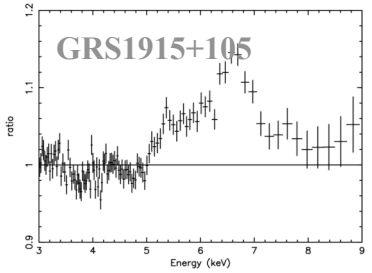


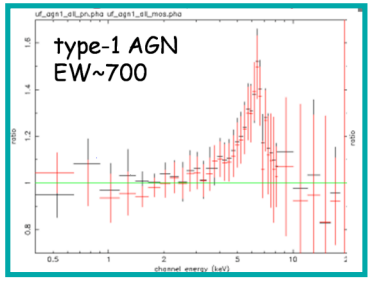


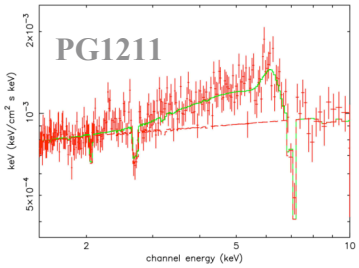


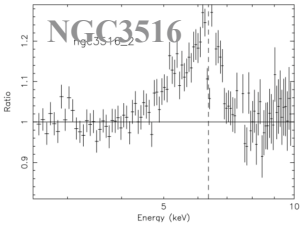


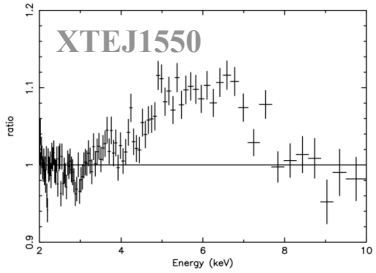


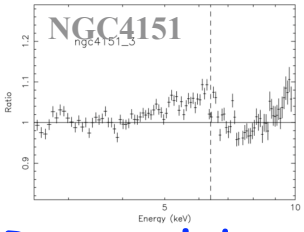


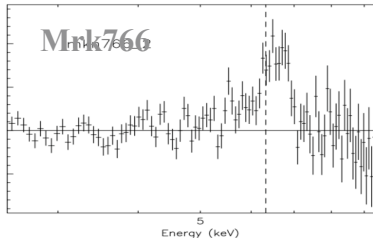




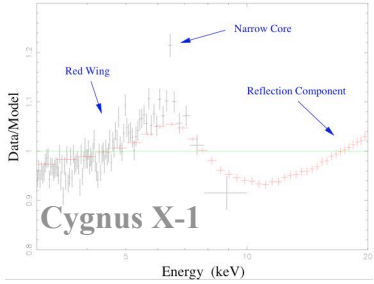








Similar line profiles from stellar-mass and super-massive black hole systems… demonstrates insensitivity of line profile to mass



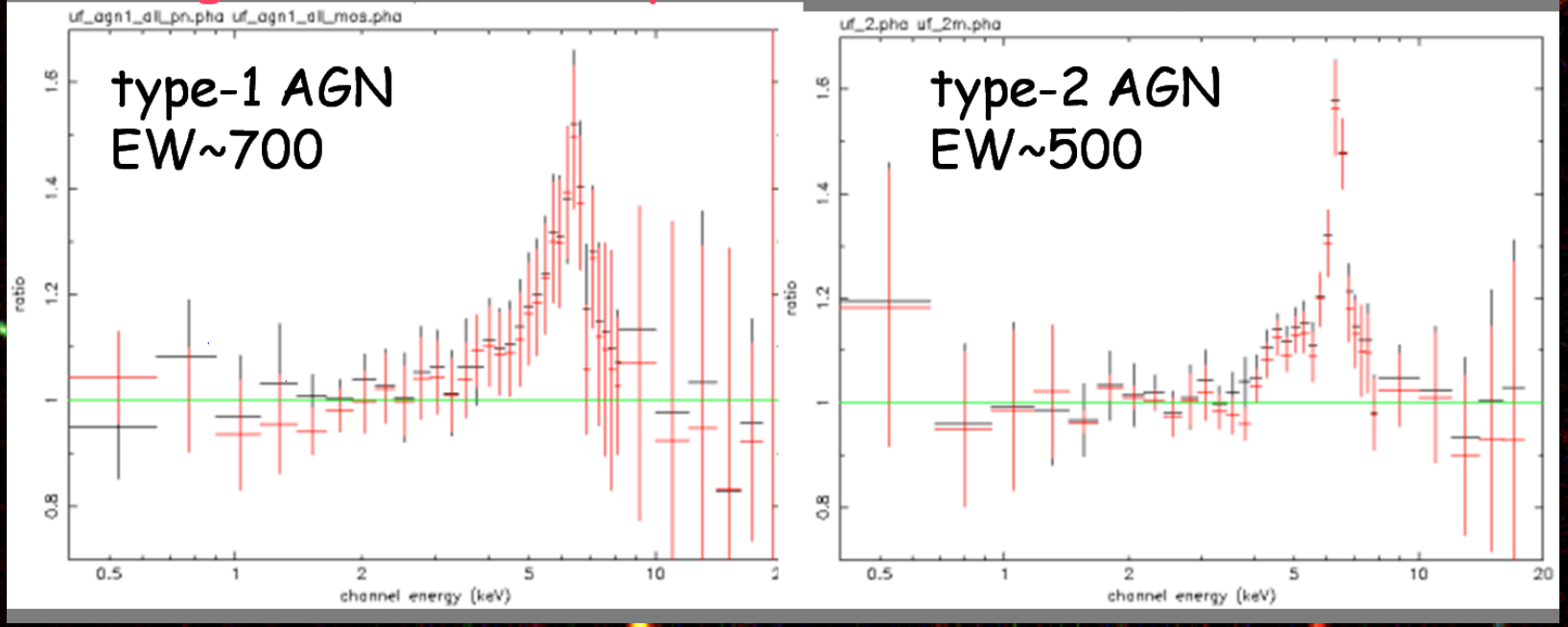
C Reynolds

Lockman Hole

Hasinger

800 ks XMM-Newton observation

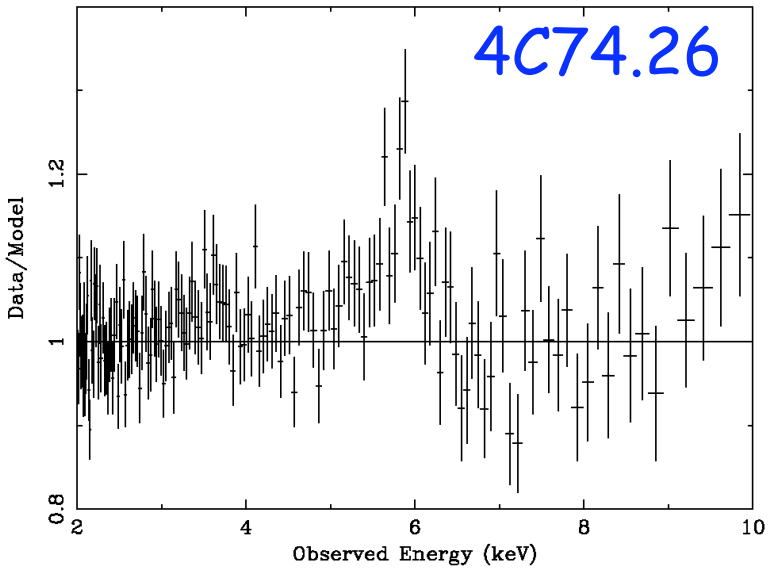
Average rest-frame spectra show relativistic Fe-lines

