An X-ray View of NLS1

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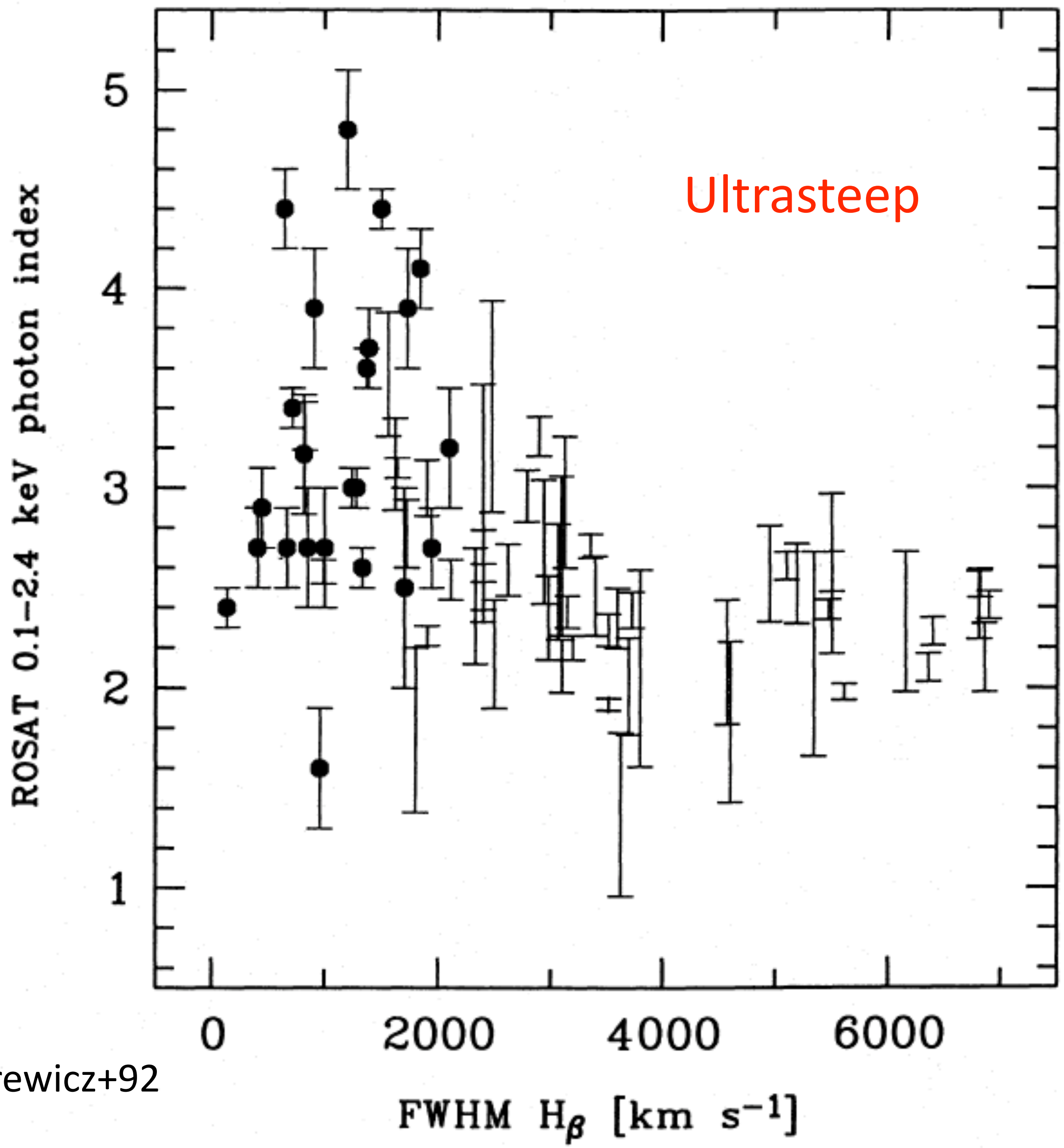
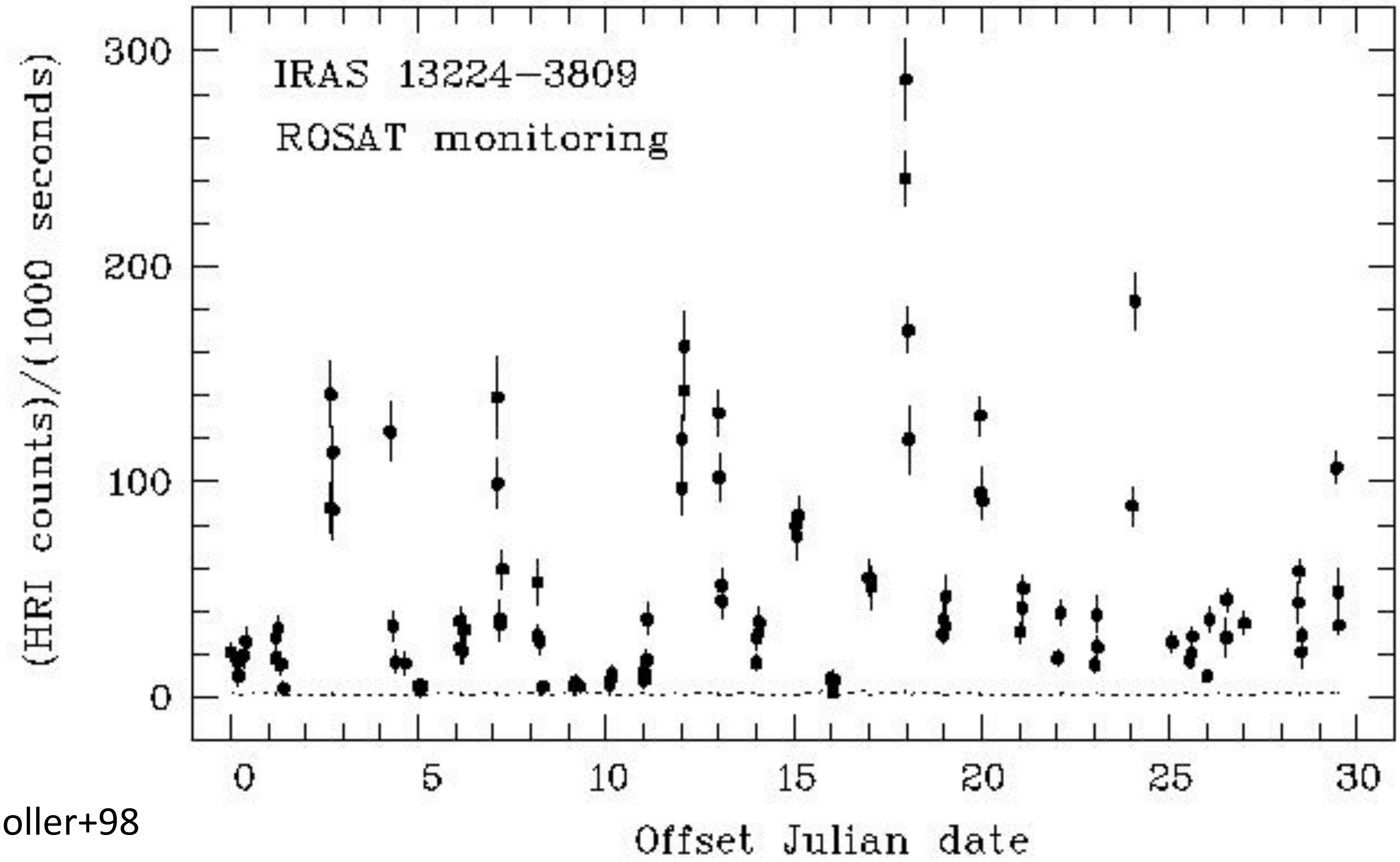
With thanks to

Abdu Zoghbi, Luigi Gallo, Yasuo Tanaka, Giovanni Miniutti, Chris Reynolds, Thomas Boller, Neil Brandt, Norbert Schartel, Phil Uttley and others

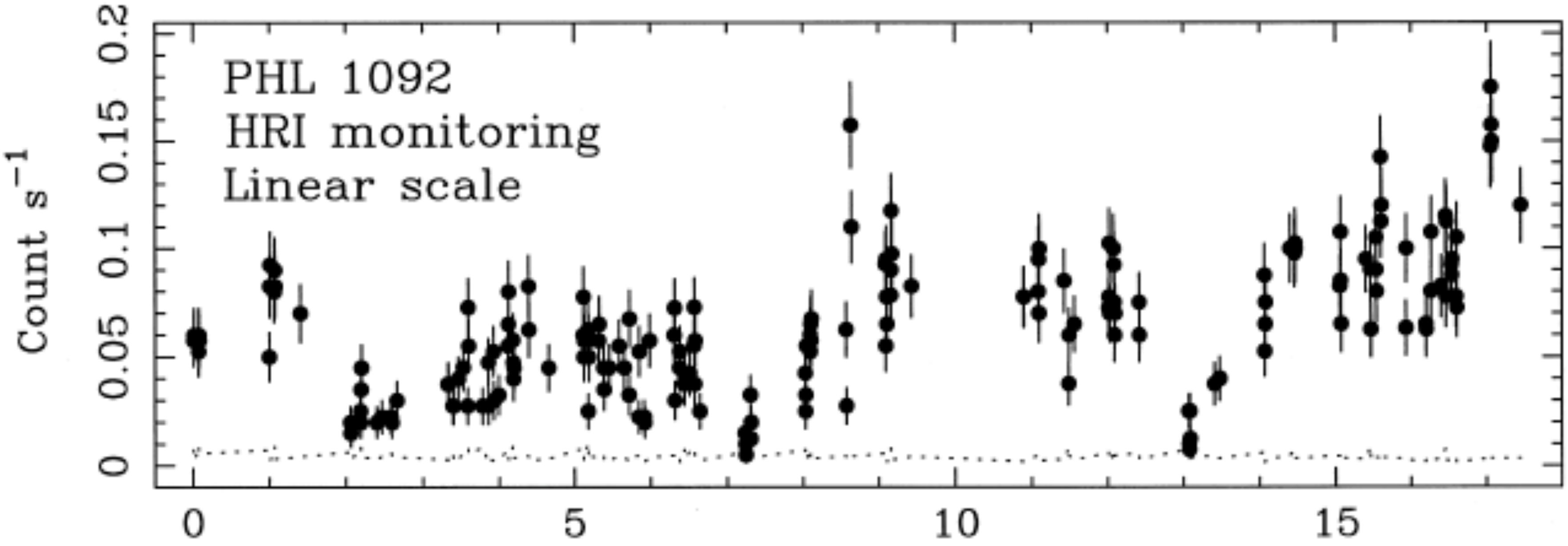


See also Puchnarewicz+92

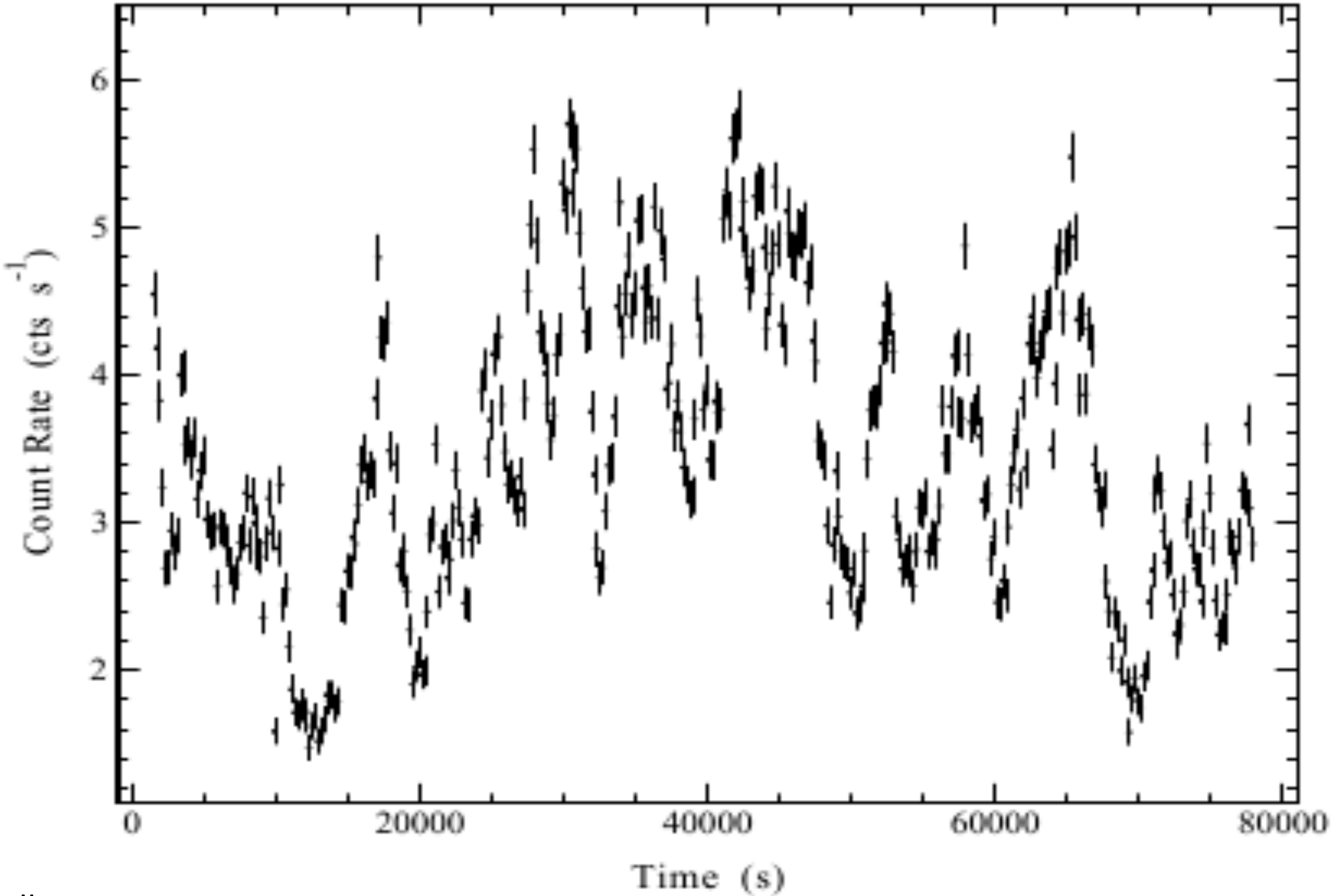
Extreme X-ray variability



Boller+98


PHL 1092
HRI monitoring
Linear scale
Count s^{-1}
0
0.05
0.1
0.15
0.2
5
10
15

1H0707-495



Gallo+04

X-rays and NLS1

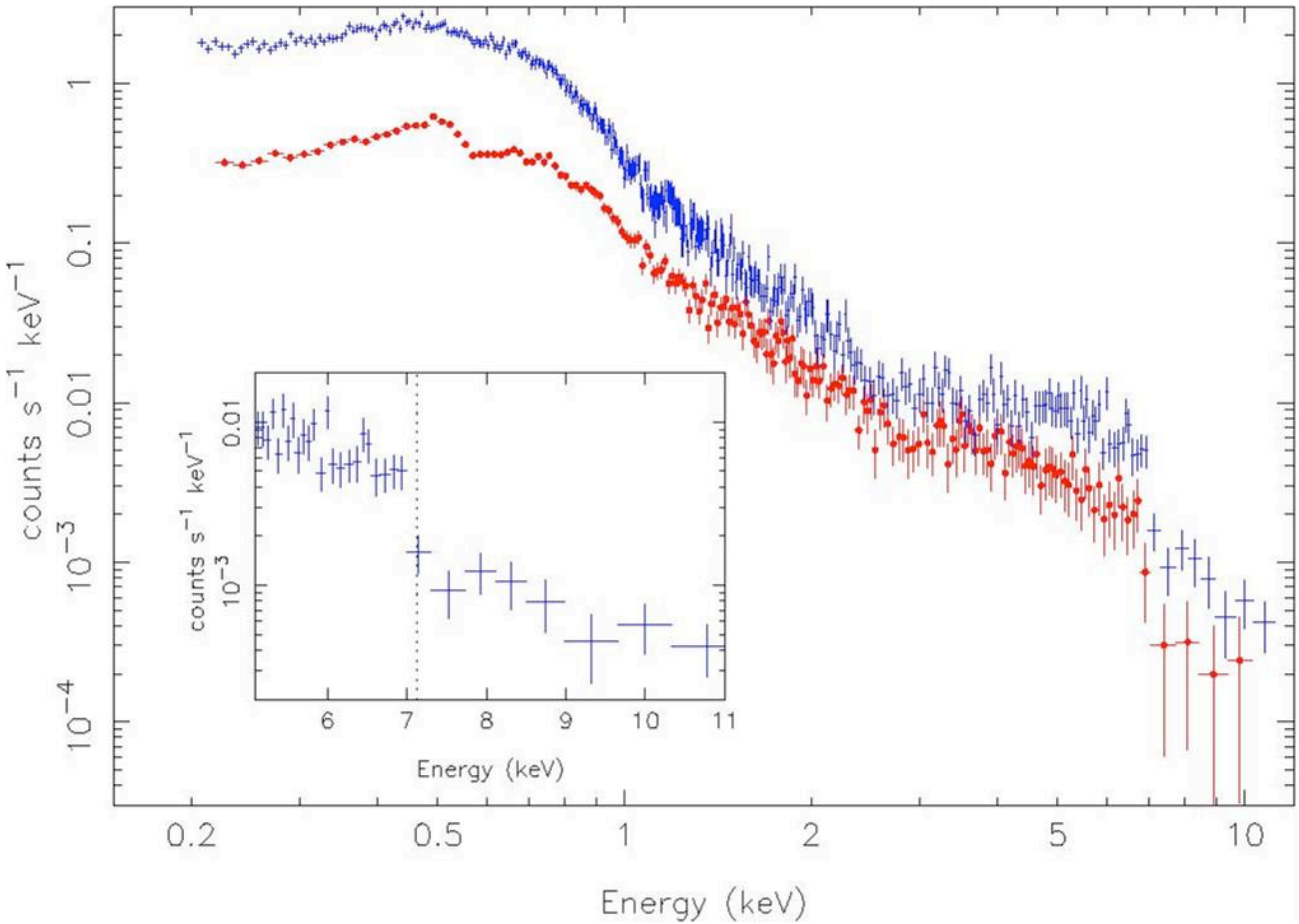
- None in Piccinotti HEAO-1 A2 sample
- (But 1H0707 from HEAO-1 A4 instrument)
- 10% in Einstein low z AGN samples
- 40% in ROSAT samples
- Few in deep fields
- Mostly due to very steep soft X-ray spectra of NLS1

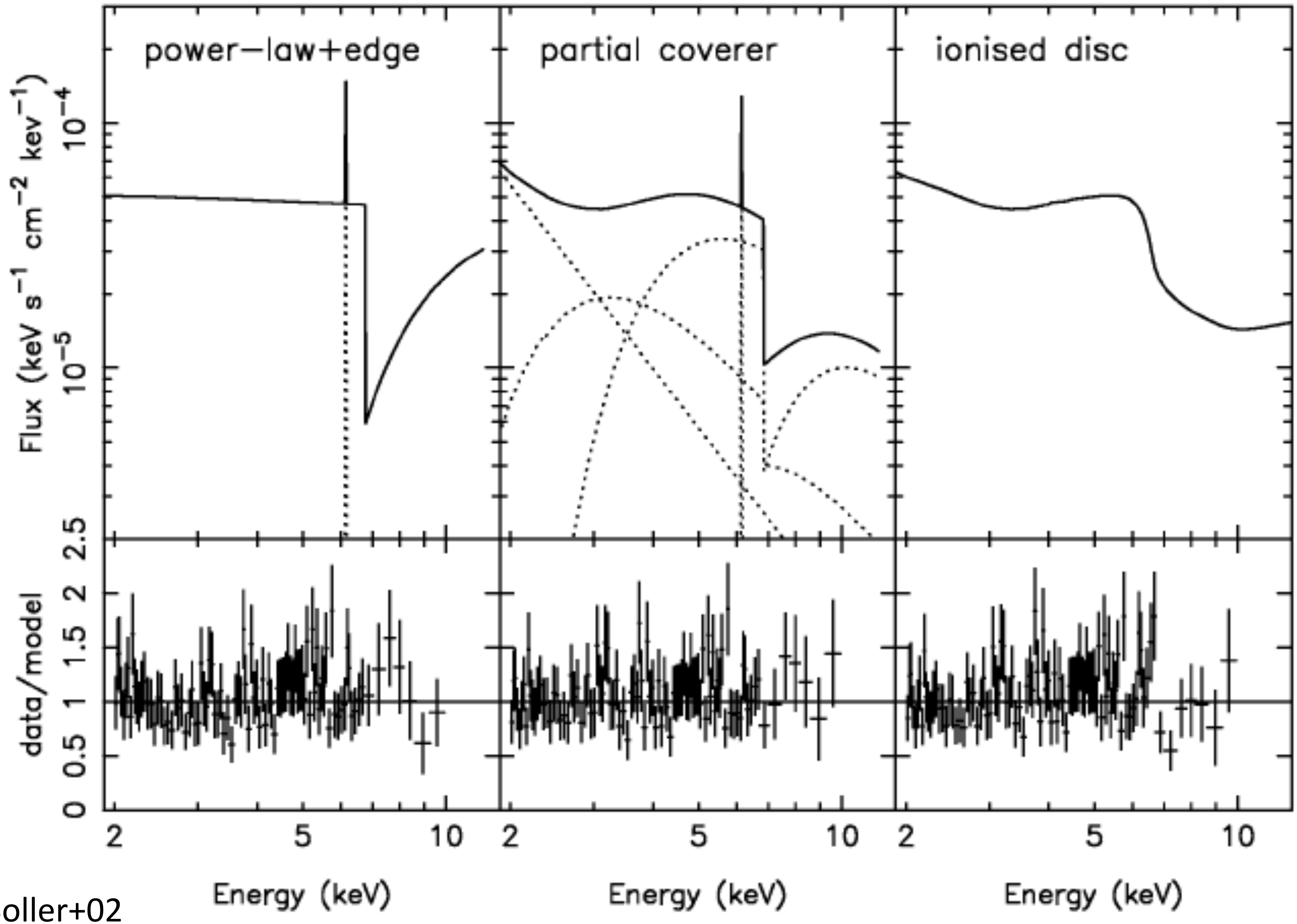
  (from Grupe00)

- Extreme variability supports low mass BH
- High luminosities then imply high Eddington fraction –> close to Eddington limit

