Is the light bending effect at work in the core of NGC 4051 and IRAS 13224-3809?

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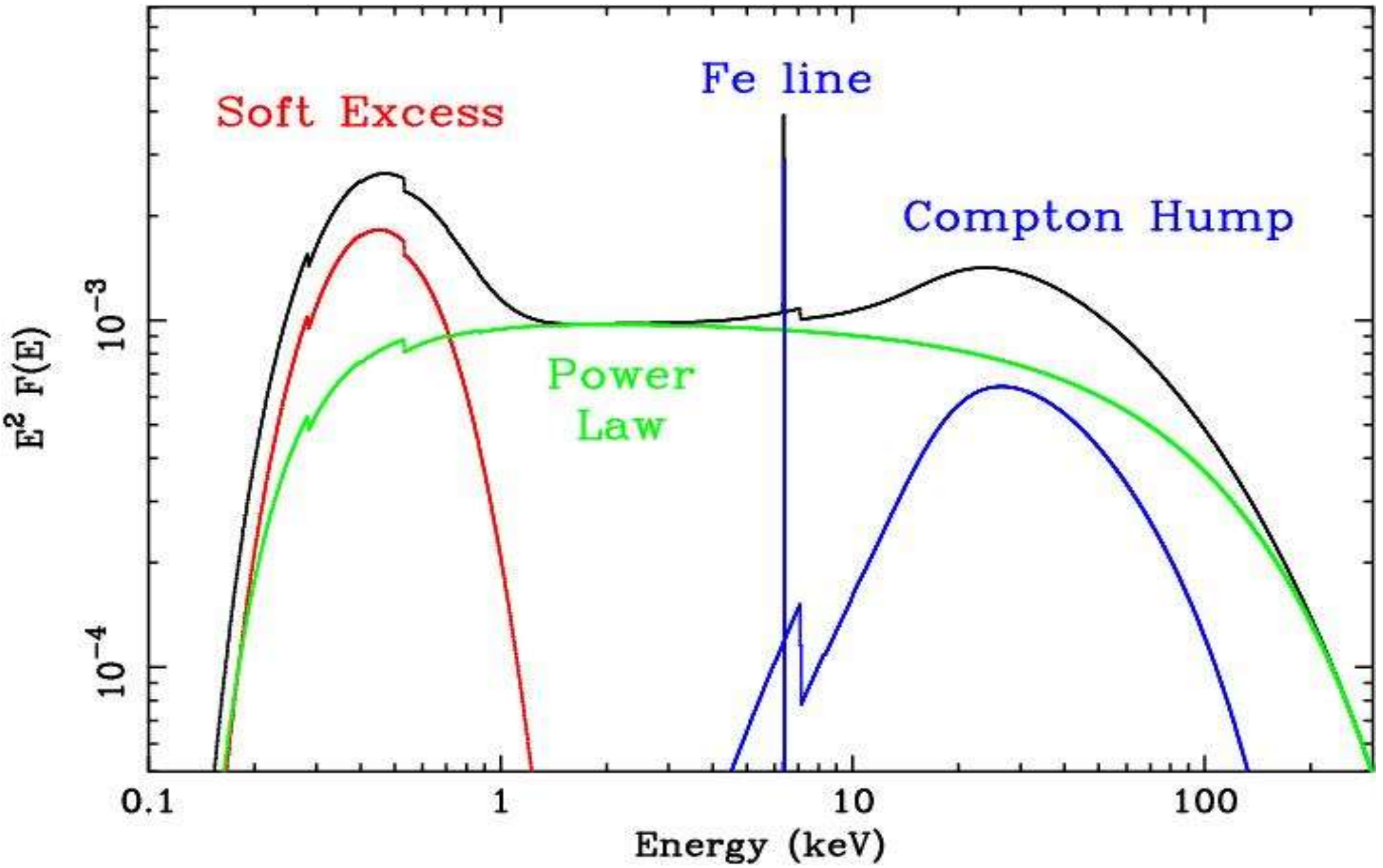