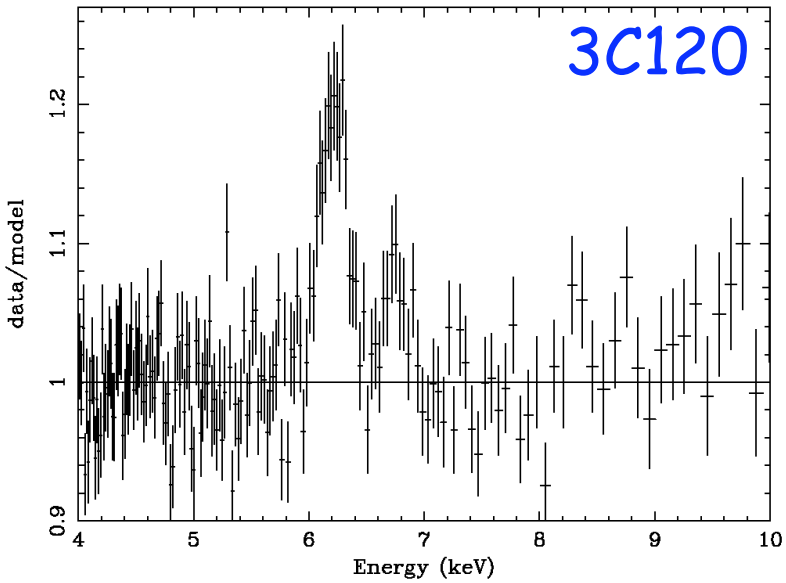


Streblyanskaya et al 2004

See also Brusa et al

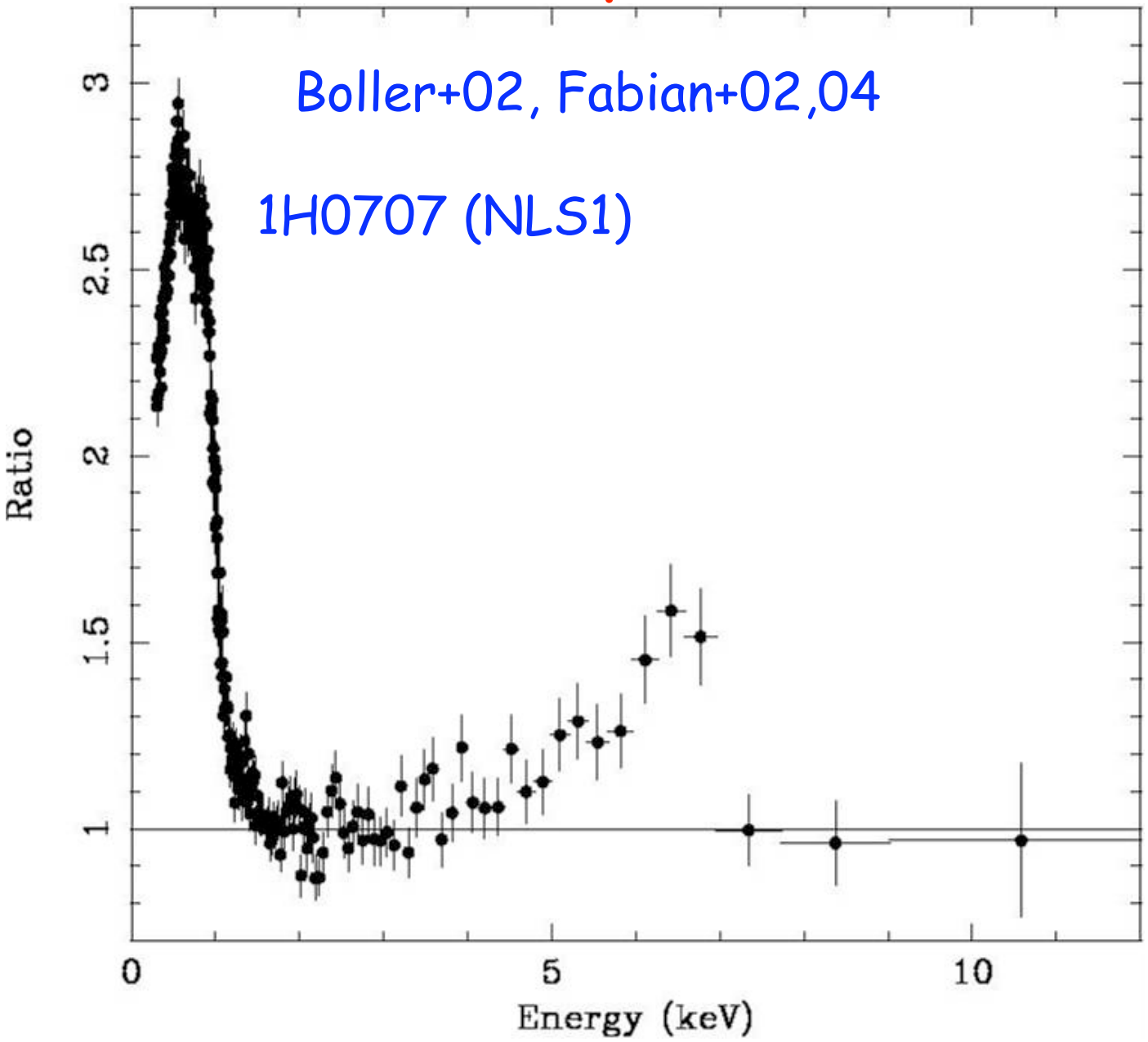
Jetted Radio Sources

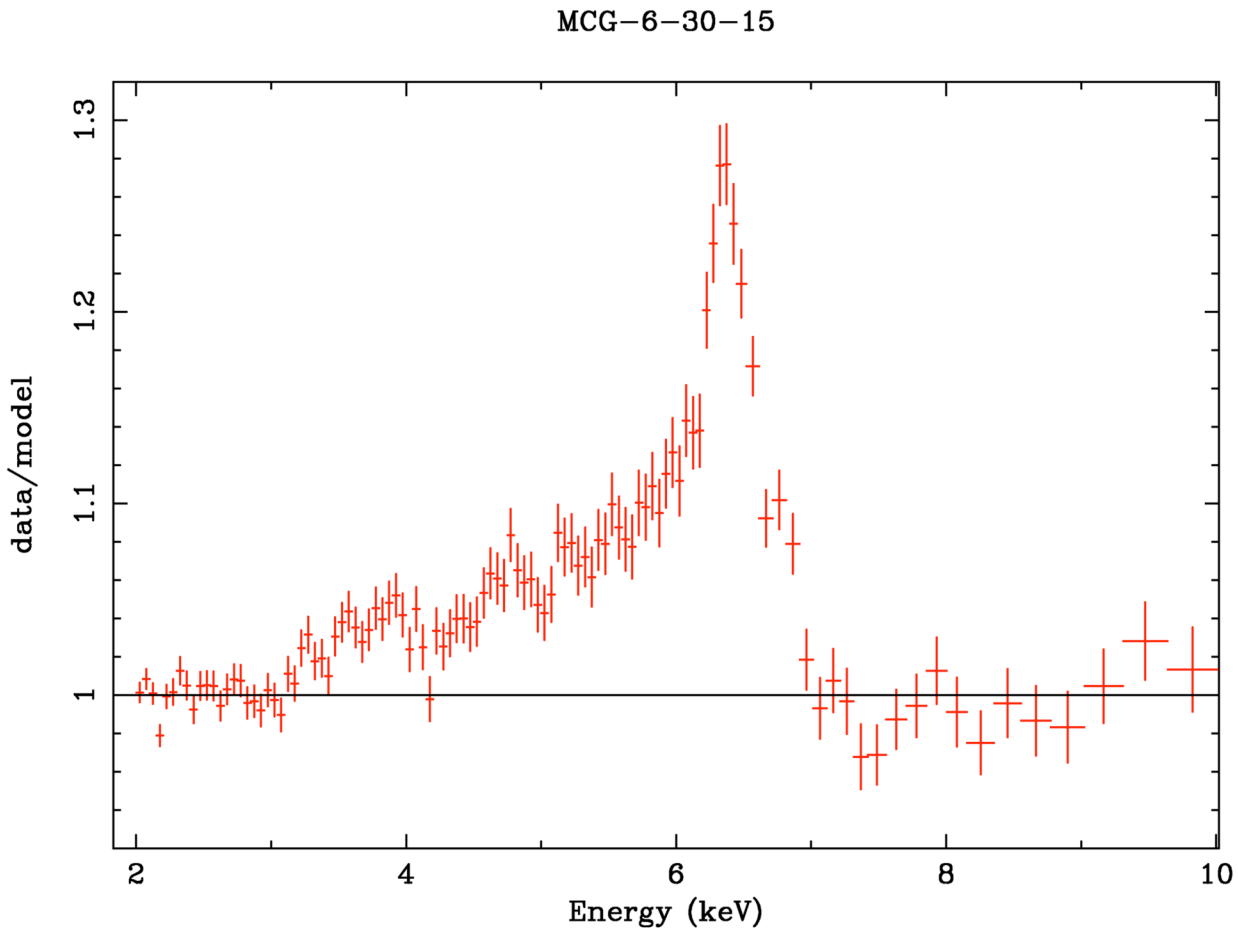




Ballantyne+04,05

Is it absorption or a line?