- XMM reveals sharp drop around 7 keV in some objects

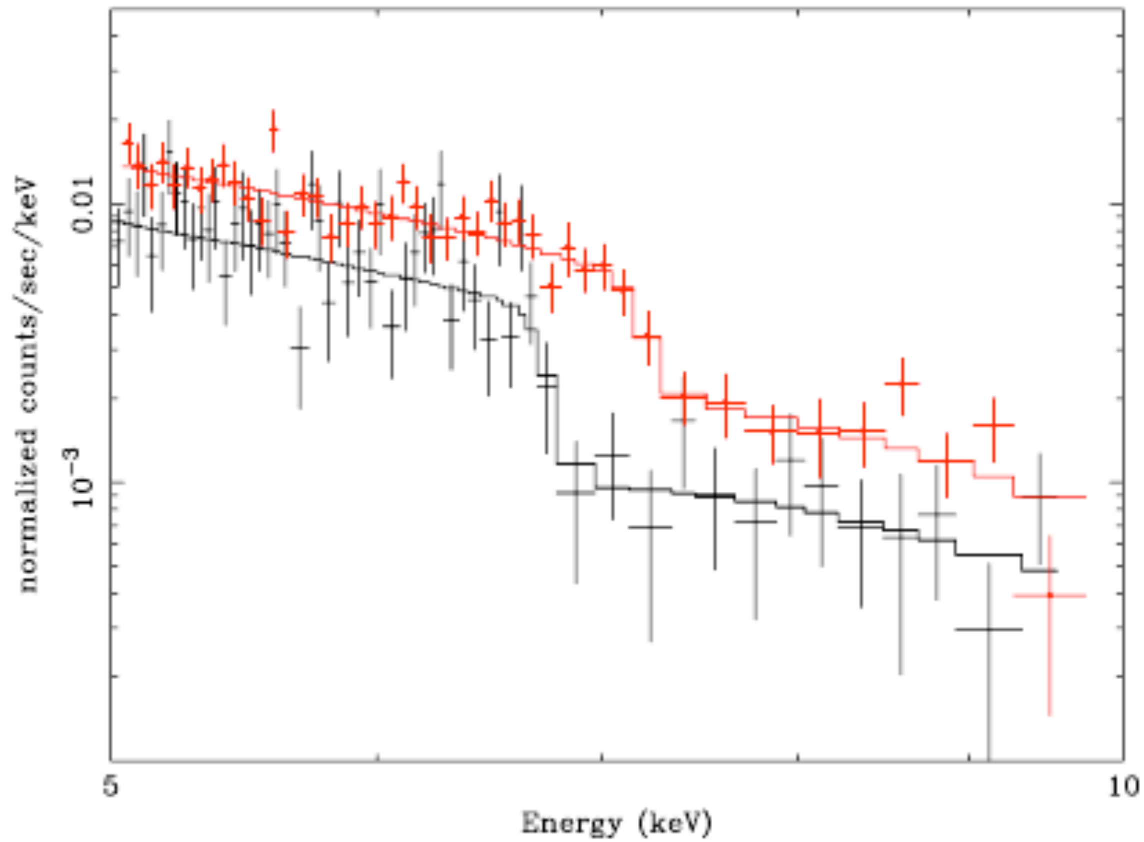
1H0707 Boller+02; Gallo+04





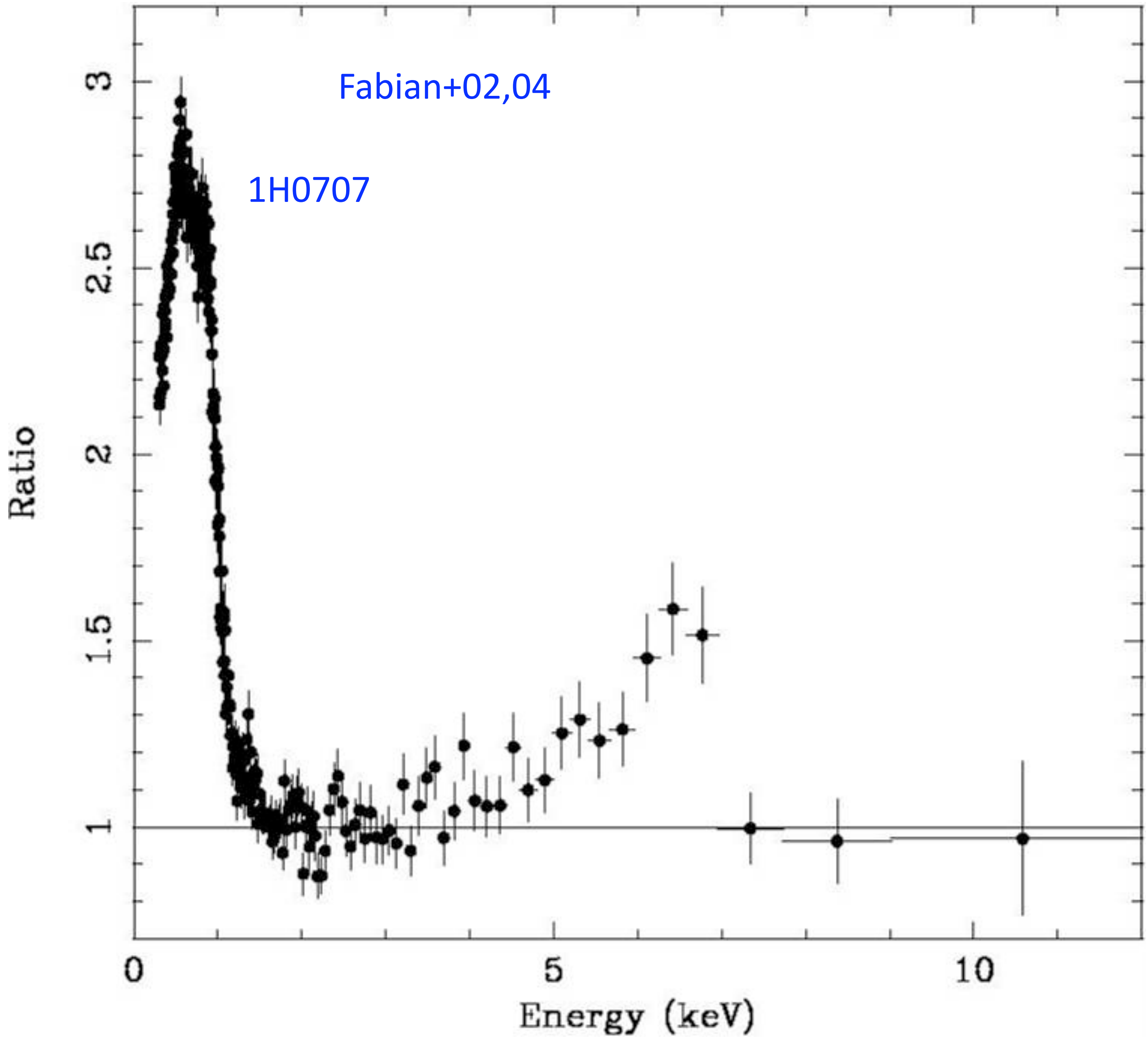
power−law+edge
partial coverer
ionised disc
Flux (keV s^{-1} cm^{-2} kev^{-1})
10^{-4}
10^{-5}
2.5
data/model
2.5
2
1.5
1
0.5
0
2
5
10
Energy (keV)
Energy (keV)
Energy (keV)

Boller+02

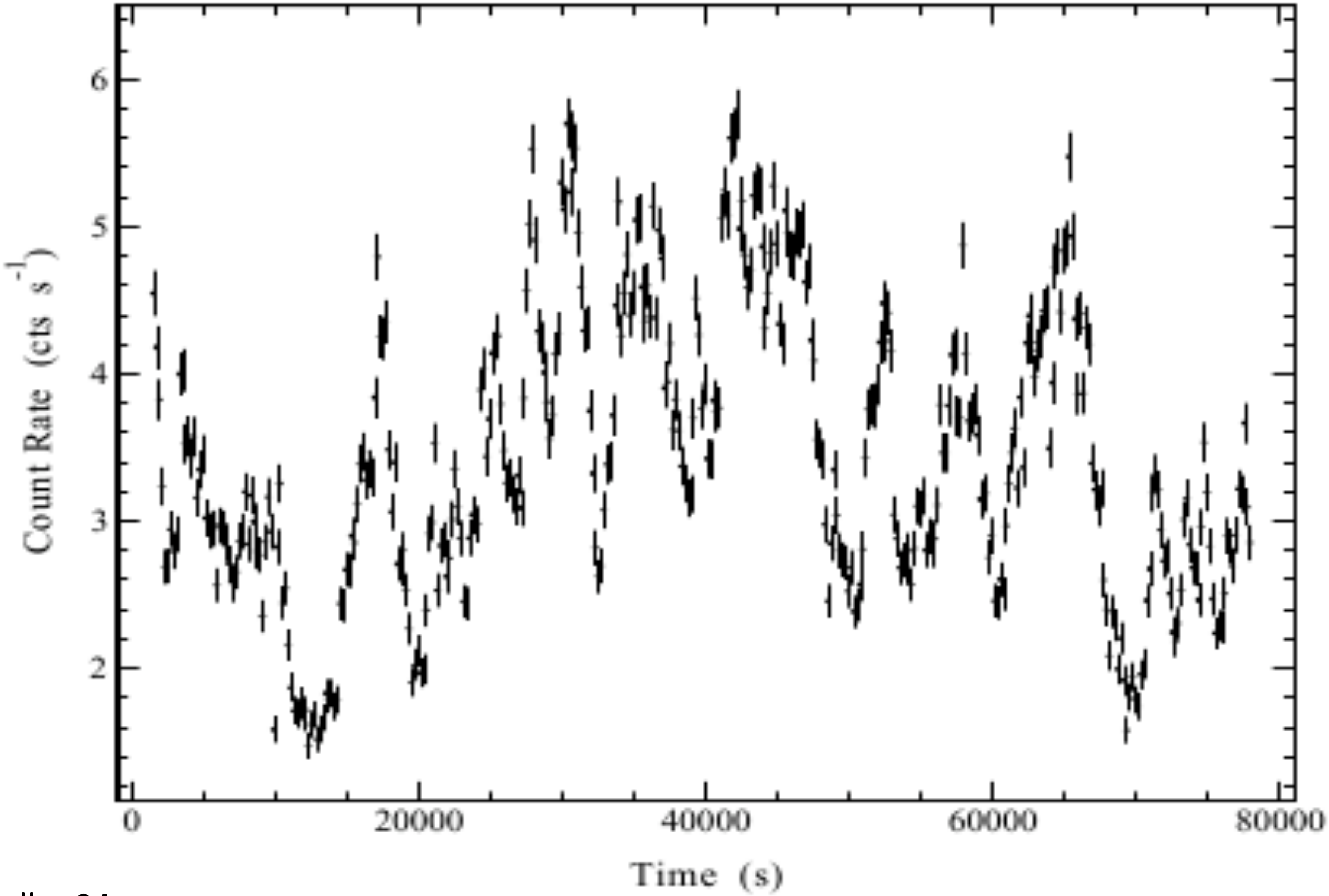


Gallo+04

Is it absorption or a line?



1H0707-495

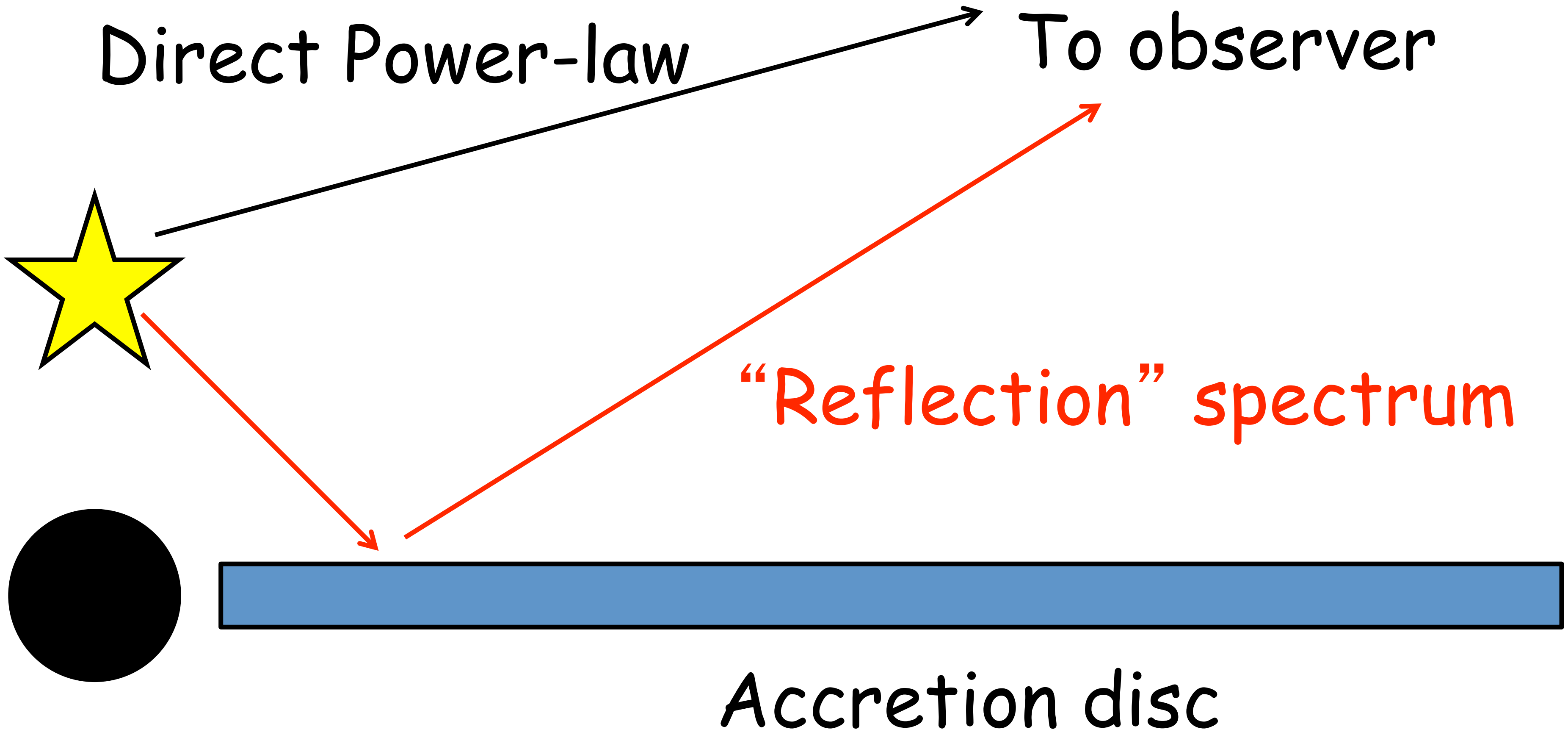


Gallo+04

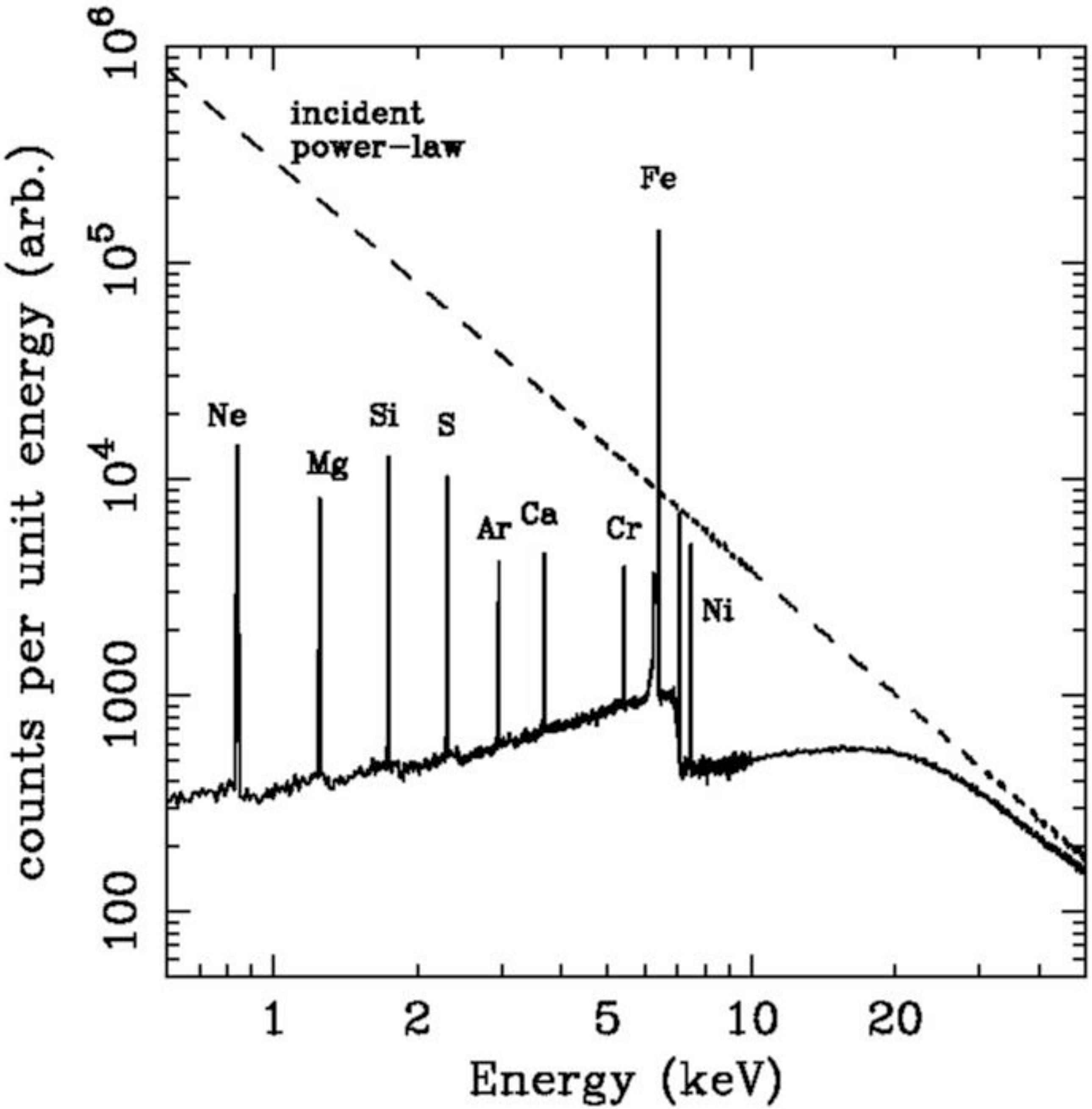
Issues raised by Rapid Variability

- Doubling time t implies from causality that emission and absorber region have size r < vt
- If t < 1000s and M~3x10^6 Msun (e.g. NLS1) and v is dynamical velocity, then r < 10 r_s
- The rapid variability seen in 1H0707 and IRAS13224 cannot be due to an extensive (r~100s r_s) emission, absorption or scattering region but must be compact and from < 10r_s

Partial covering absorption models must address cloud survival



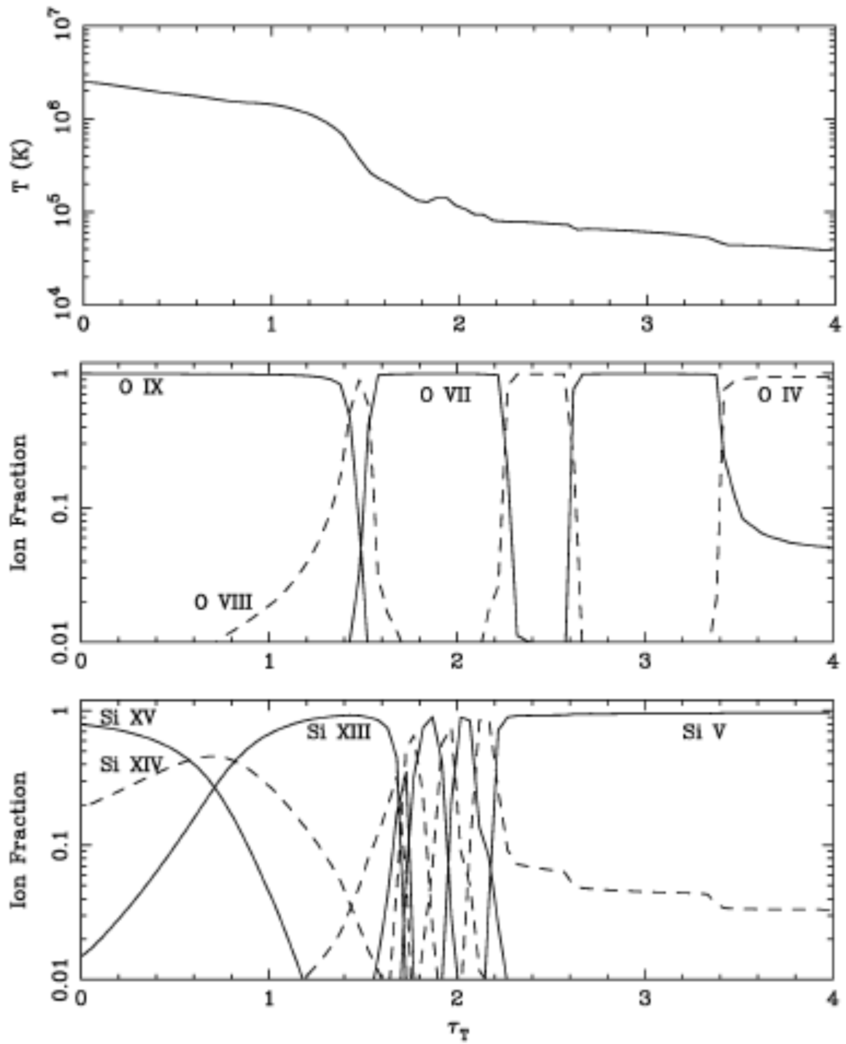
Why might we expect to see a broad iron line?