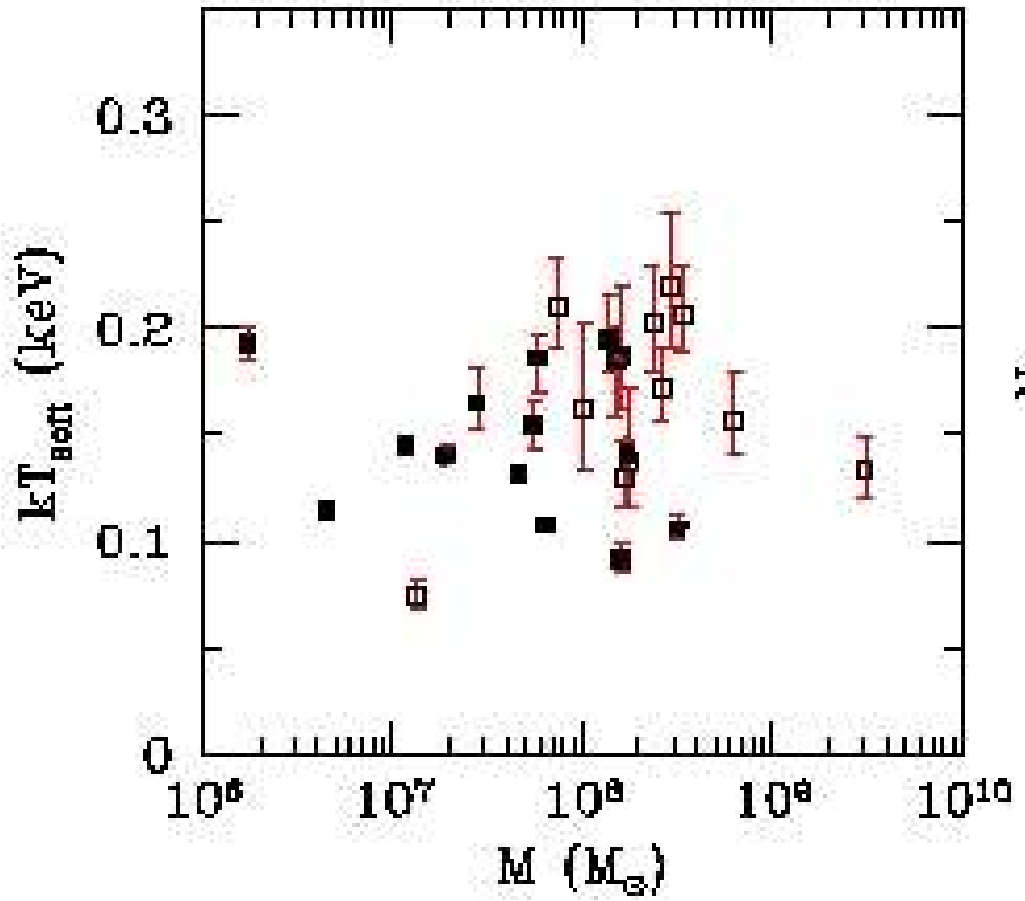
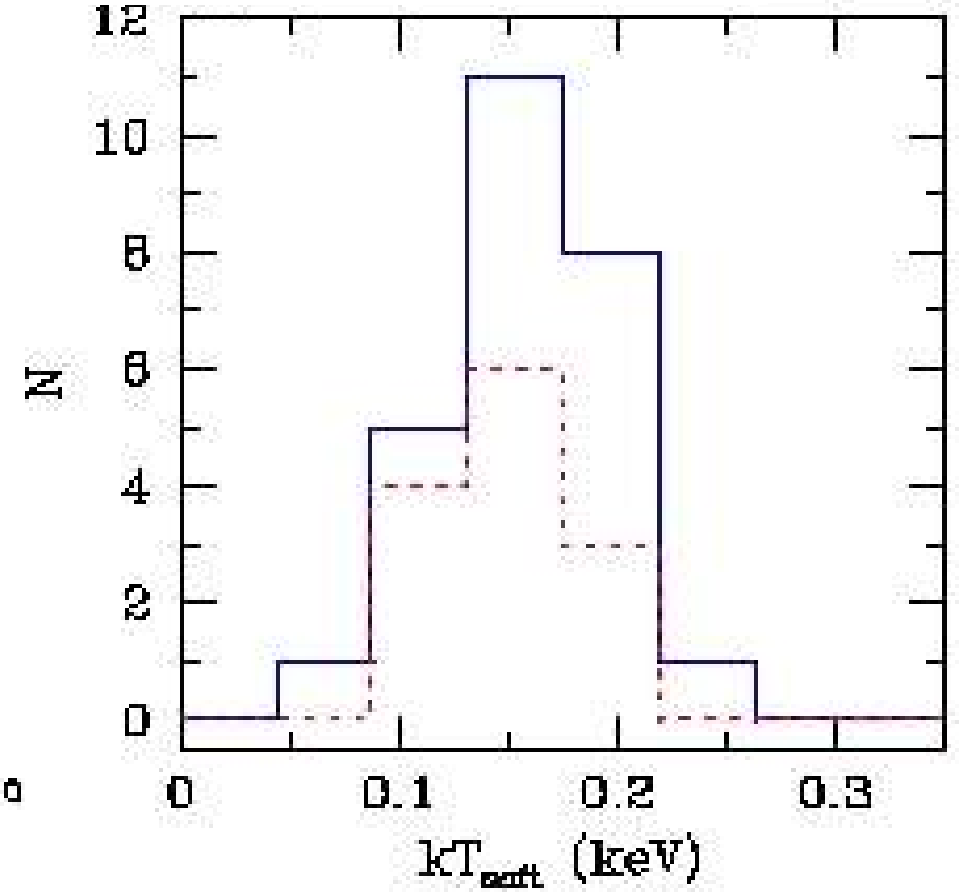
The typical X-ray spectrum of a Seyfert 1 galaxy



