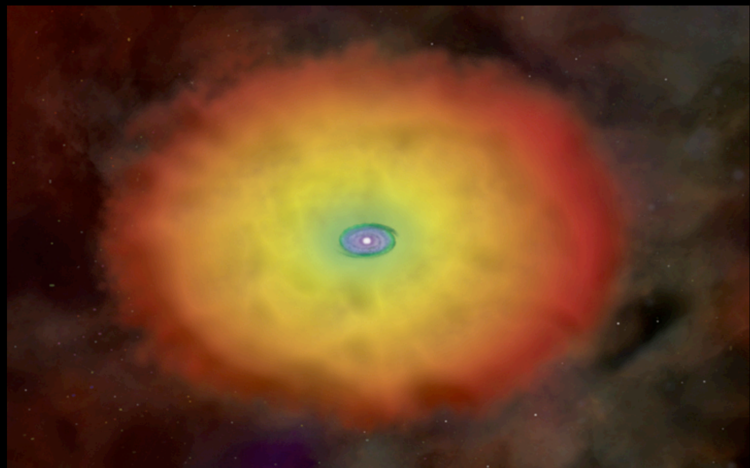
An explanation for the soft X-ray excess in AGN



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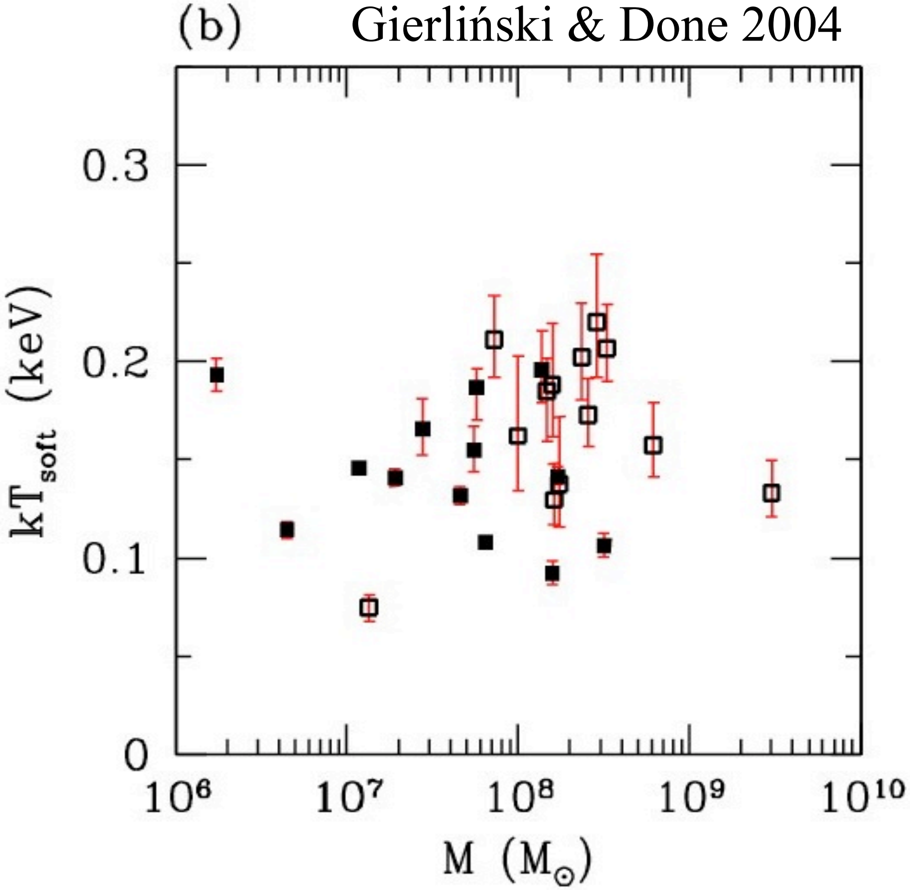
Suzaku Team

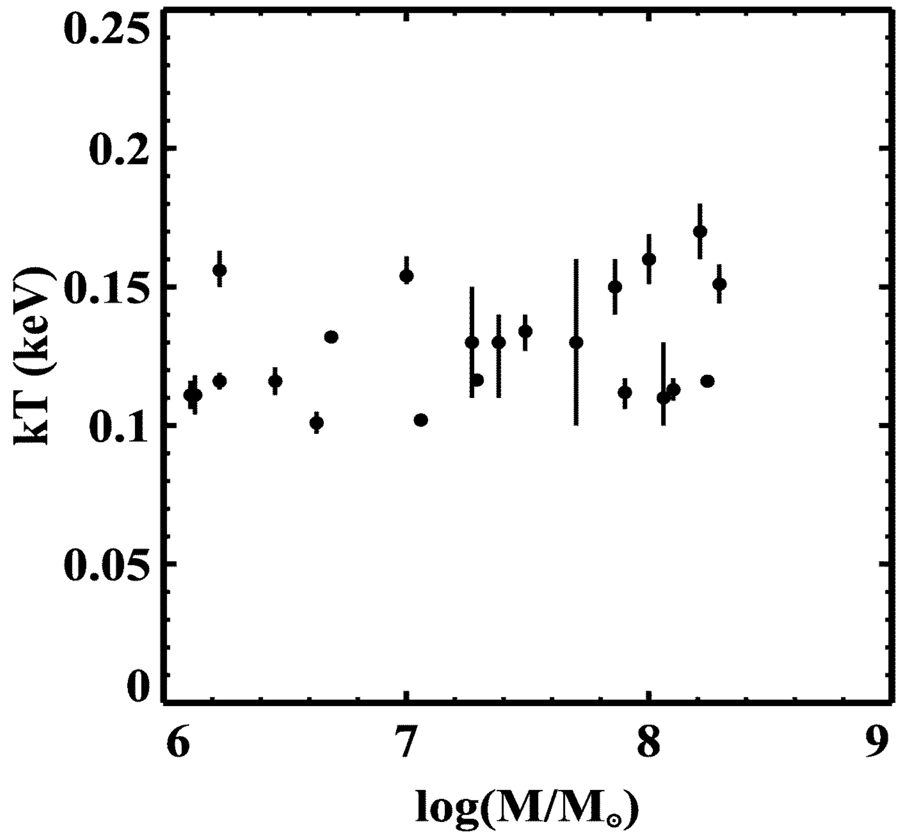
Soft excess

The soft excess is at a constant temperature over a large range in quasar characteristics, as shown by Walter and Fink (1993), Czerny et al. (2003), Gierliński and Done (2004), Porquet et al. (2004).... Our survey shows similar behaviour.

Gierliński & Done 2004



Crummy et al. 2006



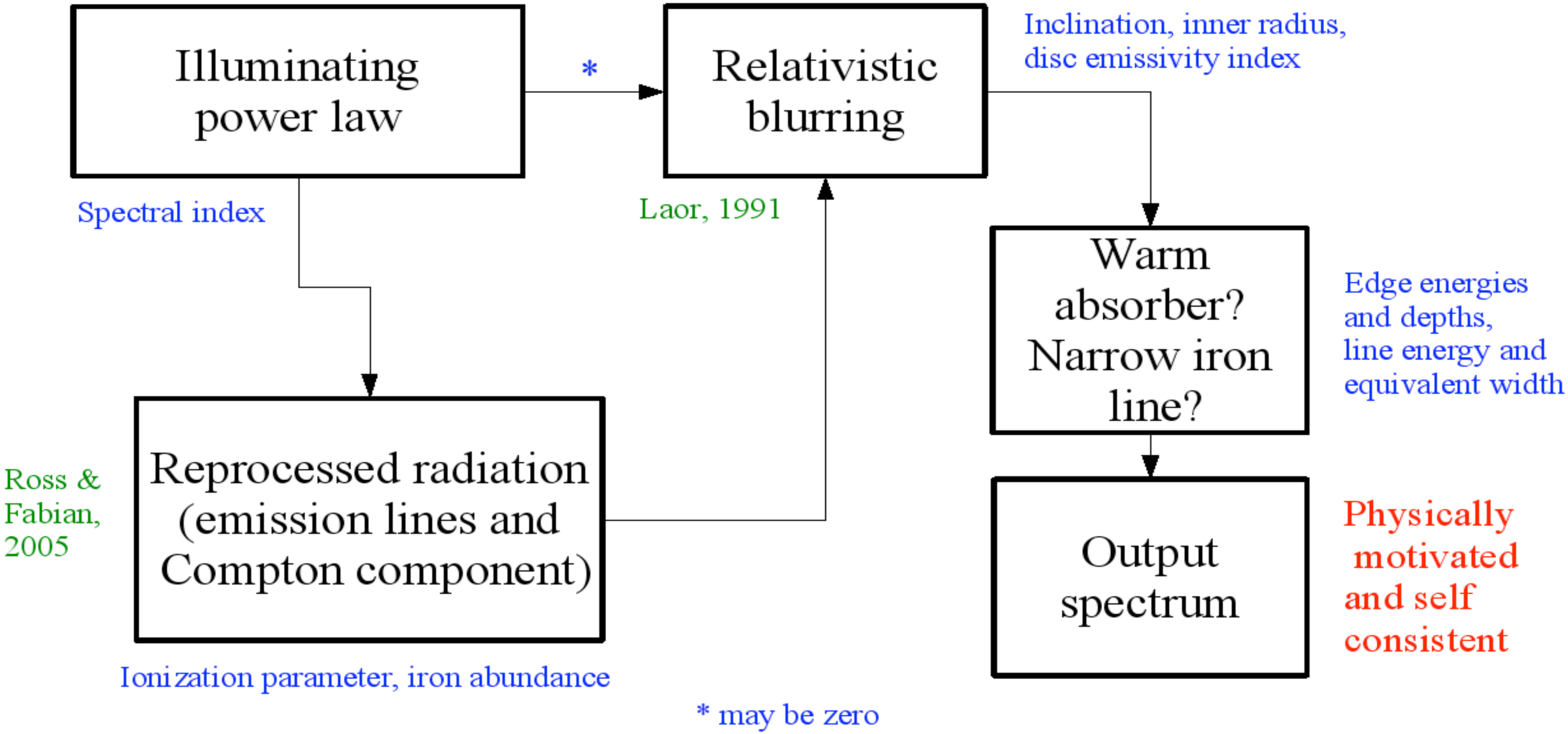
Analysis

Fitting two models in xspec. We also model any extra cold absorbing continuum local to the source.

