[type 1] AGN spectroscopy and timing

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CENTRO DE ASTROBIOLOGÍA

CSIC

INTA

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Outline

A brief intro to X-ray emission from accreting BHs

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X-ray soft excess and (possible) interpretations

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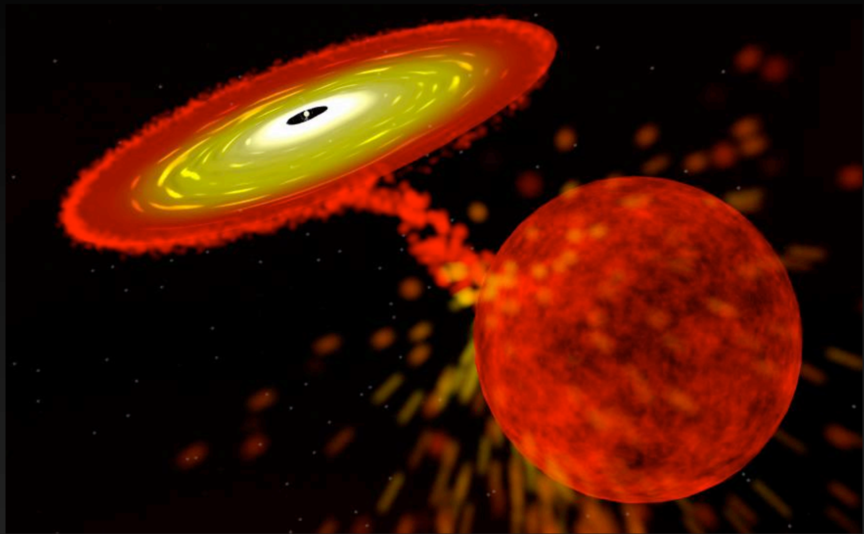
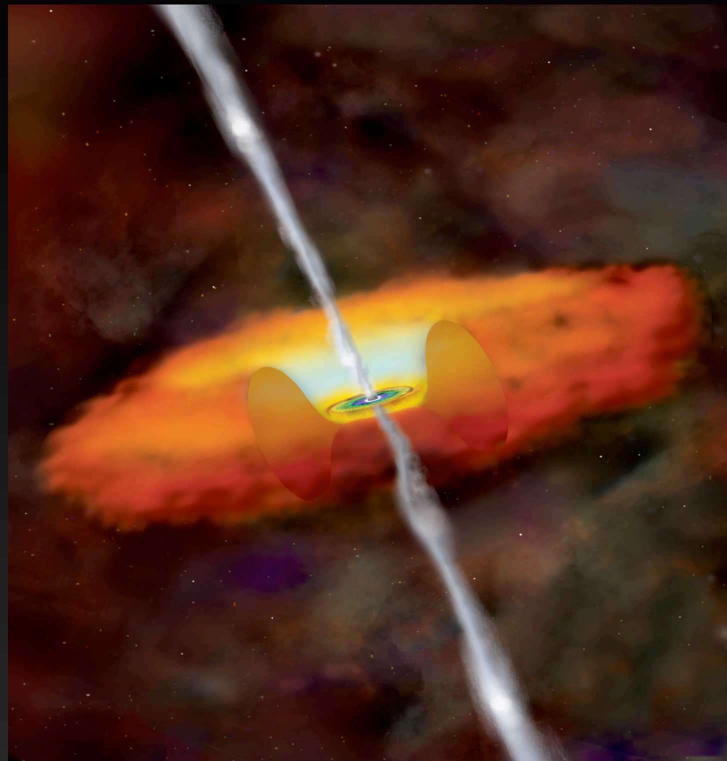
Conclusions: do we have a template ?

Accreting BHs





The two flavours of accreting BH:

stellar mass BHs scattered in Galaxies (X-ray binaries)
supermassive BHs in the center of Galaxies (AGN and quasars)

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Accreting BHs

The accreting gas is heated by friction and emits as a blackbody

$$kT_{BB} = k\left(\frac{L}{A\sigma}\right)^{1/4} = k\left(\frac{L}{4\pi R^2\sigma}\right)^{1/4}$$

by using

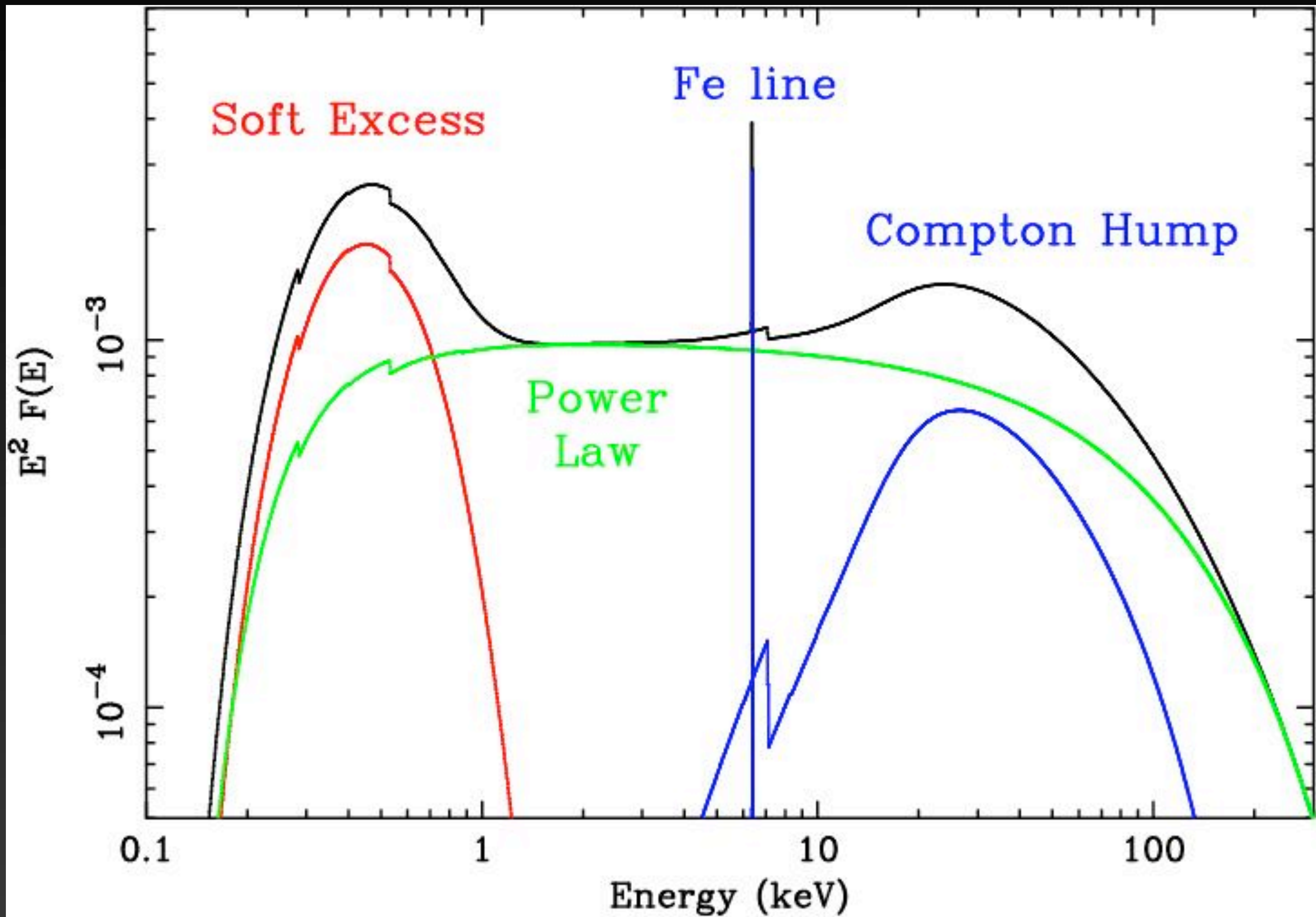
$$L = L_{Edd} \cong 1.3\times 10^{38}\left(\frac{M}{M_\Theta}\right) erg/s$$

and a typical size of 20 r_g (= 20 M in some units)

$$kT_{BB} = k\left(\frac{1.3\times 10^{38}}{80\pi M^2\sigma}\frac{M}{M_{sun}}\right)^{1/4} \cong 1keV \times \left(\frac{M}{M_{sun}}\right)^{-1/4}$$

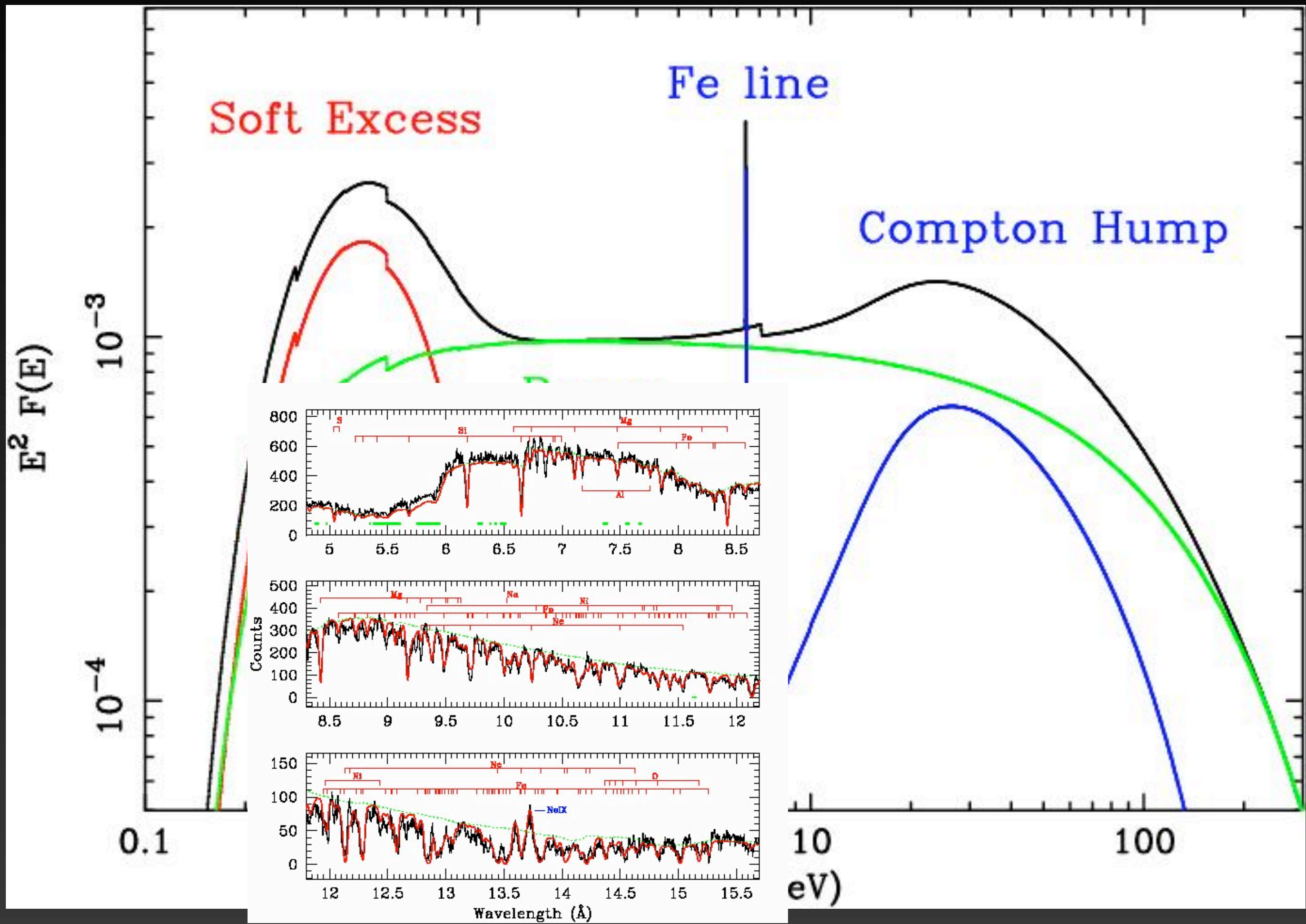
we get ~ 0.6 keV (X-rays !) for stellar mass BHs BUT
~ 0.01 keV (UV) for supermassive BHs

Accreting BHs in X-rays



Fabian & GM 09 (review)