The typical X-ray spectrum of a Seyfert galaxy: problems in the standard picture

Gierlinski & Done 04 Piconcelli et al. 05 Crummy et al. 06





T_{BB} is the same in all PG quasars

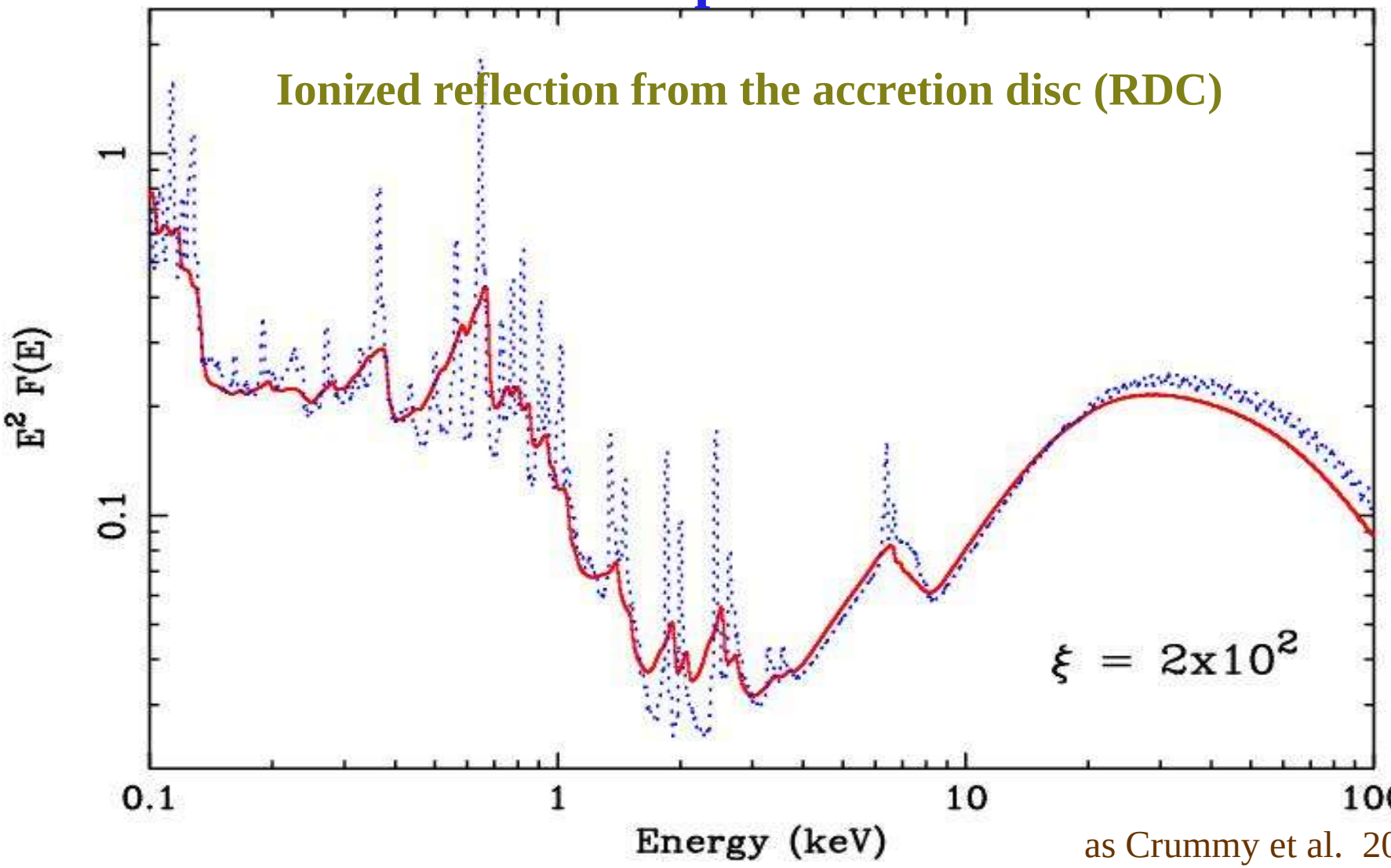
that span 4 order of magnitude in BH masses and luminosity