Reflection from cold matter

Ross+
Fabian05

STRONG IRRADIATION

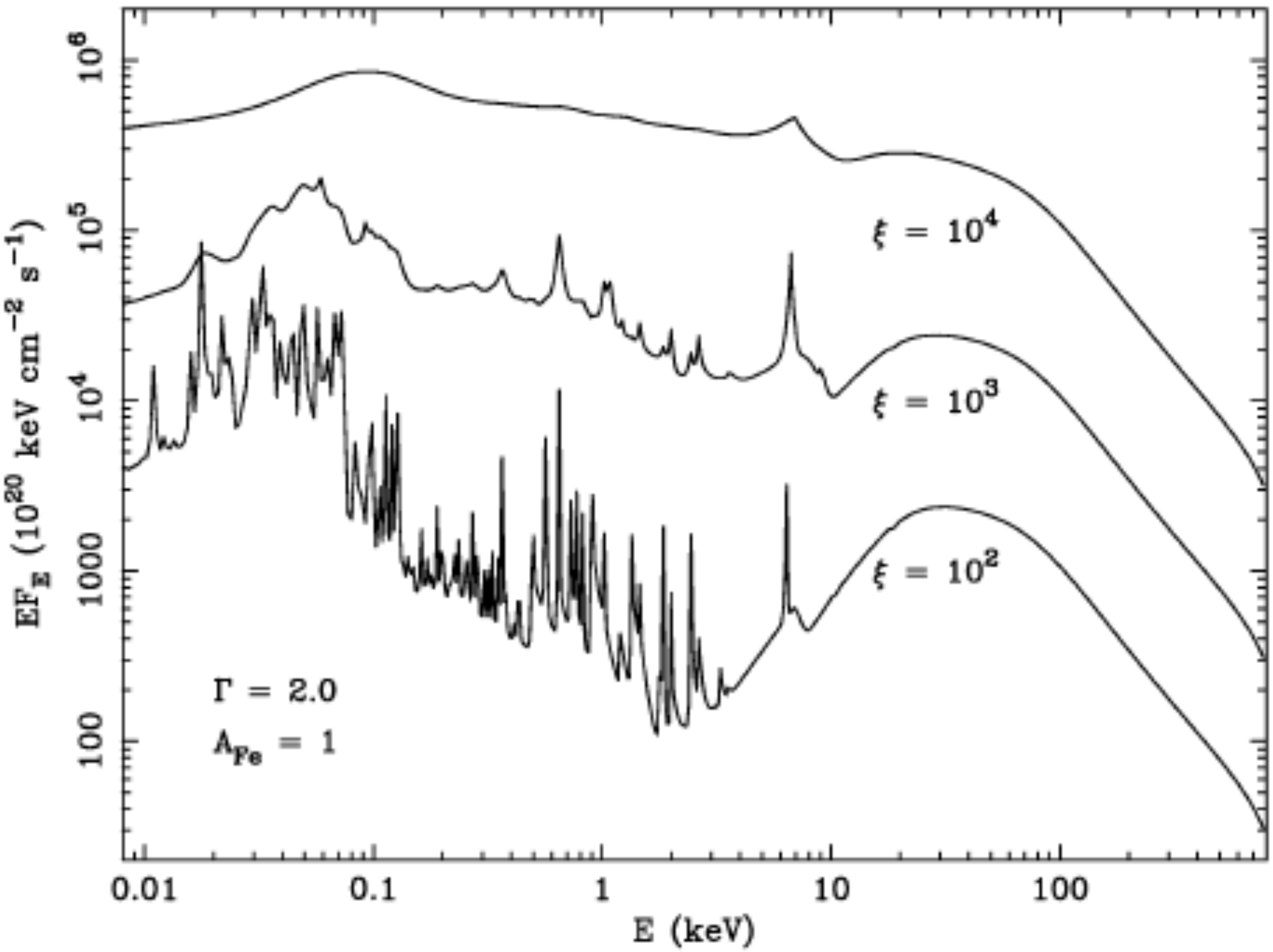


Temp

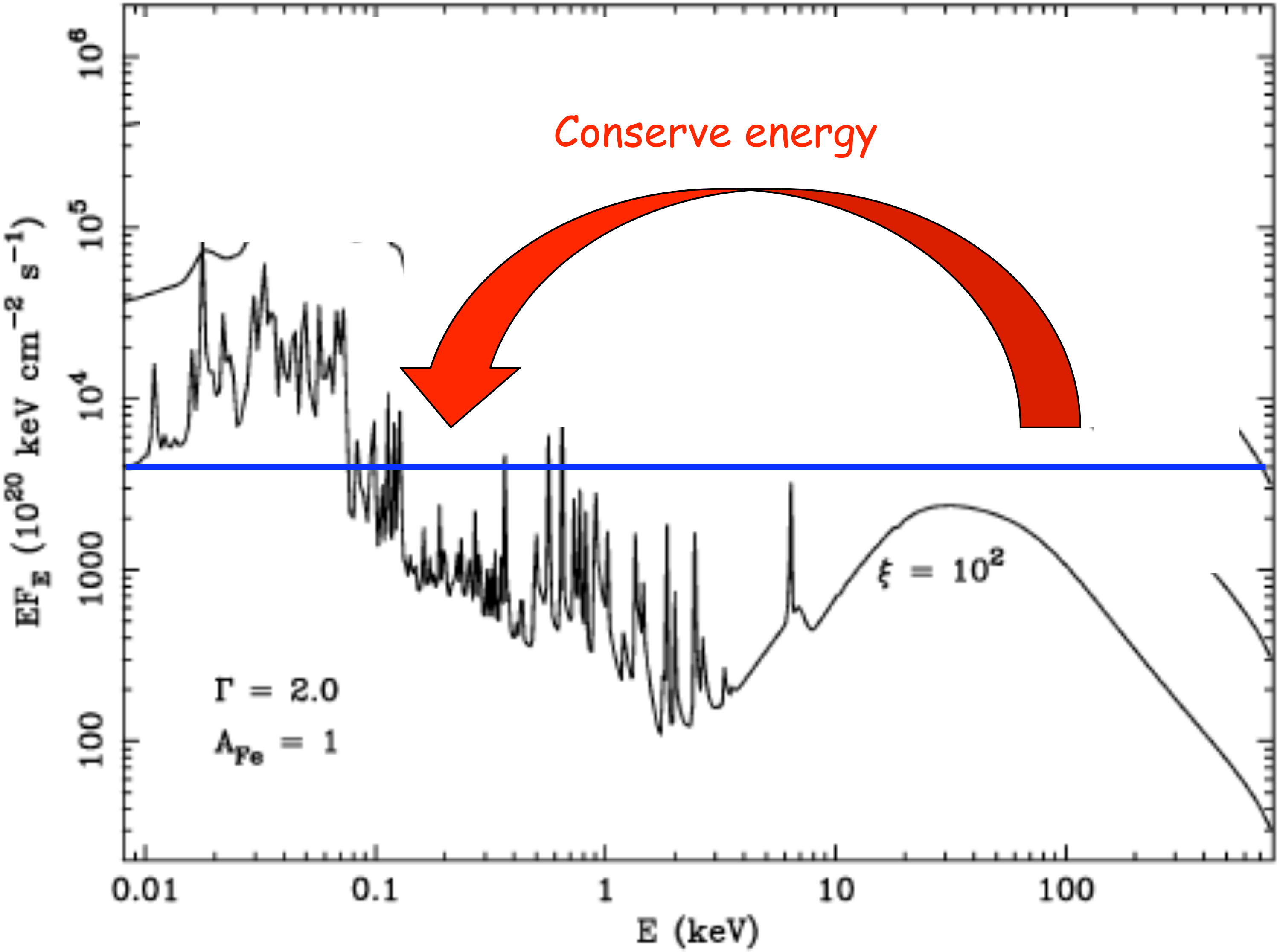
O ions

Si ions

Thomson depth in slab



EF_E (10^{20} keV cm^{-2} s^{-1})
E (keV)
$\xi = 10^4$
$\xi = 10^3$
$\xi = 10^2$
$\Gamma = 2.0$
$A_{Fe} = 1$

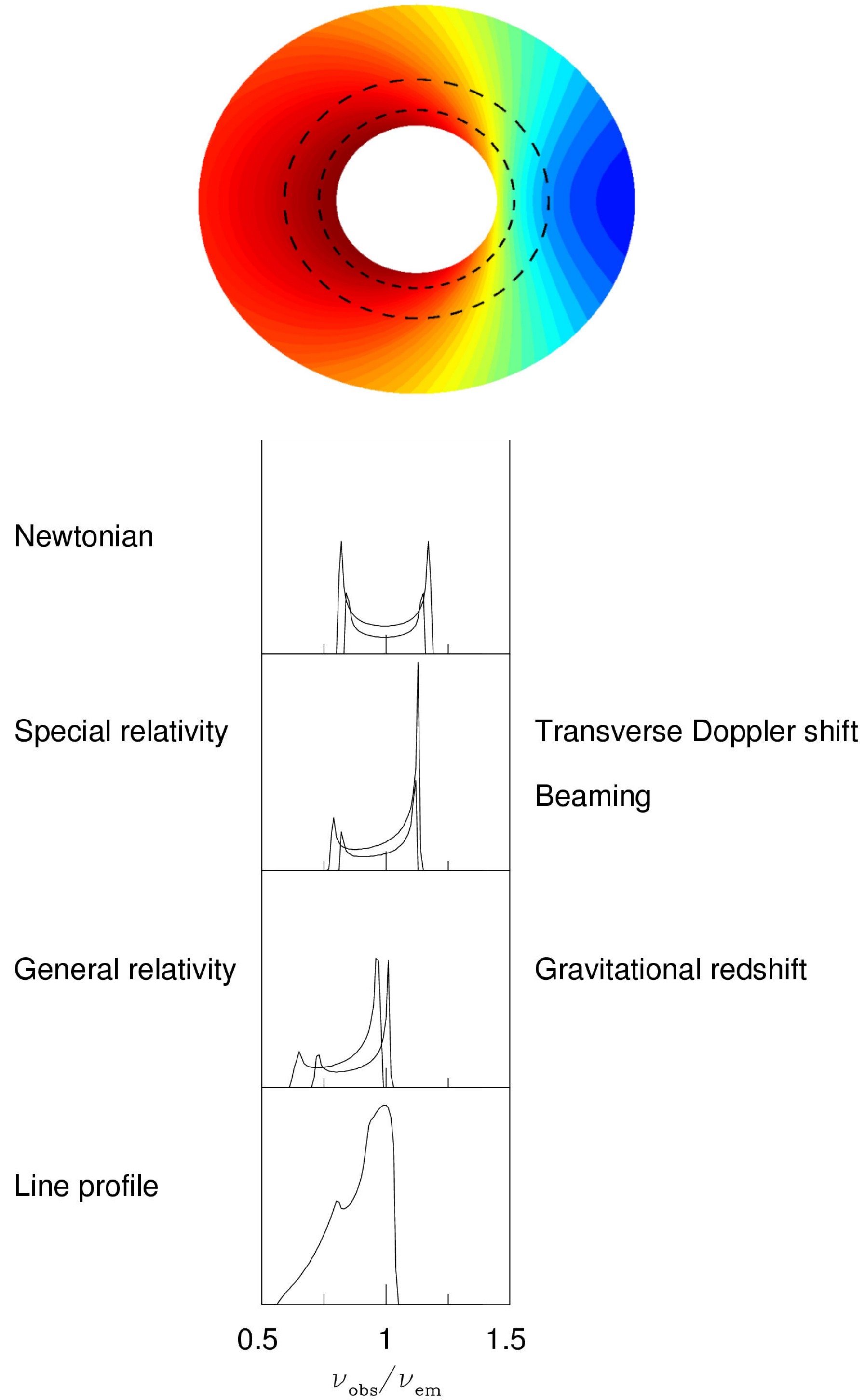


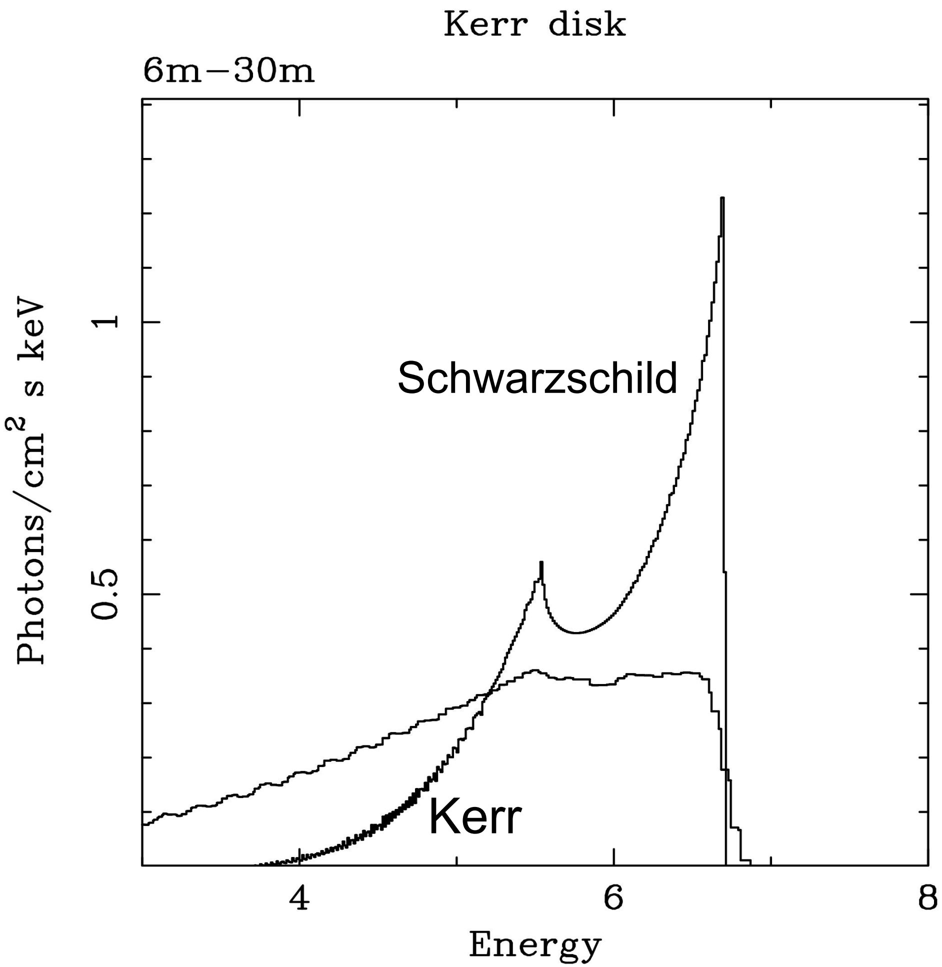
Conserve energy
$\xi = 10^2$
$\Gamma = 2.0$
$A_{Fe} = 1$
EF_E (10^{20} keV cm^{-2} s^{-1})
E (keV)