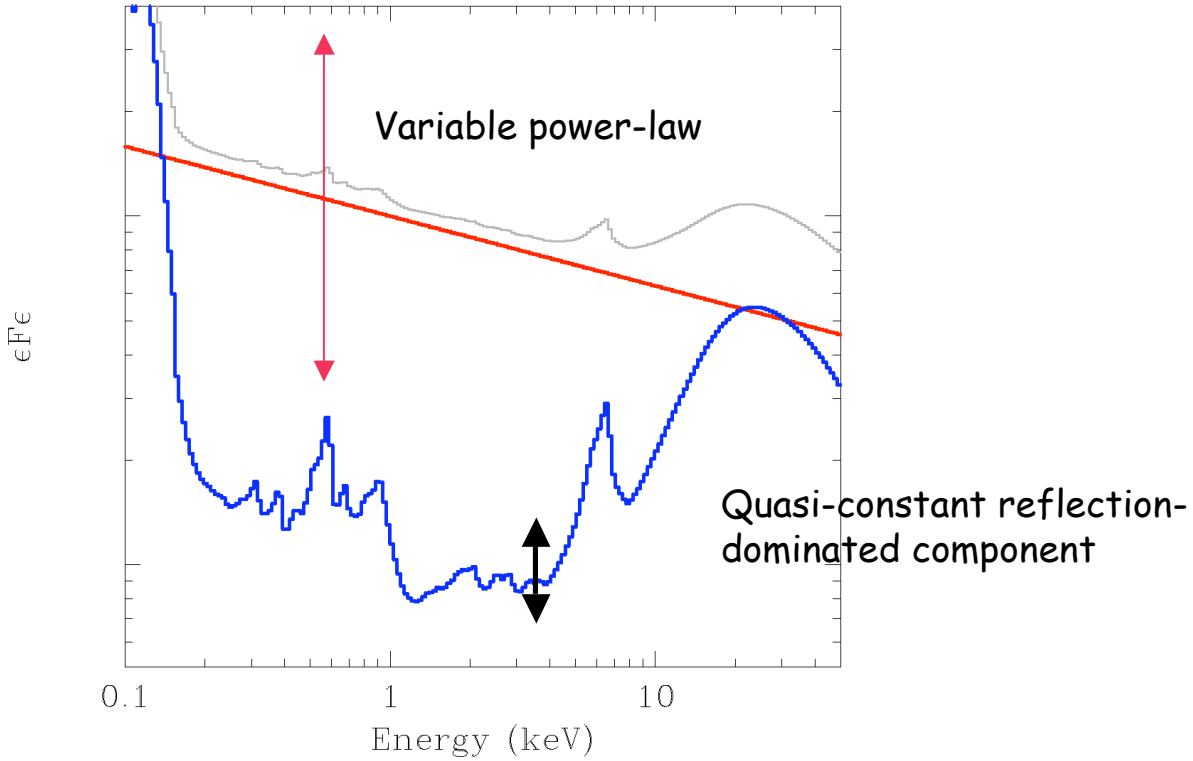




How does it vary?

Iwasawa+ Shih+ Fabian+ Vaughan+ McHardy+ Uttley+ Reynolds+

Schematic picture of the two-component model

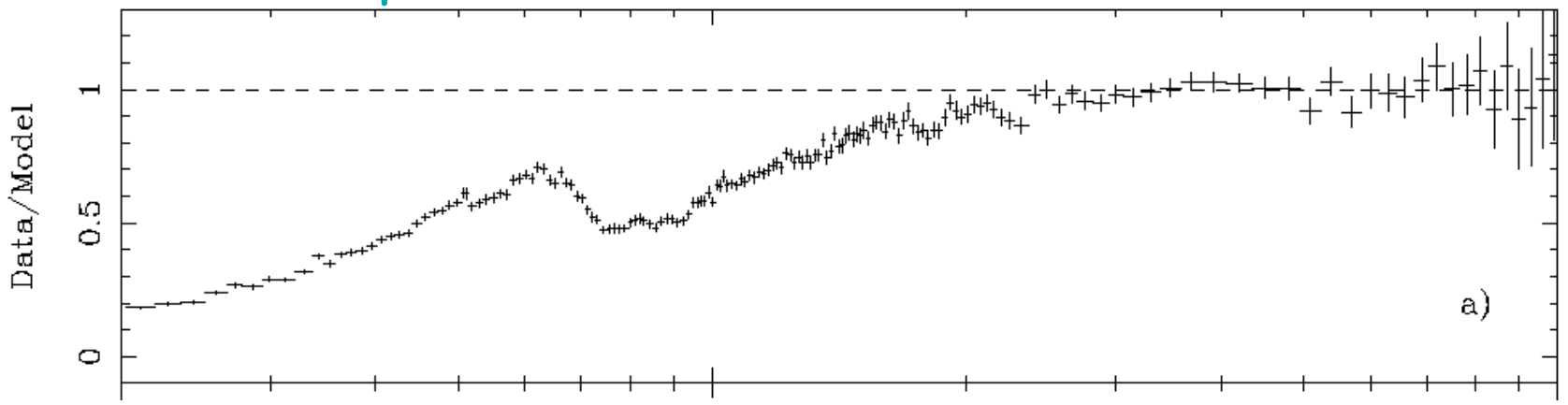


Data consistent with
highly variable power-law + quasi-constant reflection spectrum

Difference spectrum: (High flux)-(Low flux)