$T_{BB} \propto M_{BH}^{-1/4}$; $T_{BB} \propto L^{1/4}$

Origin of the soft excess? ⇒ **no standard black body?**

⇒ **tied to atomic processes (absorption/reflection)?**

The typical X-ray spectrum of a Seyfert galaxy: a new interpretation



as Crummy et al. 2006

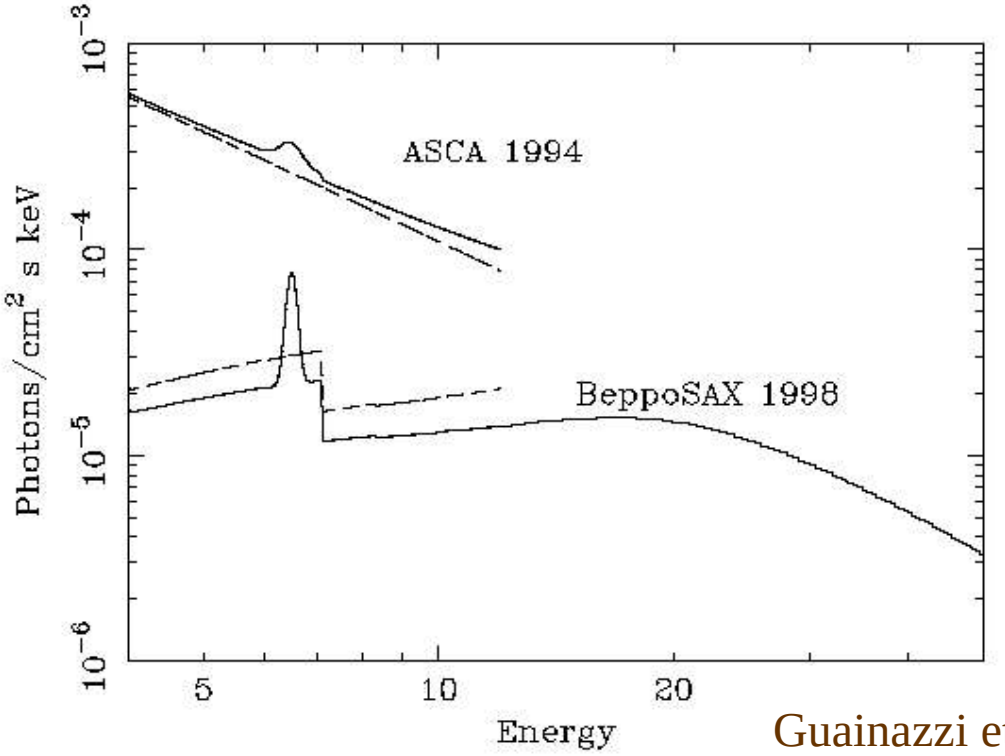
ionized reflection from the disc (RDC) could explain the soft excess

$\Rightarrow$ origin of the soft excess no more black body

To disentangle the different decompositions $\Rightarrow$ detailed spectral variability

NGC 4051

- **Narrow Line Seyfert 1**
- **z=0.002336**
- **$L_{[2\text{-}10\ keV]} \cong$ few $\times 10^{41}$ erg s^{-1}**
- **$M_{BH} \cong 3\text{–}5 \times 10^5\ M_{Sun}$**



Guainazzi et al. 1998

★ $\Rightarrow$ **source switched off**
$\Rightarrow$ leaving **residual reflection**

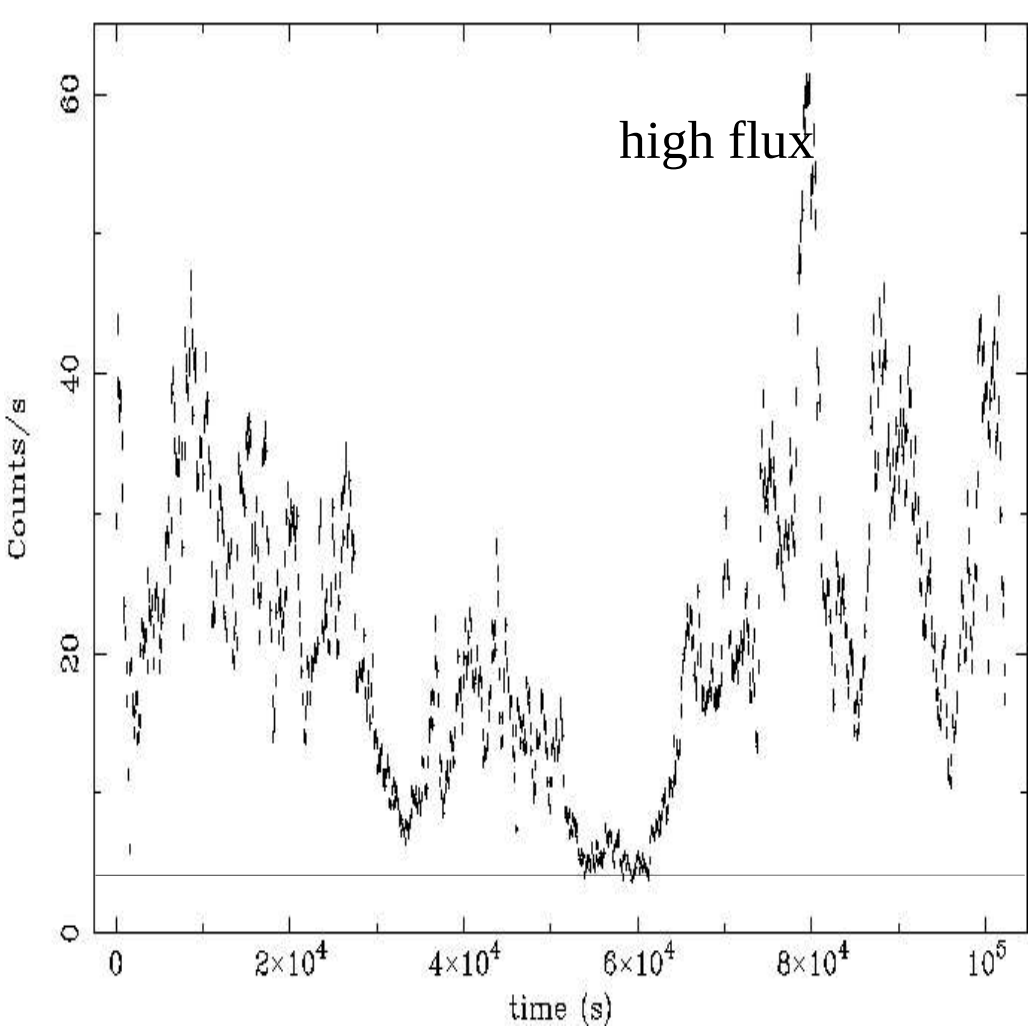
★ $Flux_{2\text{-}10\ keV} = 1.26 \times 10^{-12}$ erg cm^{-2} s^{-1}