Accreting BHs in X-rays



Krongold et al 03

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The X-ray soft excess

Simple definition

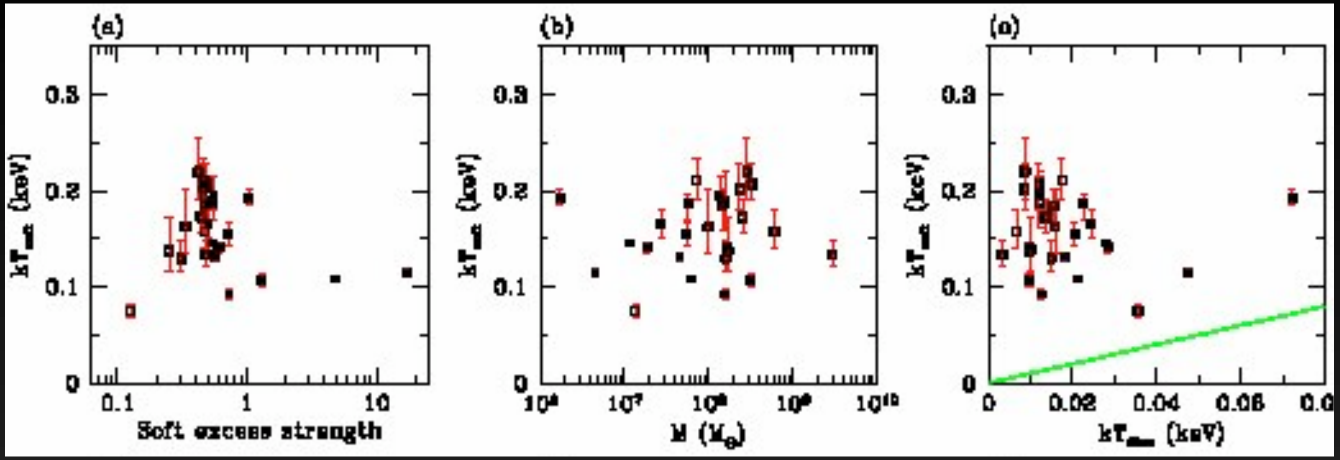
extrapolation of the best-fitting 2-10 keV continuum reveals excess X-ray emission typically below ~ 1 keV

It is typically stronger and more extreme in NLS1 galaxies but almost ubiquitous in relatively unabsorbed Seyfert 1 and QSO

→ has to be related to fundamental processes

Its spectral shape is remarkably uniform and closely resembles optically thick thermal emission with typical kT ~ 150 eV and very little spread

The X-ray soft excess



Gierlinski & Done 04

Not only the shape is TOO uniform to be thermal, the kT is also TOO hot

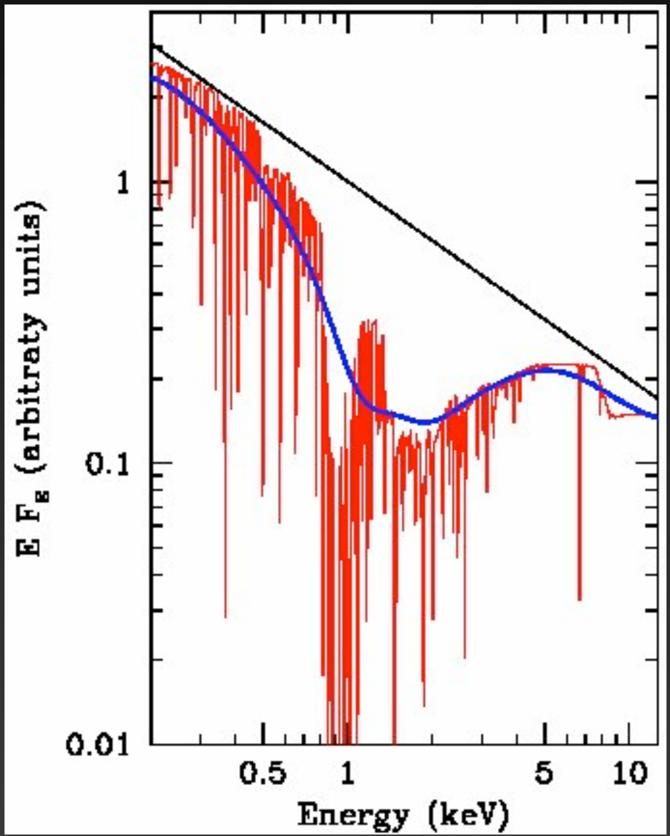
This simple fact seems to rule out a thermal origin and calls for interpretations invoking physical processes with typical energies that are independent on (e.g.) BH mass

Atomic processes may then be invoked (e.g. absorption and reflection)

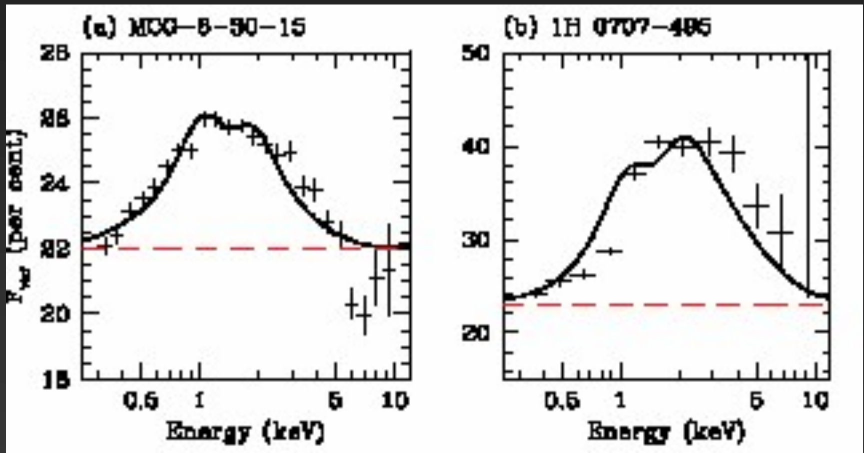
The X-ray soft excess

Absorption:

larger opacities in the intermediate ~1-2 keV band in partially ionized gas may be responsible for a spurious soft excess



Potentially also explains the energy-dependent X-ray variability in many sources

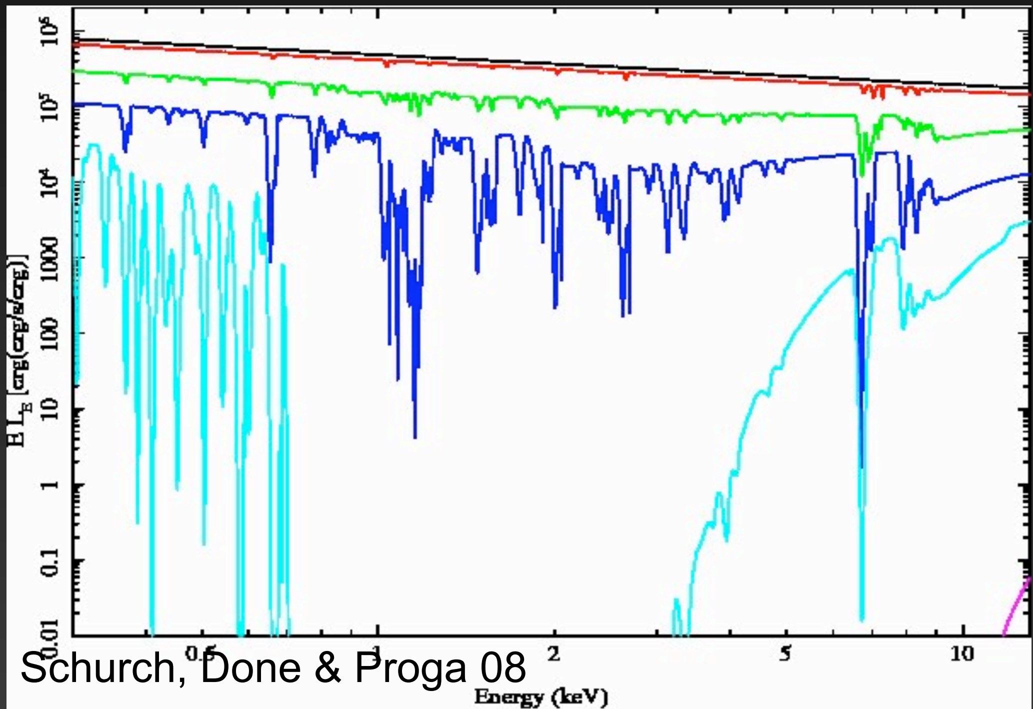


Gierlinski & Done 04,06

The X-ray soft excess

However smearing velocities are likely too extreme and unrealistic with terminal outflow v ~ 0.9 c

Recent numerical simulation show that in realistic cases far too many sharp absorption features are seen and models cannot reproduce the observed smooth soft excesses

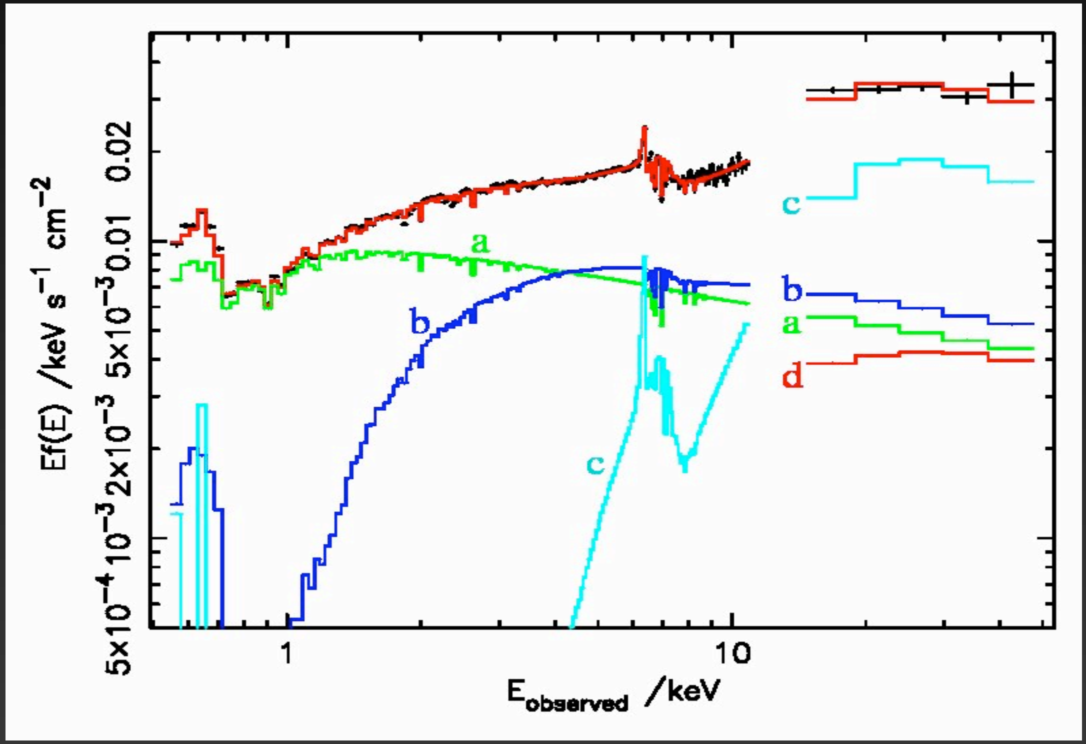


Schurch, Done & Proga 08

The X-ray soft excess

The sharp absorption features may be more subtle if PC is at work

One such model was presented e.g. for the case of MCG-6-30-15 with multiple PC (5 abs zones of which 2 are global and gratings-detected)