is a power-law modified by absorption

Ratio to power-law

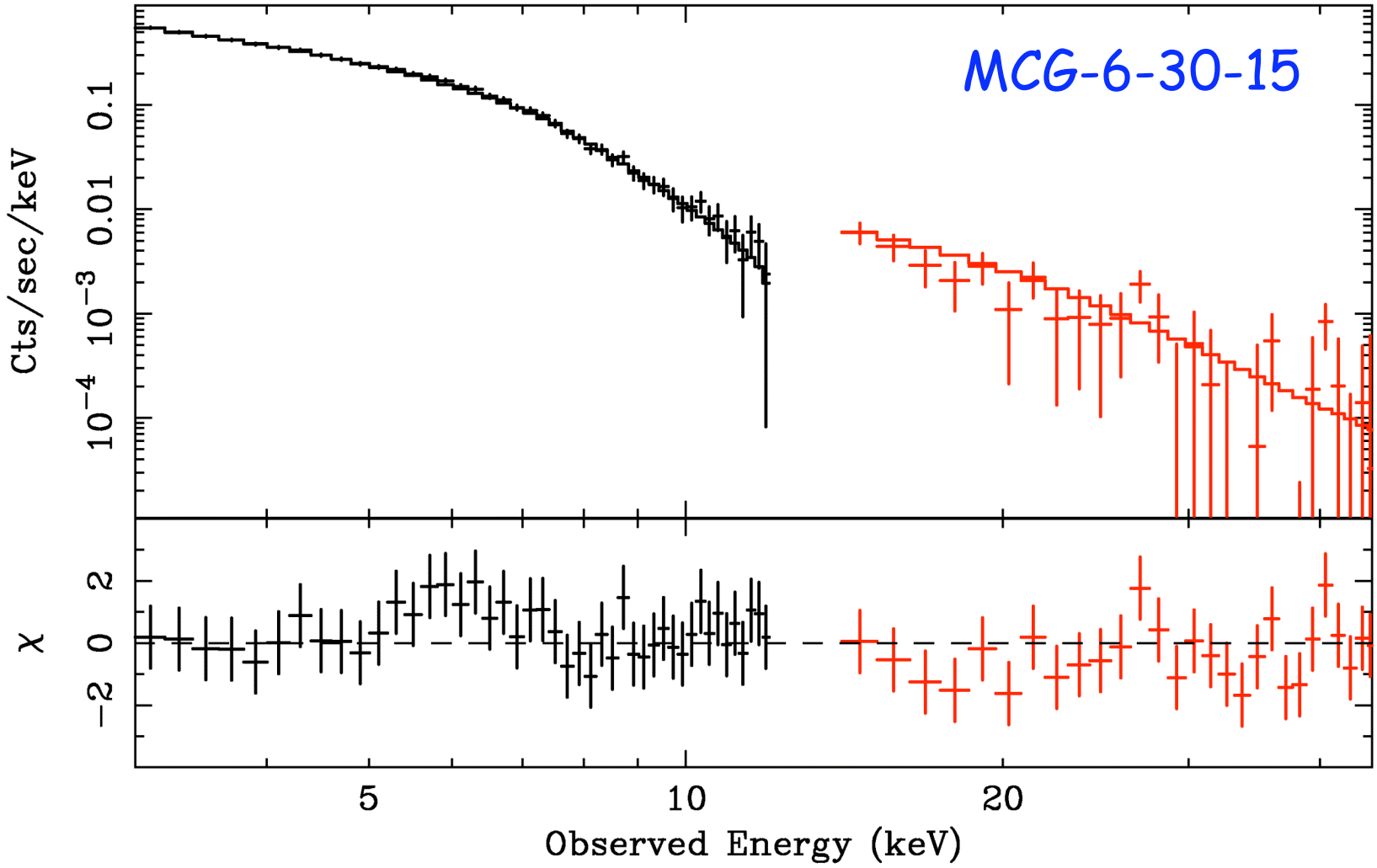


1 keV

10 keV

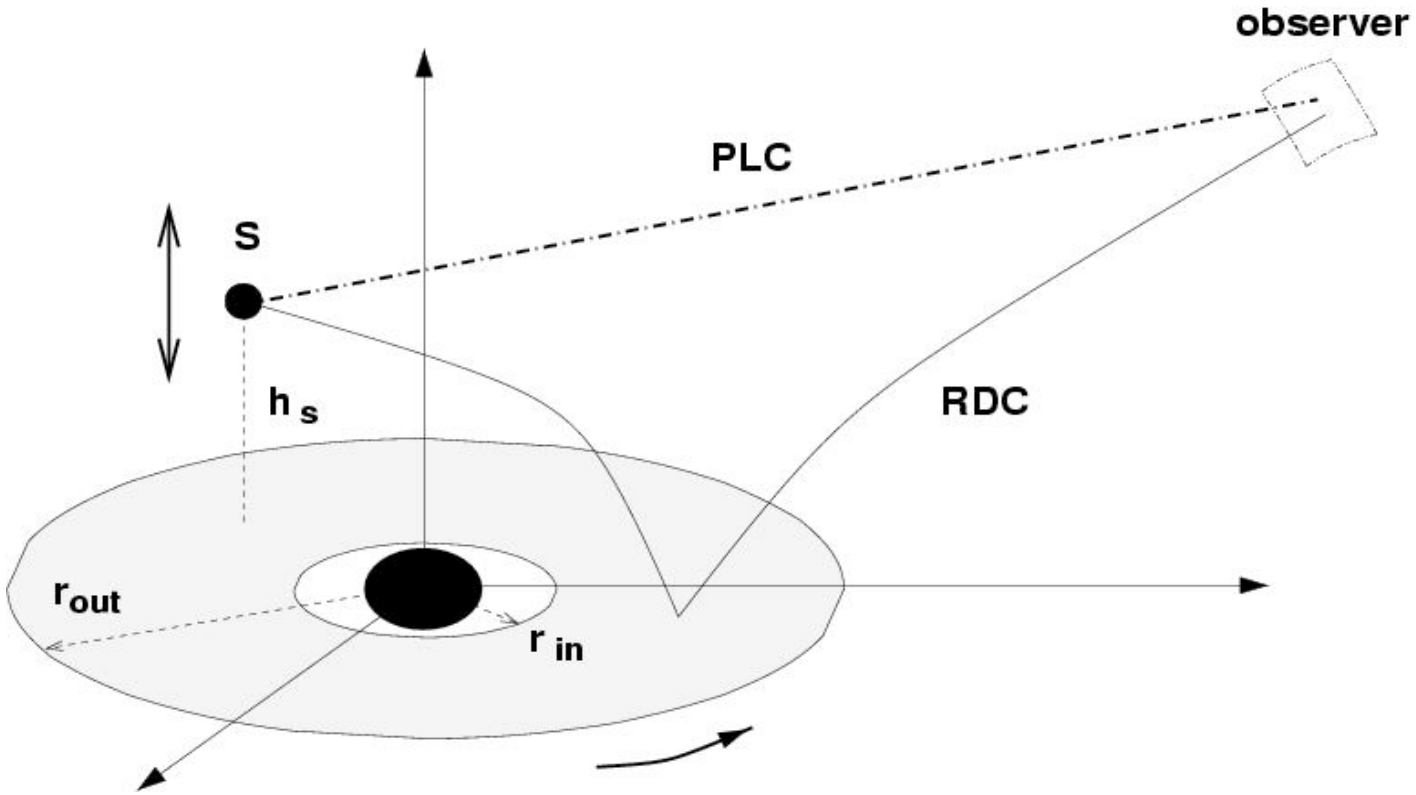
So we know which large scale features are due to absorption