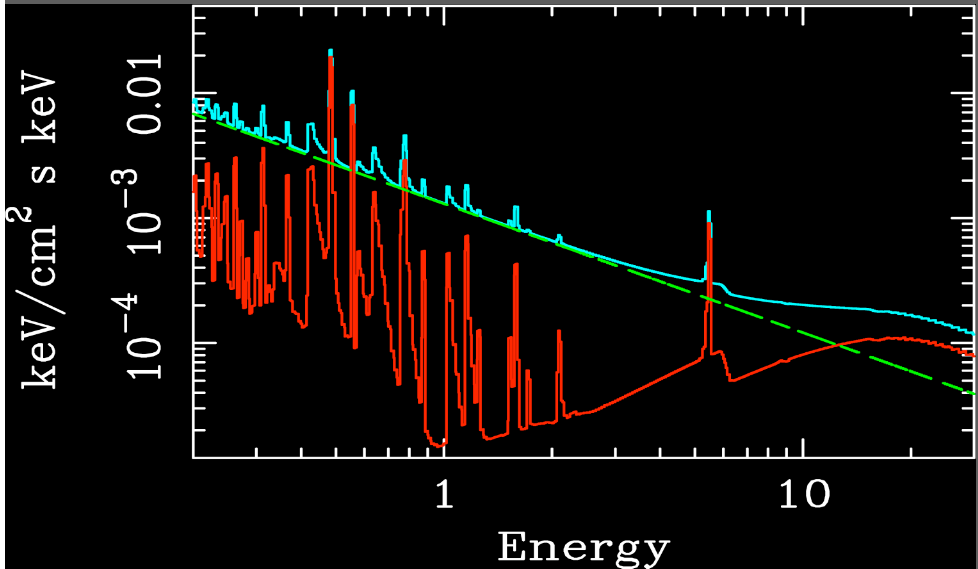
- Power law
- P.L. + black body — Soft Excess
- P.L. + B.B. + absorption edges — Warm Absorber
- P.L. + B.B. + edges + Gaussian — Iron Emission
- Relativistically blurred photoionized disc
- Disc + edges
- Disc + edges + Gaussian

Relativistically blurred photo-ionized disc model

Degrees of freedom – not very many

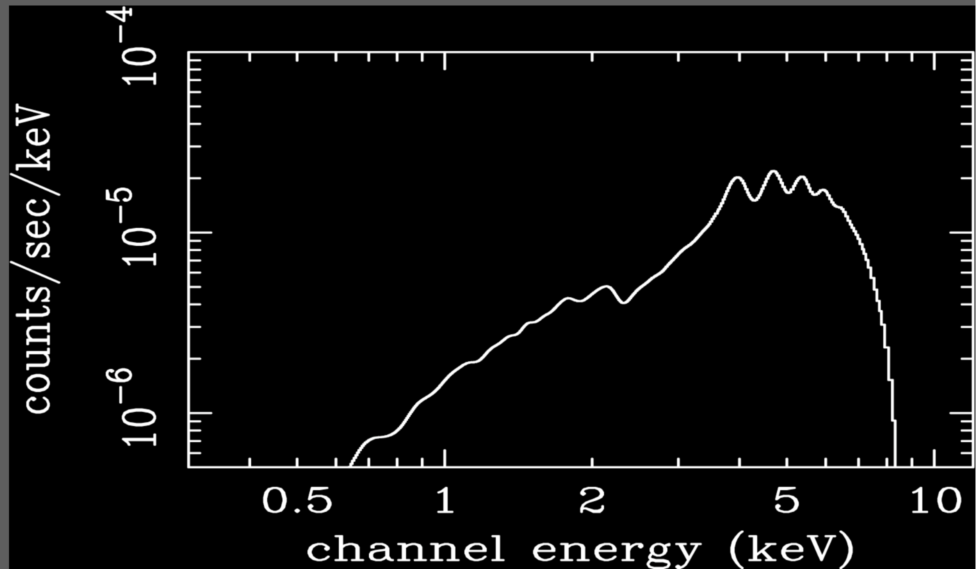


Relativistically blurred photo-ionized disc model (part 2)