Miller et al 08

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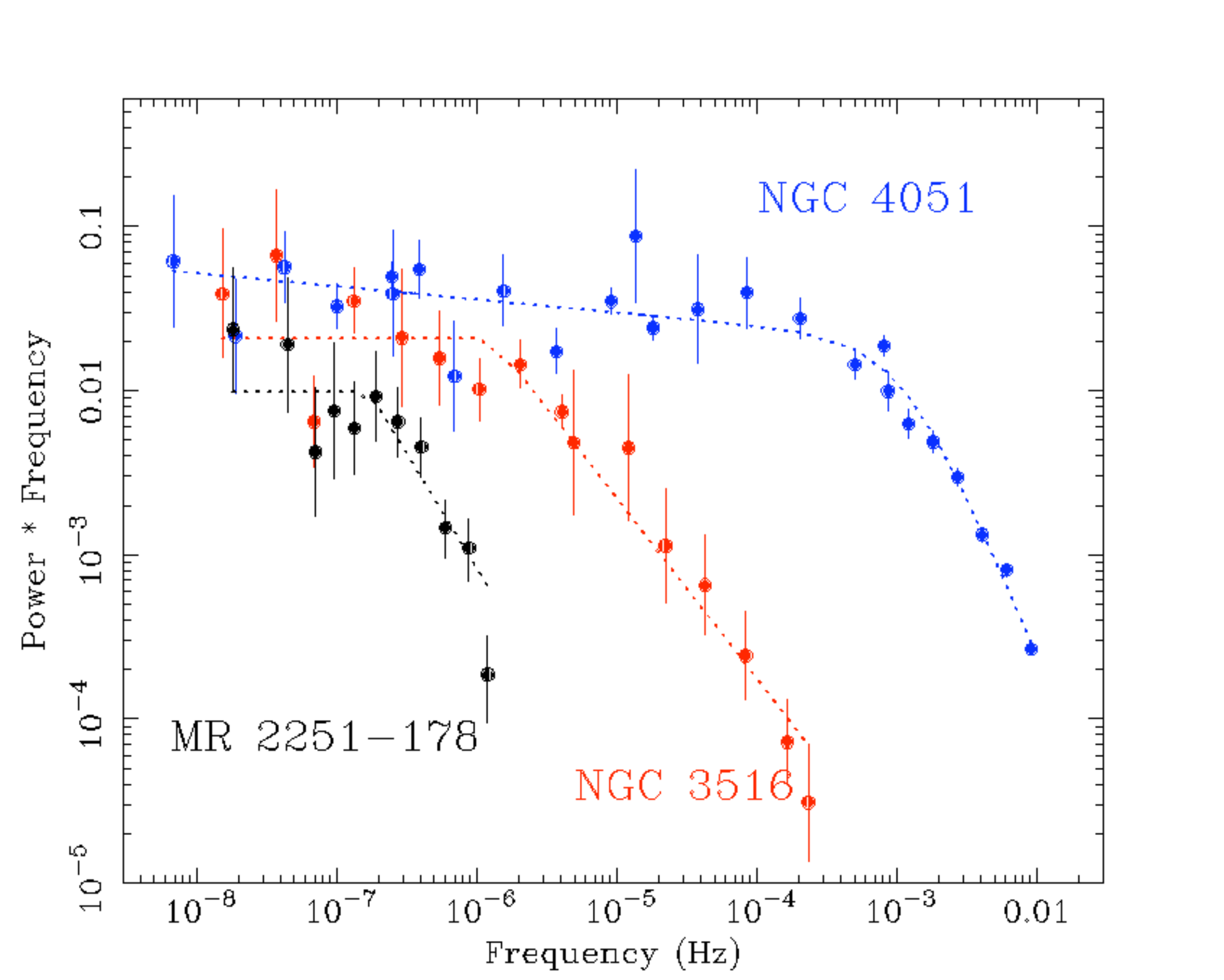
The X-ray soft excess

While the model reproduces the X-ray spectra it can explain the X-ray variability of the source only by assuming that most of the X-ray variability is not intrinsic but rather associated with PC variations (covering fraction)

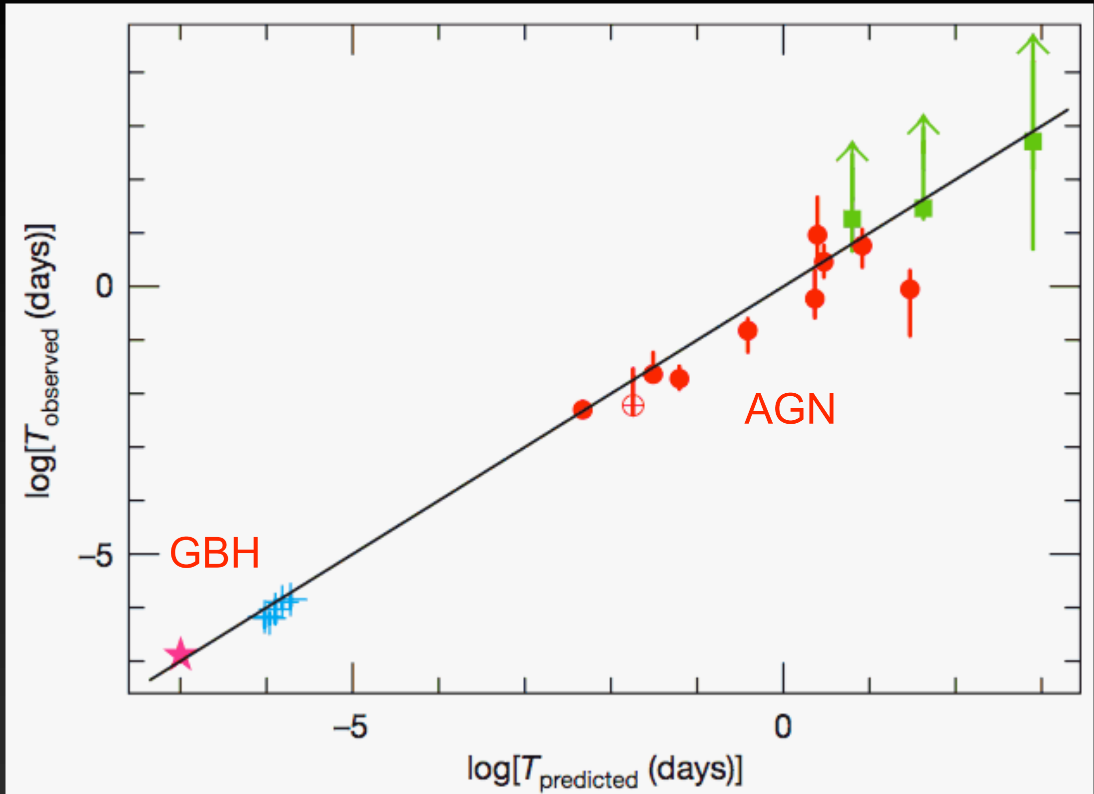
This implies that the properties of X-ray variability in Galactic BH and AGN are driven by very different processes (one being intrinsic the other due to intervening matter)

But we have good indication that this is not the case and that AGN variability can be scaled from GBH making use of M and Mdot only

The X-ray soft excess



The X-ray soft excess



$T_B \sim M^2 / L_{bol}$

$\sim M / \dot{M}_{Edd}$

McHardy et al 06

which is one piece of evidence for common variability properties among accreting BHs at all scales

It seems unlikely that variability is driven by significantly different processes in the two classes

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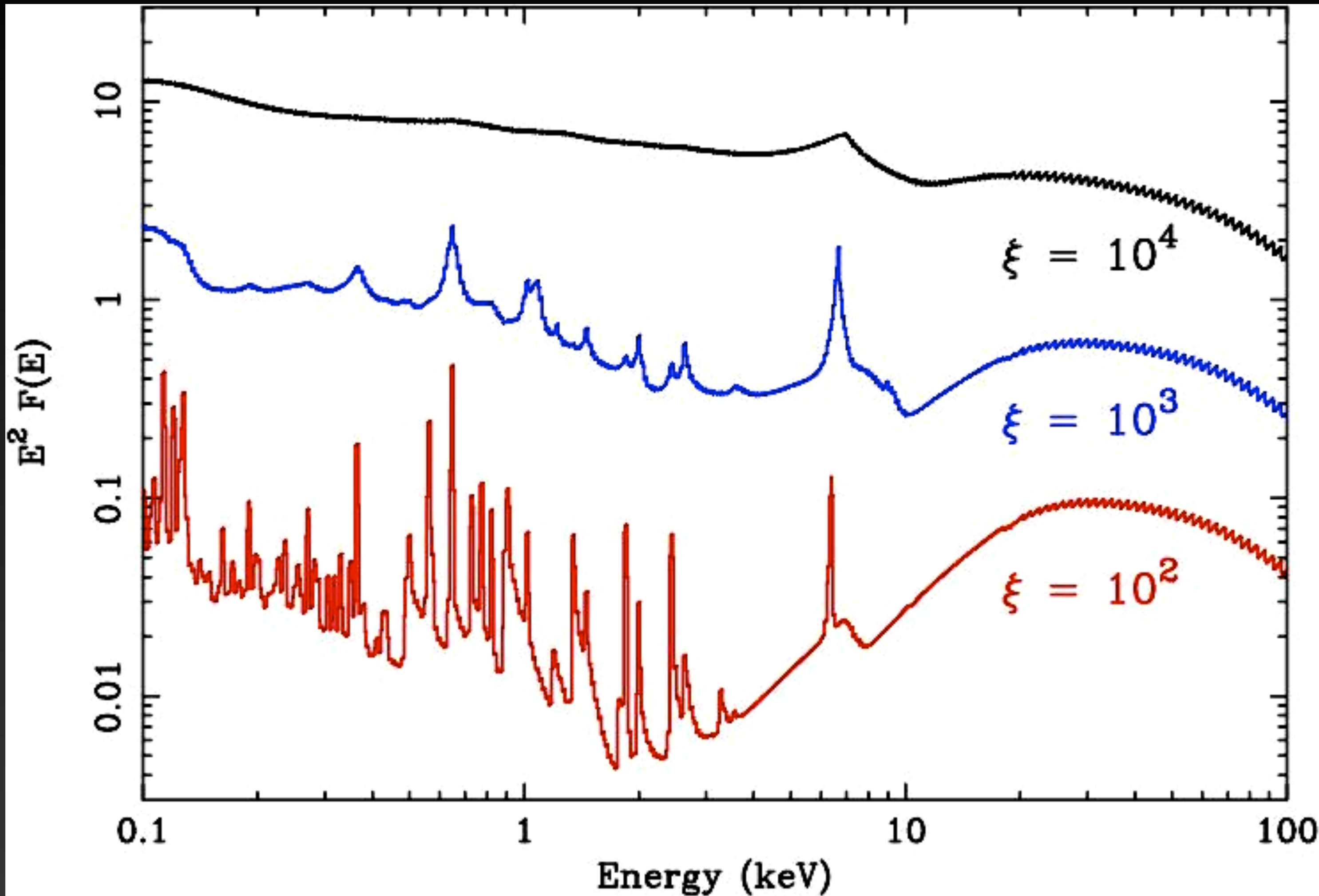
Relativistic disc reflection



Fabian & GM 09 thanks to Randy Ross

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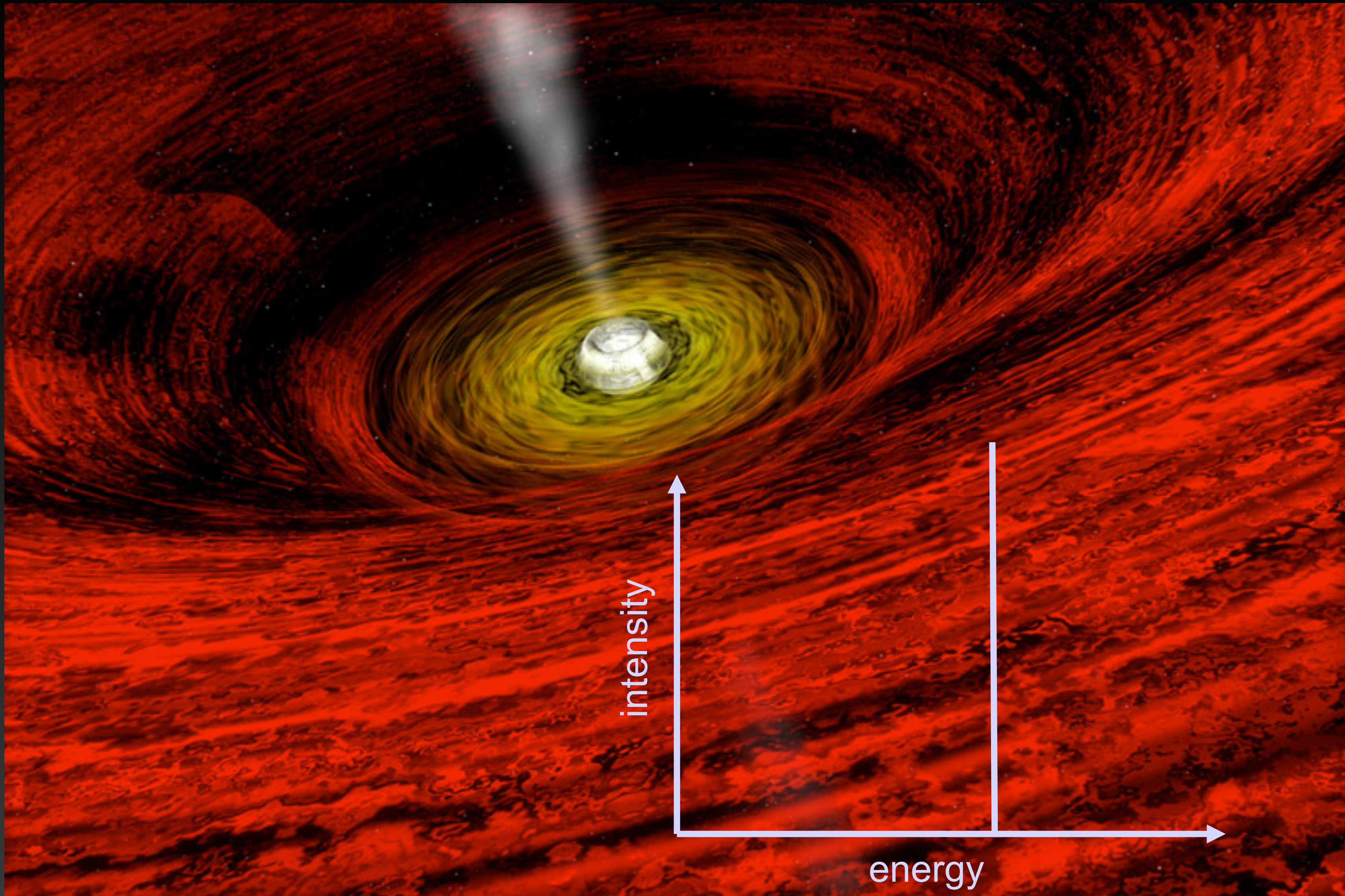
Relativistic disc reflection