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 rg

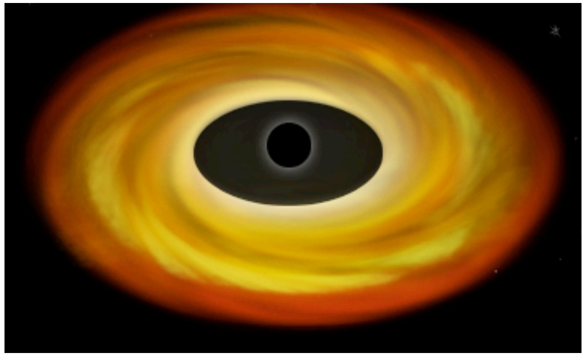


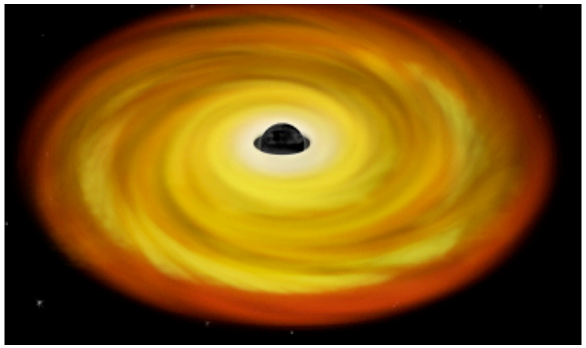


Fabian+89, Laor 90…

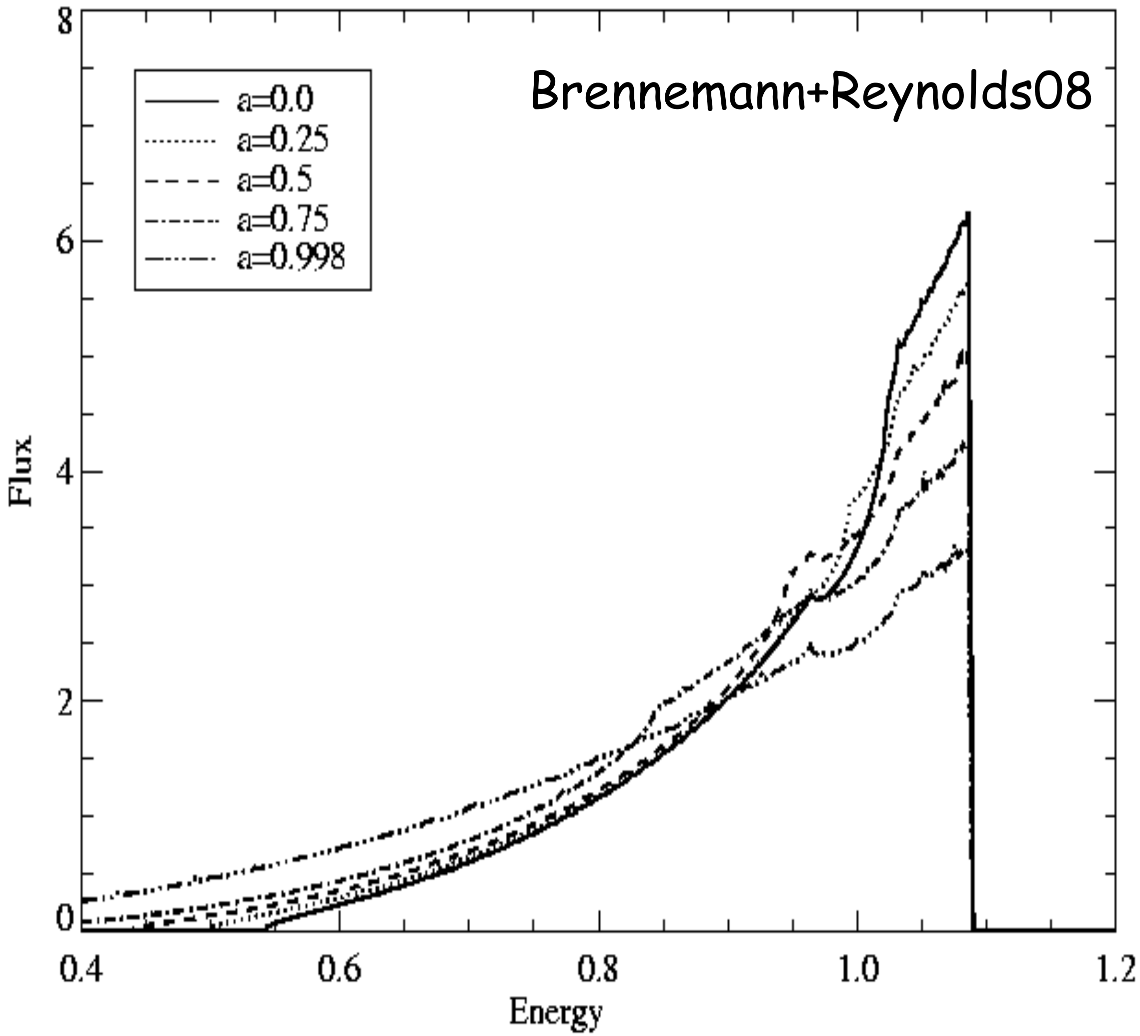
Black Hole Spin

No spin

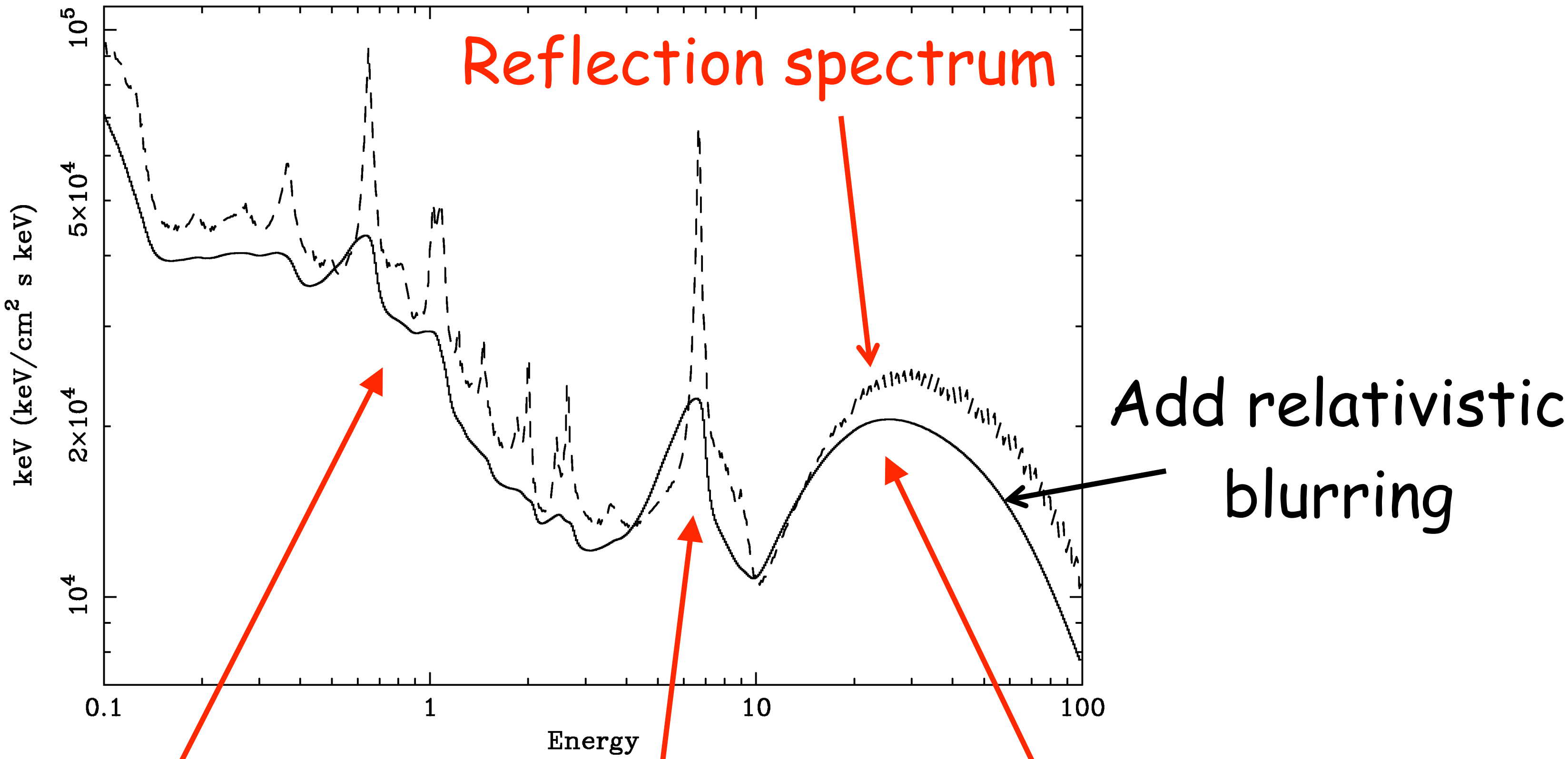




Max spin



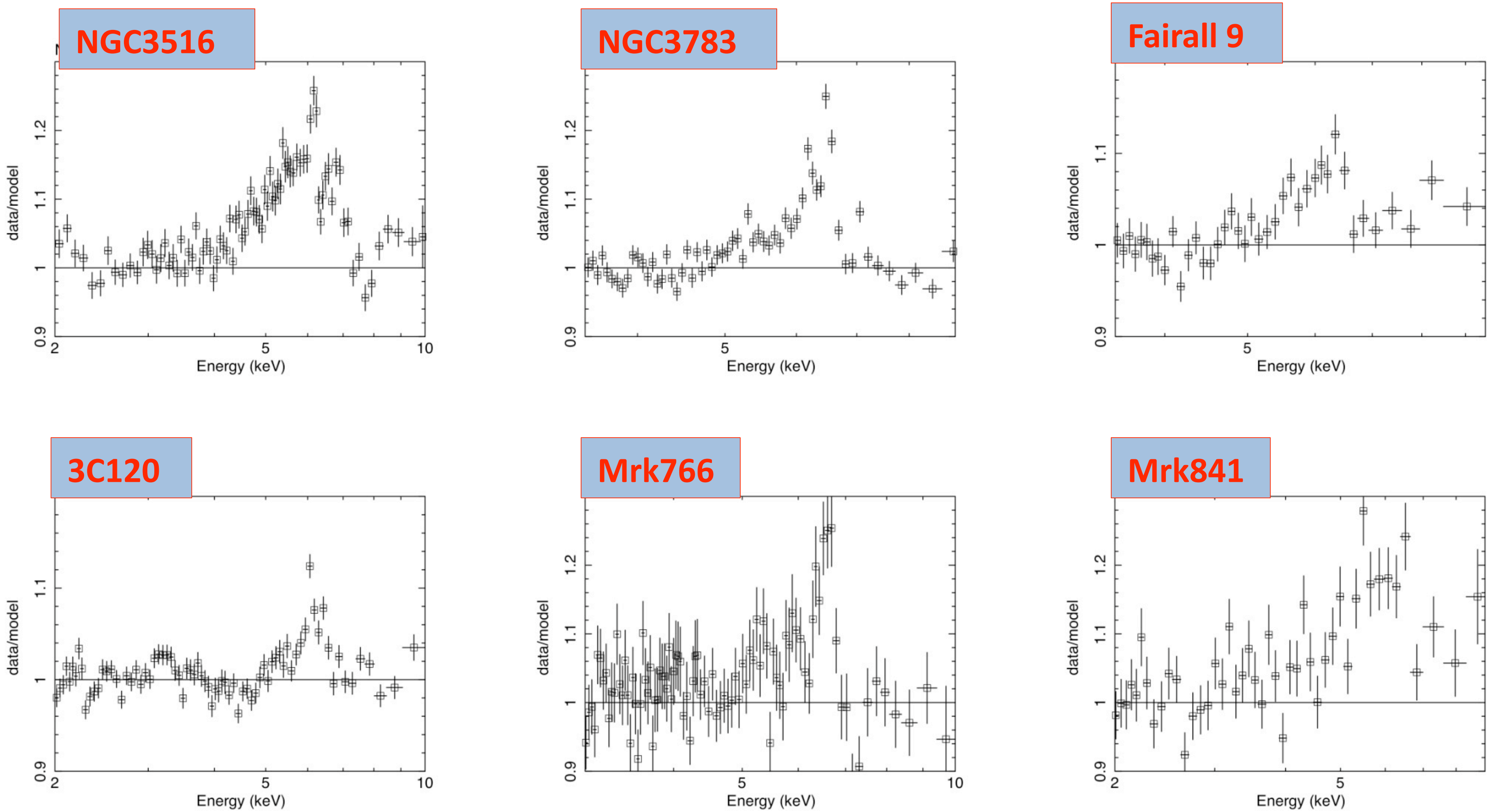
Reflection in accreting BH



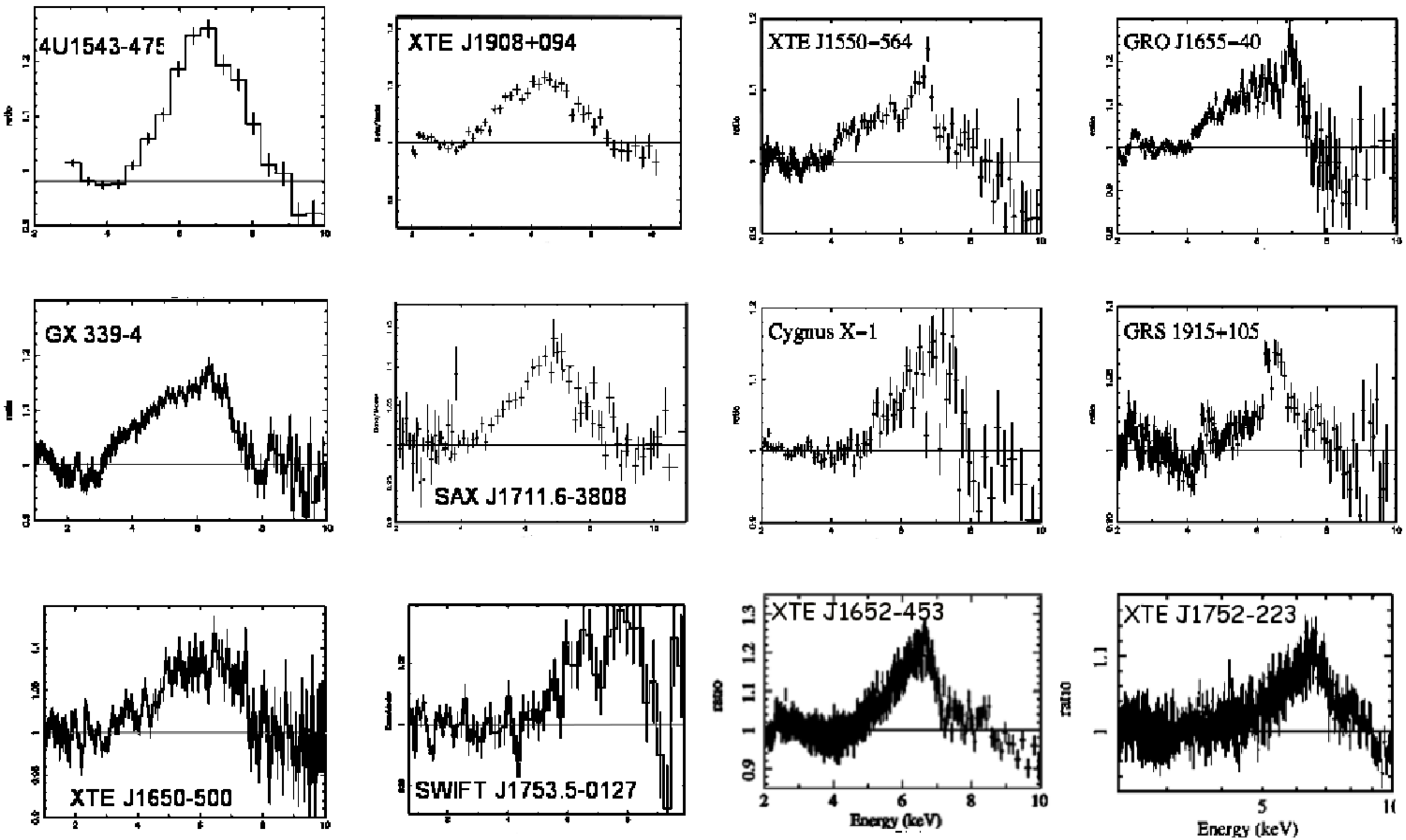
Soft excess - broad iron line - Compton hump

Suzaku AGN Spin Survey

C.Reynolds (PI), L.Brenneman, A.Fabian, K.Iwasawa, J.Lee, J.Miller, R.Mushotzky, K.Nandra, M.Nowak, R.Reis, M.Trippe, M.Volonteri