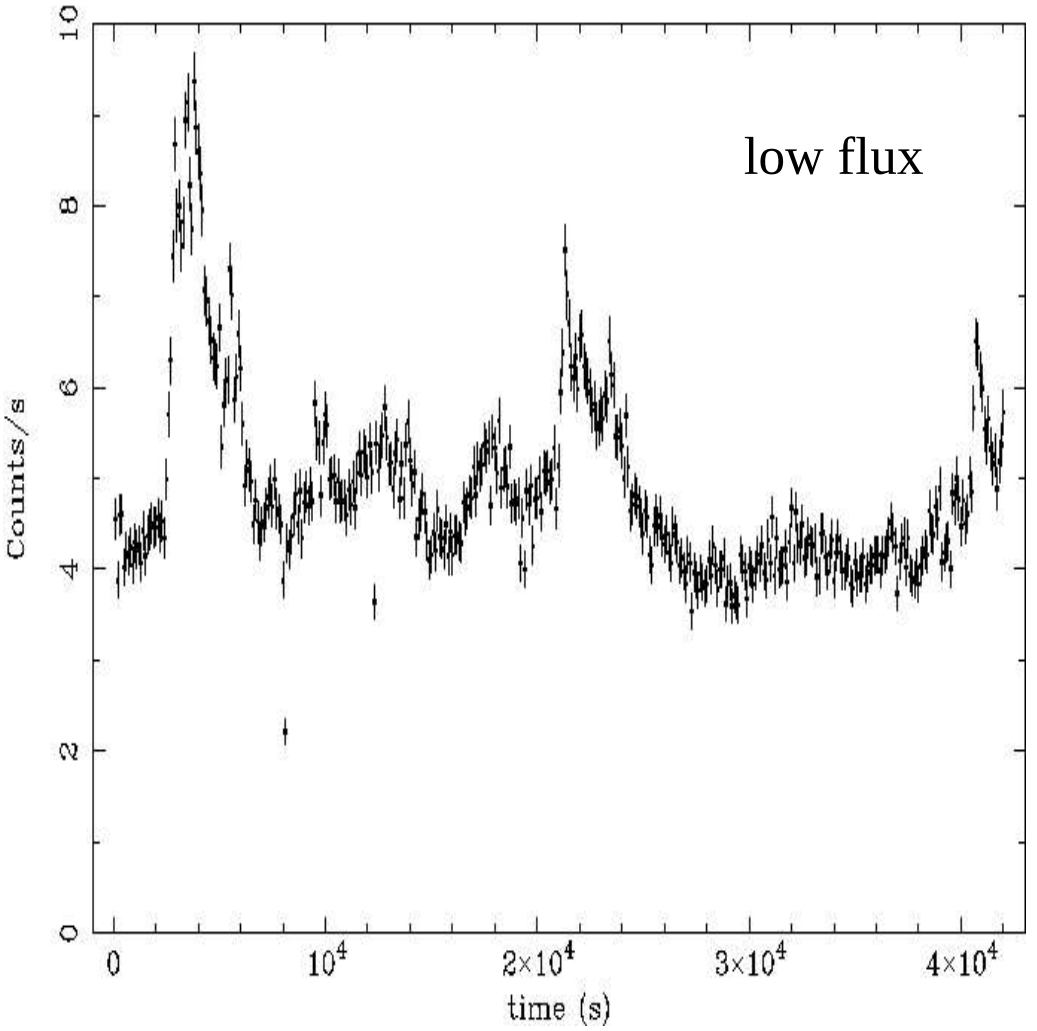
2 XMM-Newton observations:

2001-05-16 rev. 263 $flux_{2\text{-}10\ keV} = 2.3 \times 10^{-11}$ erg cm^{-2} s^{-1}
2002-11-22 rev. 541 $flux_{2\text{-}10\ keV} = 0.58 \times 10^{-11}$ erg cm^{-2} s^{-1}

Pounds et al. 2004; Uttley et al. 2004; Feňovčík et al. A&A sub.; Krongold et al. ApJ sub.
Ponti et al. 2006 $\Rightarrow$ detailed time resolved spectral variability