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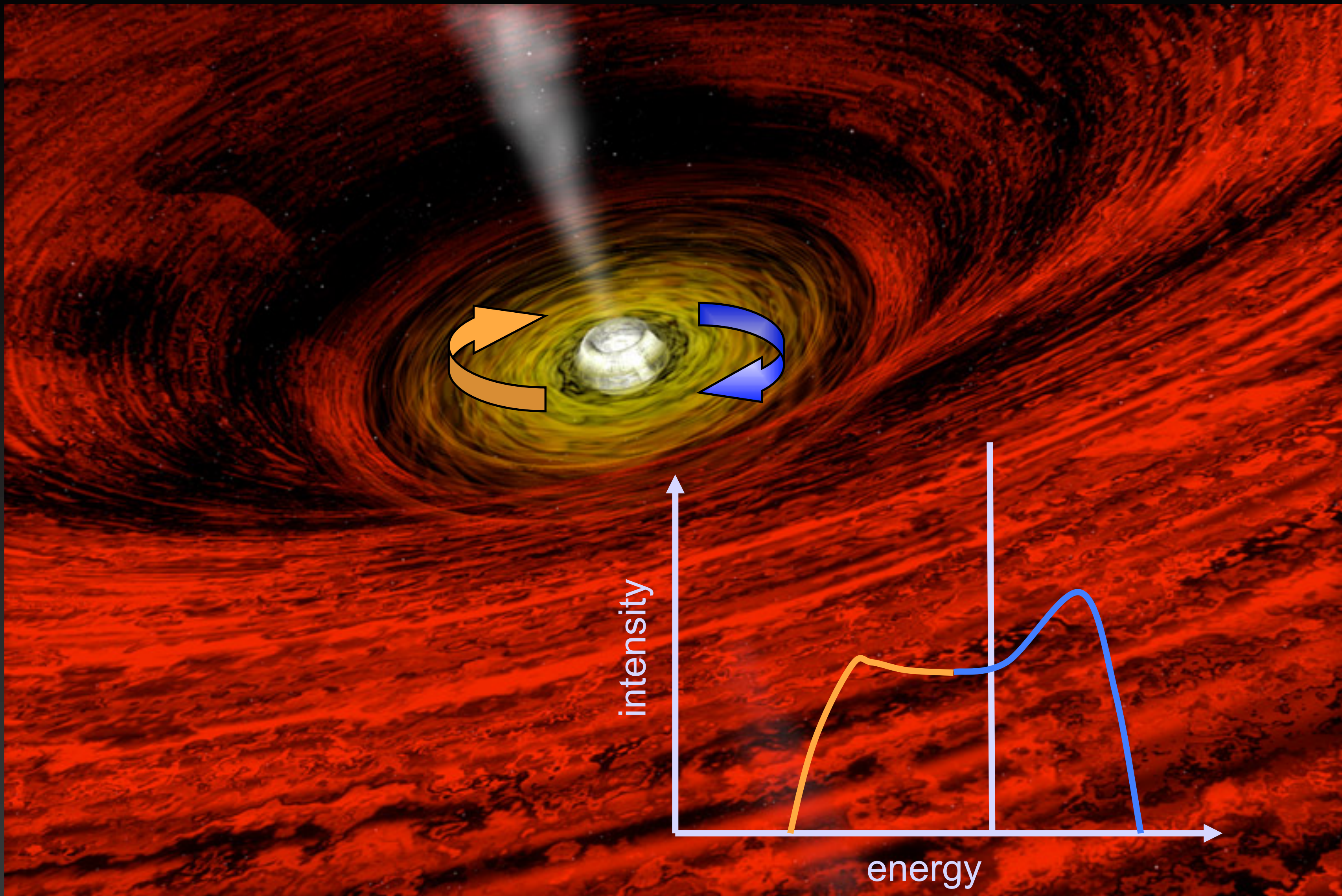

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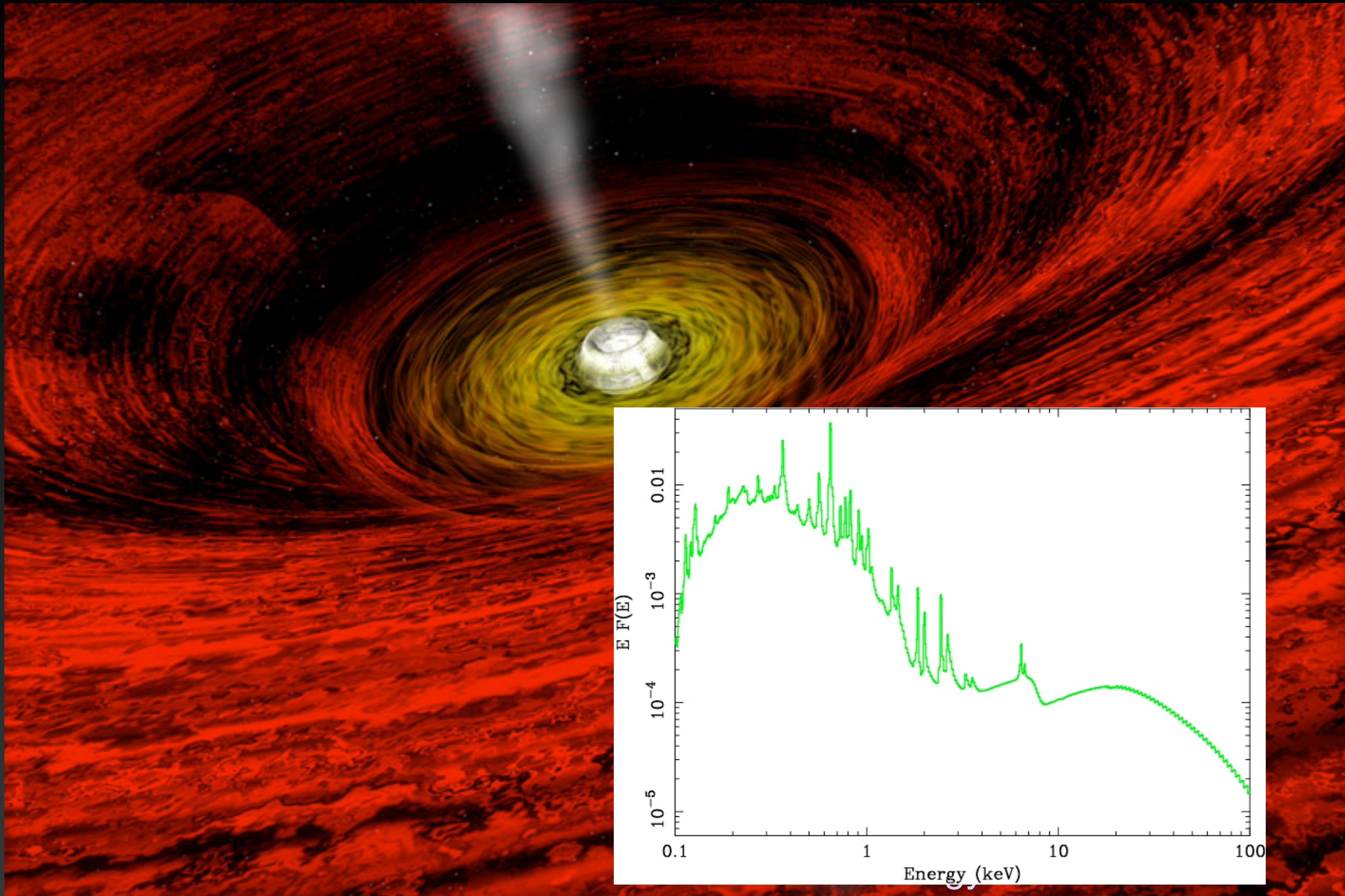
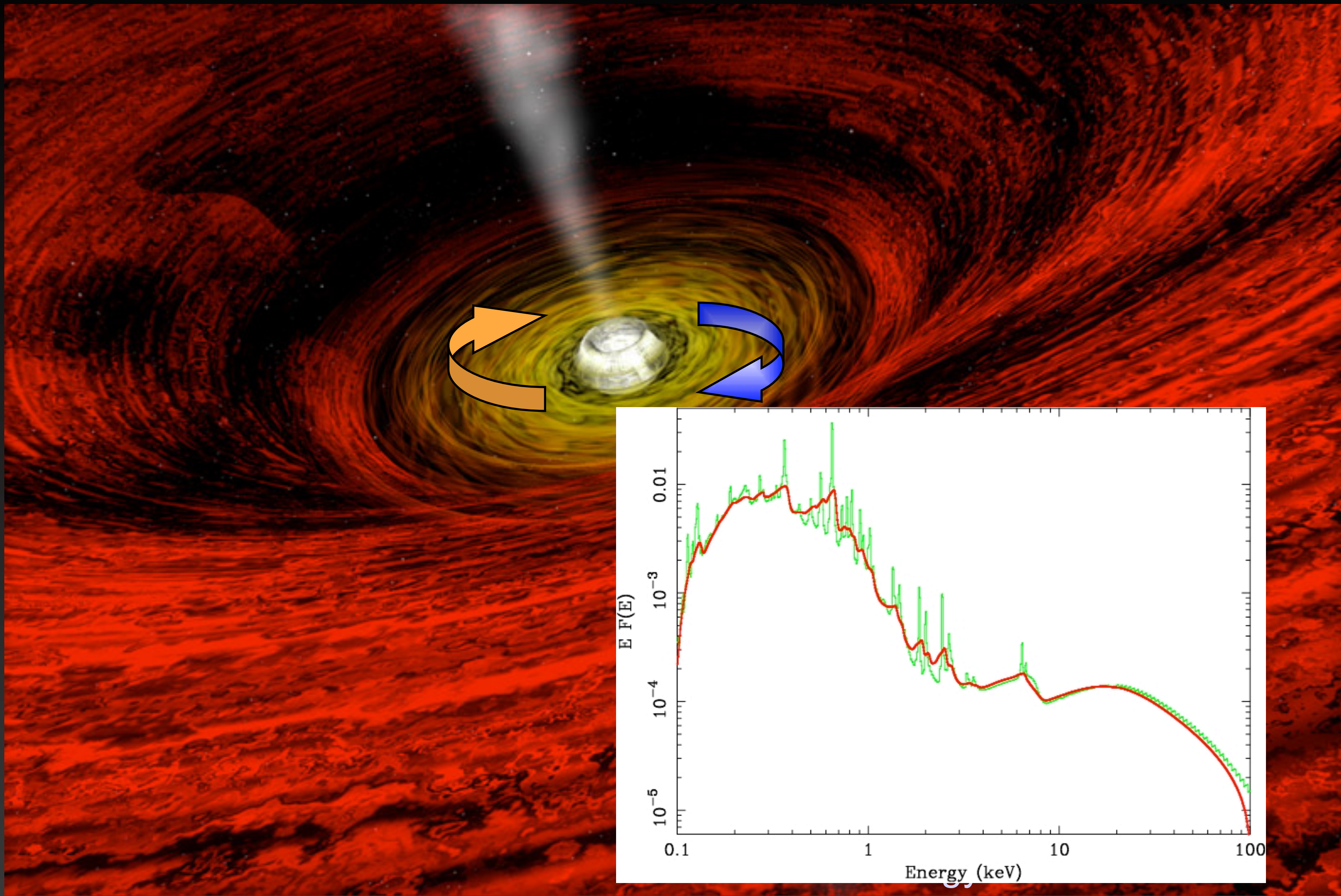
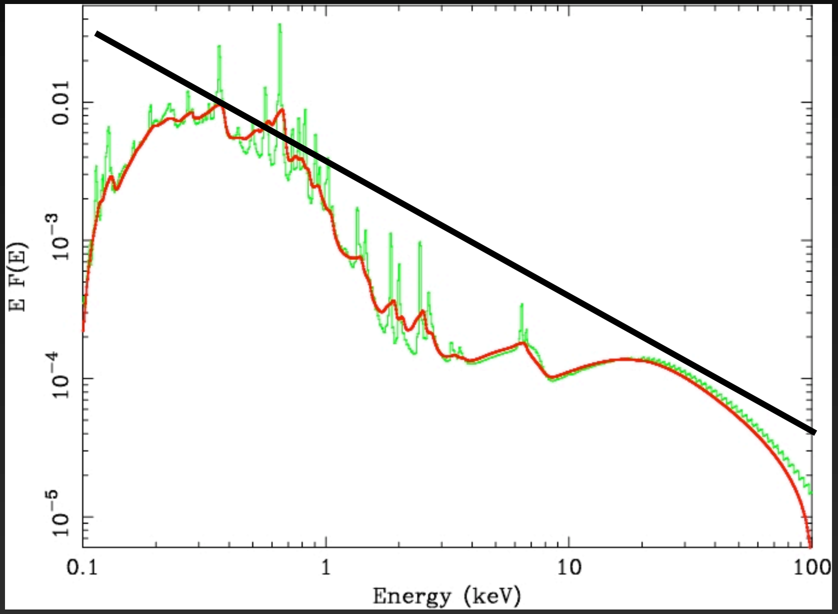