Suzaku difference spectrum



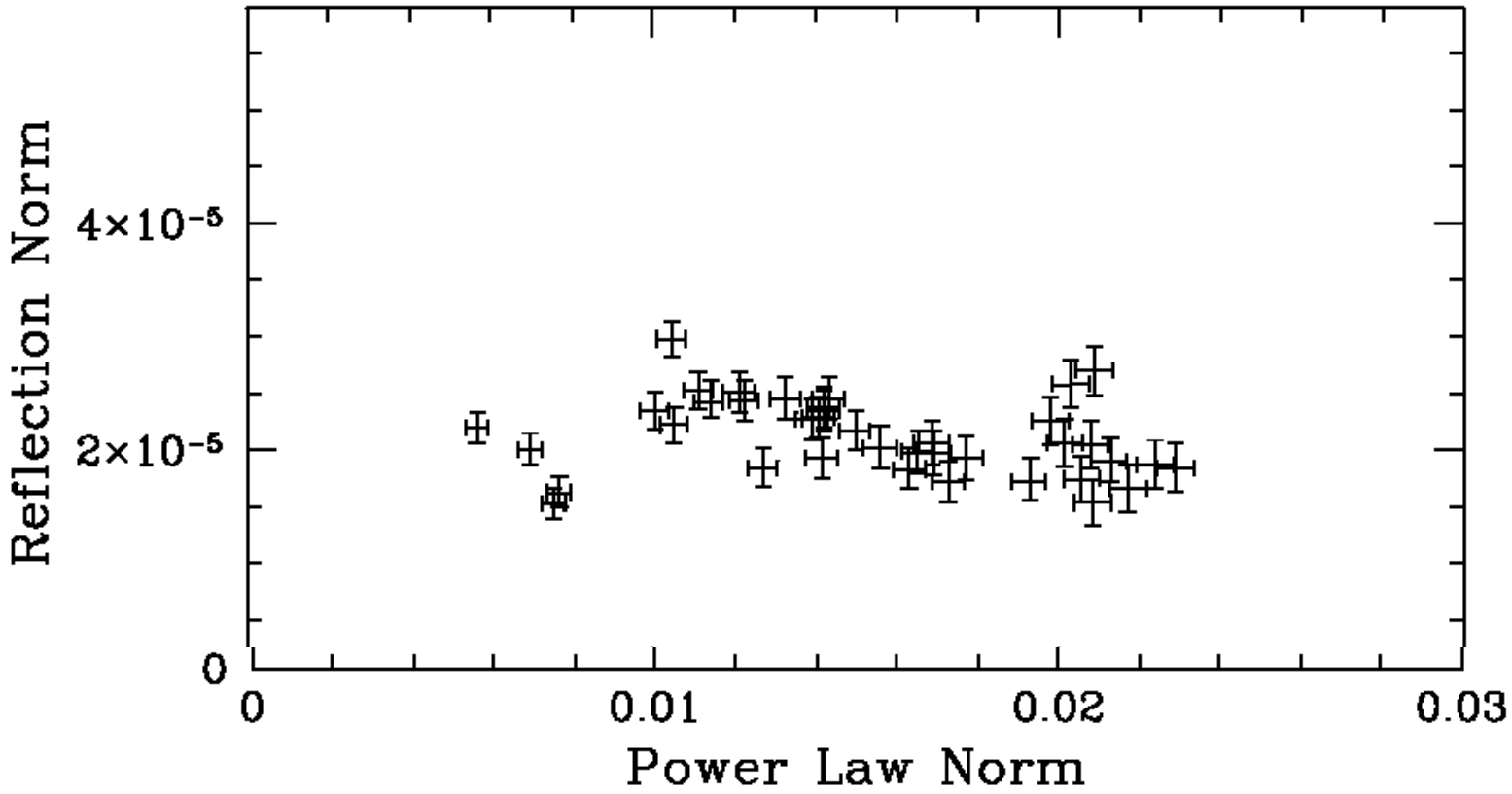
Miniutti+06

Light bending model in Kerr spacetime

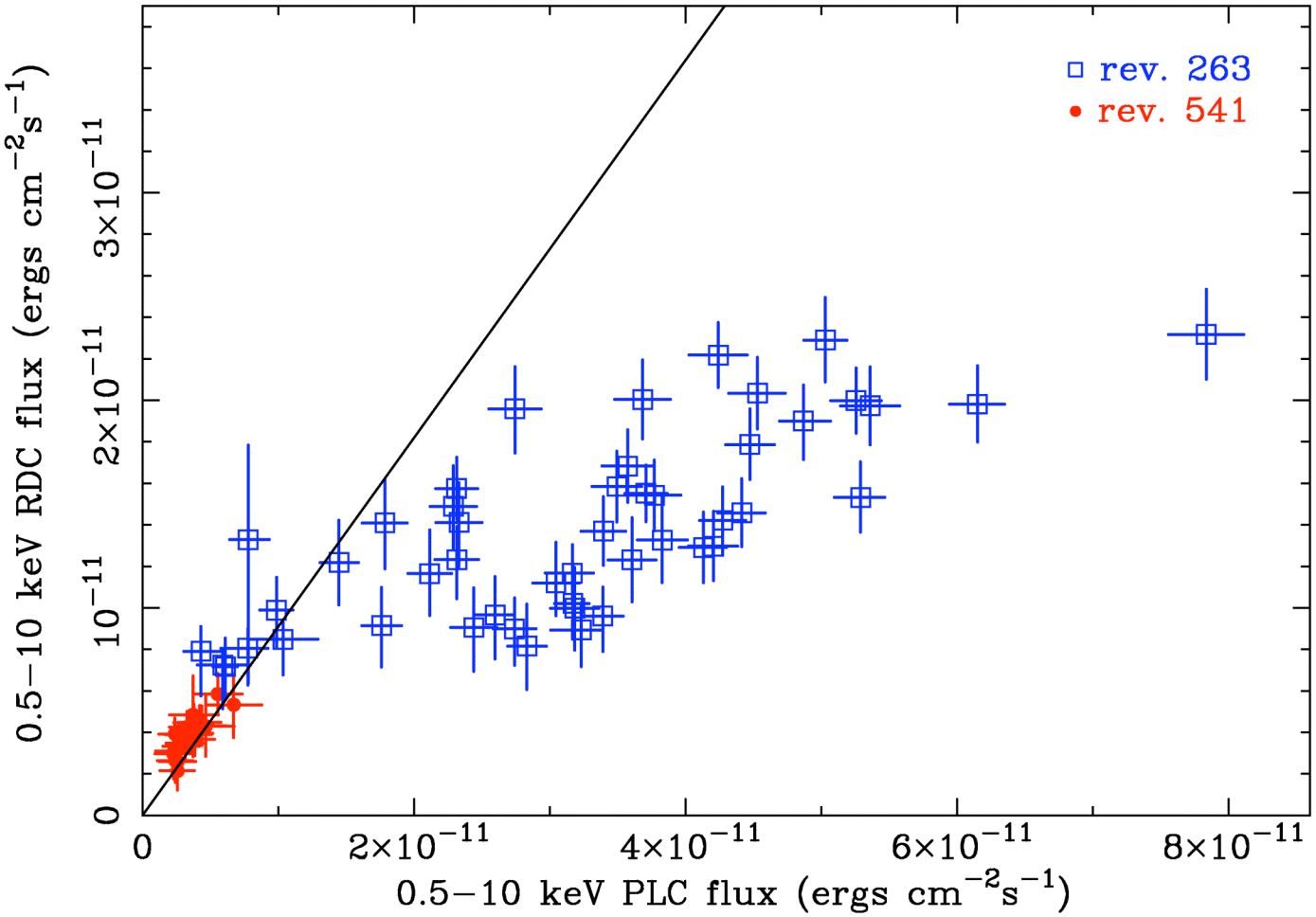


Miniutti et al 03; Miniutti & Fabian 04; earlier work by Matt+
see also Tsuebsuwong, Malzac+06