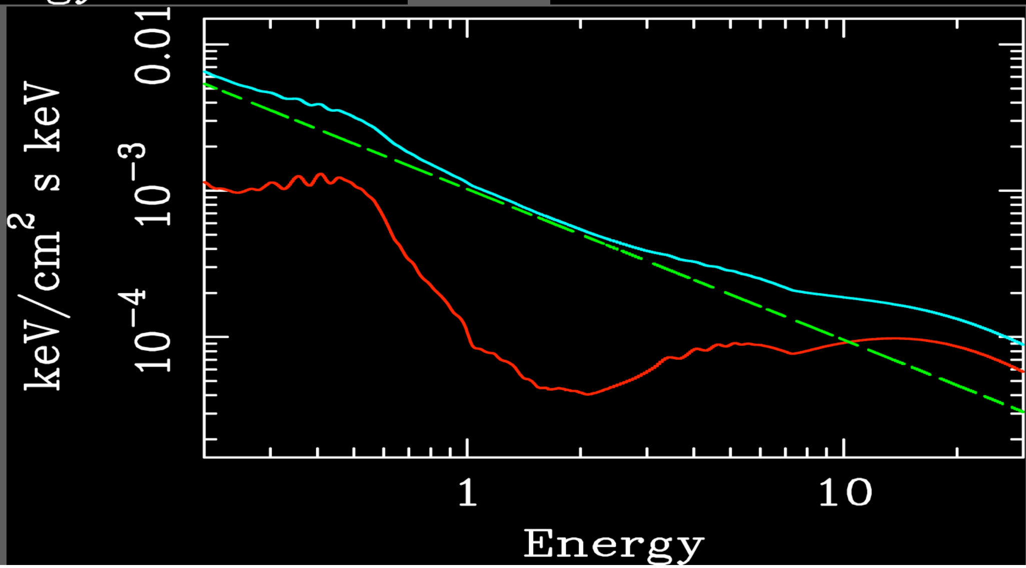
Reflection and power law

*



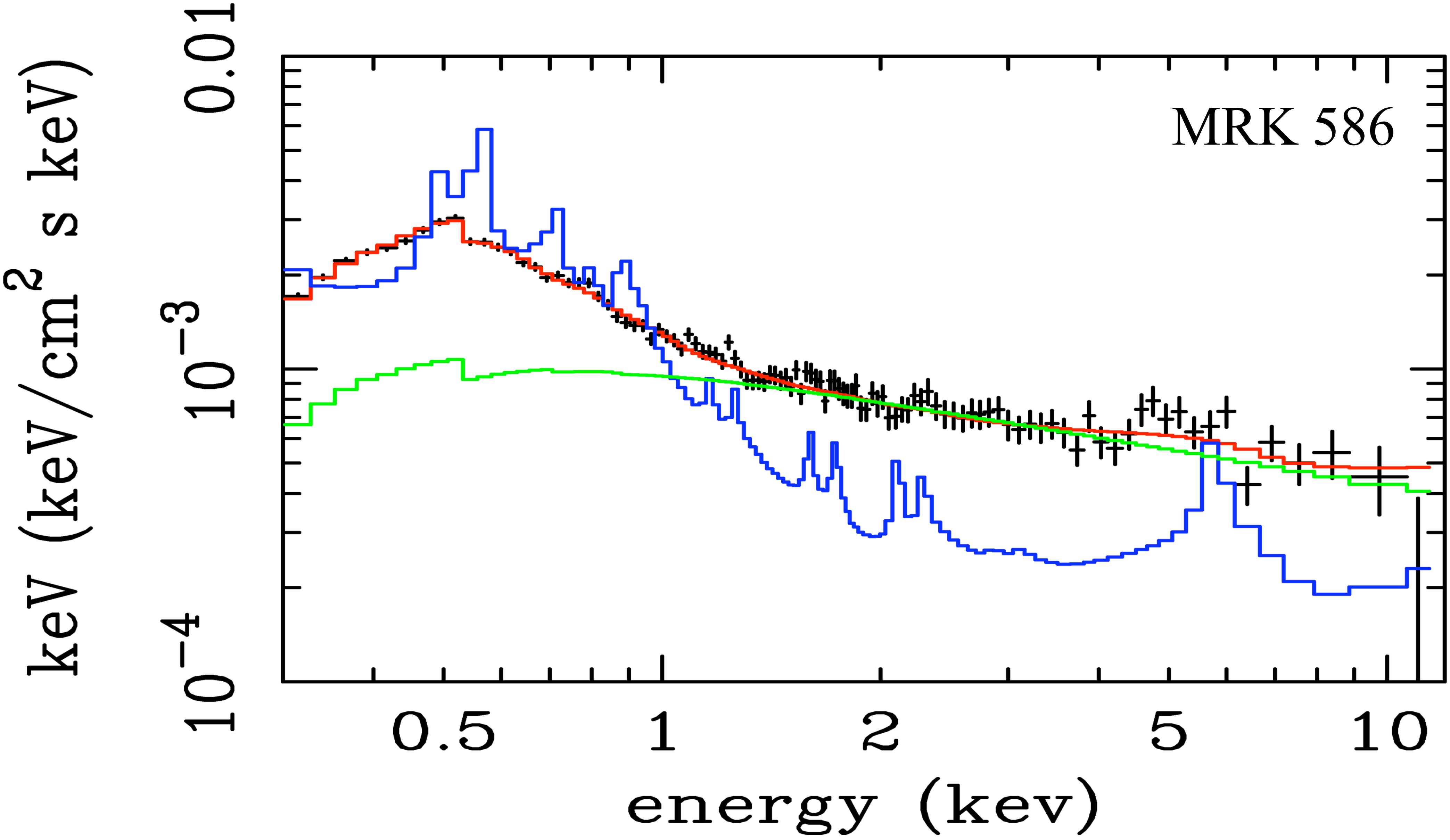
Laor line

=

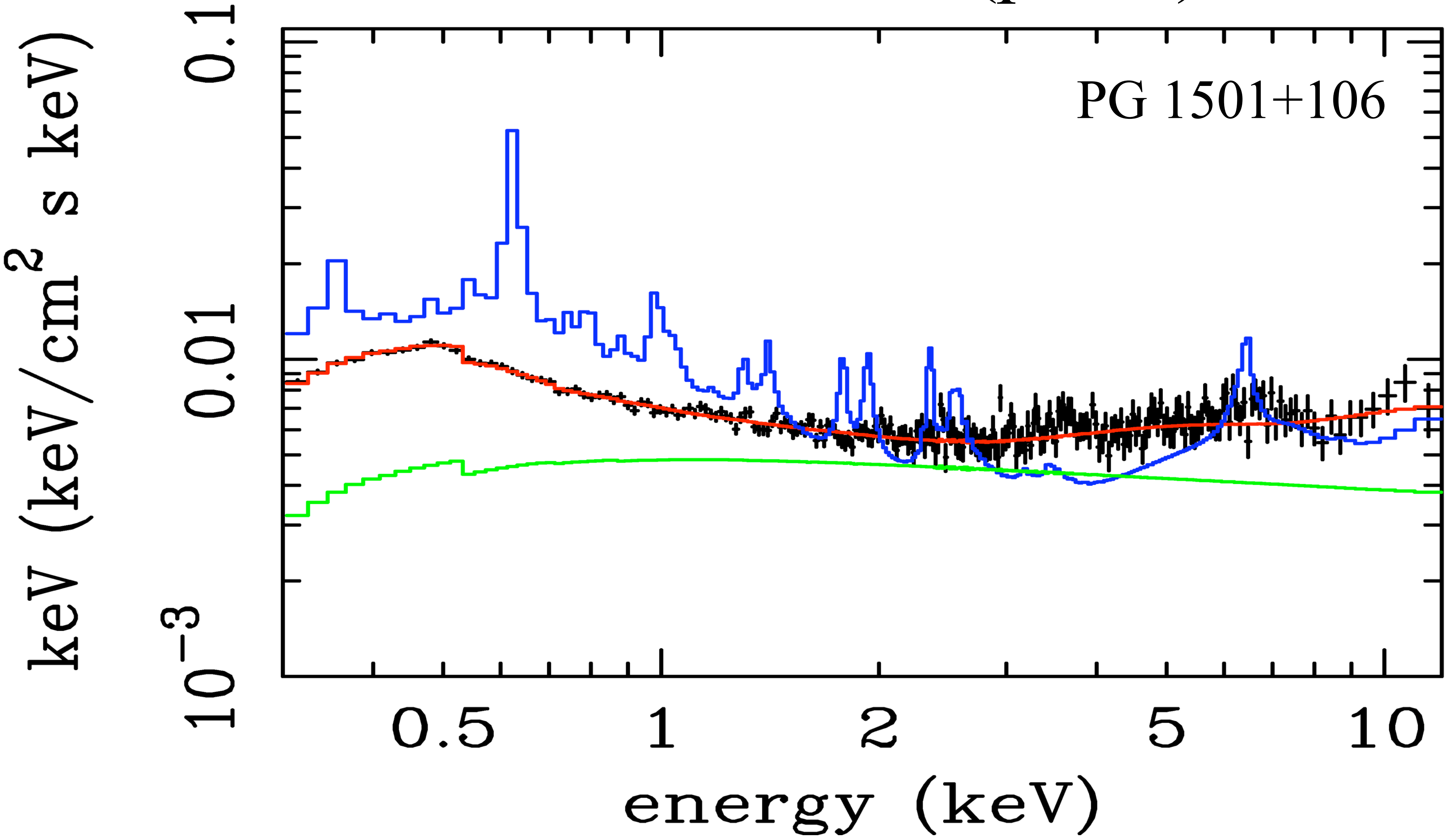


PG 1202+281

Relativistically blurred photo-ionized disc model fits

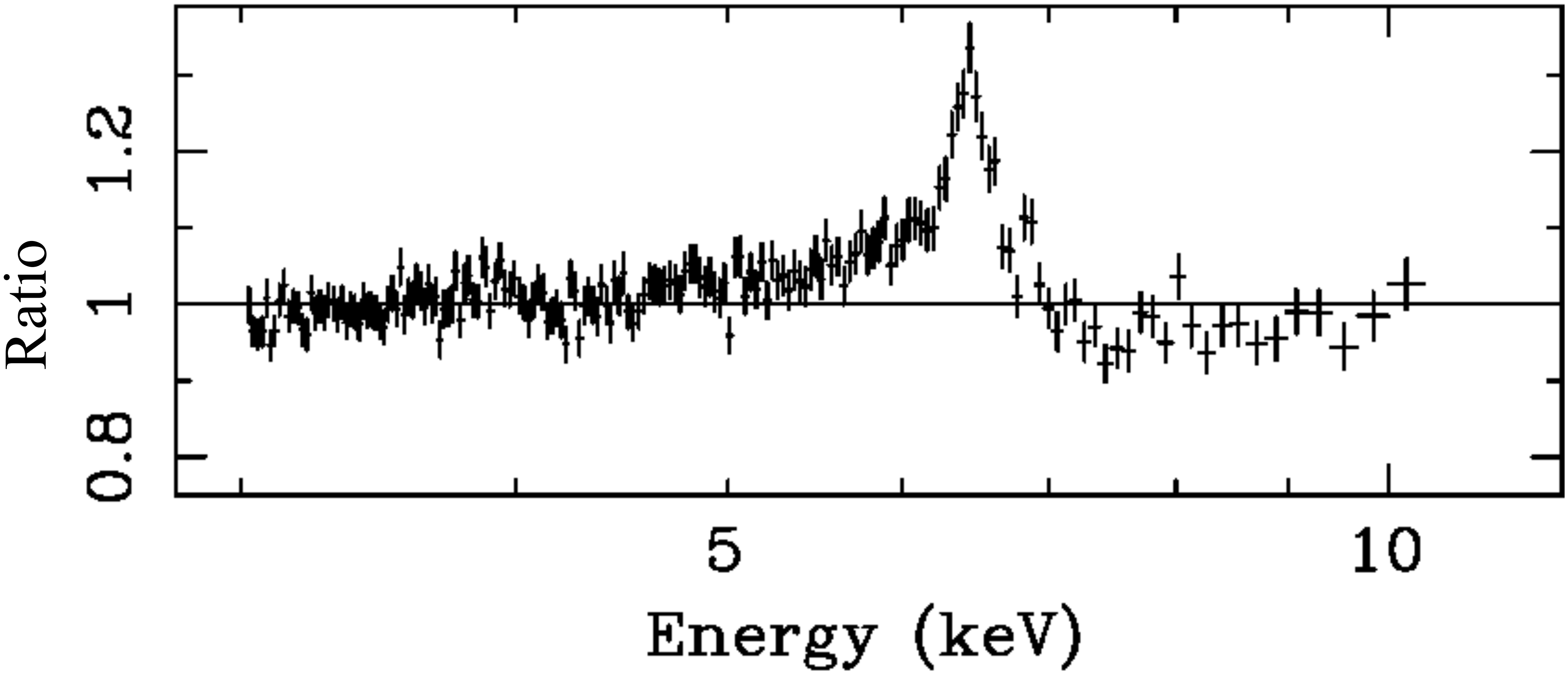


Relativistically blurred photo-ionized disc model fits (part 2)