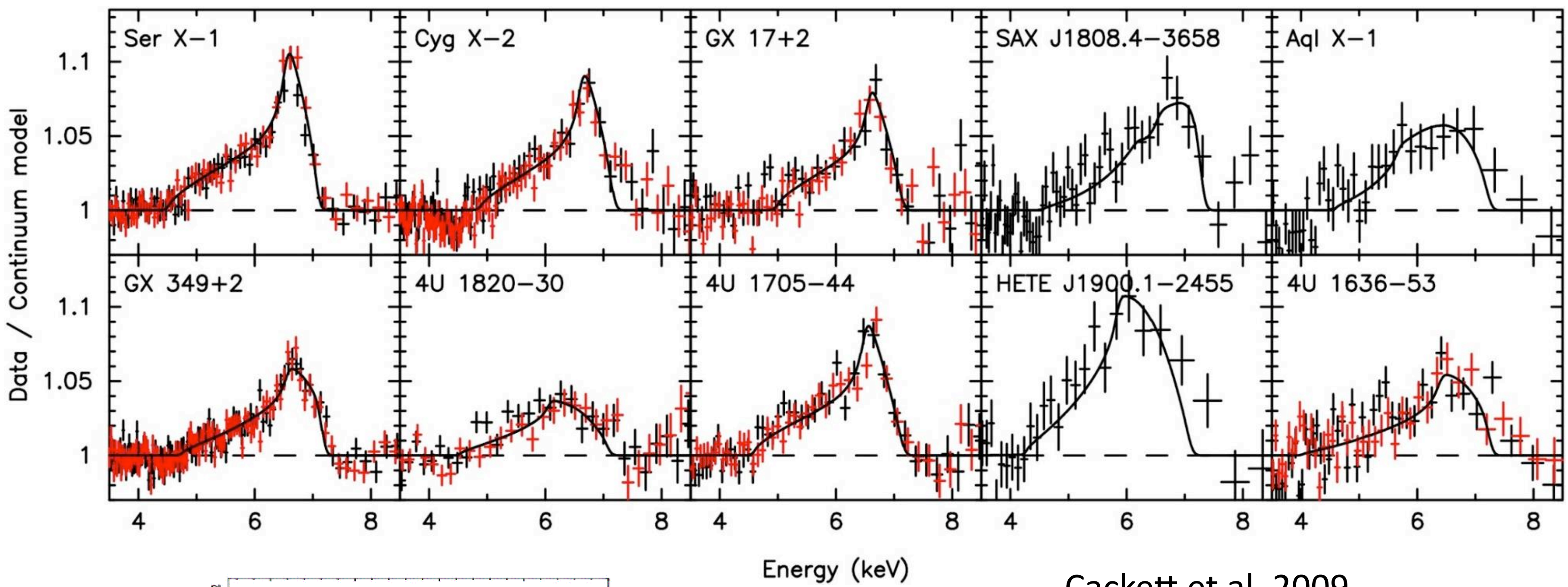


BH X-ray binaries

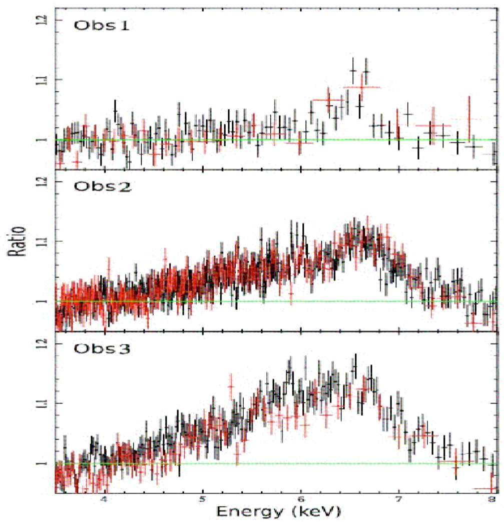


Originally compiled by J. M. Miller

Neutron Star Binaries

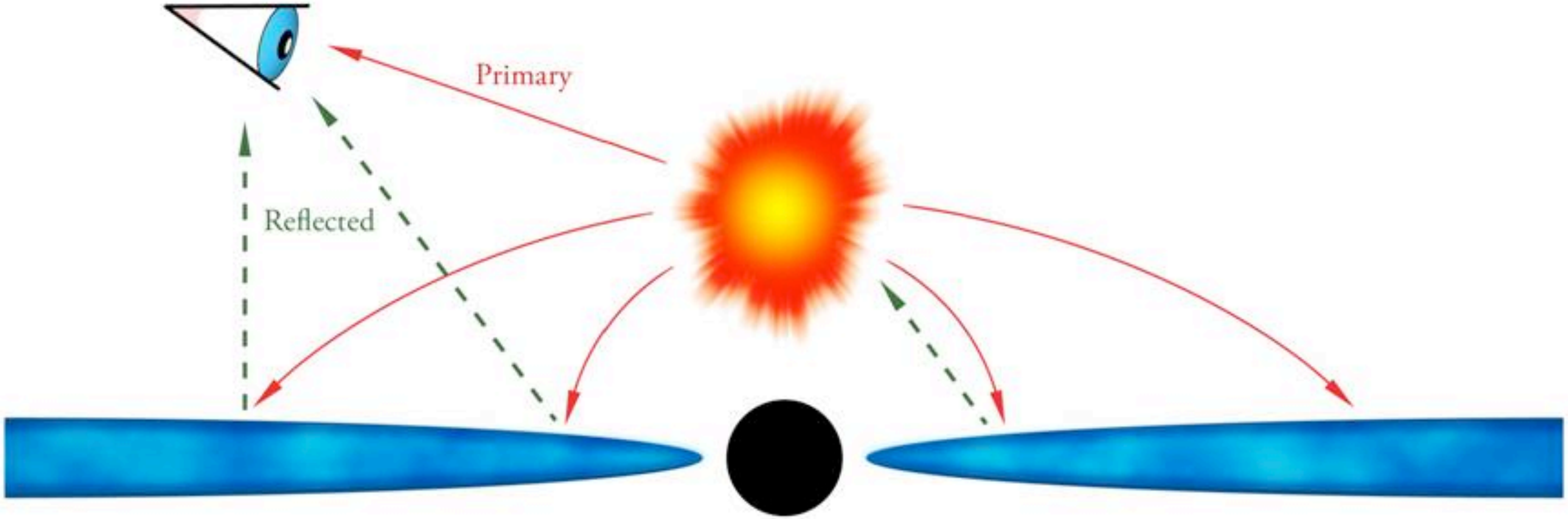


Cackett et al. 2009



4U1705-44
Reis+09
R_{in}=10.5r_g

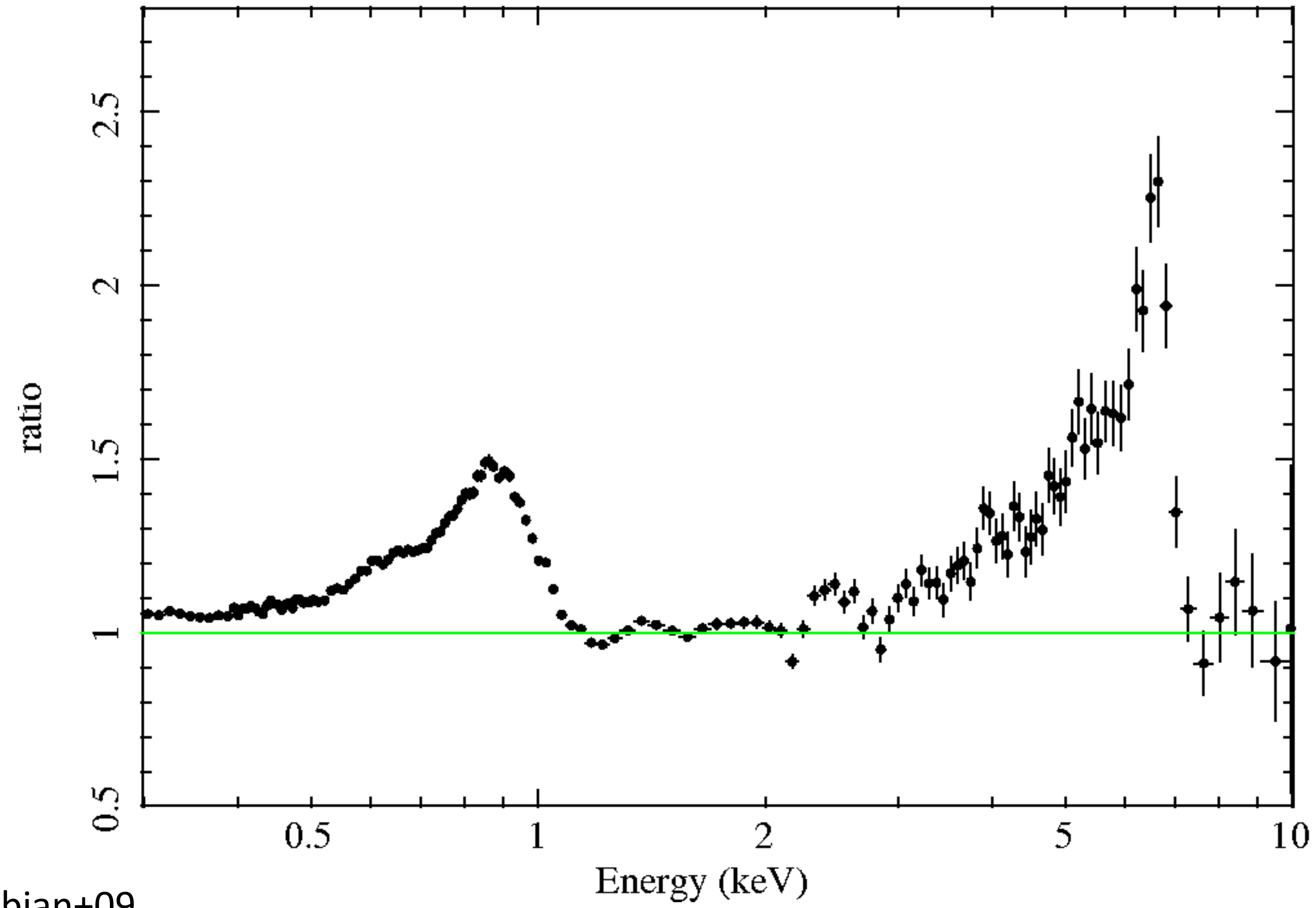
Strong light bending close to BH



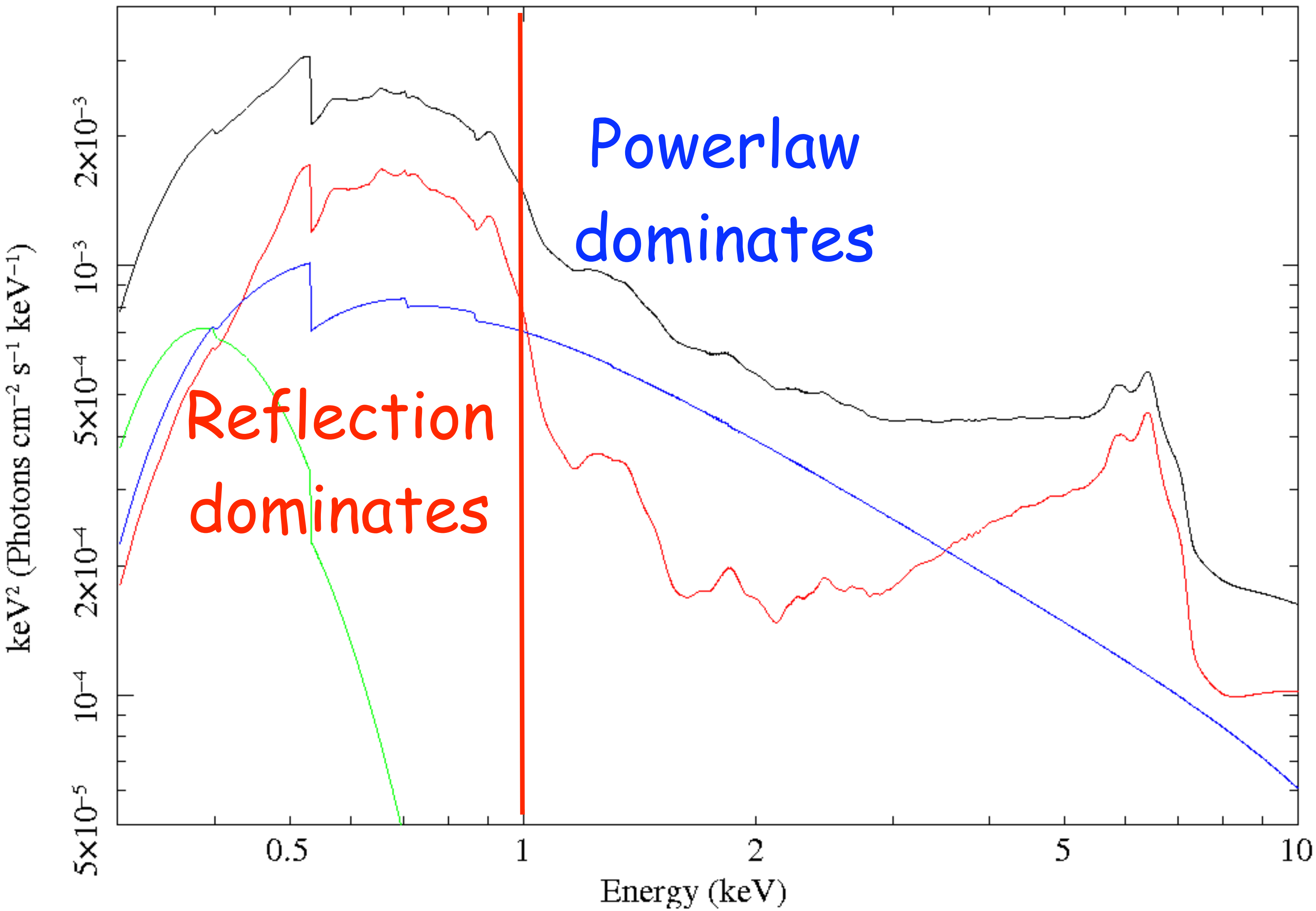
Martocchia&Matt, Miniutti&Fabian

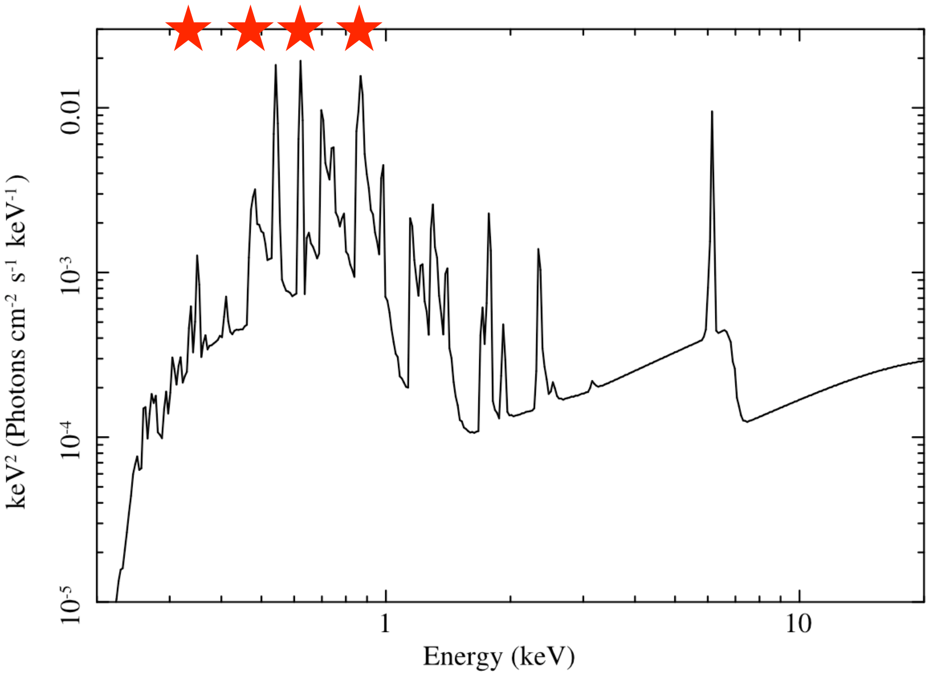
GR + lightbending make emissivity steep

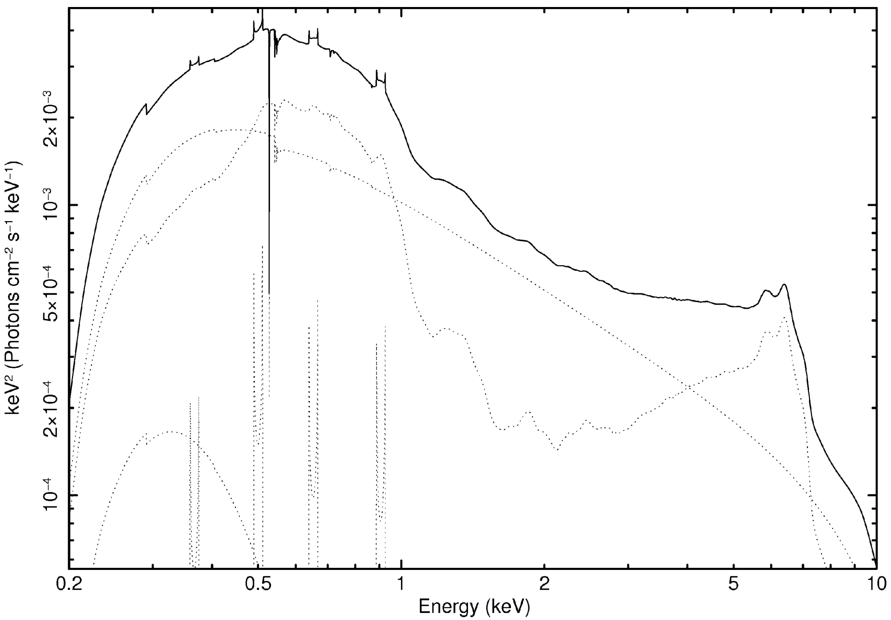
Broad iron-L and iron-K emission lines in NLS1 1H0707-495



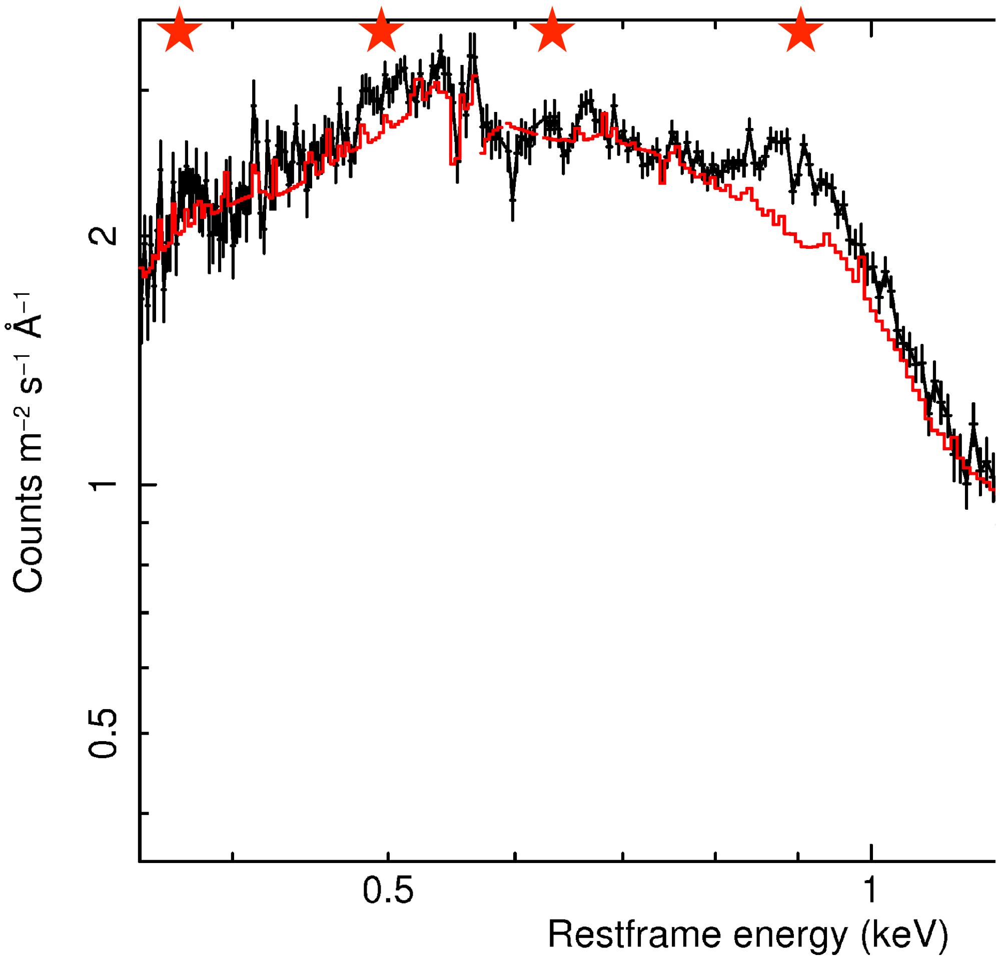
Fabian+09


Powerlaw dominates
Reflection dominates
keV² (Photons cm⁻² s⁻¹ keV⁻¹)
2×10⁻³
10⁻³
5×10⁻⁴
2×10⁻⁴
10⁻⁴
5×10⁻⁵
0.5
1
2
5
10
Energy (keV)



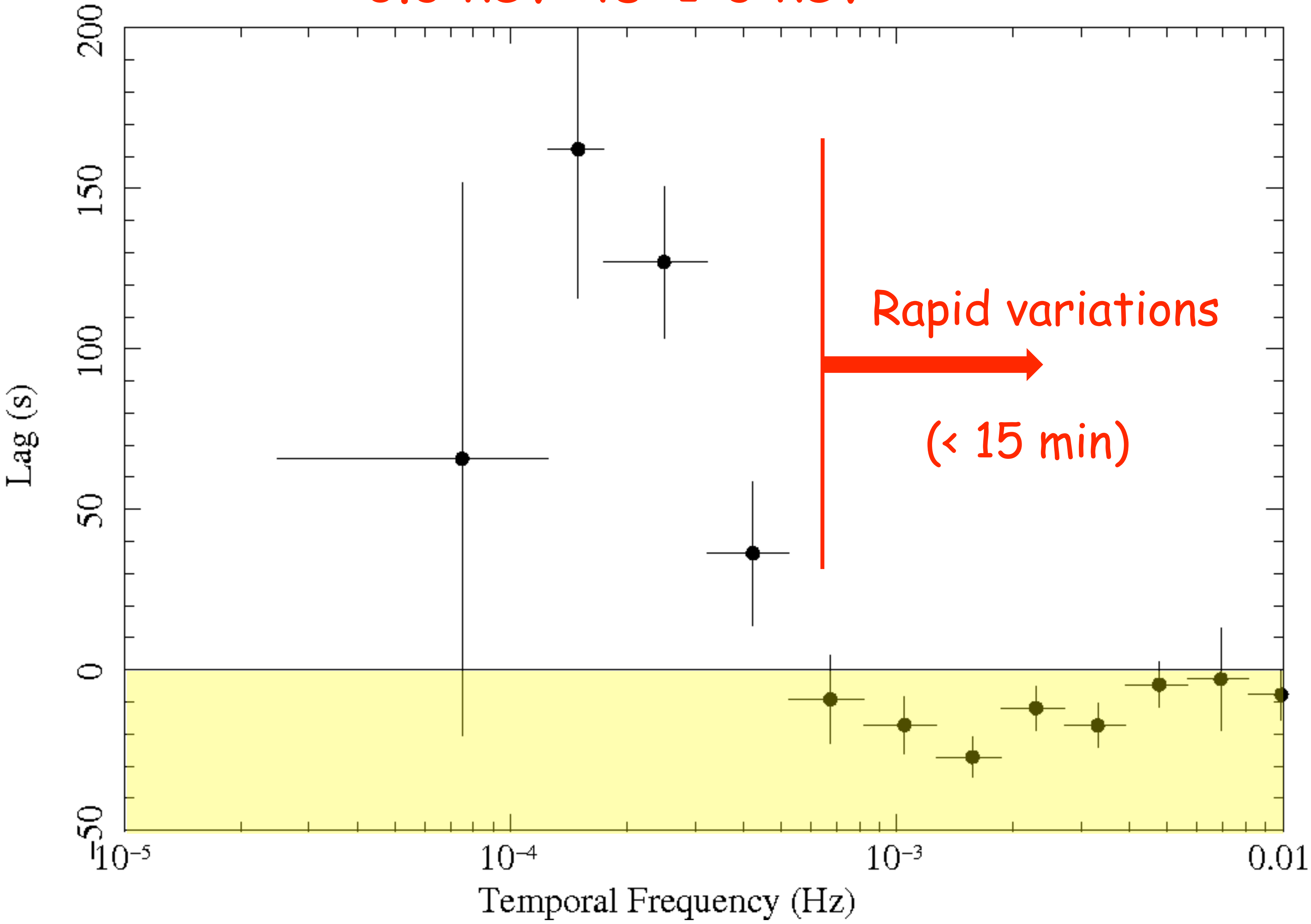


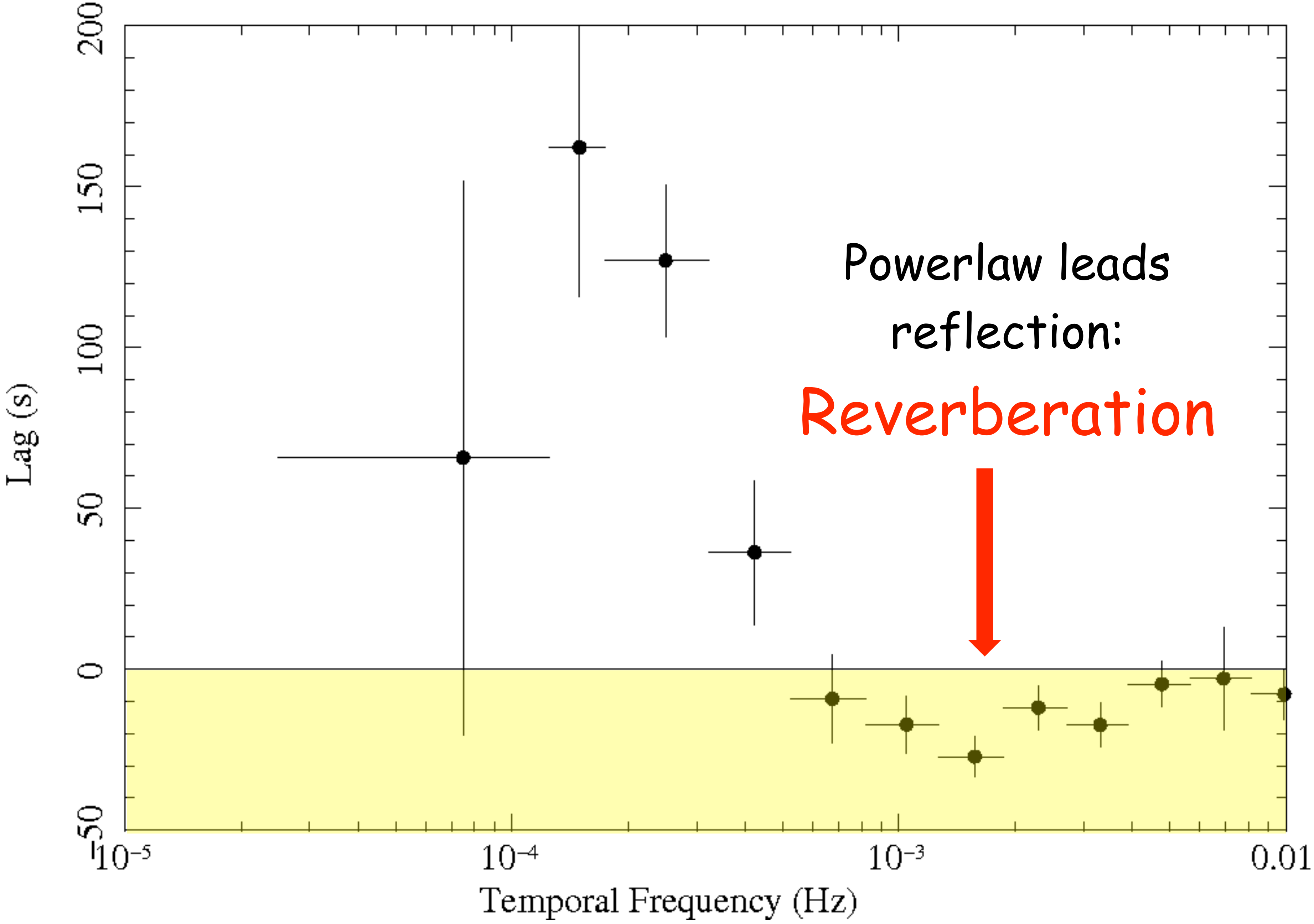
RGS



Blustin&Fabian09

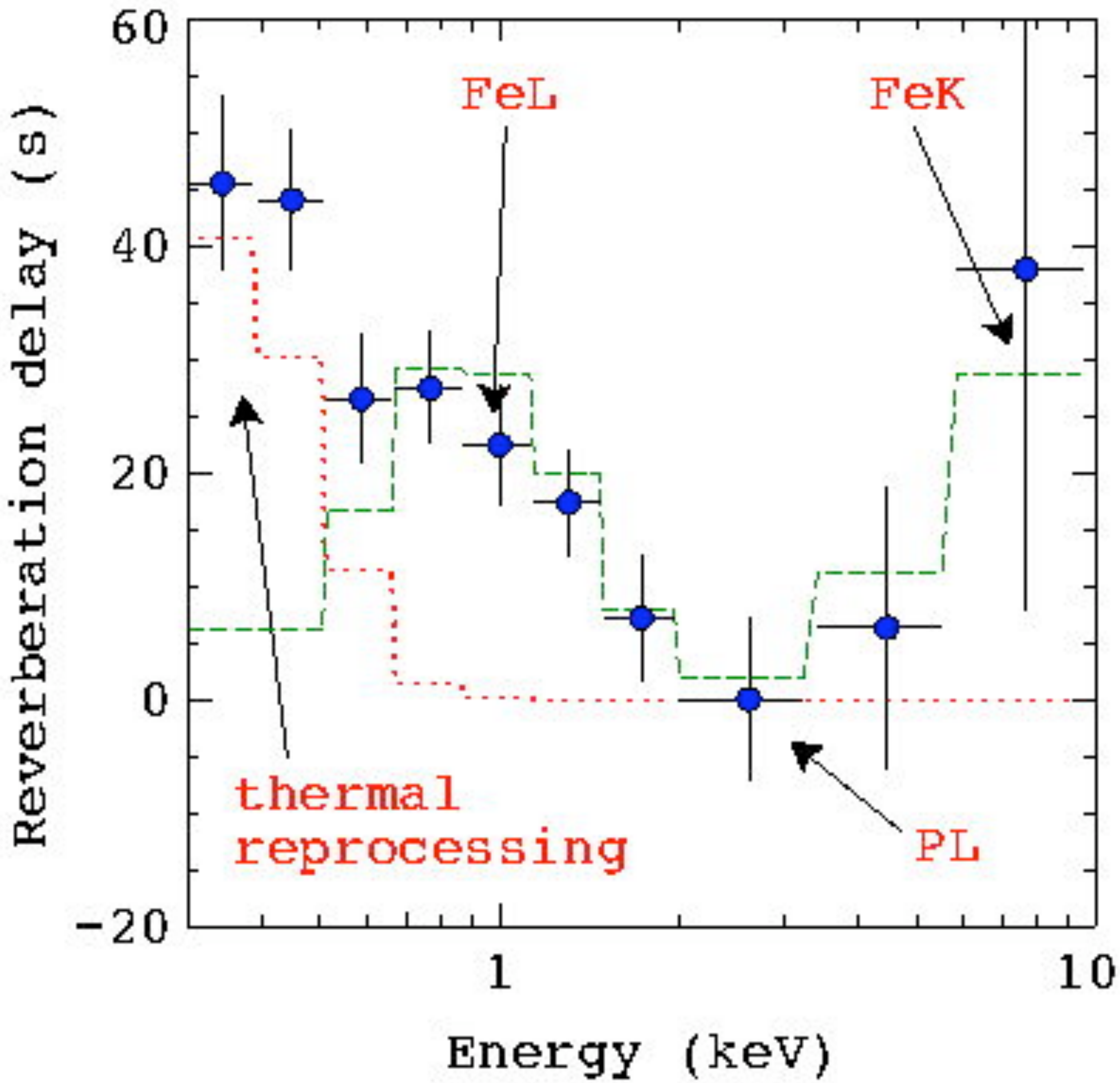
0.3 keV vs 1-3 keV





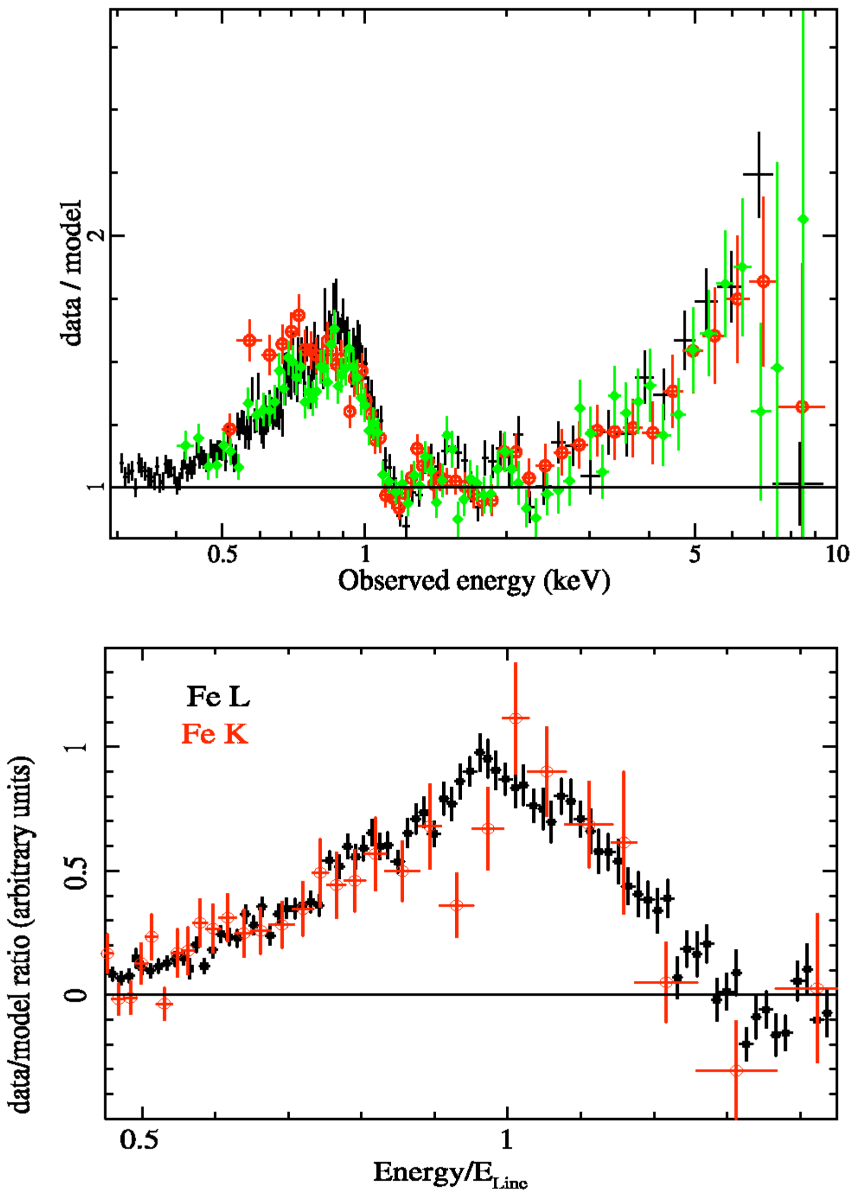
See Abdu Zoghbi's talk for more on reverberation