Relativistic disc reflection



Relativistic disc reflection

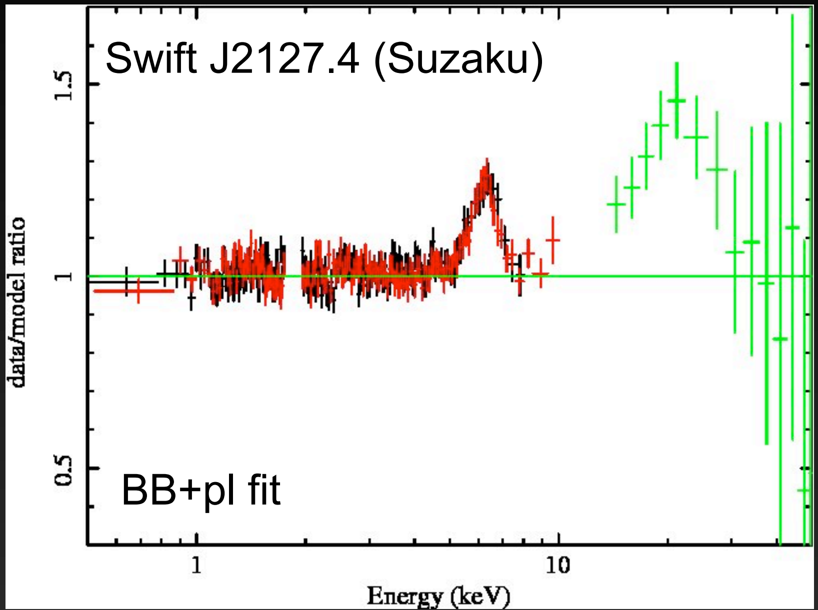
Like absorption, reflection off partially ionized material can produce smooth and uniform soft excesses in AGN

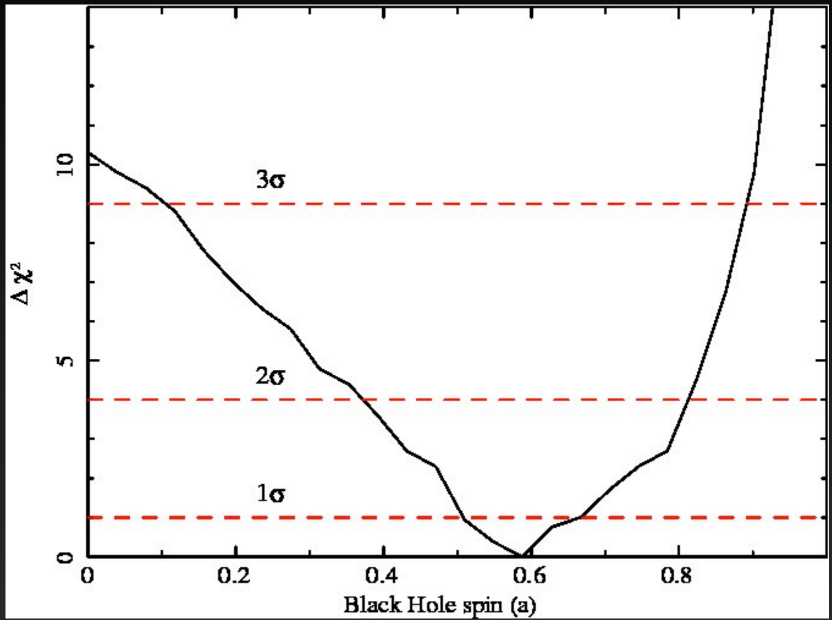


The soft excess smoothness comes for free thanks to relativistic blurring and its strength is mainly dictated by the reflection fraction

Relativistic disc reflection

Broad Fe K: not only MCG-6





GM et al 09

Power law + disc reflection model explains soft excess and broad Fe K and a measure of the BH spin can be inferred

a ~ 0 is excluded but just at the 3σ level
a ~ 0.998 is excluded at more than 5σ

Relativistic disc reflection

Fairall 9 with Suzaku

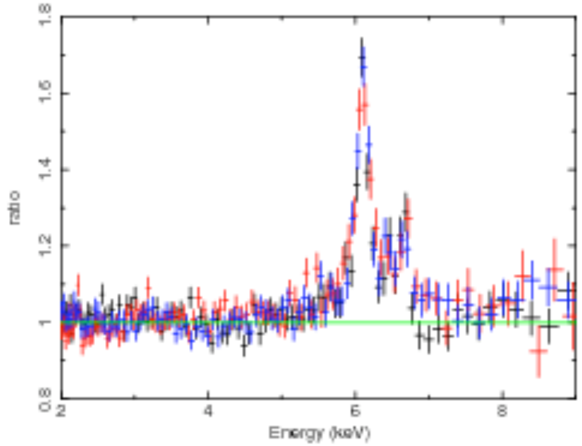
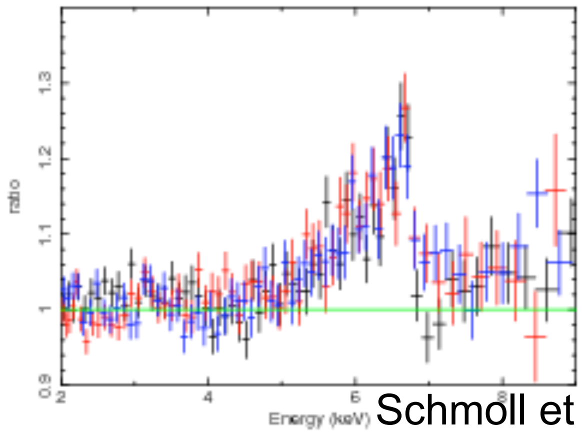
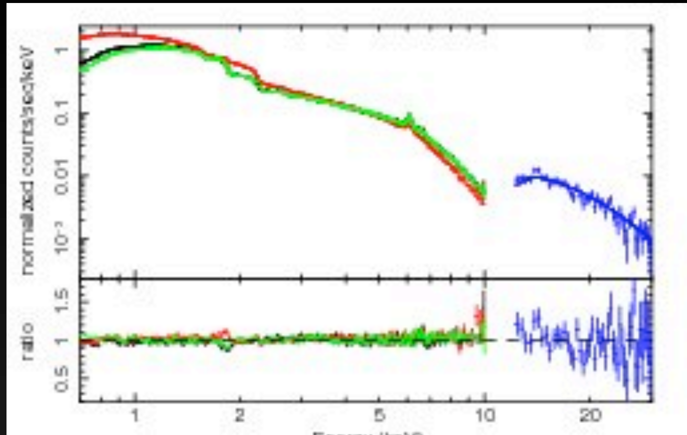
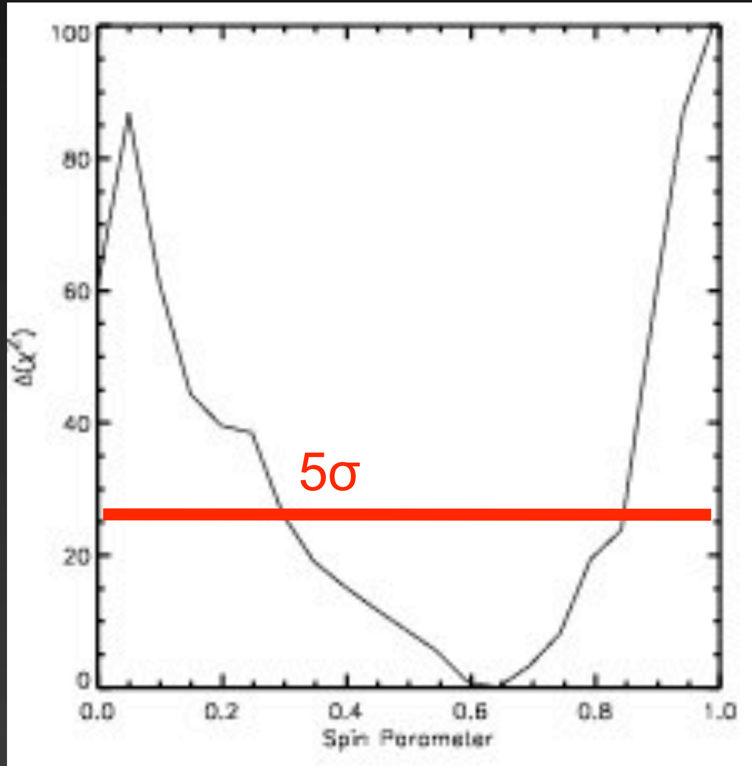


FIG. 2.— The plot above shows the data/model ratio in Fe K region that results from a simple power-law fit to the data. The narrow Gaussian peak near 6.1 keV (6.4 keV in the rest frame) is due to reflection from distant gas. A broad diskline component is also clearly present. The XIS0, XIS1, and XIS3 spectra are shown in black, red, and blue, respectively.



Schmoll et al 09



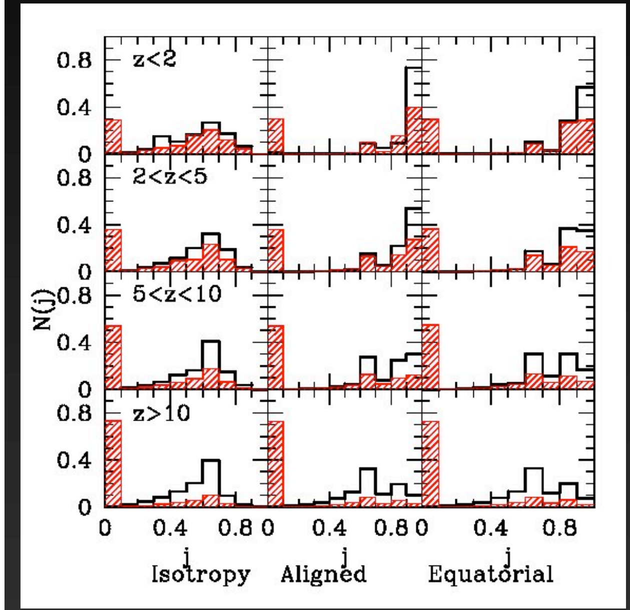


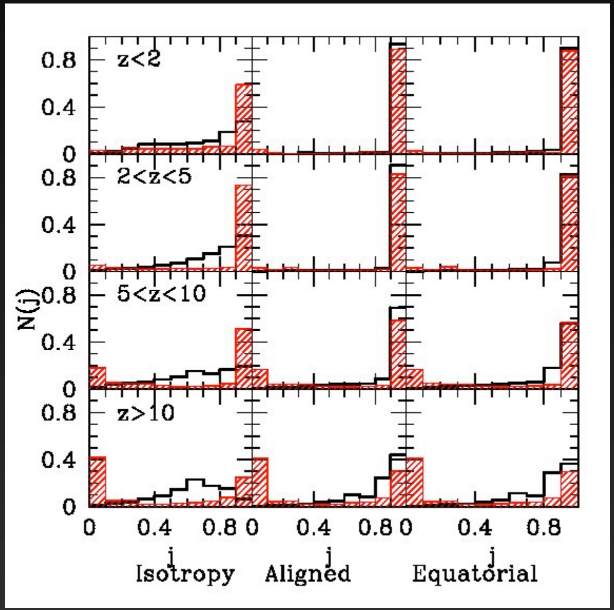
Why do we care about AGN BH spin ?