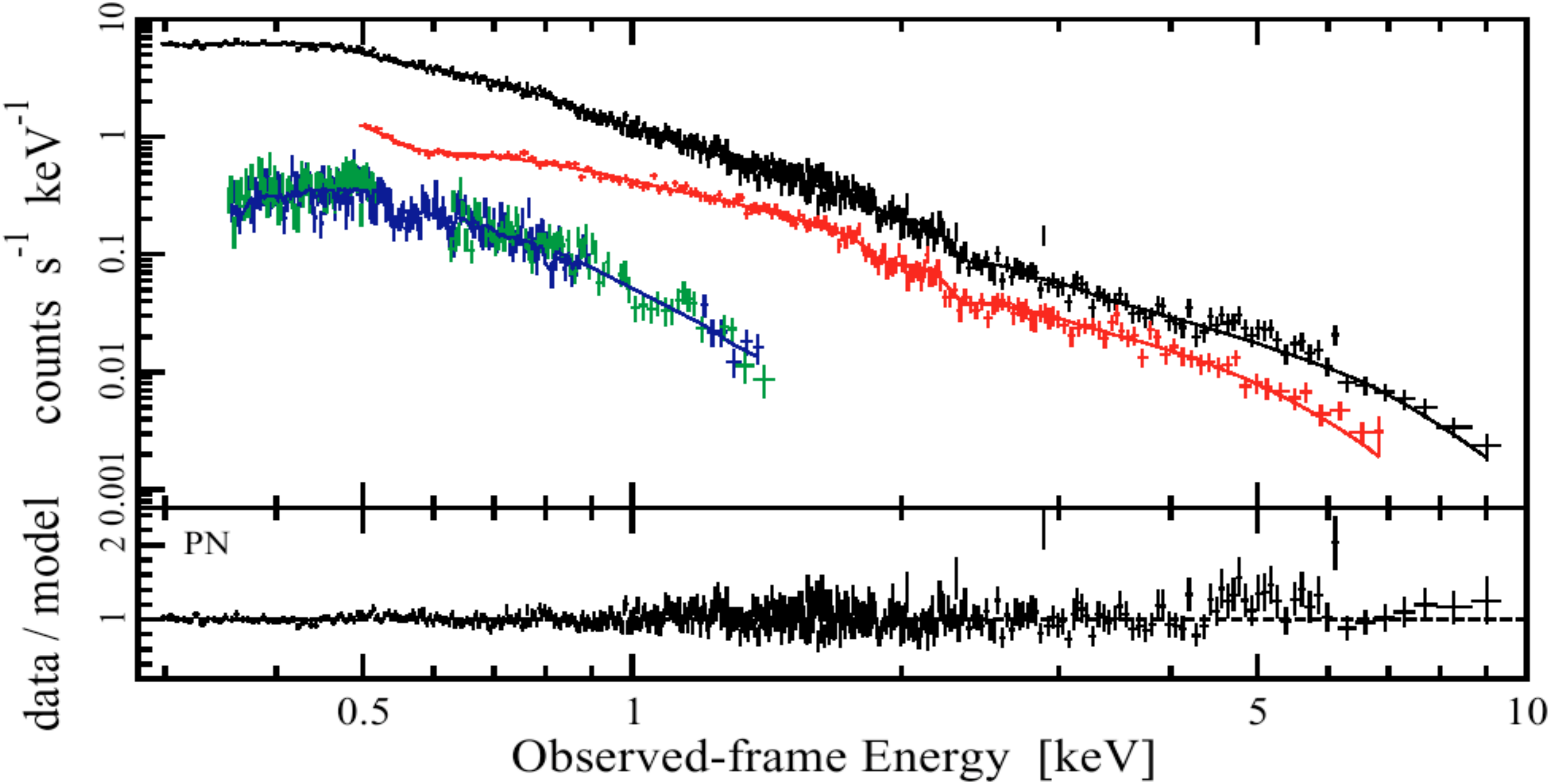
Iron lines

MCG –6-30-15 iron line from XMM (Vaughan and Fabian 2004)



"Broad relativistic lines were detected in three objects, less than 10% of the QSOs in the sample" - Jiménez-Bailón et al. 2005

Iron lines (part 2)



MRK 586 (NAB 0205+02) from Gallo et al. 2004. Power law and black body model. Residuals consistent with a Laor iron line.
Soft excess consistent with the iron line.

Relativistically blurred photo-ionized disc model results

- Naturally explains "soft excess" and its constant temperature
- Explains some spectral features that could otherwise be interpreted as absorption edges
- Explains the apparent absence of broad iron lines in most quasars
- Explains all major spectral features of all quasars surveyed*

*when you add necessary edges and cold iron lines to account for gas in the line of sight and a torus

Relativistically blurred photo-ionized disc model vs simple model

- In 11 of 34 sources there is no power law component, in these sources the blurred reflection component entirely reproduces the spectrum
- Warm absorber in only 7 of 34 sources, vs 18 of 34 for simple model
- Average reduced chi-squared of 1.06 compared to 1.13 for simple model, 27 of 34 sources show an improved fit – the disc model is a better fit to the data

Reflection component or reflection dominated

When we measure the amount of flux coming from the reflection component as a fraction of the total flux ("flux fraction"), we seem to find two populations. 2/3 of the sources have a flux fraction 0.25-0.8, 1/3 have a flux fraction of 1 (0.98<). How can the disc be illuminated by light we can't see?

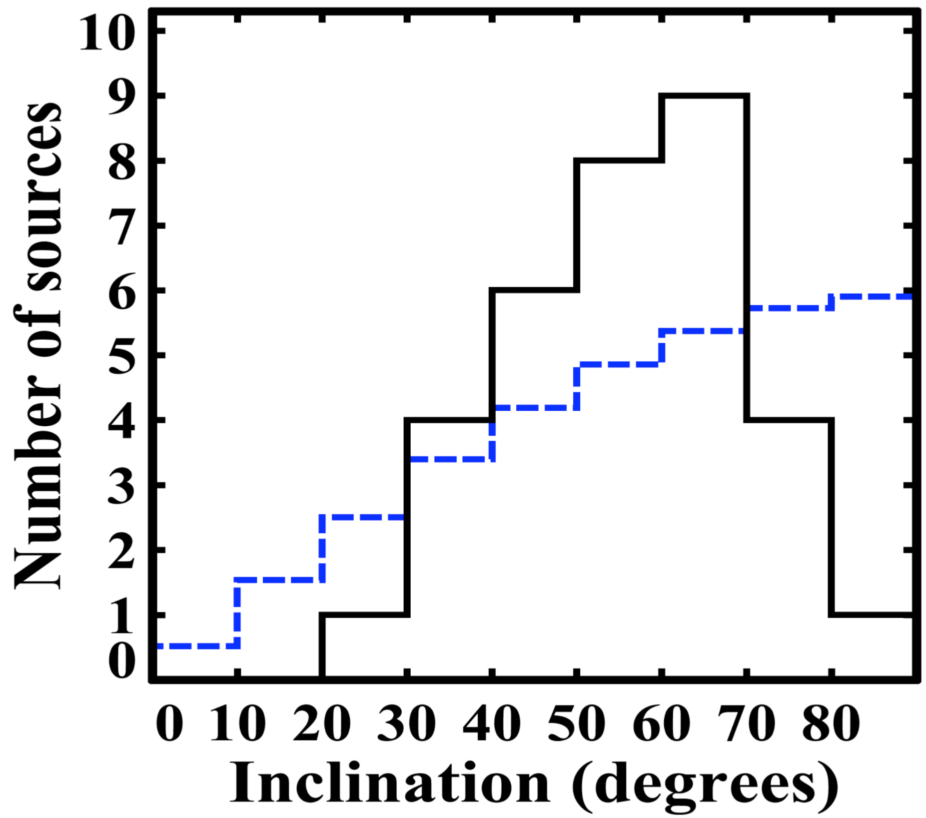
- Data quality problems – eliminated, but small sample size
- Obscuration of the power-law source – odd setup
- Extreme light bending – an X-ray source close to a black hole, above the plane of the disc has most of its radiation bent onto the disc by the hole's gravity
- Clumpy accretion disc - Malzac

What can the disc model tell us

Inclinations:

- Clearly different from random
- Spans 20º – 90º
- The deficit above 70º may be due to absorption from a torus. Our sample is type 1 quasars and excludes strongly absorbed sources.

Some support for the unified model.