Zoghbi+11

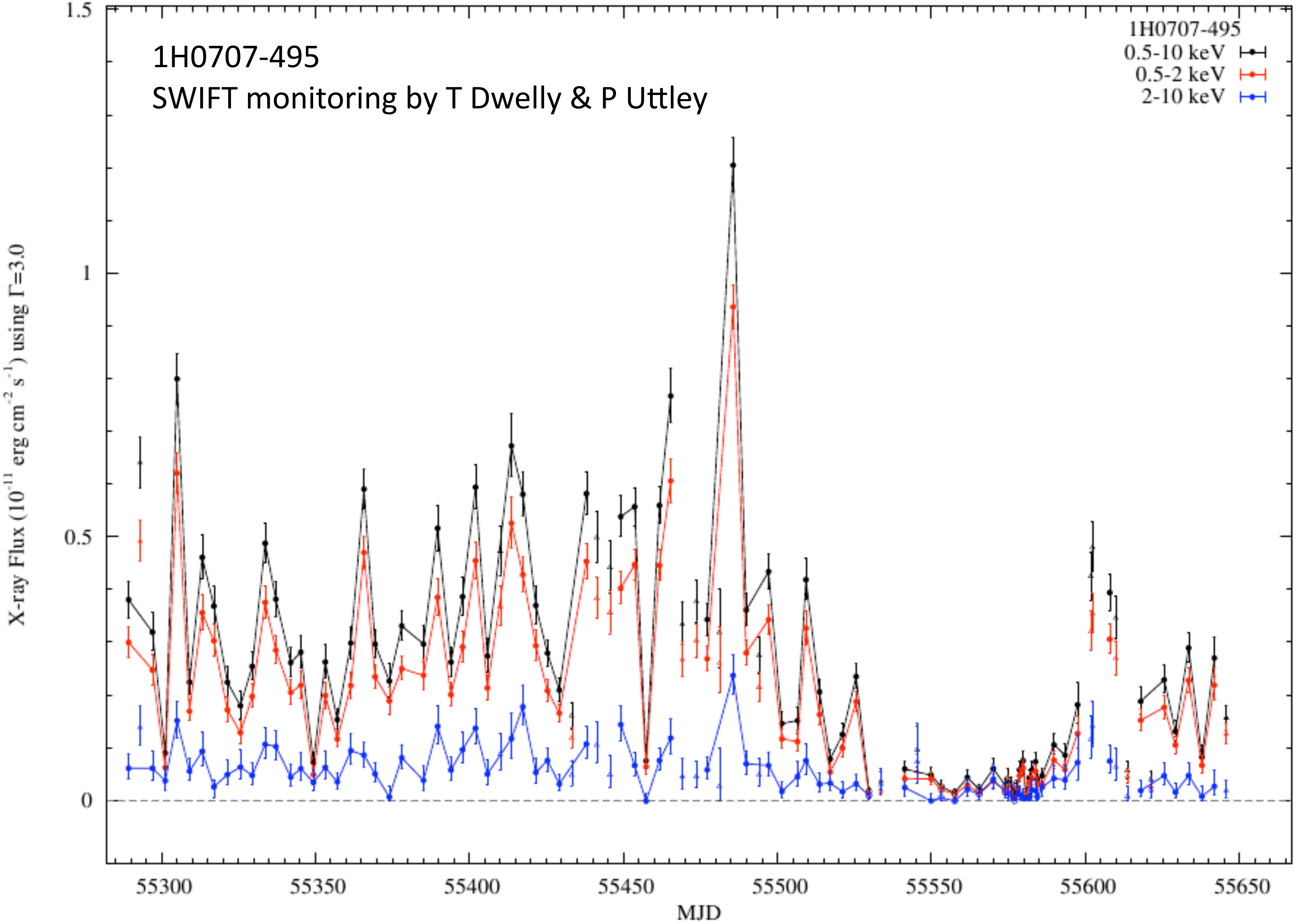


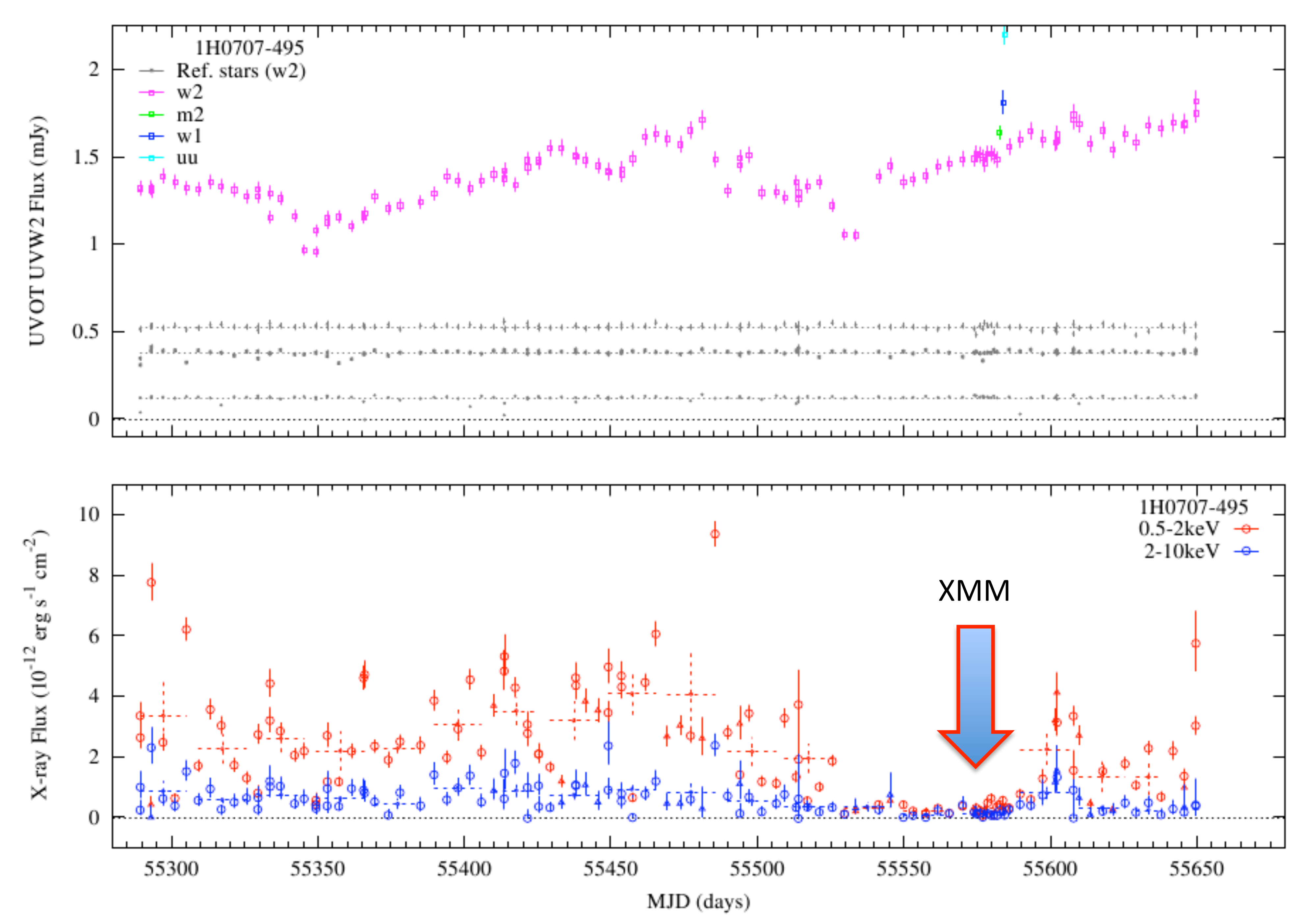
FeL
FeK
thermal
reprocessing
PL
Reverberation delay (s)
Energy (keV)
60
40
20
0
-20
1
10

IRAS13224 Ponti+09



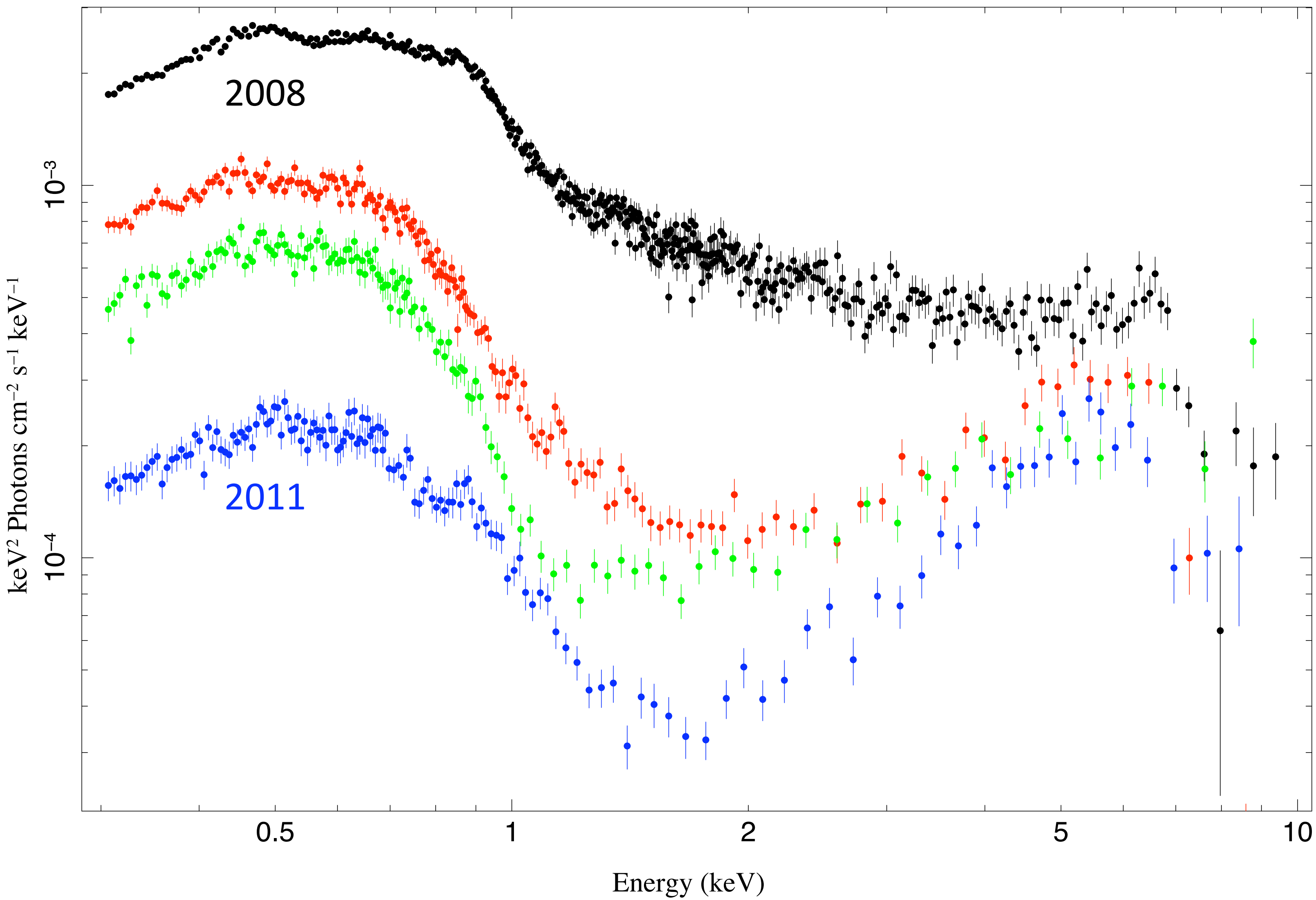
2011 Update


1H0707-495
SWIFT monitoring by T Dwelly & P Uttley
1H0707-495
0.5-10 keV
0.5-2 keV
2-10 keV
X-ray Flux (10^{-11} erg cm^{-2} s^{-1}) using Γ=3.0
MJD
1.5
1
0.5
0
55300
55350
55400
55450
55500
55550
55600
55650

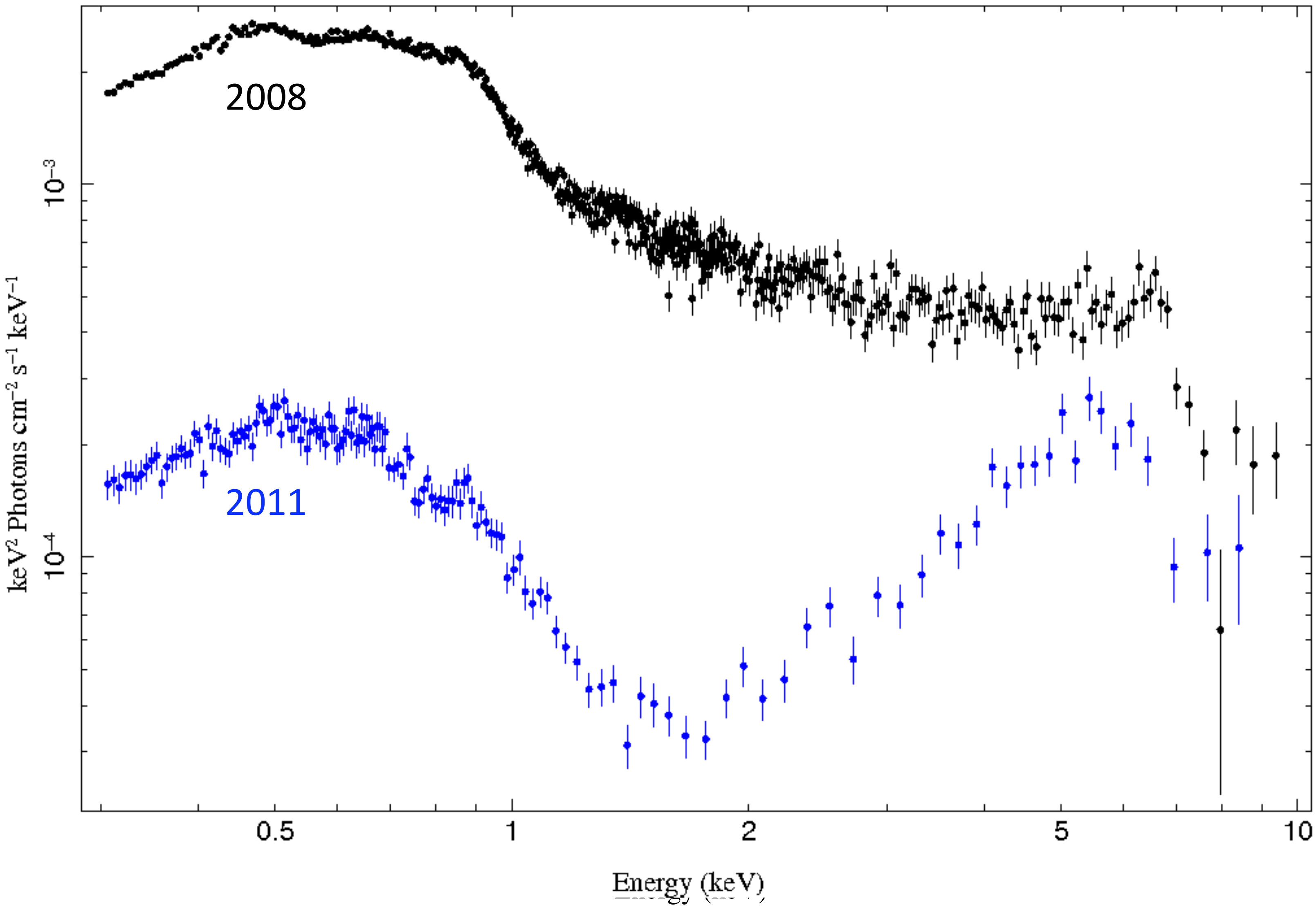


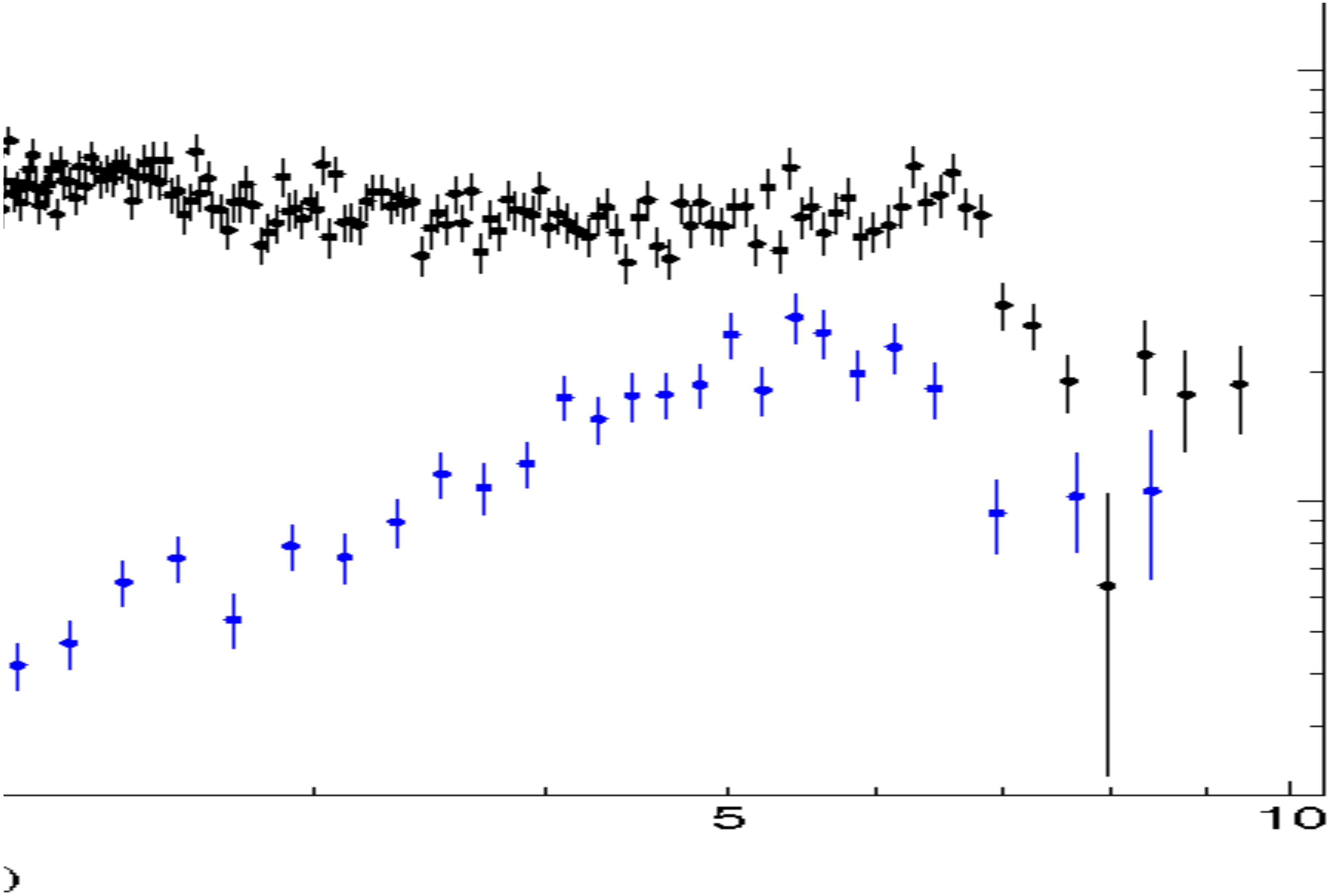
1H0707-495
Ref. stars (w2)
w2
m2
w1
uu
UVOT UVW2 Flux (mJy)
0
0.5
1
1.5
2
1H0707-495
0.5-2keV
2-10keV
XMM
X-ray Flux (10^{-12} erg s^{-1} cm^{-2})
0
2
4
6
8
10
55300
55350
55400
55450
55500
55550
55600
55650
MJD (days)