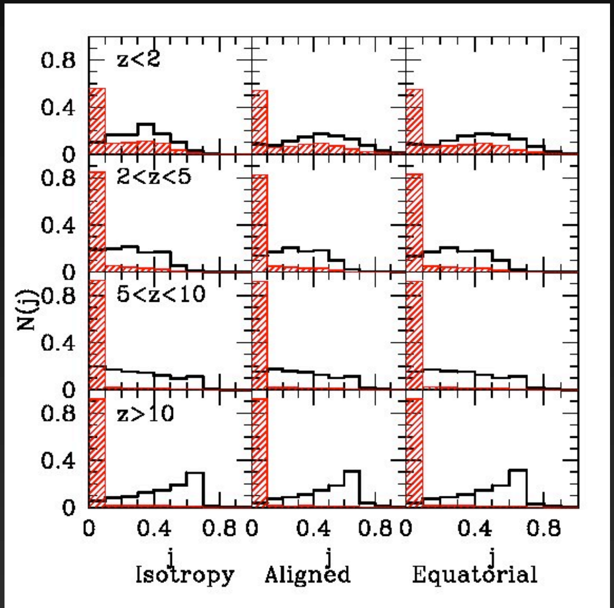
mergers only
a ~ 0.7

mergers + coherent
high a

mergers + chaotic
low a



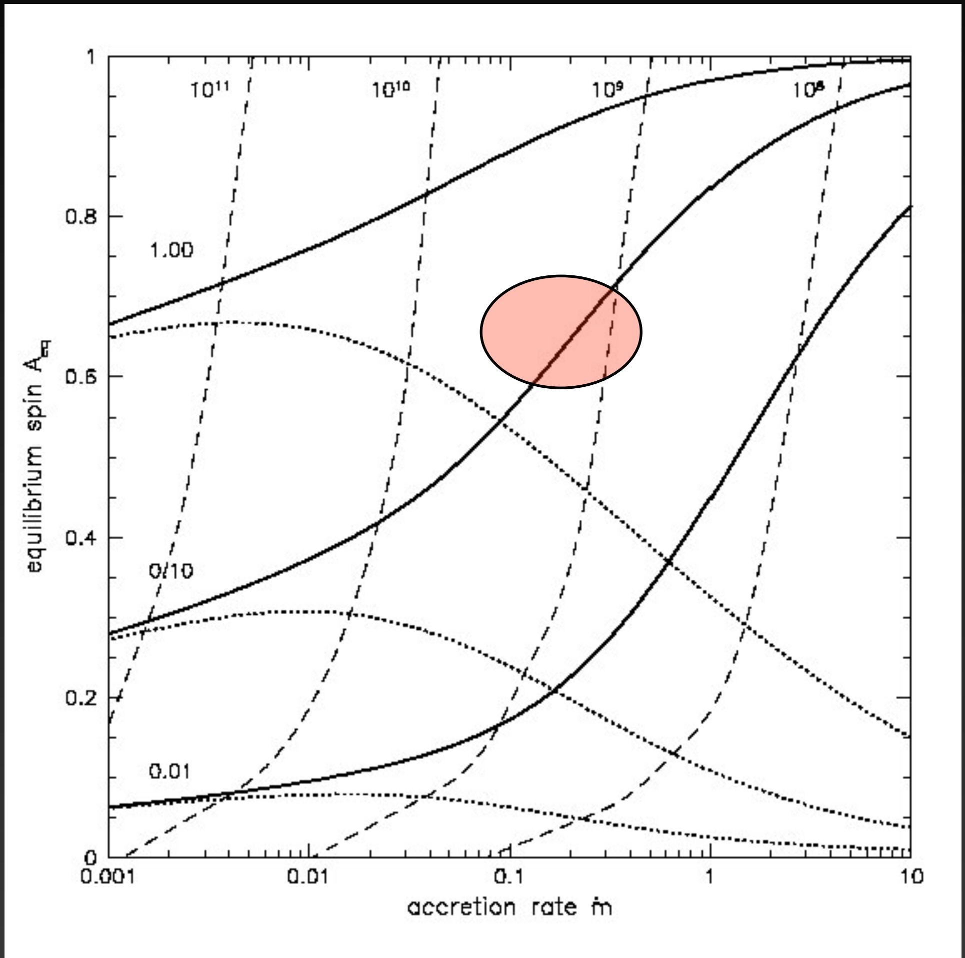




Berti & Volonteri 08

Why do we care about AGN BH spin ?

a further possibility: magnetic extraction of rotational energy (BZ) ?



Moderski, Sikora & Lasota 98

The special case of 1H 0707-495

This is an AGN belonging to the class of NLS1 galaxies

It is remarkable in the X-rays:

large amplitude and fast X-ray variability

huge soft X-ray excess

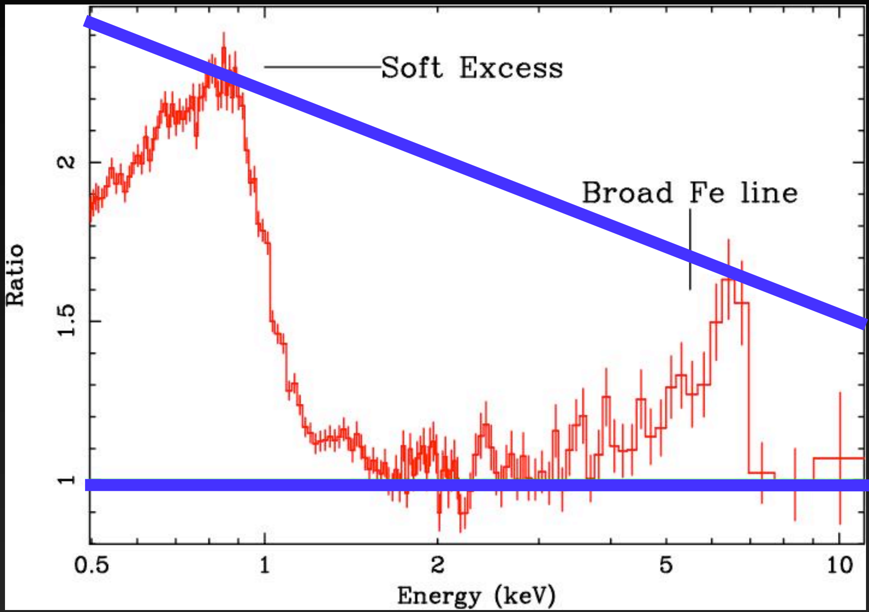
extreme spectral curvature at Fe energies (Boller et al 02)

All these properties are observed in almost all (unobscured) AGN to a much lesser extent

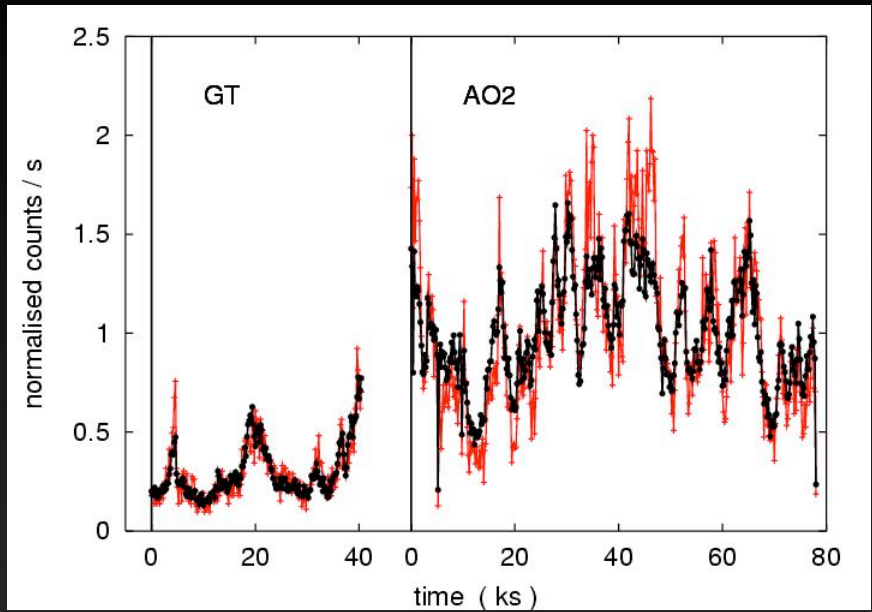
but Nature seems to have found one (actually two…) extreme object for us to study to perhaps infer the general properties of all of them

[see talk by A. Zoghbi for much more details]

The special case of 1H 0707-495



Fabian, GM et al 04



Fabian, GM et al 04

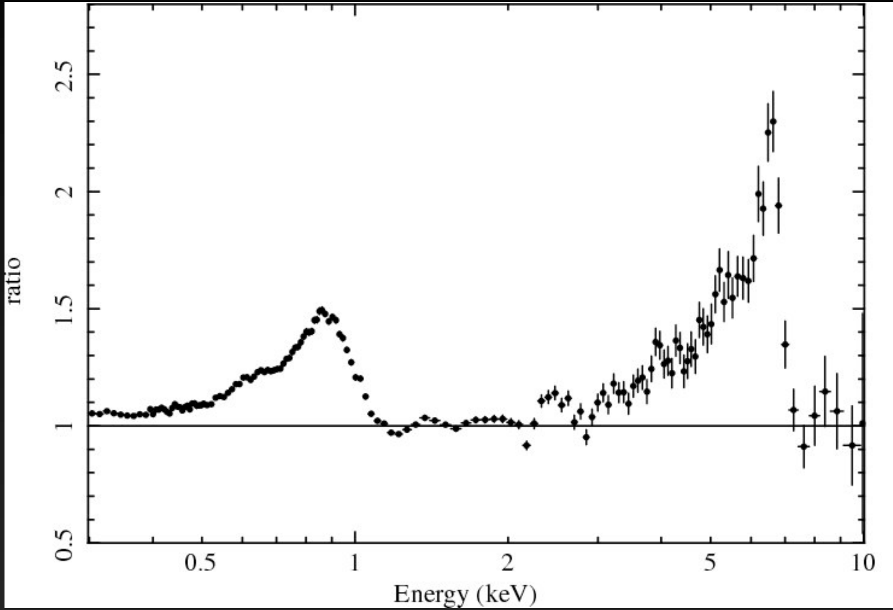
Two main competing interpretations:

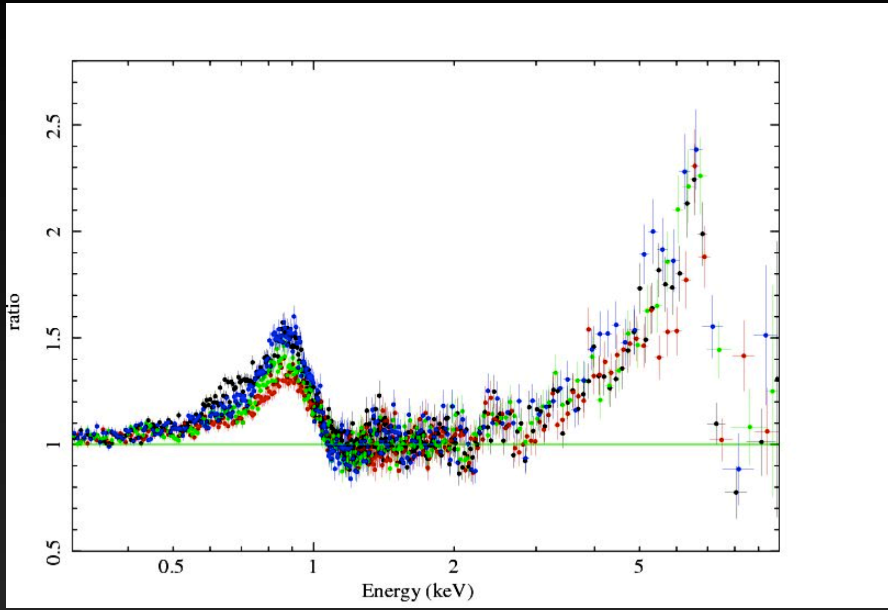
absorption

reflection

but distinguishing between the two models spectroscopically is difficult if not impossible

The special case of 1H 0707-495





ratios of the data to a simple power law + BB model

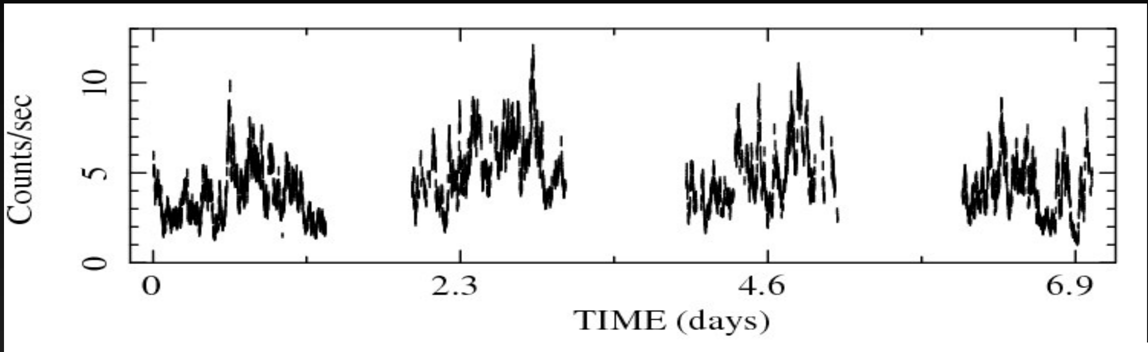
time-averaged   orbit by orbit

two unambiguous features appear between 0.5-1 keV and 4-7 keV

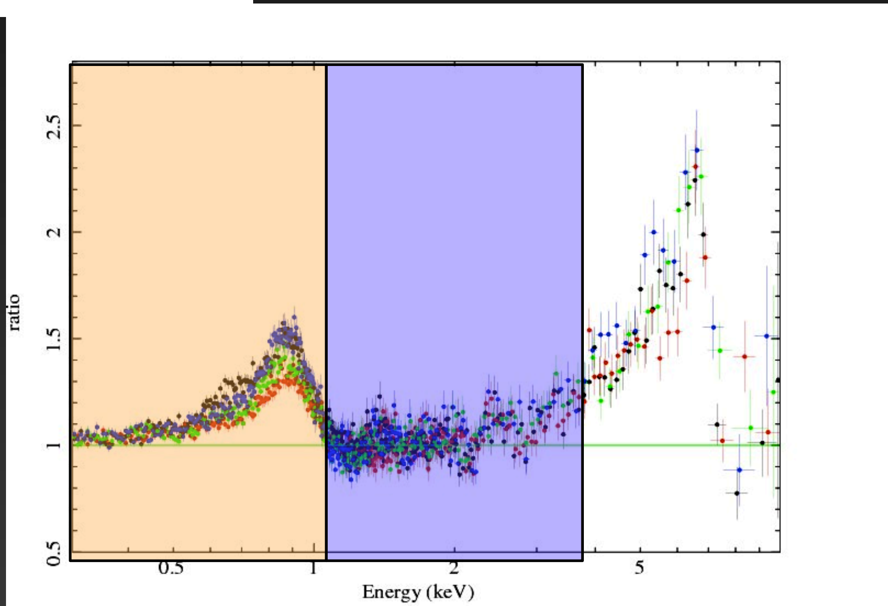
and they can be interpreted as broad Fe L and K lines coming from the same medium with huge reflection fraction and high Fe abundance

The special case of 1H 0707-495

Again absorption models may work, but what about variability?