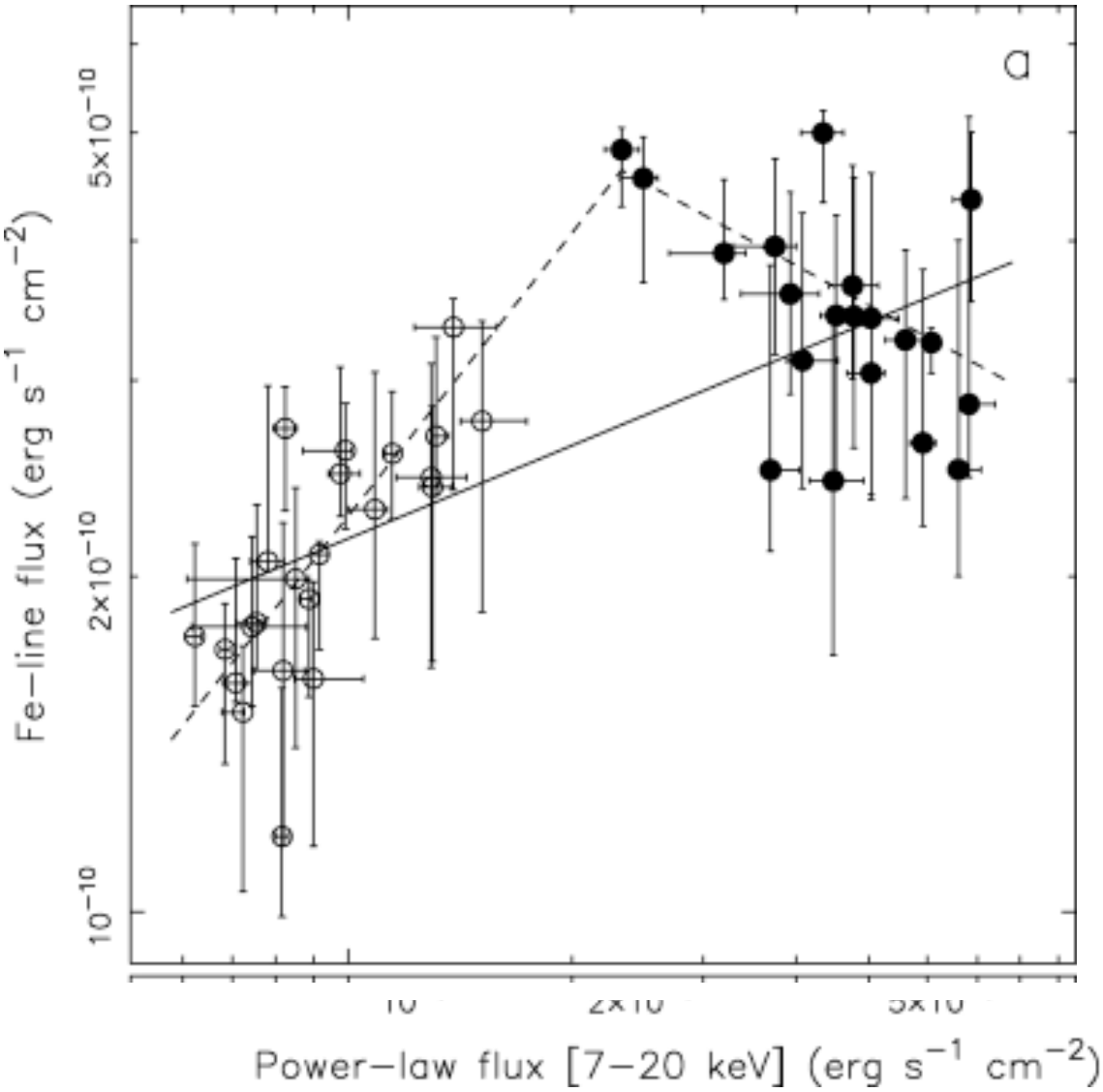
MCG-6 XMM 2000+2001 data
Larsson+06



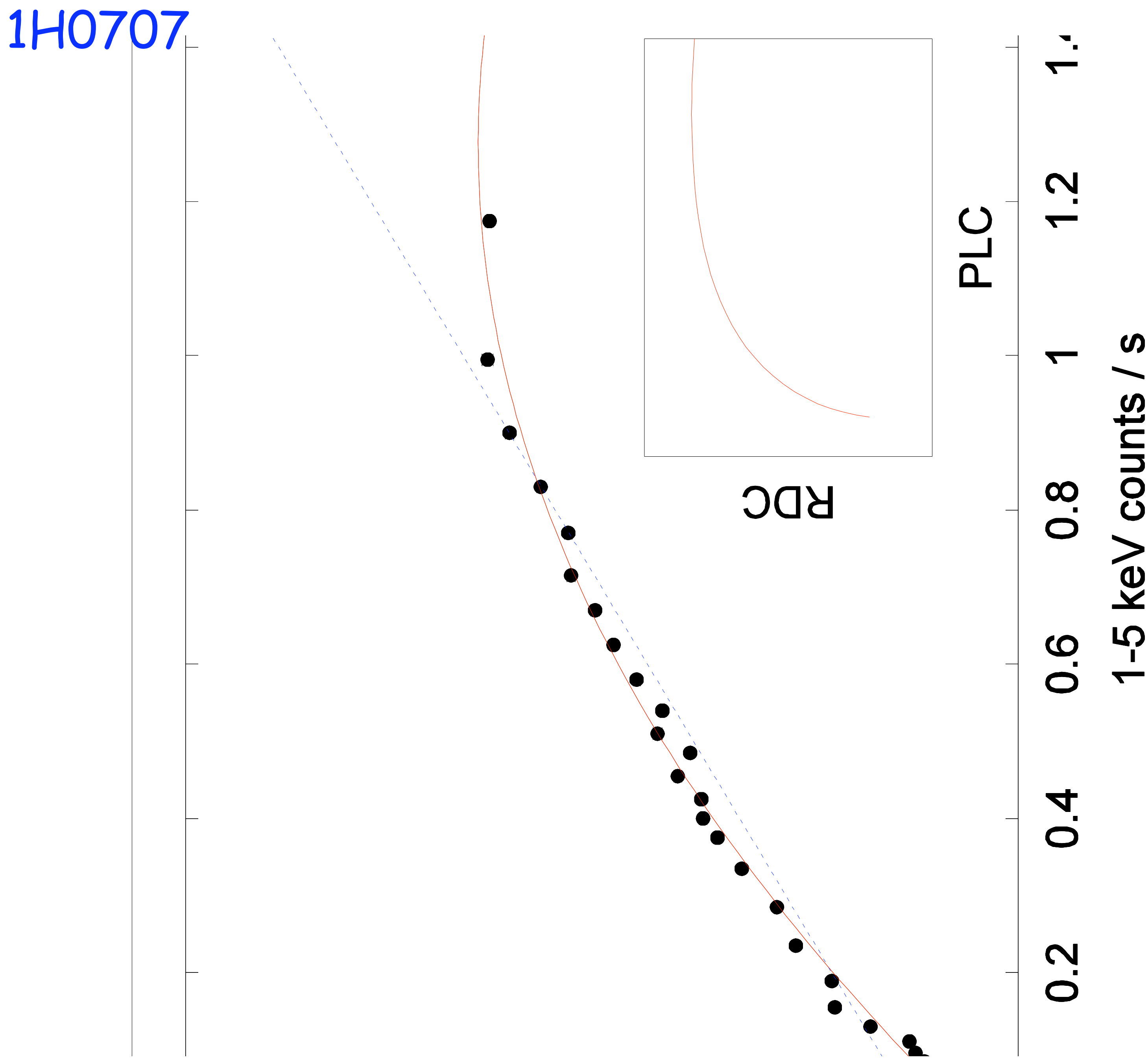
NGC4051 (Ponti+06)