Light curves



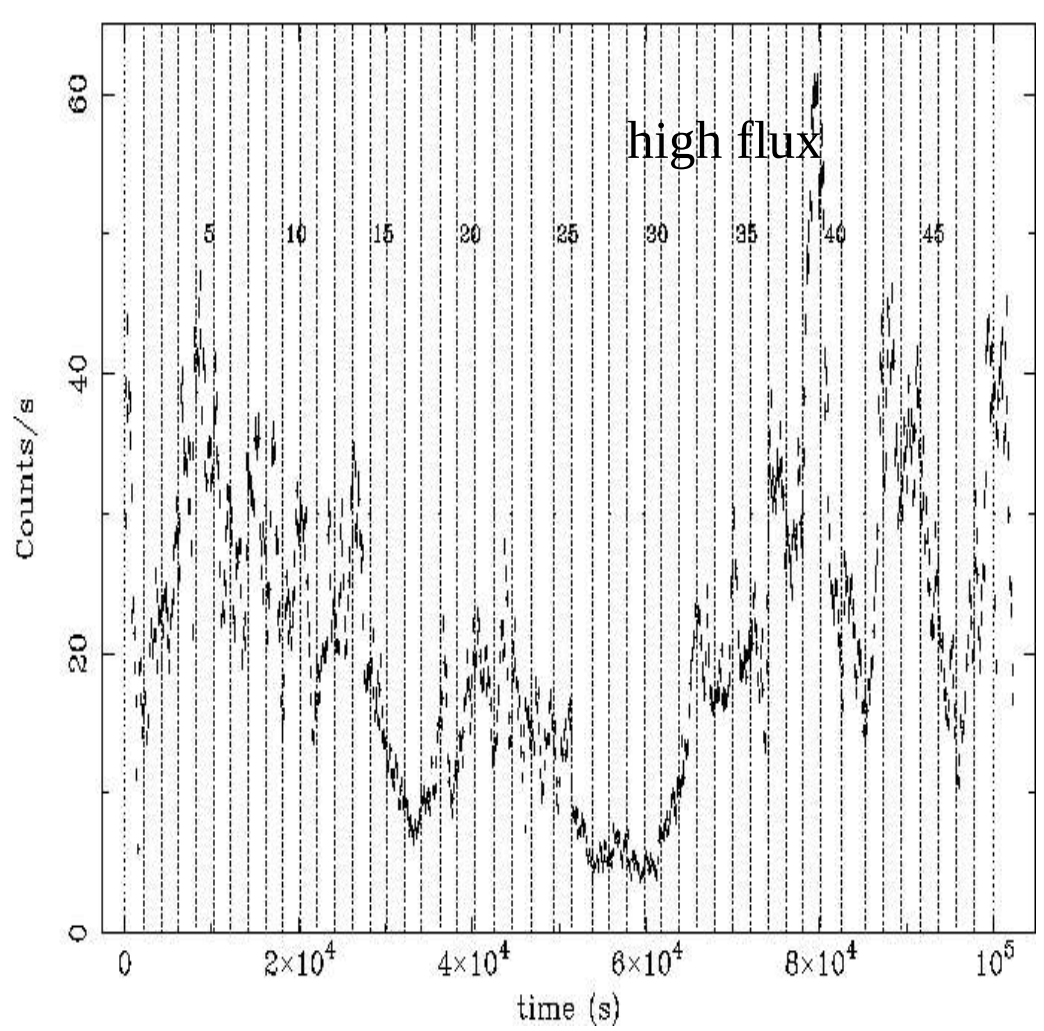


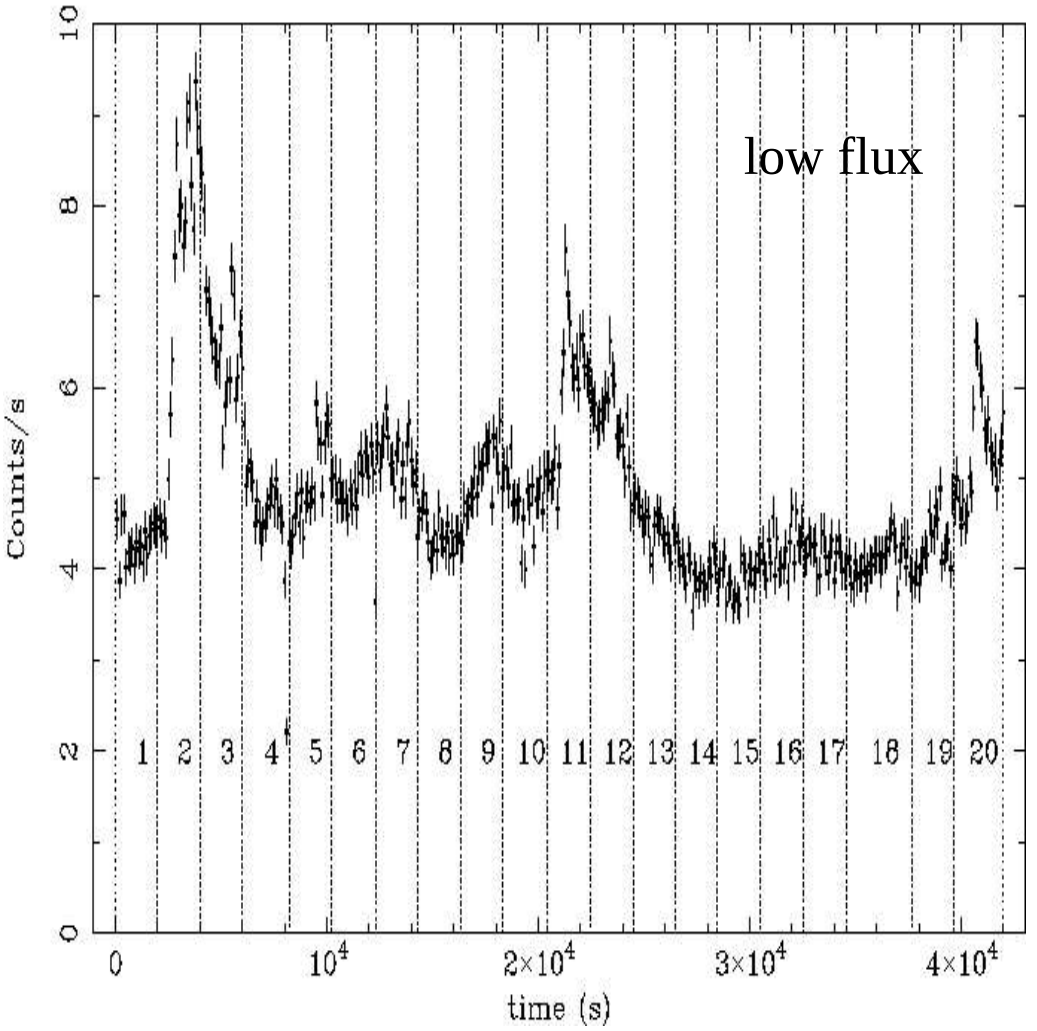
★ **ΔF~3 in 1000 s**

Pounds et al. 2004

★ **Mean spectrum study loses information**

Light curves





ΔF~3 in 1000 s

Ponti et al. 2006

Mean spectrum study loses information

⇒ Time resolved spectral analysis in ~2 ks long periods.