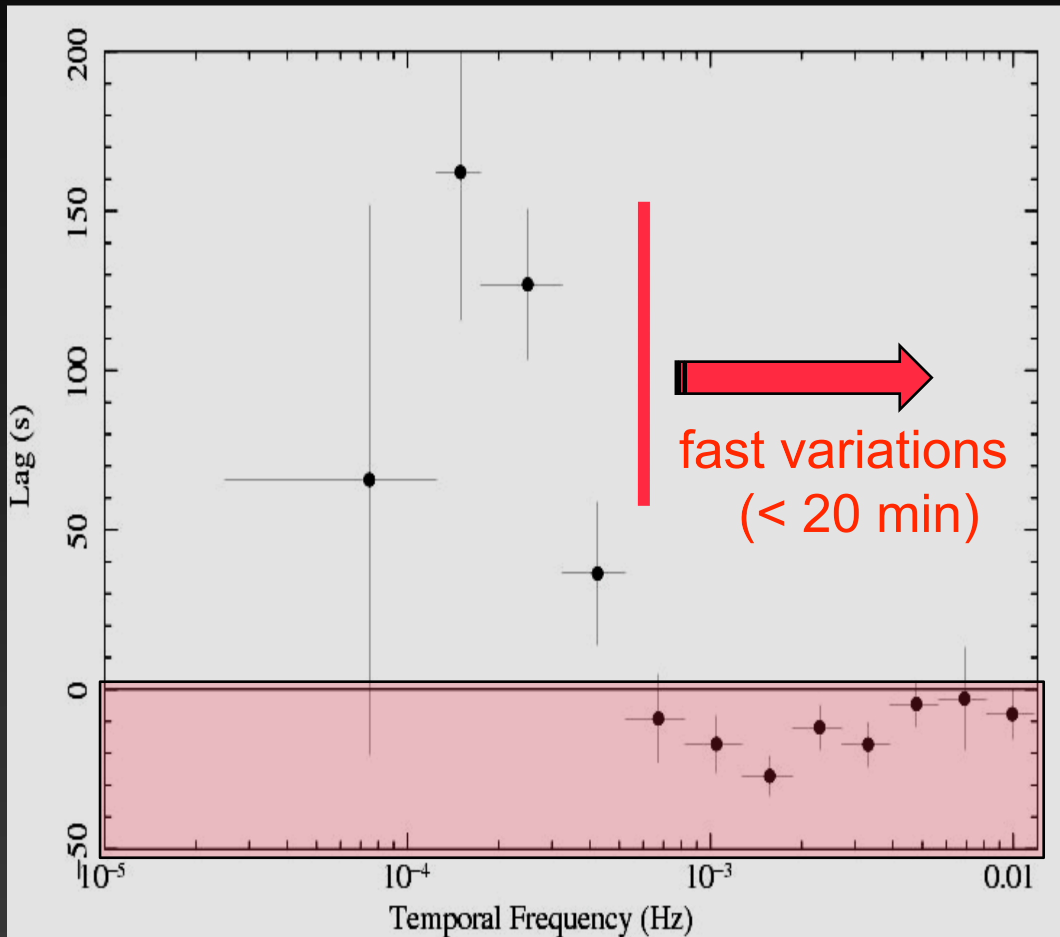


the two competitors
(absorption and reflection)
predict very distinct properties



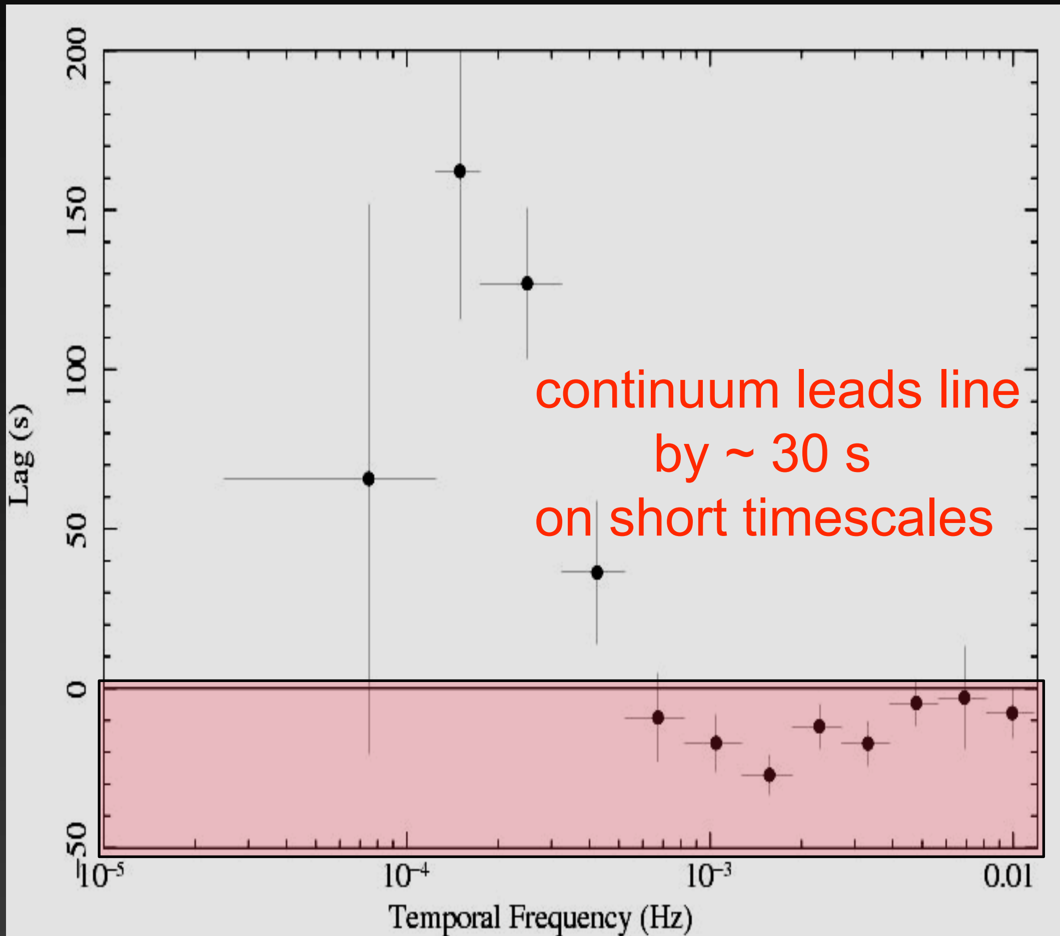
The special case of 1H 0707-495

Looking for time lags between lines and continuum: the most crucial result



The special case of 1H 0707-495

Looking for time lags between lines and continuum: the most crucial result



The special case of 1H 0707-495

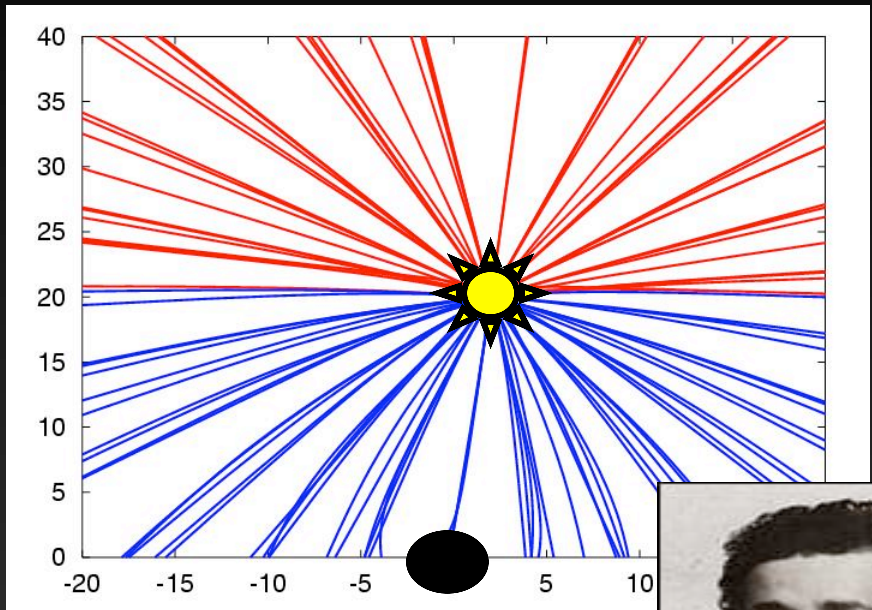
The observed lag means that

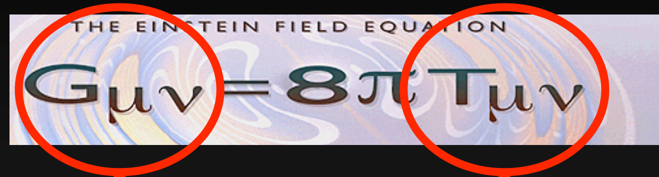
- the soft X-ray spectrum (Fe L) has to be reprocessed emission
- if it was the same continuum the lag would be in the opposite direction
- absorption is then ruled out
- the magnitude of the lag (~ 30s) is dictated by light travel time:
  - the X-ray corona is very close to the BH (few r_g)
  - the BH mass is likely 3-5 x 10^6 $M_\odot$

The special case of 1H 0707-495

Problem: why is reflection so strong?

GM & Fabian 04

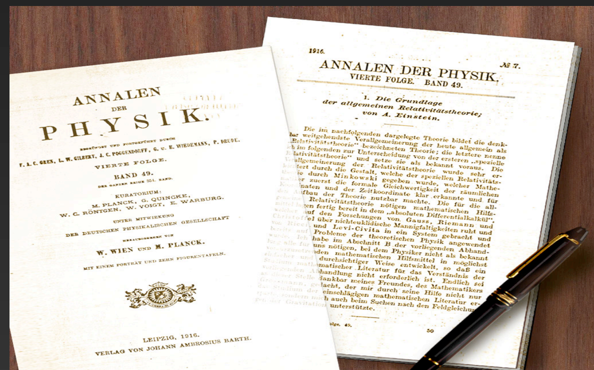




geometry

energy

Einstein
1879-195
5



General Relativity
1916

The special case of 1H 0707-495

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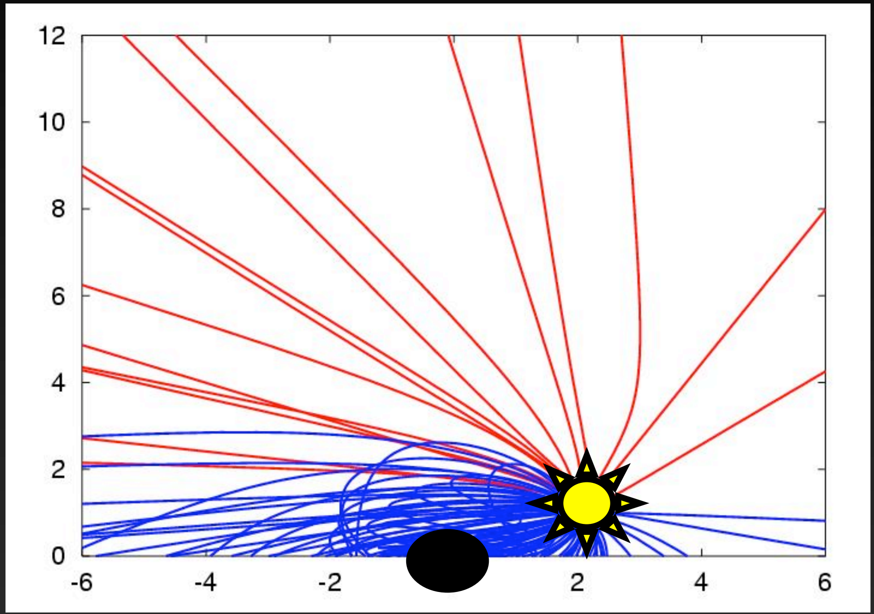
GM & Fabian 04