XMM observation PI N. Schartel

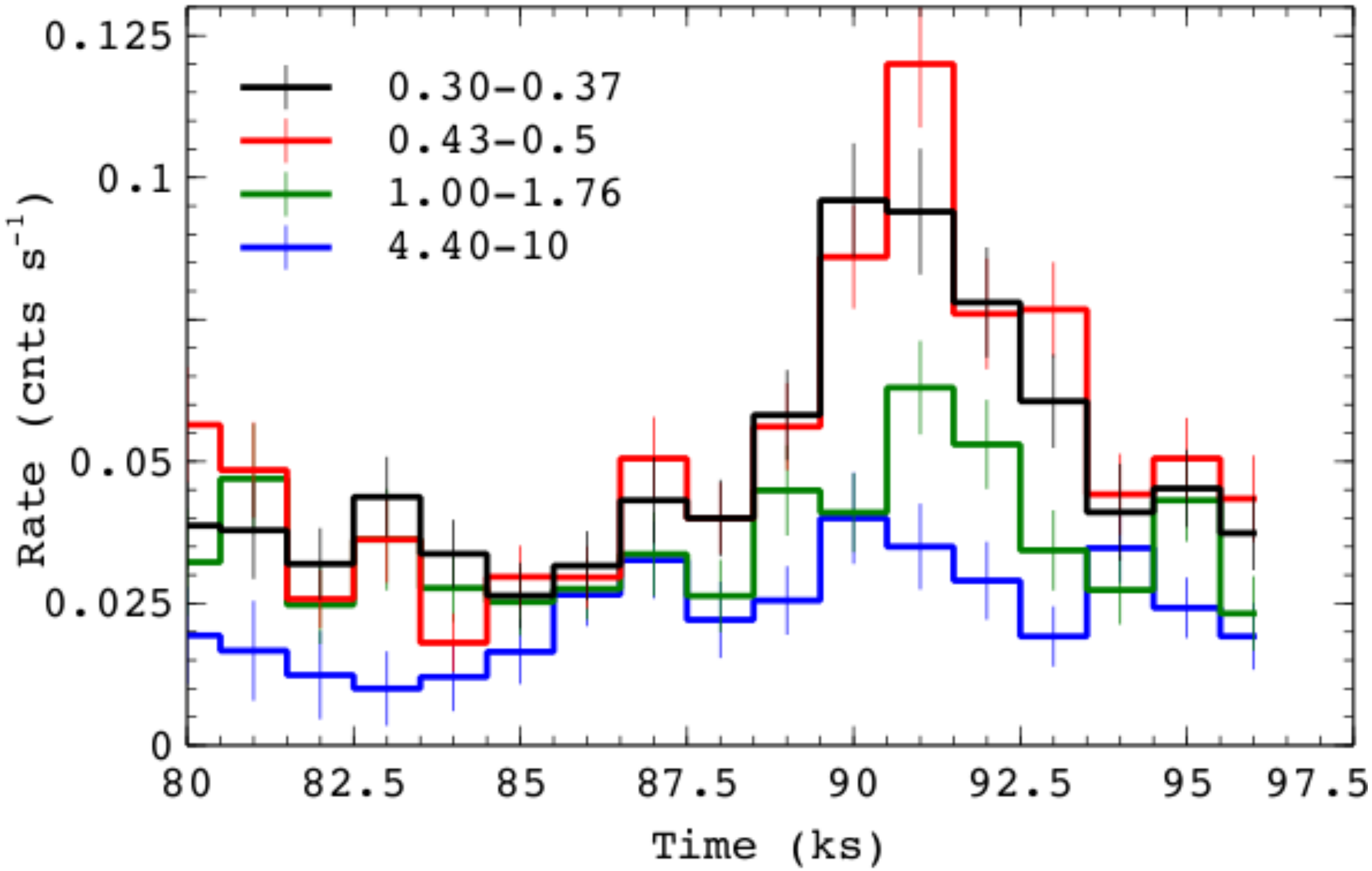


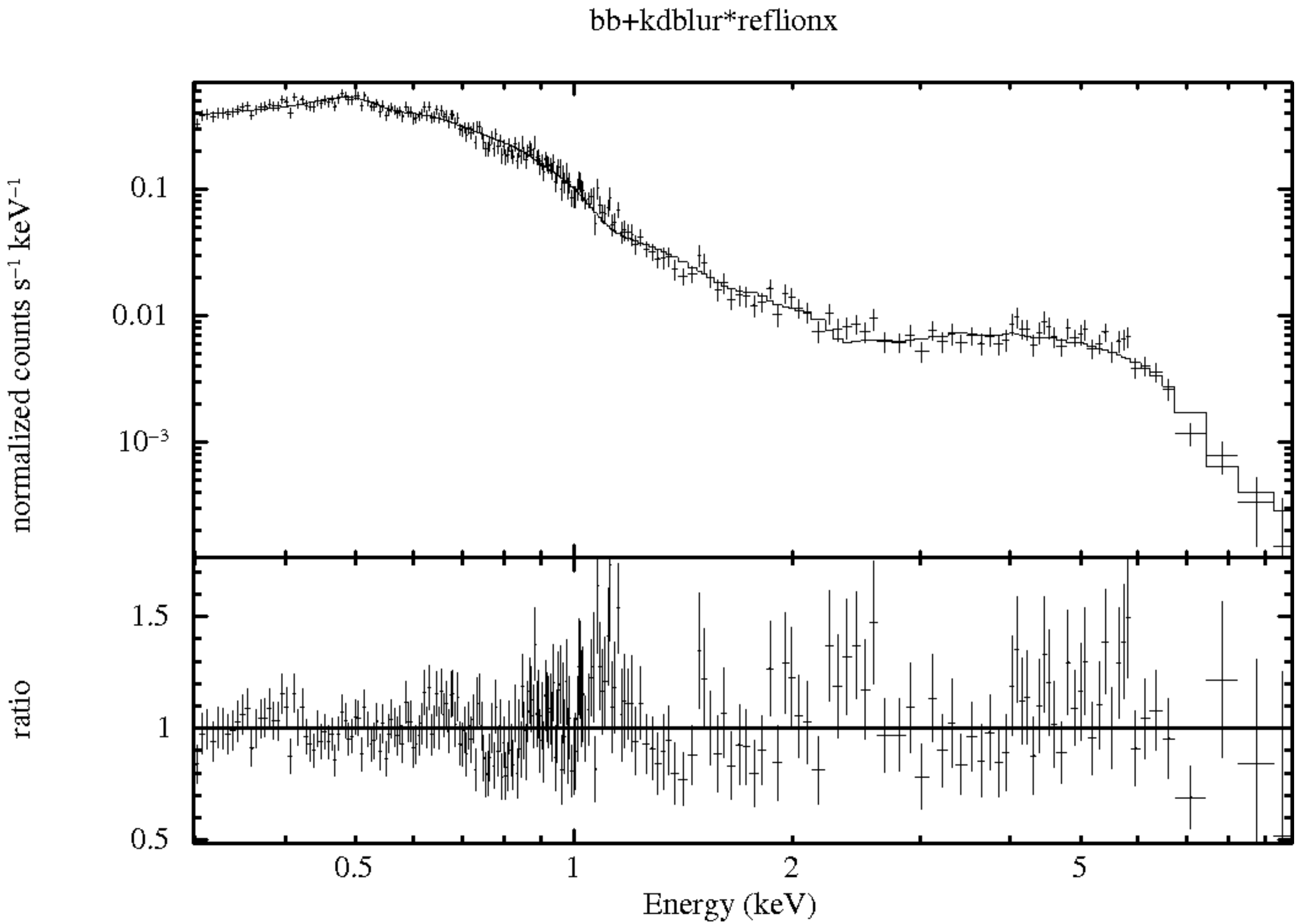
XMM observation PI   N. Schartel

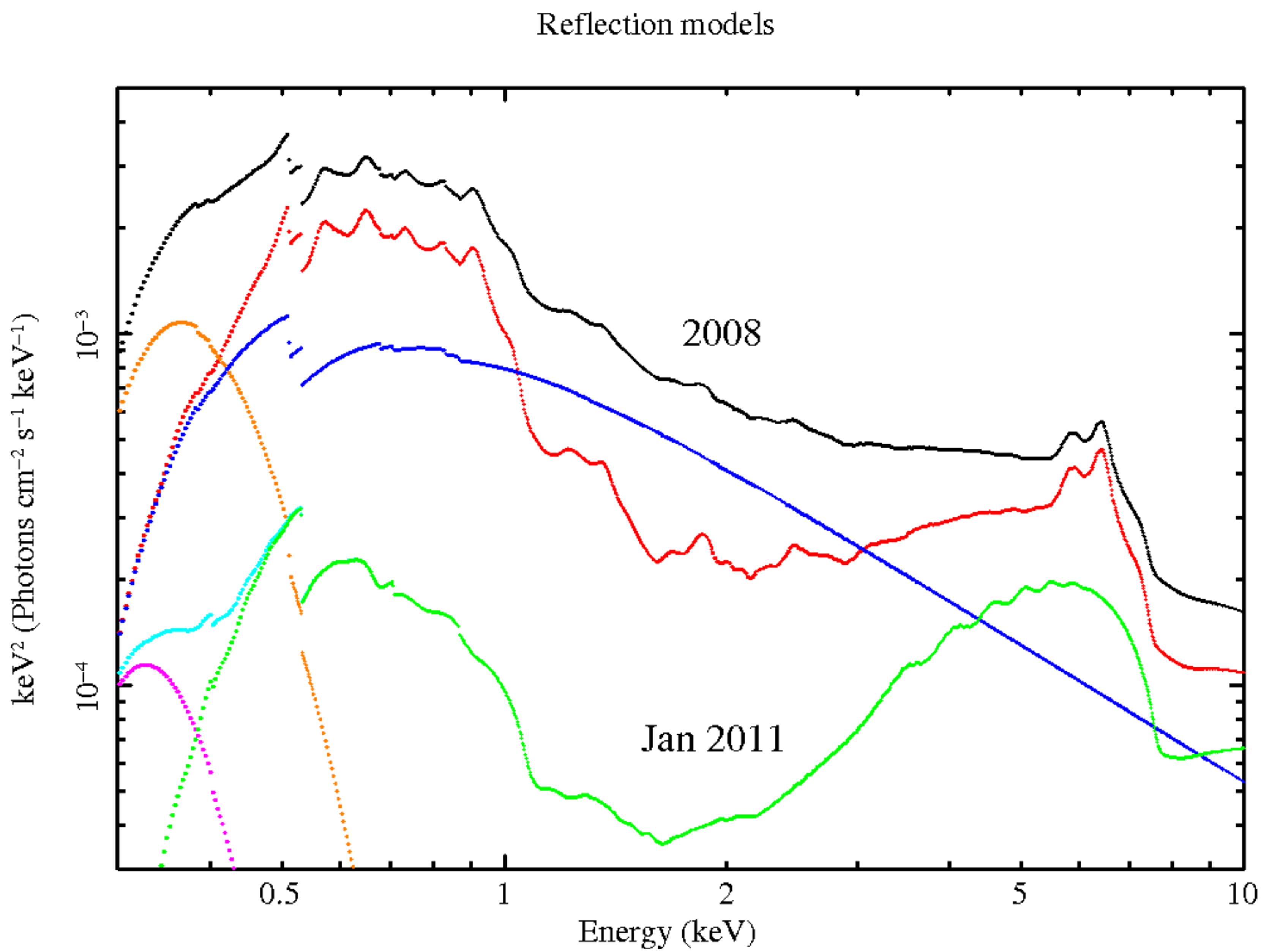




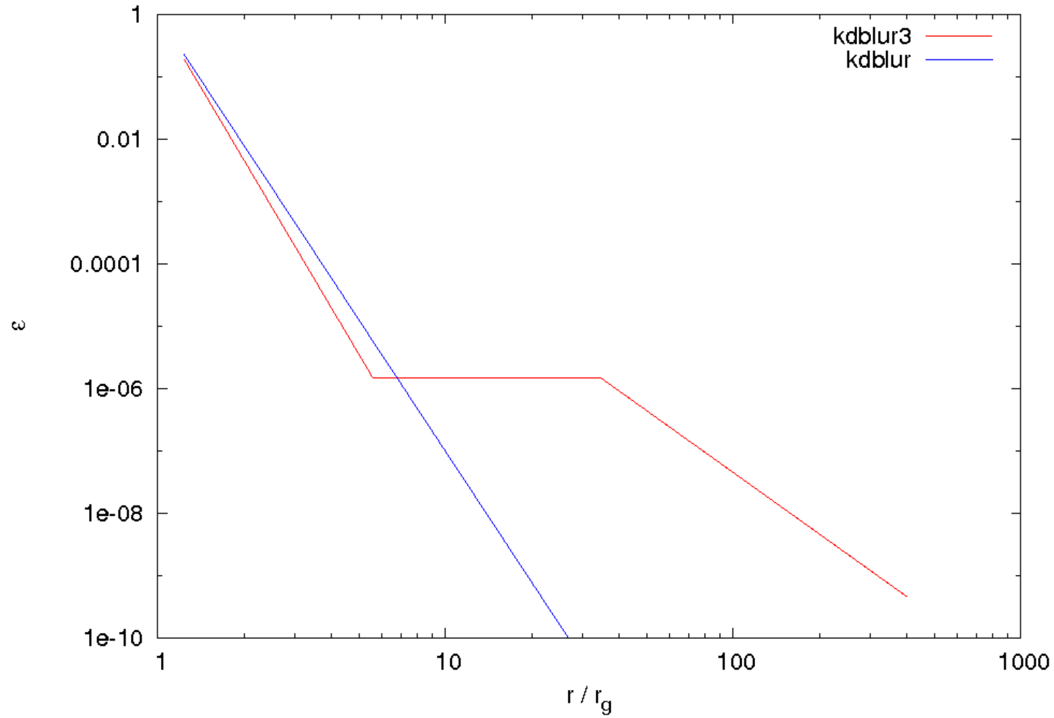
5
10
)

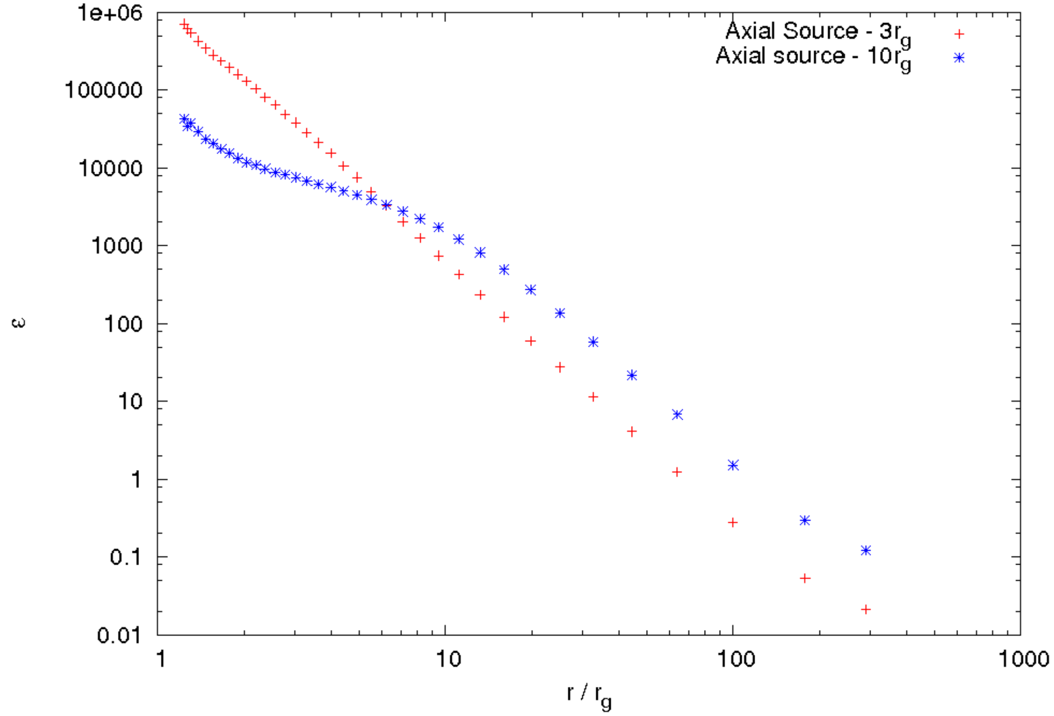

0.30-0.37
0.43-0.5
1.00-1.76
4.40-10
Rate (cnts s^{-1})
Time (ks)
0.125
0.1
0.05
0.025
0
80
82.5
85
87.5
90
92.5
95
97.5


bb+kdblur*reflionx
normalized counts s⁻¹ keV⁻¹
0.1
0.01
10⁻³
ratio
1.5
1
0.5
0.5
1
2
5
Energy (keV)



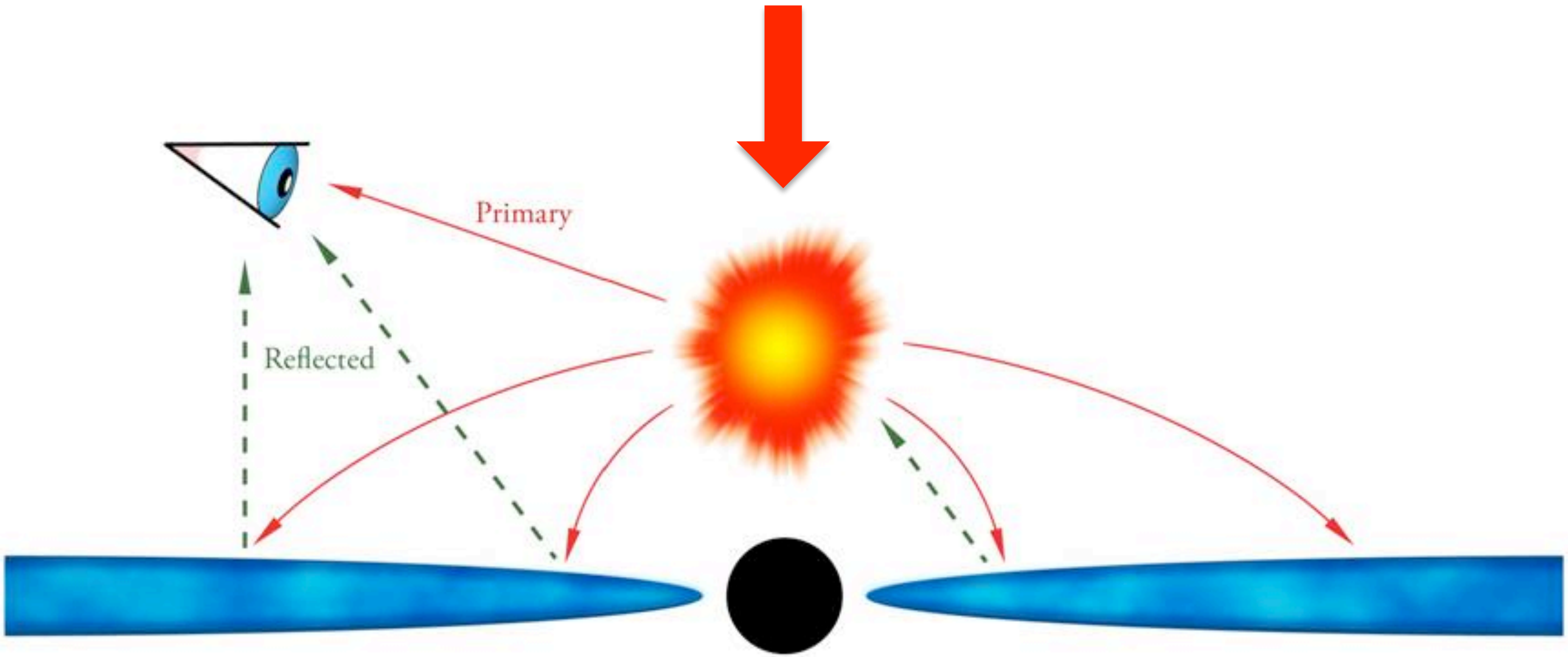
Reflection models
2008
Jan 2011
keV² (Photons cm⁻² s⁻¹ keV⁻¹)
10⁻³
10⁻⁴
0.5
1
2
5
10
Energy (keV)



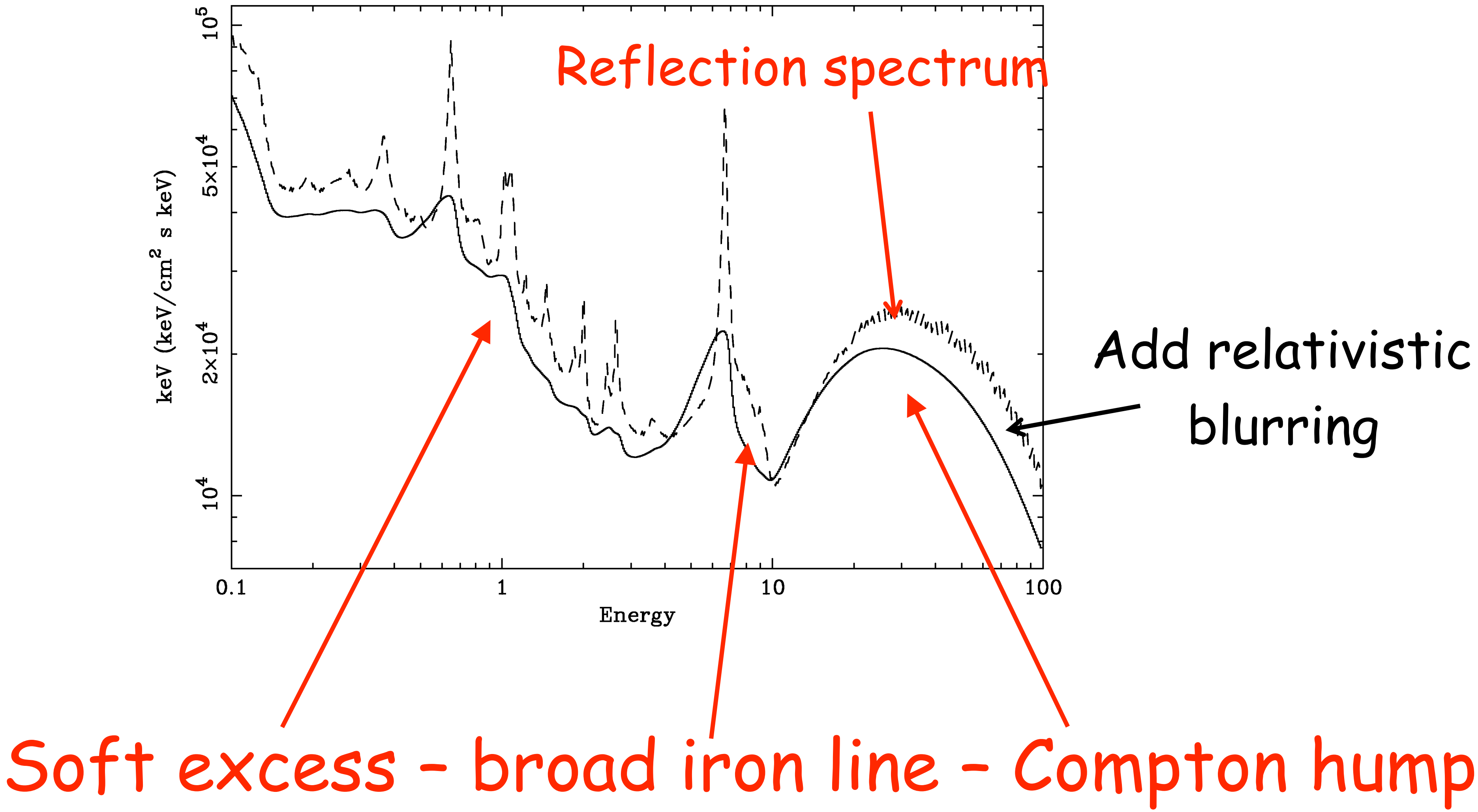


Behaviour consistent with powerlaw source moving closer to the BH

D. Wilkins
In progress

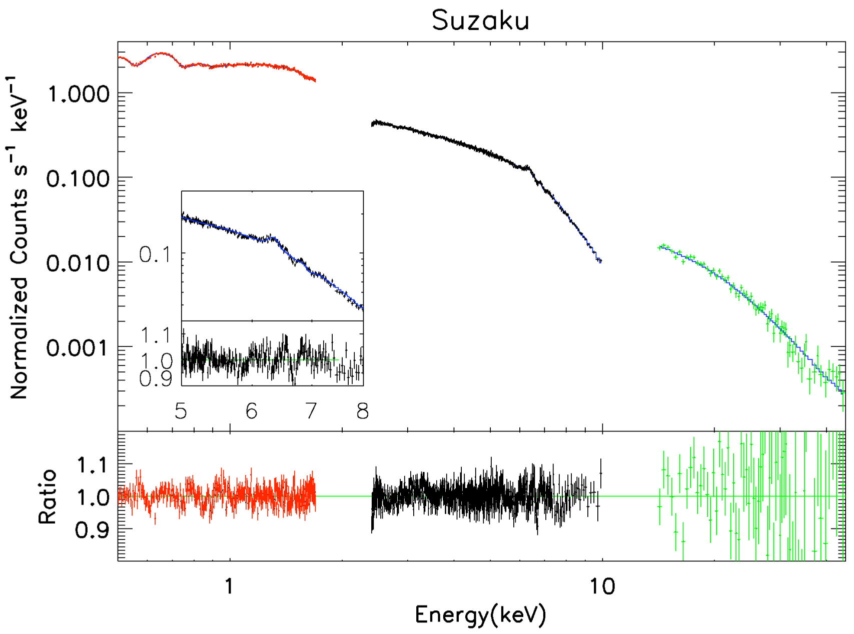

Primary
Reflected

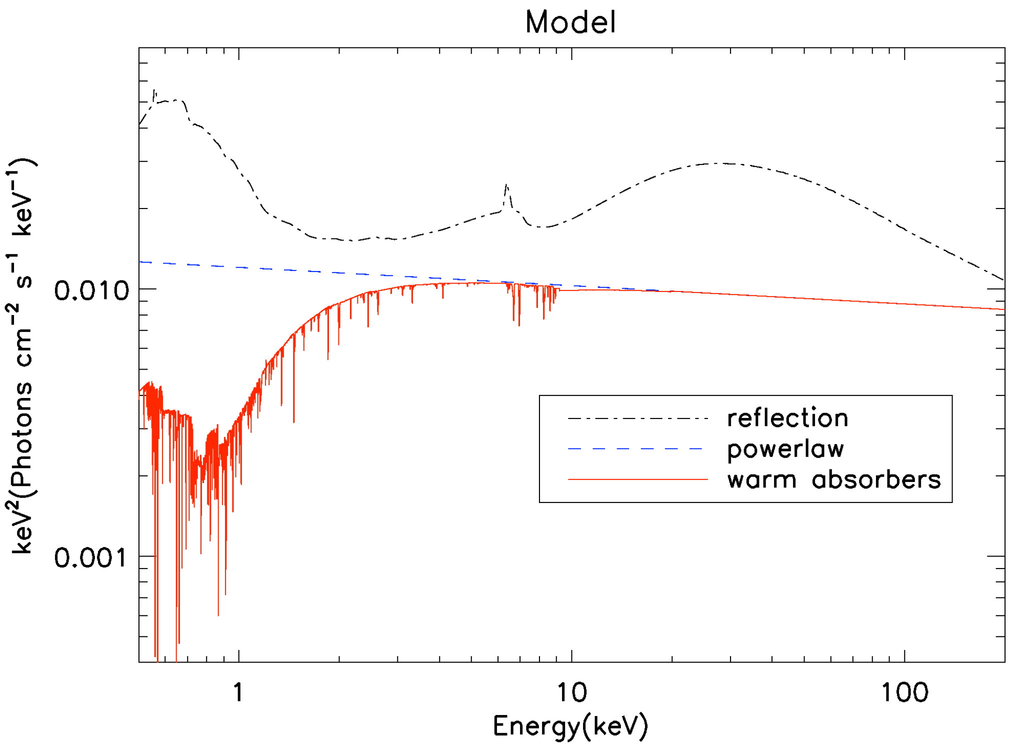
Blurred reflection is standard ingredient in accreting BH