⇒ **Test if models are valid in every moment**

Constant components in NGC 4051

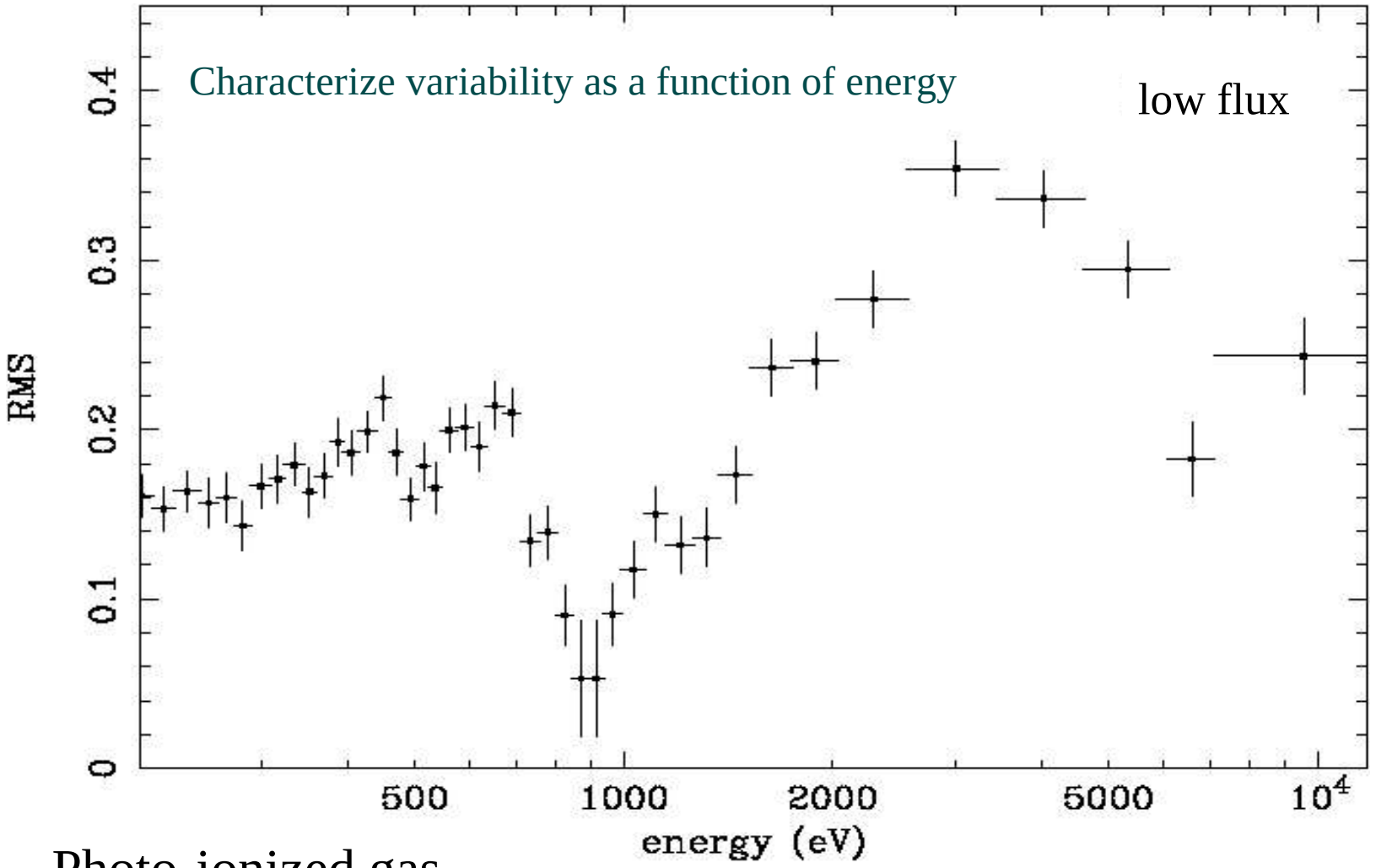


Photo-ionized gas

- **At 0.9-1 keV:**
  Ne IX + Oxygen Recombination Continuum + Fe L complex