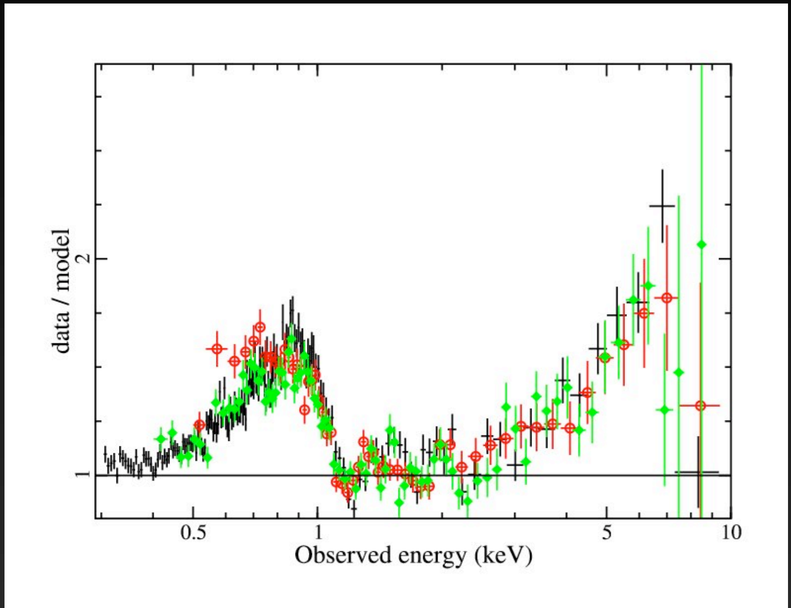


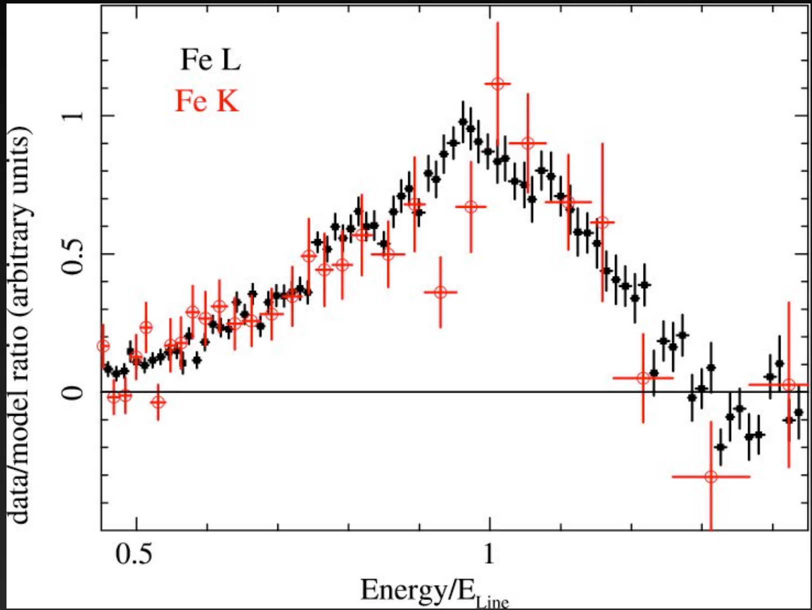
GR light bending

It is a natural consequence of having a X-ray corona close to the BH as demonstrated by the ~30s lag

Is 1H 0707-495 a unique case ?

Well, there is another suspect: IRAS 13324-3809





Ponti et al 09, MNRAS submitted

Is 1H 0707-495 a unique case ?

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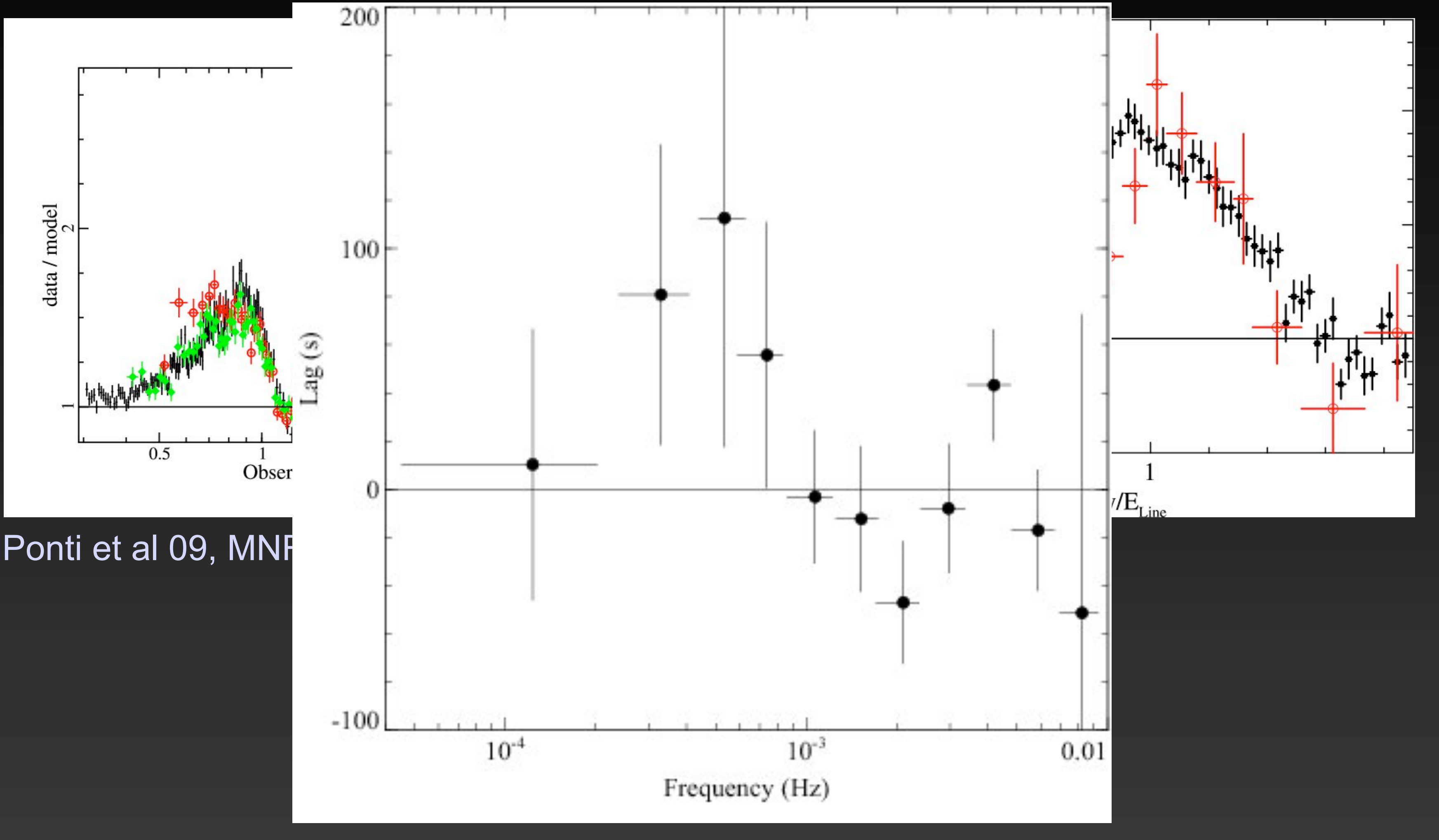
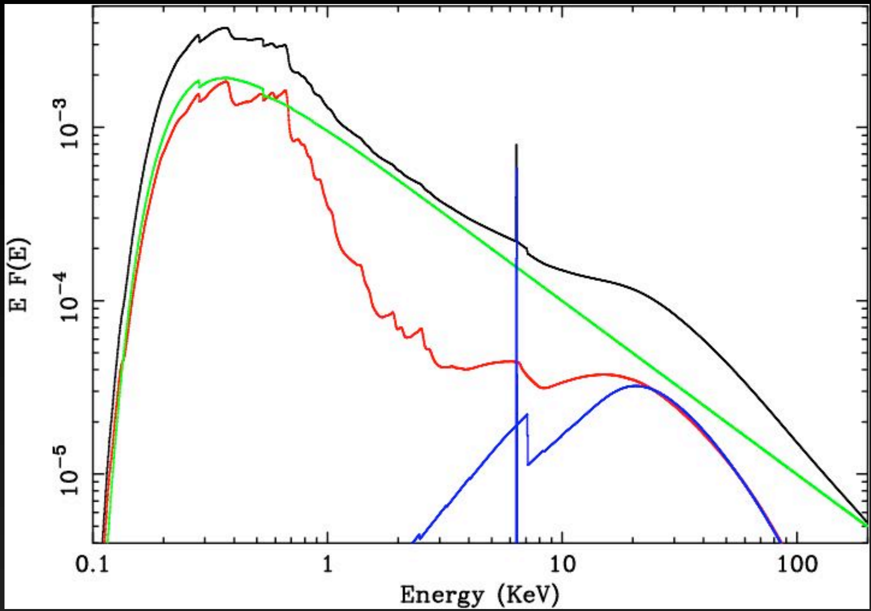
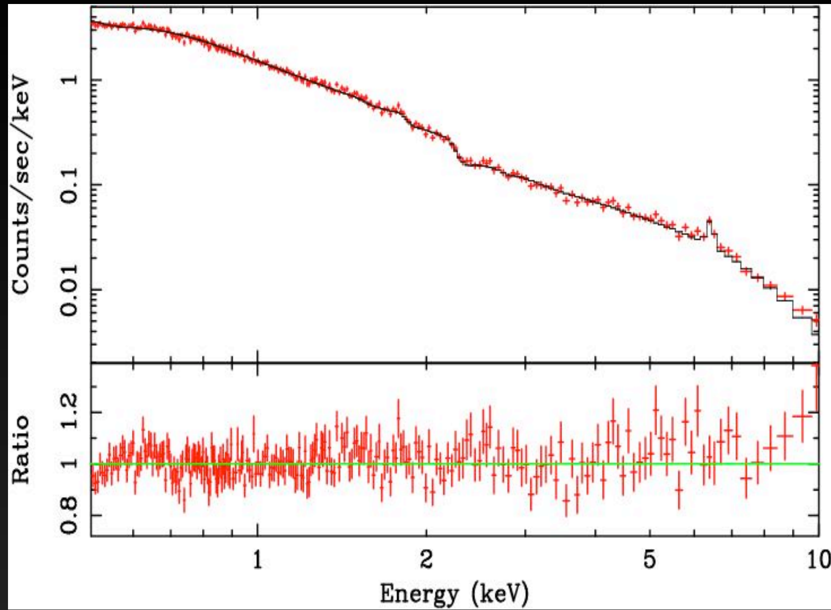


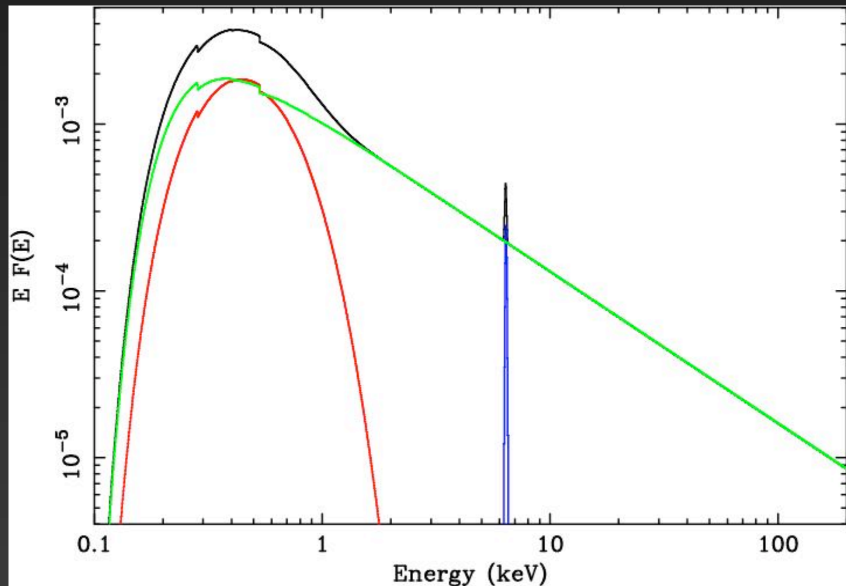
Ponti et al 09, MNR

Conclusions: do we have a template ?





What a standard one would look like



In the standard situation and with normal exposures we are unable to detect all these features except for the soft excess (which is indeed ~ ubiquitously detected)