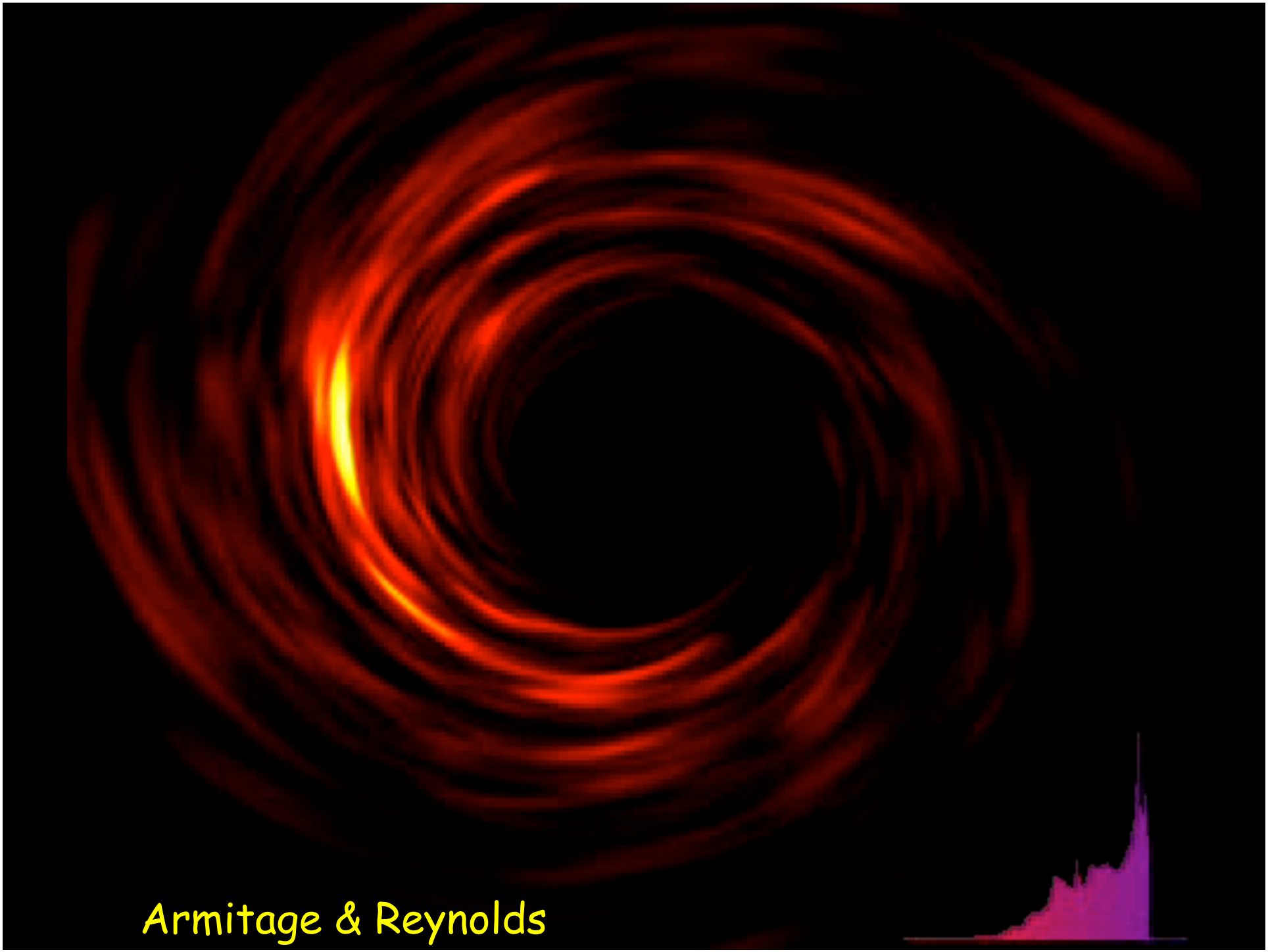


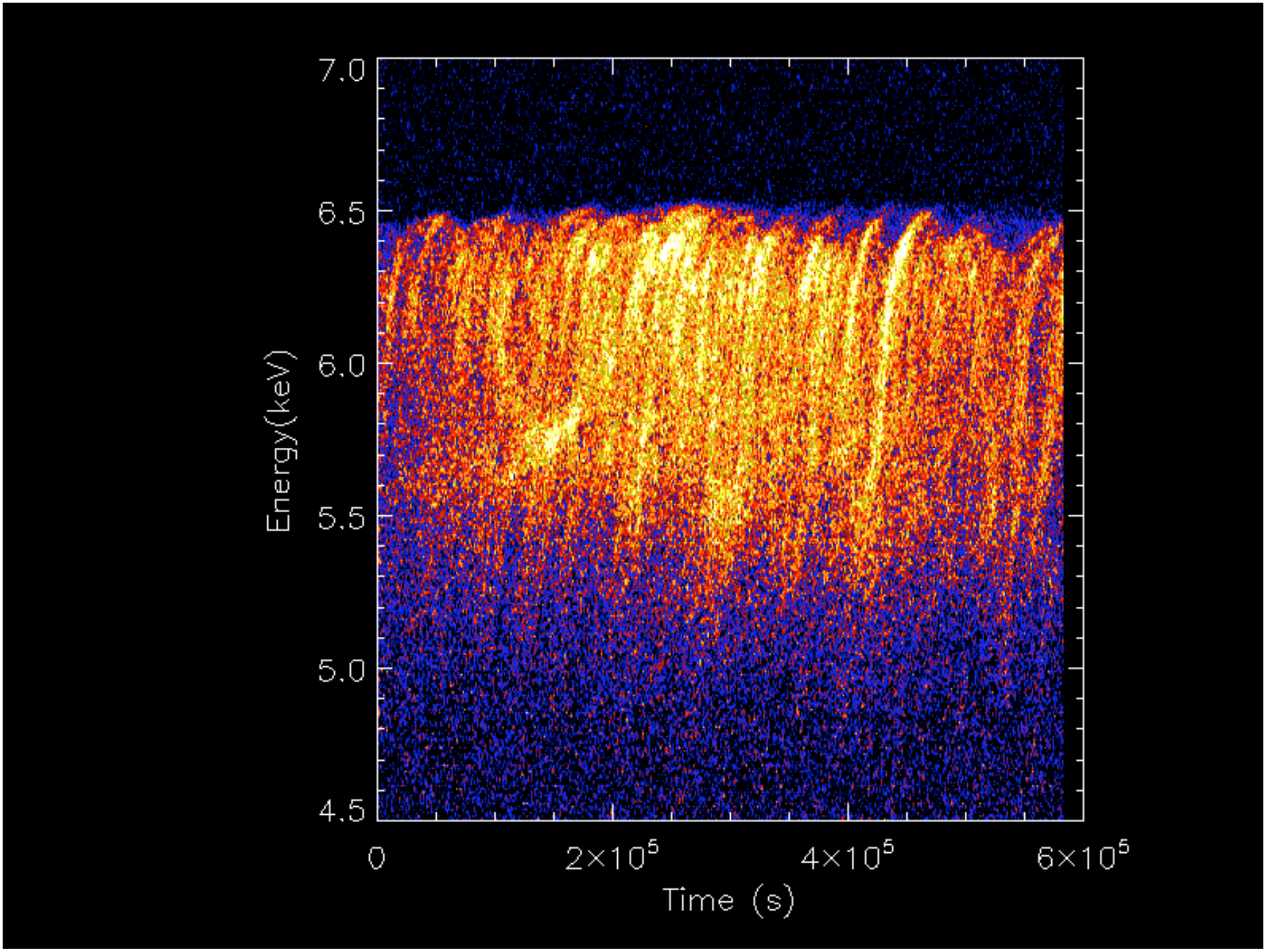
XTE J1650-500 during outburst



Rossi +05

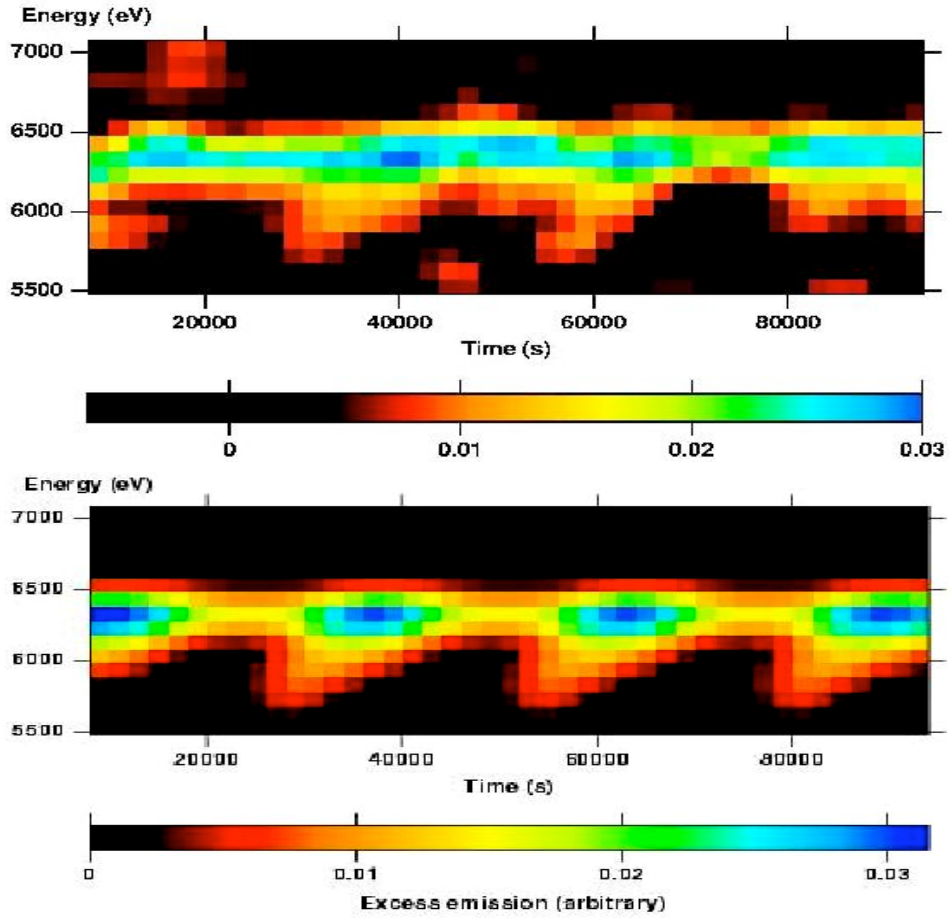

1H0707
PLC
RDC
1-5 keV counts / s
0.2
0.4
0.6
0.8
1
1.2


Armitage & Reynolds

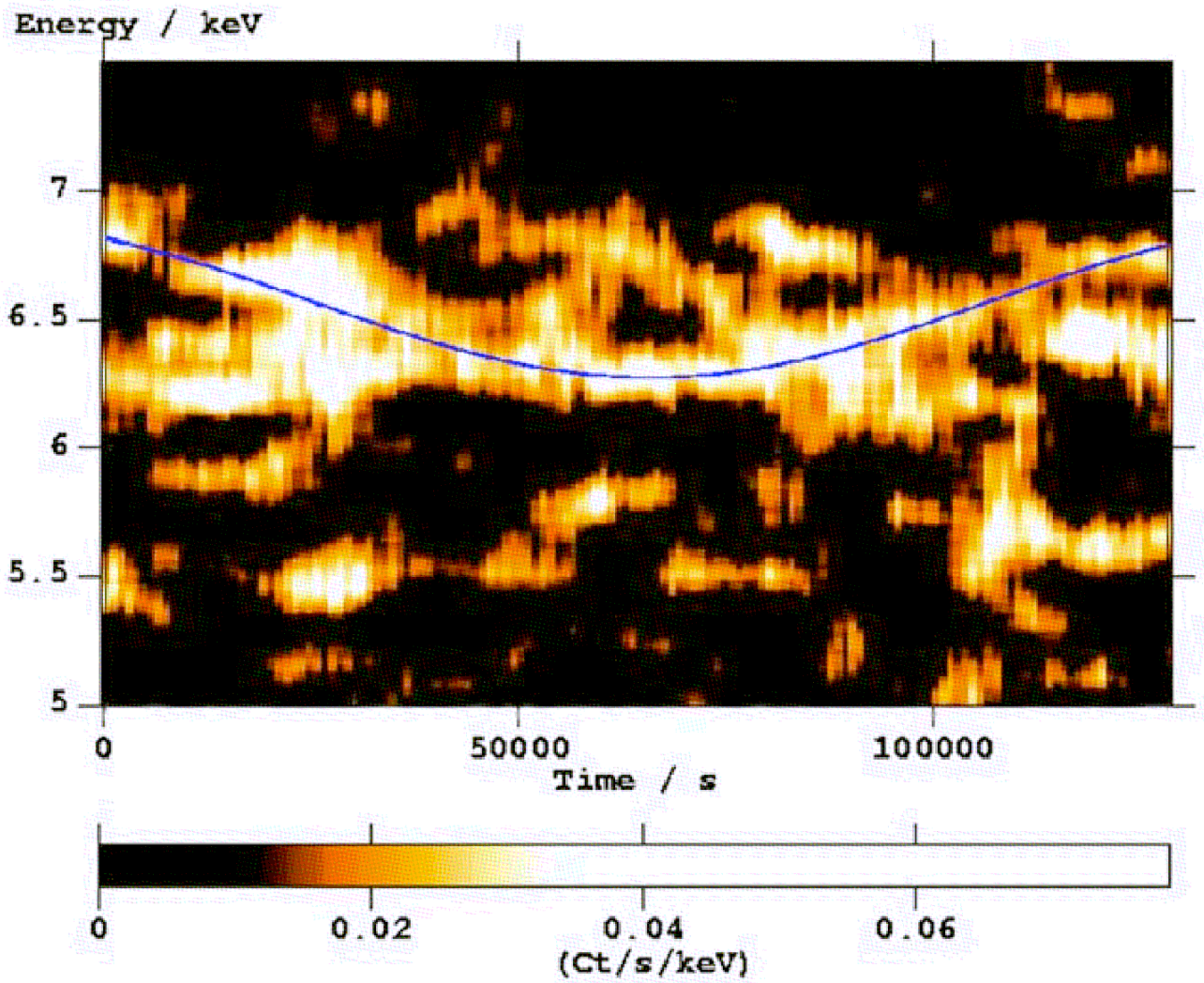

7.0
6.5
6.0
5.5
5.0
4.5
Energy(keV)
0
2×10^5
4×10^5
6×10^5
Time (s)