MCG-6-30-15 Chiang+Fabian11

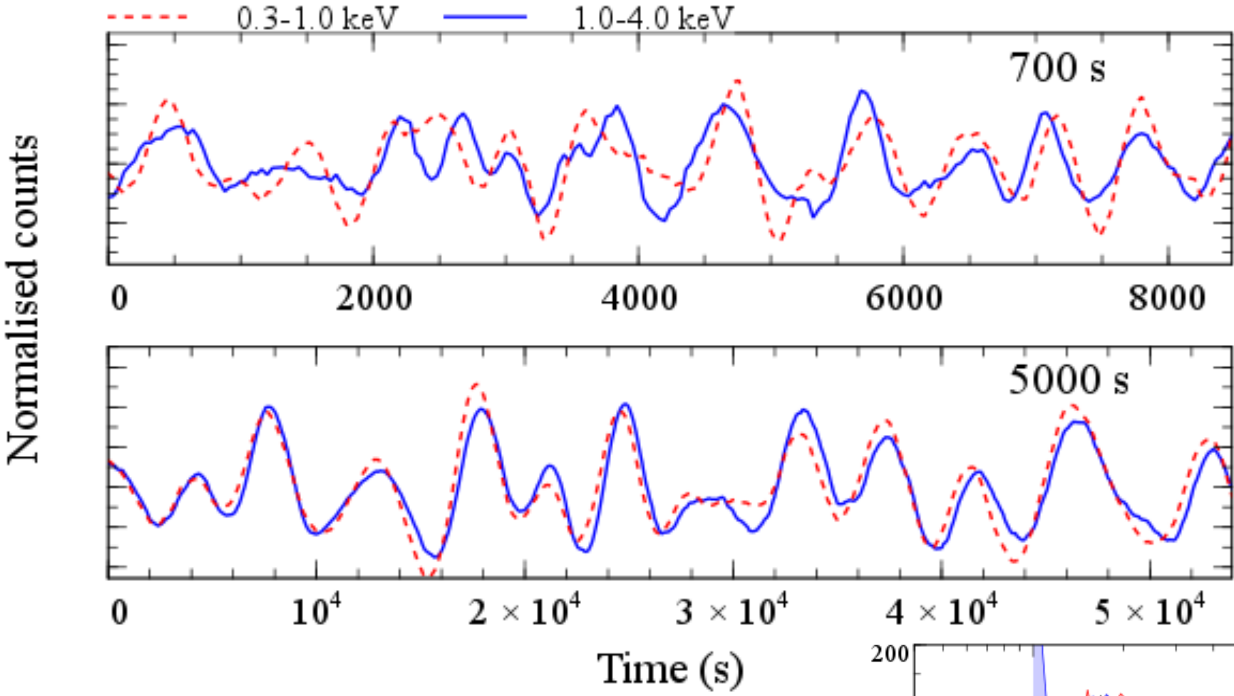
see poster outside

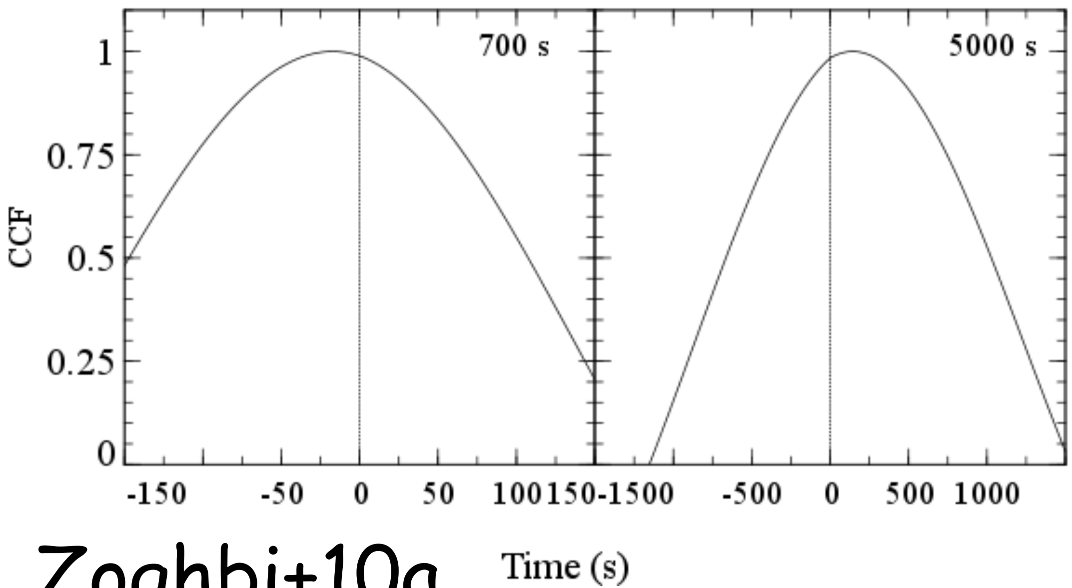


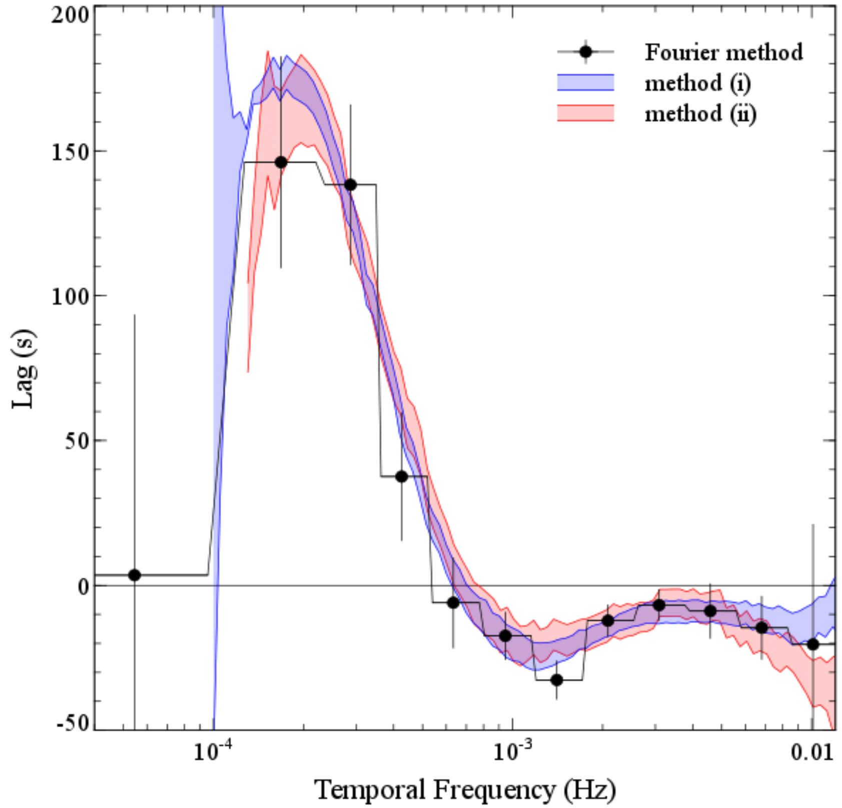


Summary

- (Some) NLS1 are extreme X-ray sources
- Consistent physical explanation for behaviour of 1H0707-495, one of the most extreme objects, involves a steep power-law continuum originating just a few gravitational radii from a rapidly spinning black hole
- Such a model may be relevant to other NLS1

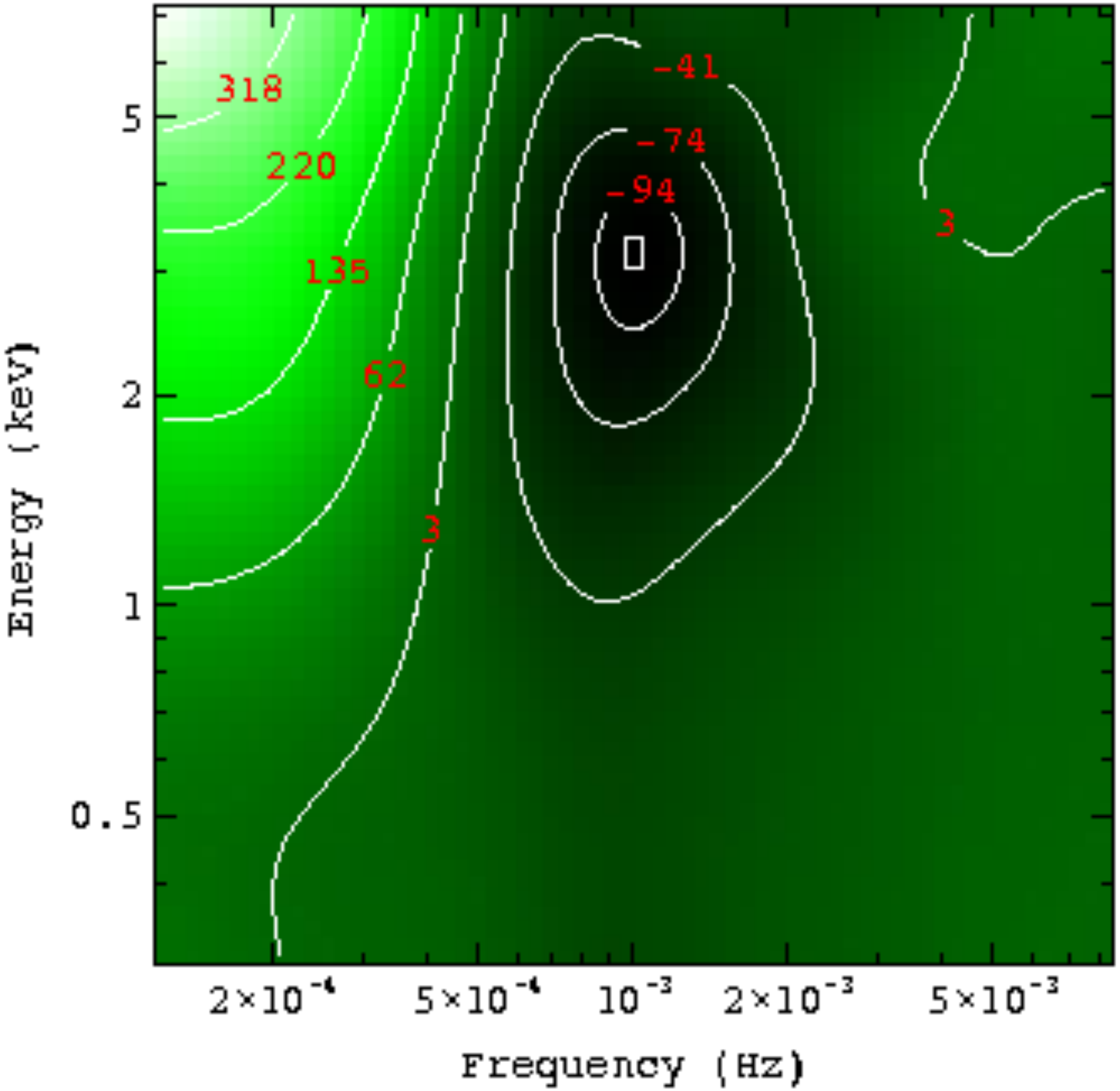

0.3-1.0 keV
1.0-4.0 keV
700 s
5000 s
Normalised counts
0
2000
4000
6000
8000
0
10^4
2×10^4
3×10^4
4×10^4
5×10^4
Time (s)


CCF
1
0.75
0.5
0.25
0
700 s
5000 s
-150
-50
0
50
100
150
-1500
-500
0
500
1000
Time (s)

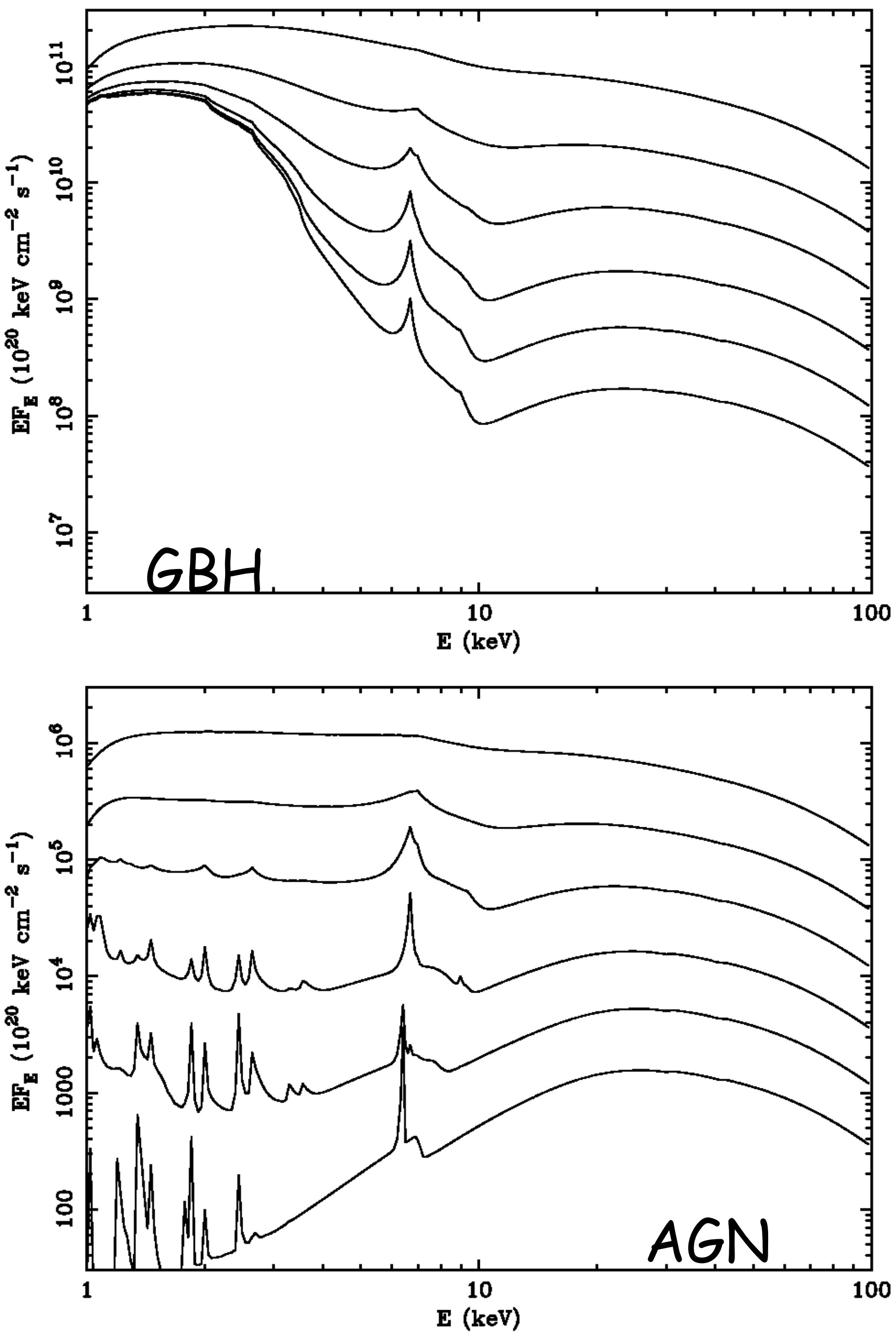

Fourier method
method (i)
method (ii)
Lag (s)
200
150
100
50
0
-50
10^{-4}
10^{-3}
0.01
Temporal Frequency (Hz)

Zoghbi+10a

- Exploring the frequency-energy axes.

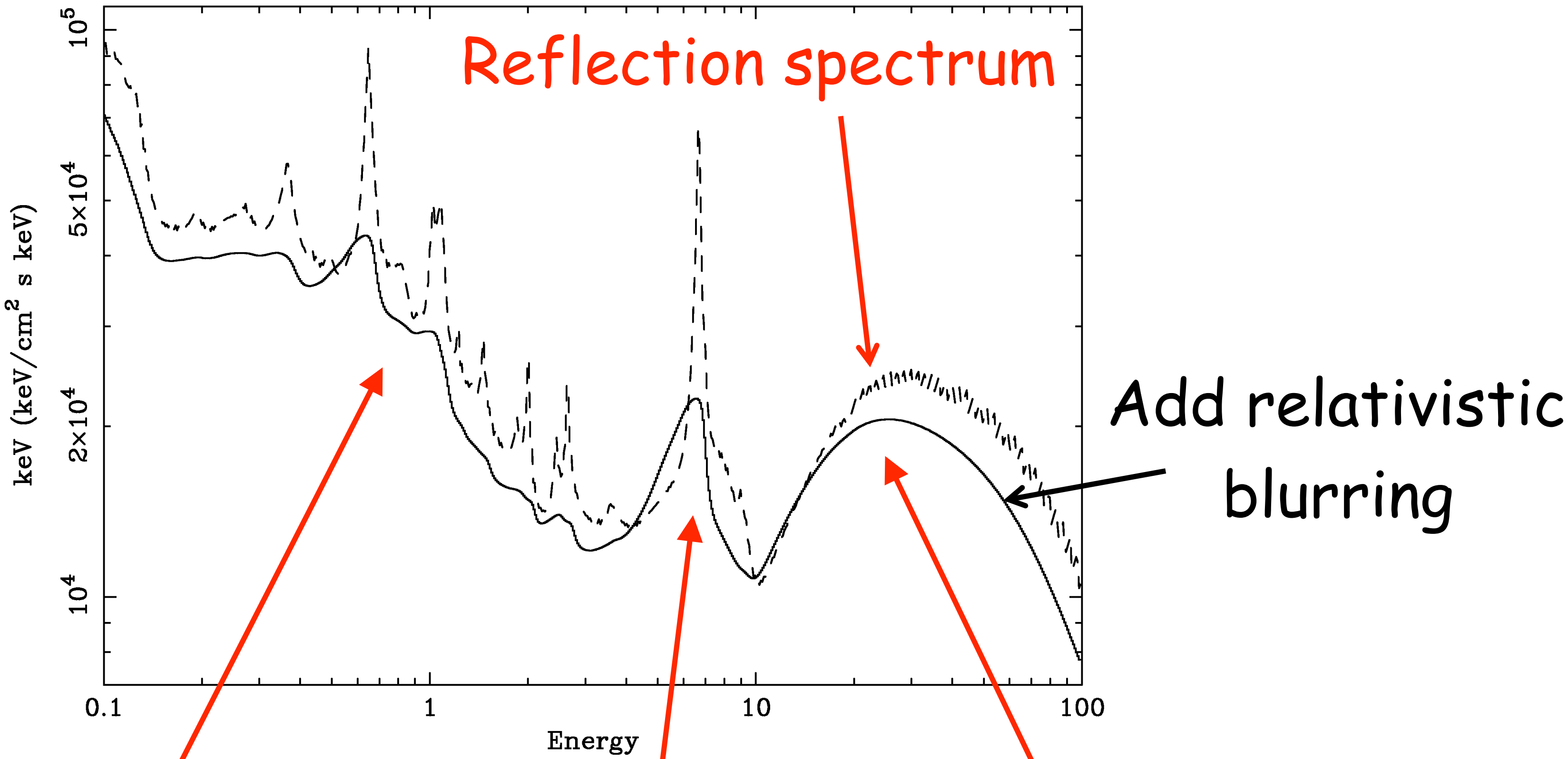


Galactic BH:
Disk hot, so line
Comptonized



Ross+Fabian07

Reflection in accreting BH



Soft excess - broad iron line - Compton hump