0º – face on, 90º – edge on
dashed line – random distribution

Caveats:

- Limb darkening affects ionization state and spectral shape
- The disc might not be coplanar with the torus
- Might be a small or no torus

What can the disc model tell us (part 2)

Black hole rotation – the iron line is not the only way to tell:

- Last stable orbit for a non-rotating black hole is 6 gravitational radii, 1.235 gravitational radii for a maximally rotating black hole
- Only 3 sources measured have a measured inner radius consistent with being higher than 6 gravitational radii, all are consistent with an inner radius below that
- 31 of the 34 sources have inner radii below 2 gravitational radii
- Almost all type 1 quasar black holes are strongly rotating

(Streblyanska et al. 2005, Volonteri et al. 2005)

Caveats:

- Maximal rotation is assumed in the blurring profile – a line profile from a non-rotating black hole doesn't fit the data well, black holes are not non-rotating
- Emission may come from inside the last stable orbit - Fabian

Conclusions

- The relativistically blurred photoionized reflection model reproduces the shape of quasar X-ray spectra
- The model explains why the soft excess is always at the same temperature
- The model fits the data better than the simple model
- The model can give us more interesting information than the simple model:
    - Black holes in quasars strongly rotate
    - The inclination of the inner discs can be measured, this may allow the unified model to be refined
    - Some information about emissivity profile available
    - Some AGN are apparently reflection dominated

Reflection and Suzaku

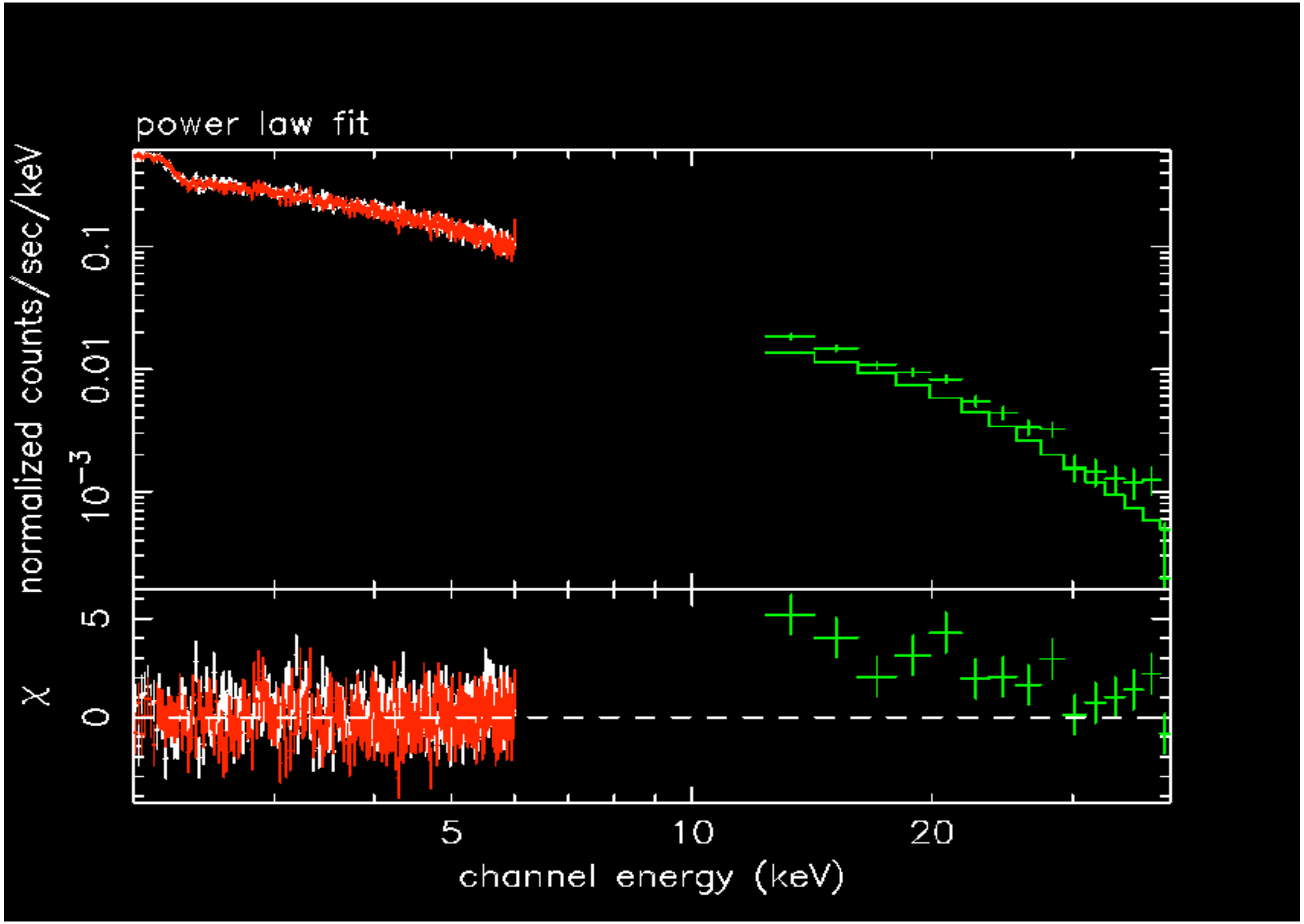
Reflection is clearest in three areas of the spectrum,
all of which are available to Suzaku

Soft excess, below ~2 keV, XIS
The shape, constant "temperature" and rapid variability are all signatures of reflection, present in almost all type 1 AGN spectra. Ambiguous by itself, there are several interpretations.

Iron line, ~6.4 keV, XIS
A relativistic iron line profile is the clearest sign of relativistically blurred reflection. Not present in all AGN spectra, either from absence of reflection or extreme blurring – extreme blurring which affects the soft excess shape.

Compton hump, around ~20 keV, HXD PIN
Variability implies reflection from near the black hole, the intrinsic width of the feature makes broadening very difficult to measure.