"Iron line hot spots" from

- orbiting coronal flares
- corrugations in disk surface
- patchy ionization structure

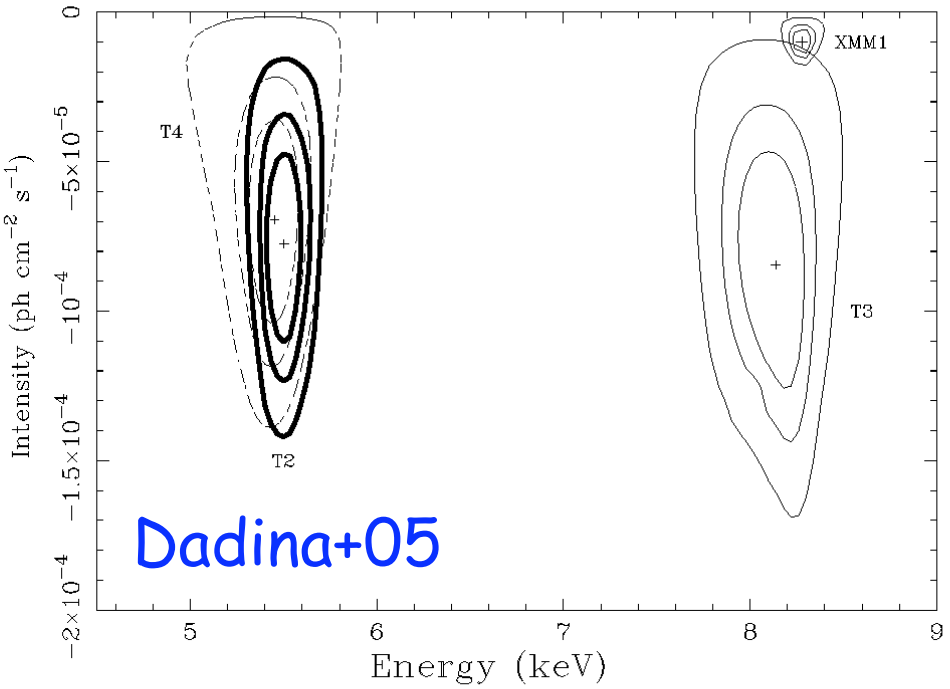


Iwasawa+05

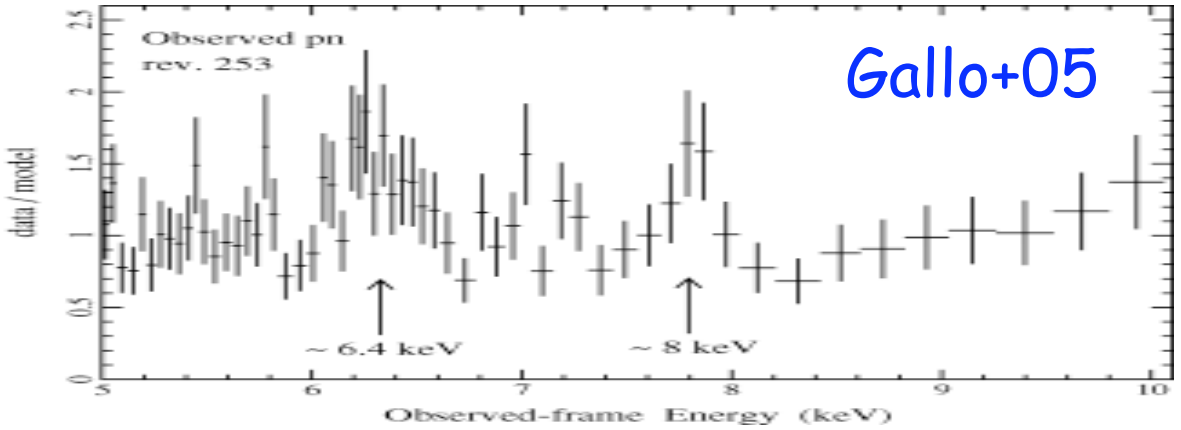


Mrk 766 Turner +05

Red+blue shifted iron lines



Dadina+05



Gallo+05

Several other examples

Future Observations with XMM

- A) Determine properties of broad lines/components in wider range of objects. More objects with >150,000 ct (Guainazzi+) – typically 100ks+

- B) Follow broad line through outburst and state change in GBH

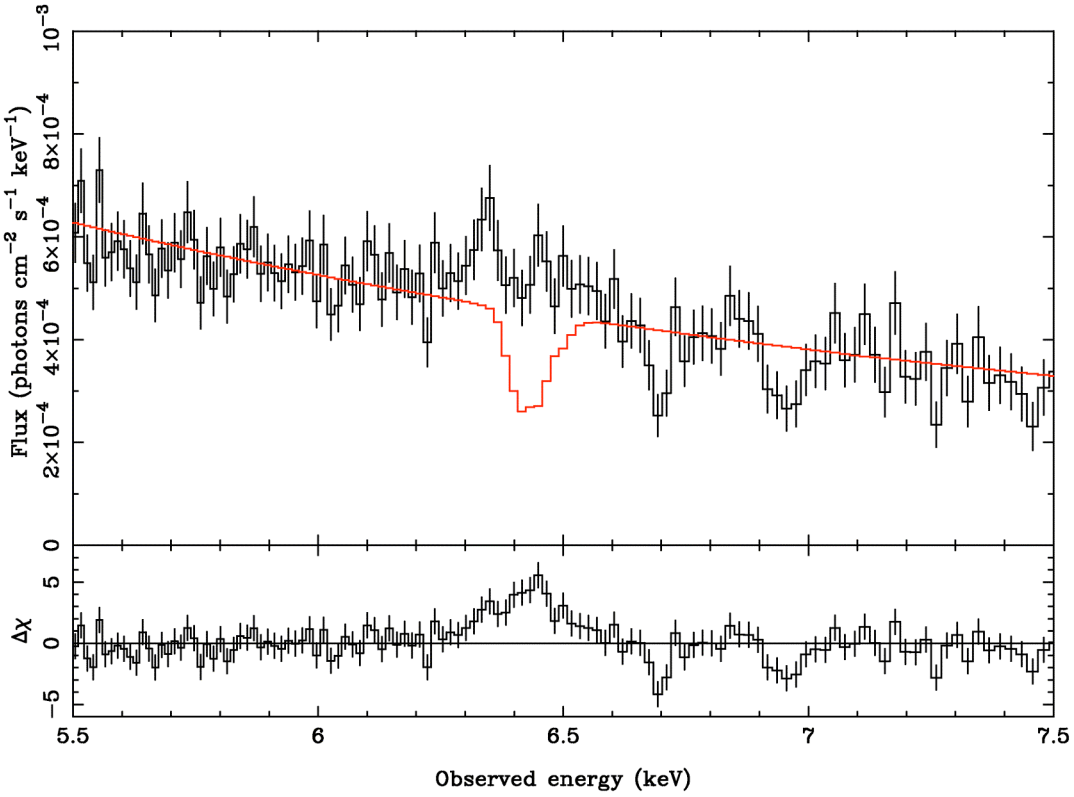
- C) Statistical studies of serendipitous objects from surveys (eg Streblyanska, Brusa…)

- D) Longer monitoring of NLS1

- E) Long observations of brightest broad line sources to monitor/understand variability

  e.g. 1Ms on MCG-6-30-15 etc

MCG-6 Young+05



Chandra HETG

Constrains absorption by highly ionized species

Implies simple absorption models for red wing do NOT work