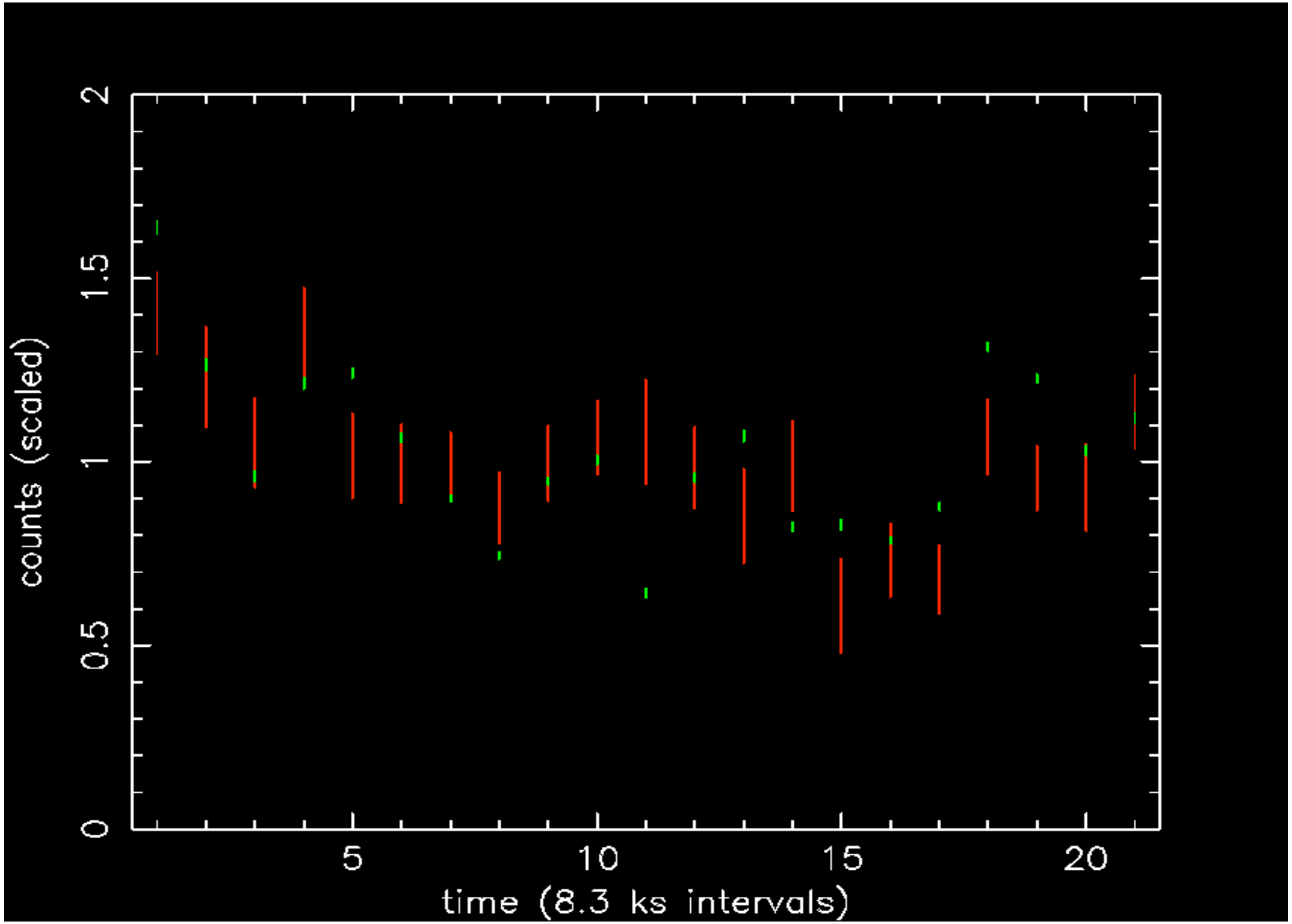
MCG -6-30-15



Power law fit,
2-6 keV and PIN

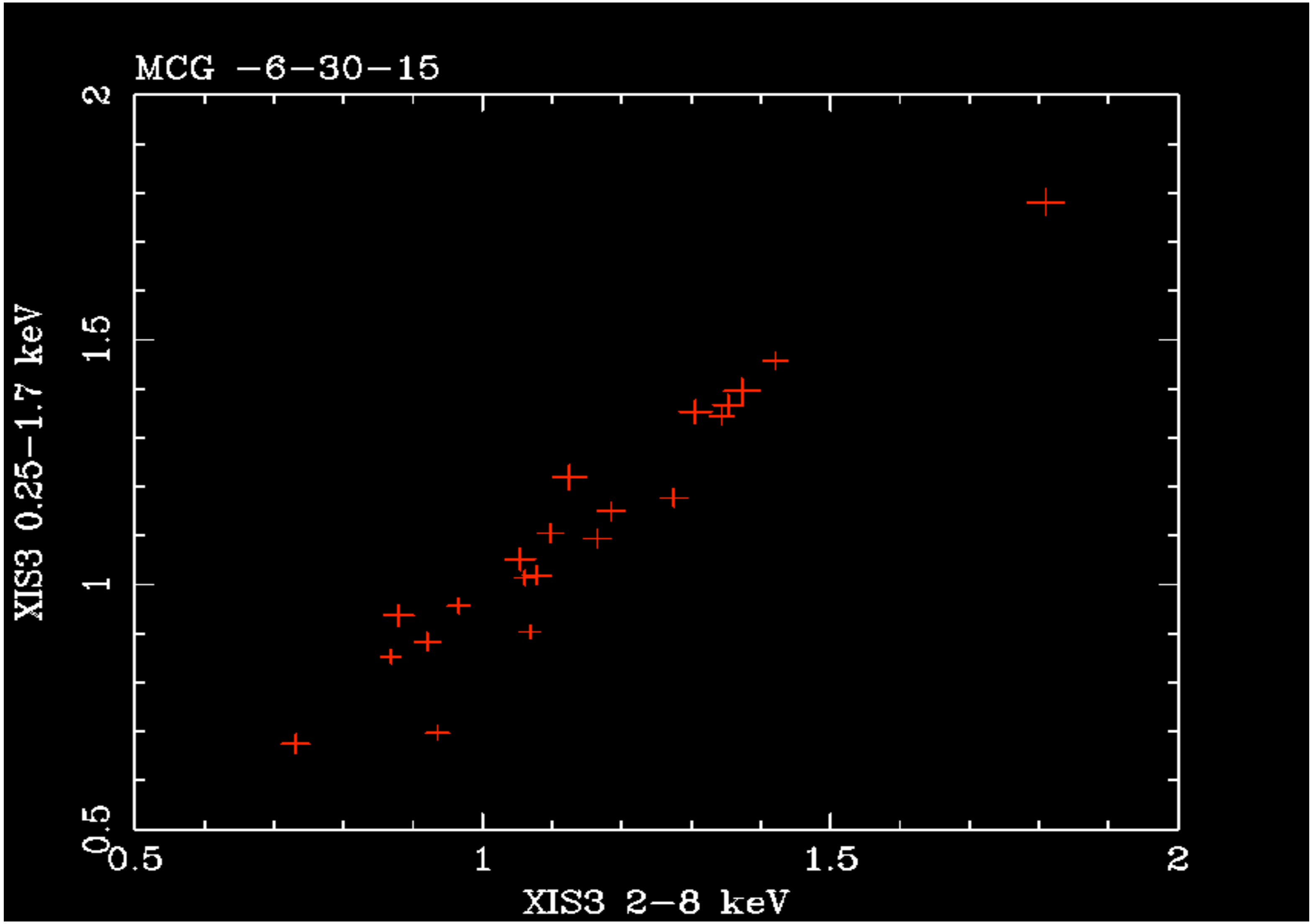
excess in PIN is
reflection (not
CXB)

MCG -6-30-15 lightcurve

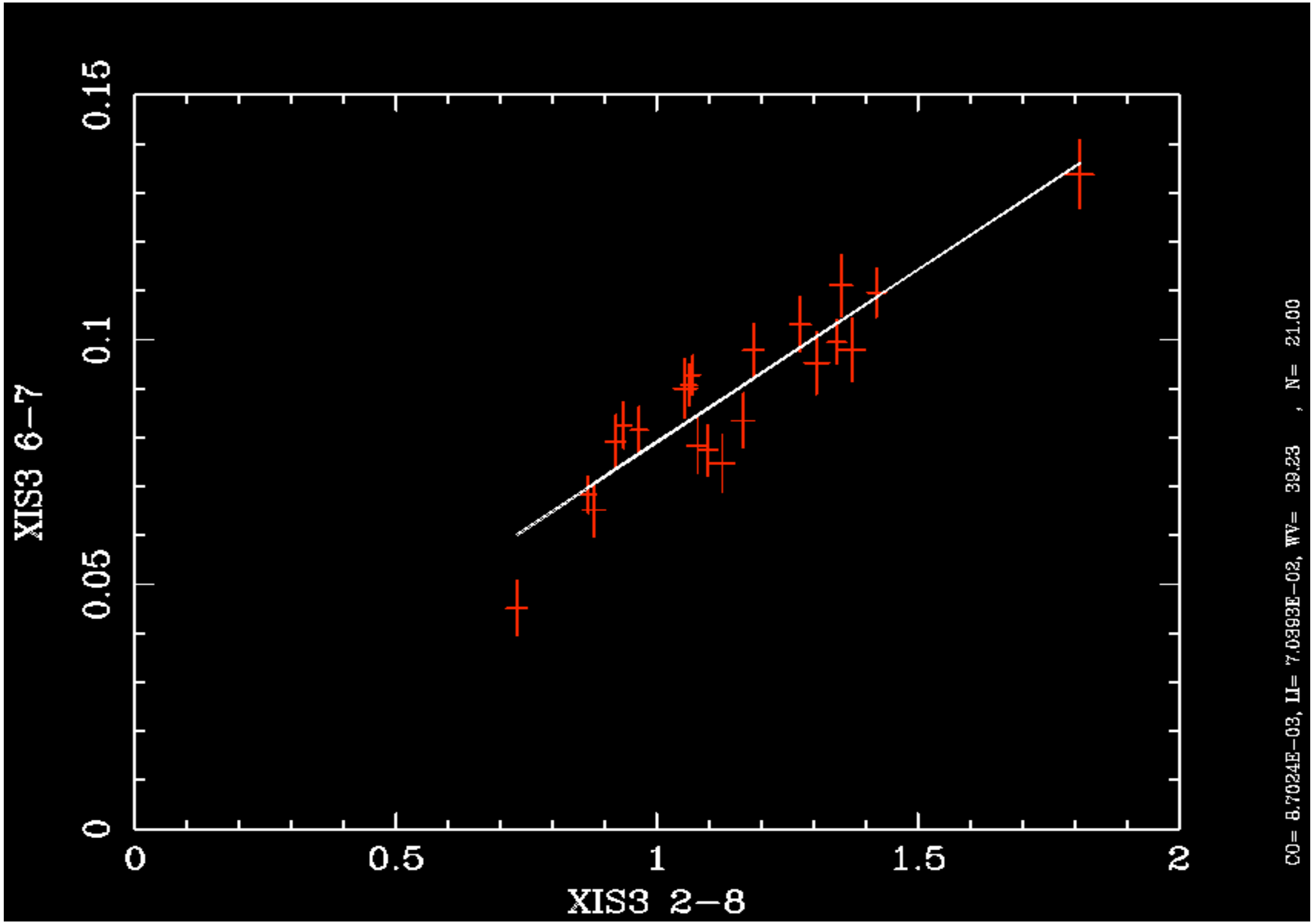


MCG -6-30-15 correlated variability

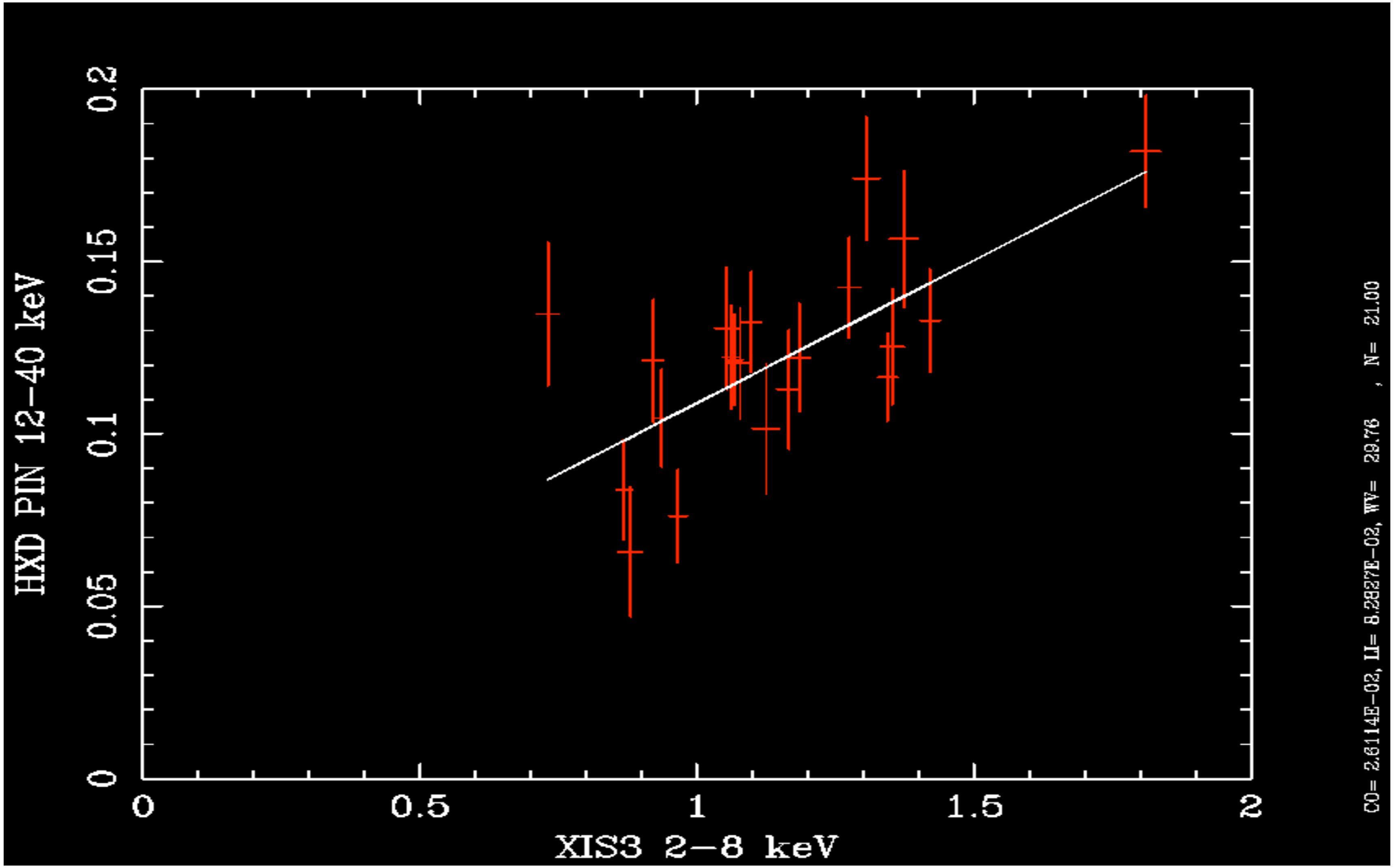
2006 longest observation



MCG -6-30-15 correlated variability



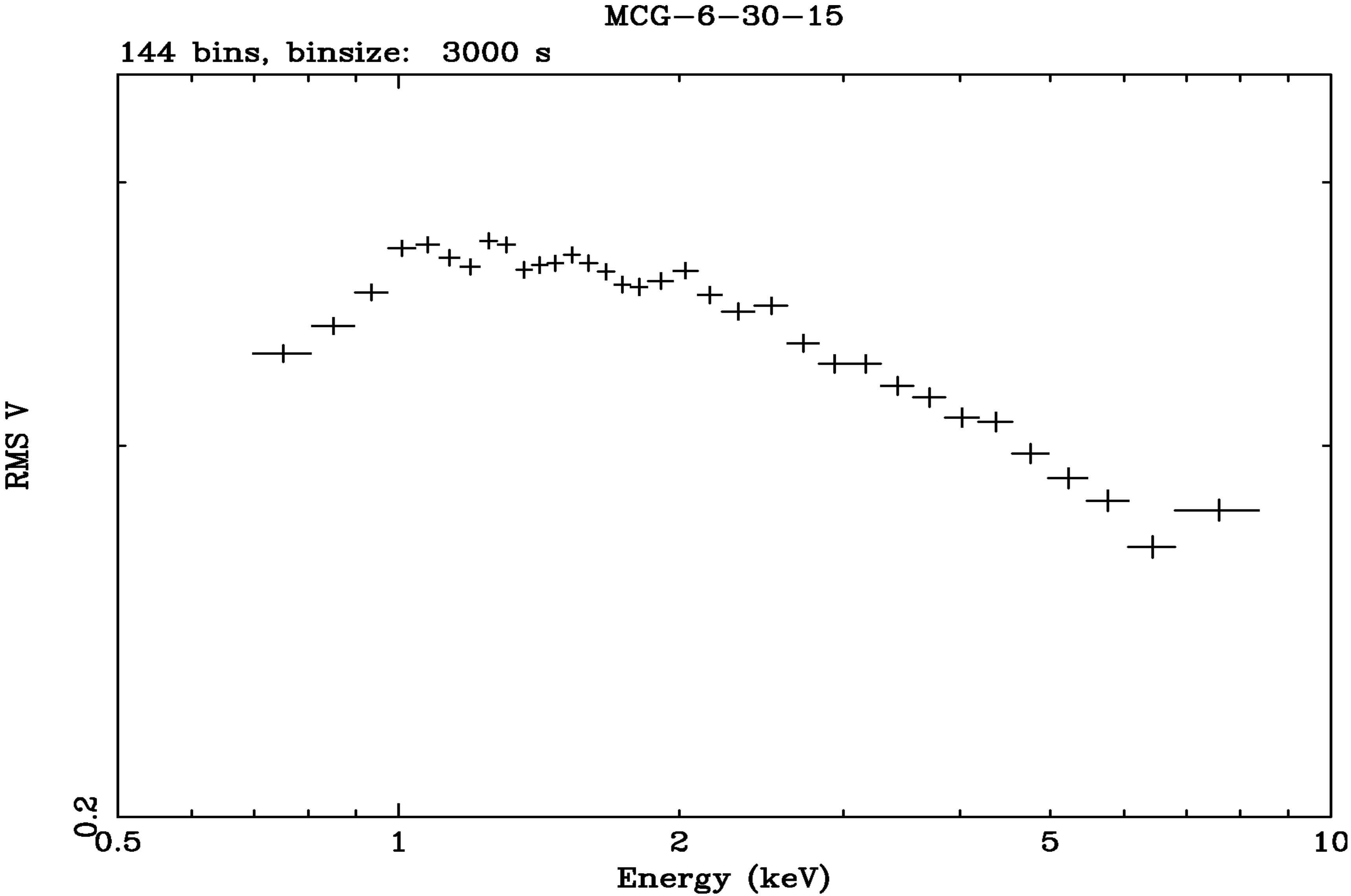
MCG -6-30-15



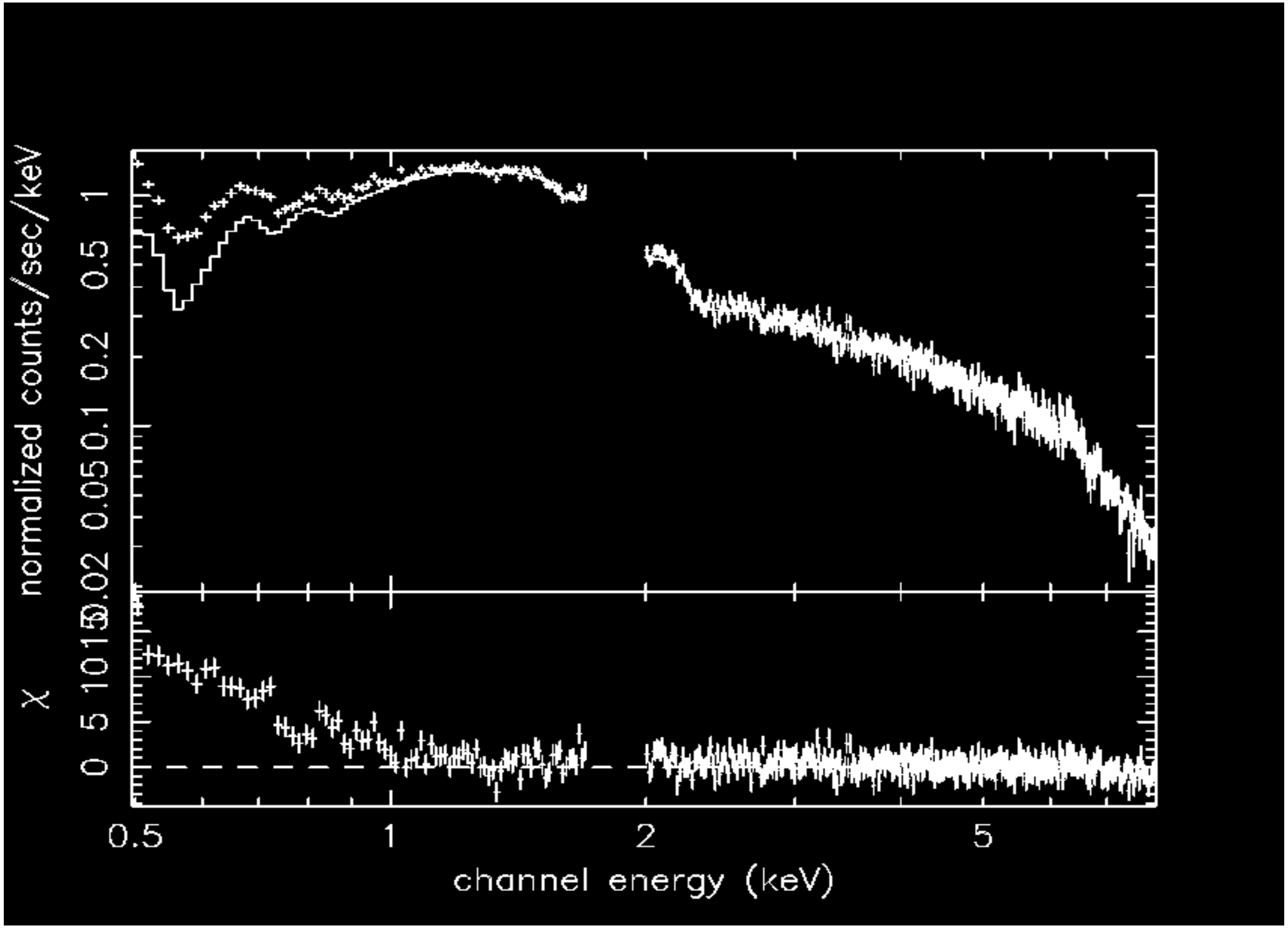
HXD PIN 12–40 keV
XIS3 2–8 keV
0
0.05
0.1
0.15
0.2
0
0.5
1
1.5
2
CO= 2.6114E–02, LI= 8.2827E–02, WV= 29.76 , N= 21.00

RMS spectrum

From Josefin Larsson

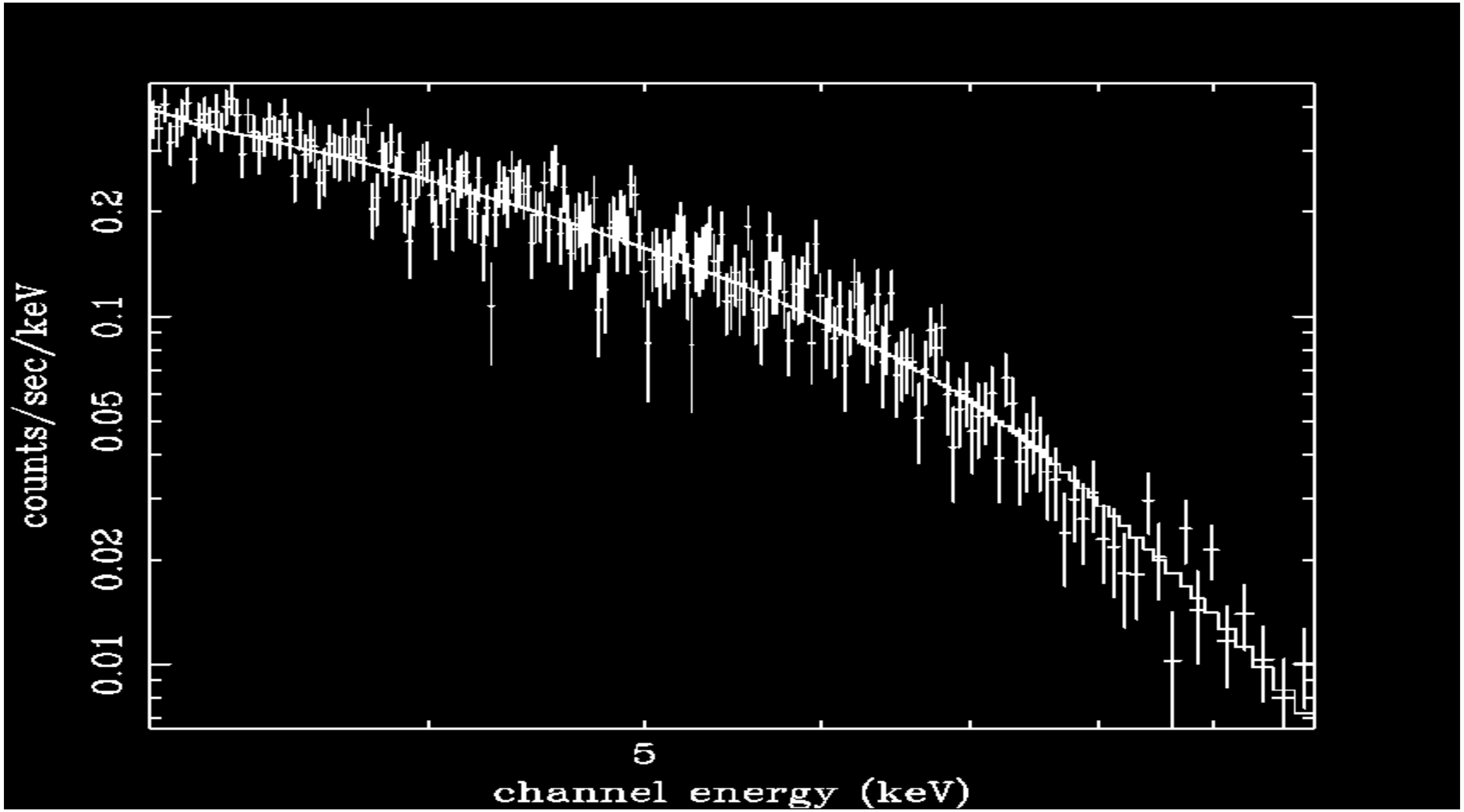


MCG -6-30-15

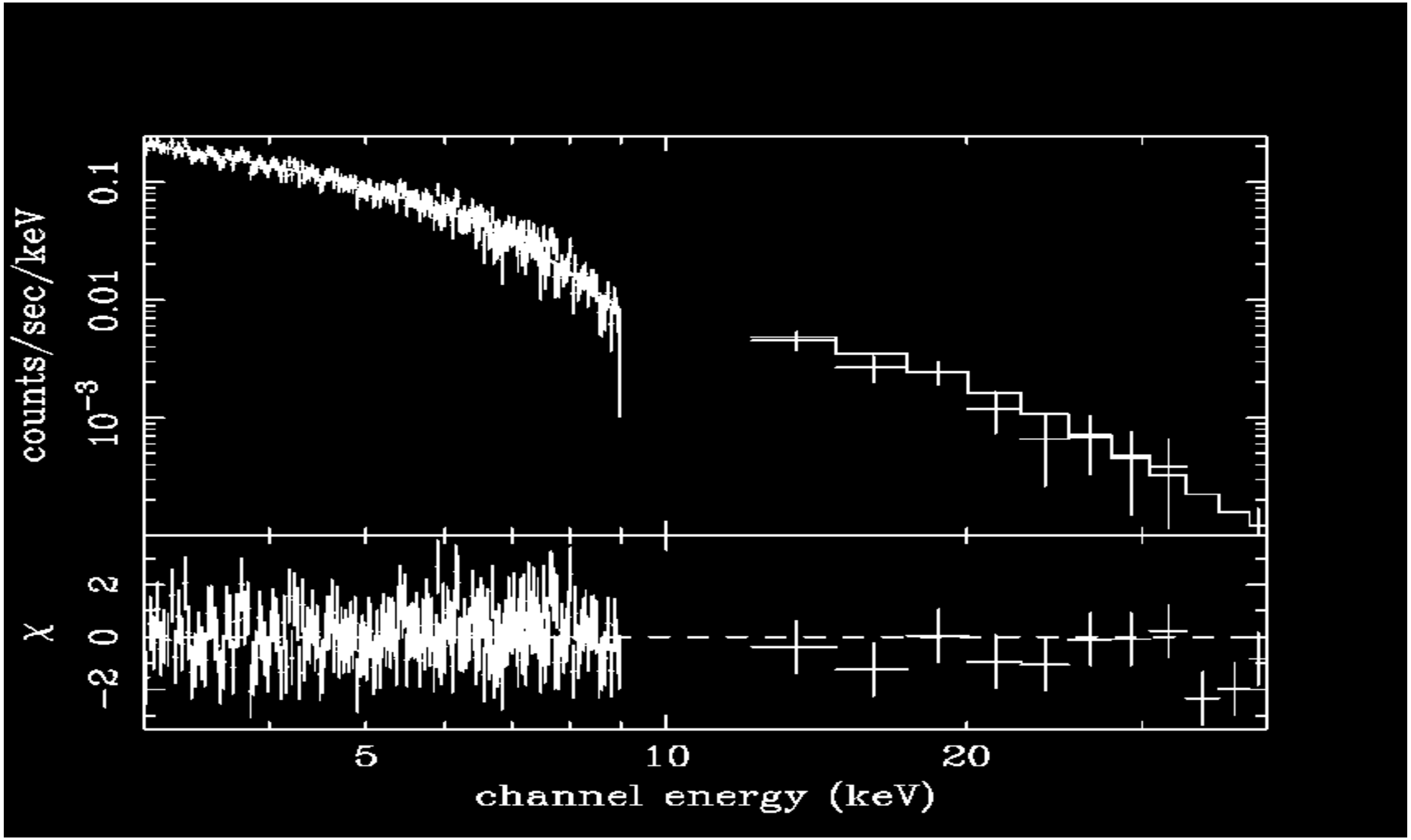

normalized counts/sec/keV
0.02
0.05
0.1
0.2
0.5
1
χ
0
5
10
15
0.5
1
2
5
channel energy (keV)

Difference spectrum

Brightest 45 ks – faintest 45 ks
Good power law: no improvement with spectral break (no curvature)
Narrow iron line consistent with zero



HXD PIN difference spectrum



Crummy, Fabian, Gallo, Ross
2006, MNRAS, 365, 1067
astro-ph/0511457

MCG -6-30-15 paper, in prep.

www-xray.ast.cam.ac.uk/~jc/kdblur.html

reflection model: “reflion”,
blurring code: “ky” from heasarc