- **Lower energy:**
  OVII and OVIII

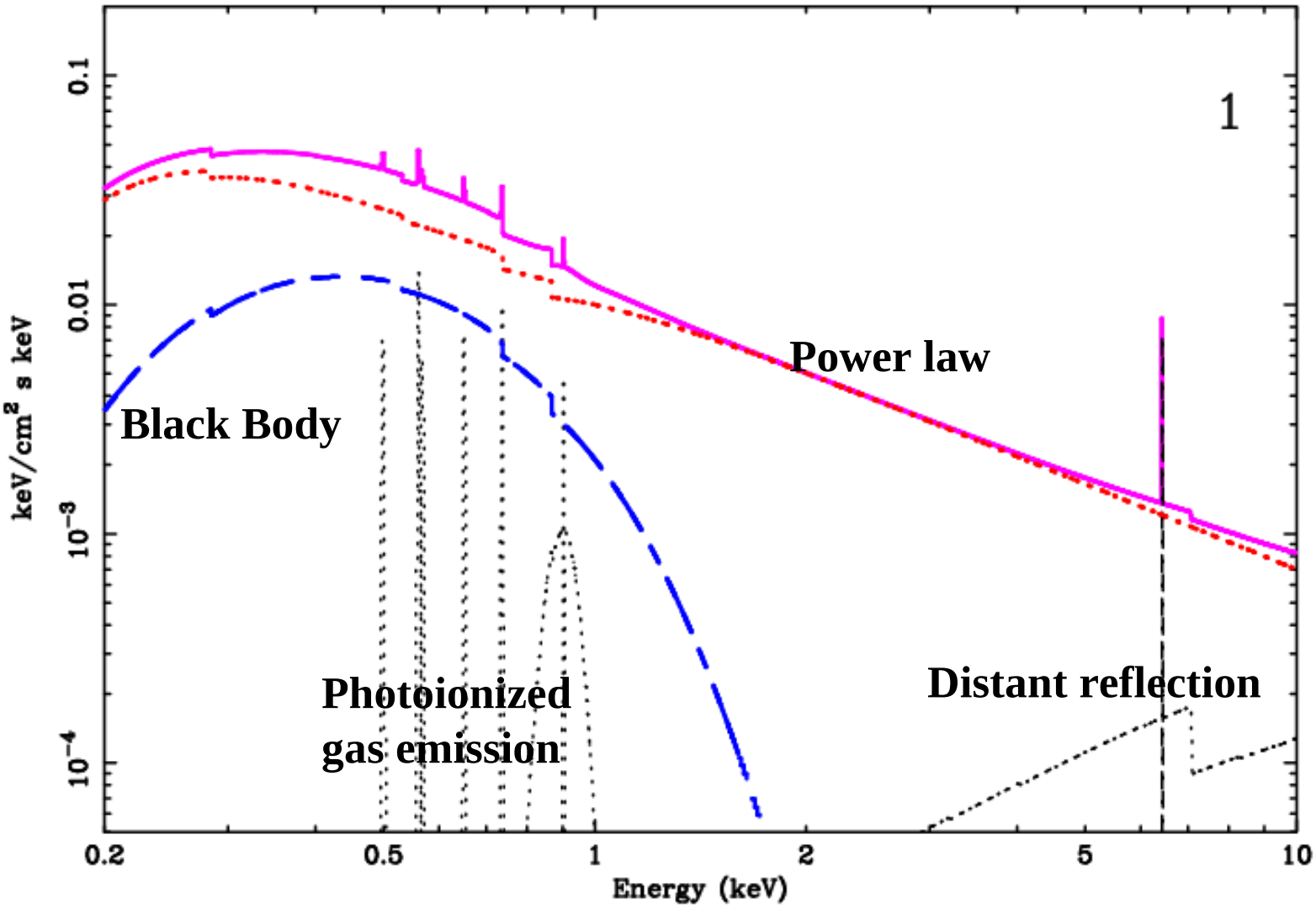
Pounds et al. 2004

Constant Reflection

- **Narrow Fe k line is consistent with previous observations EW 700 eV**

Guainazzi et al. 1998

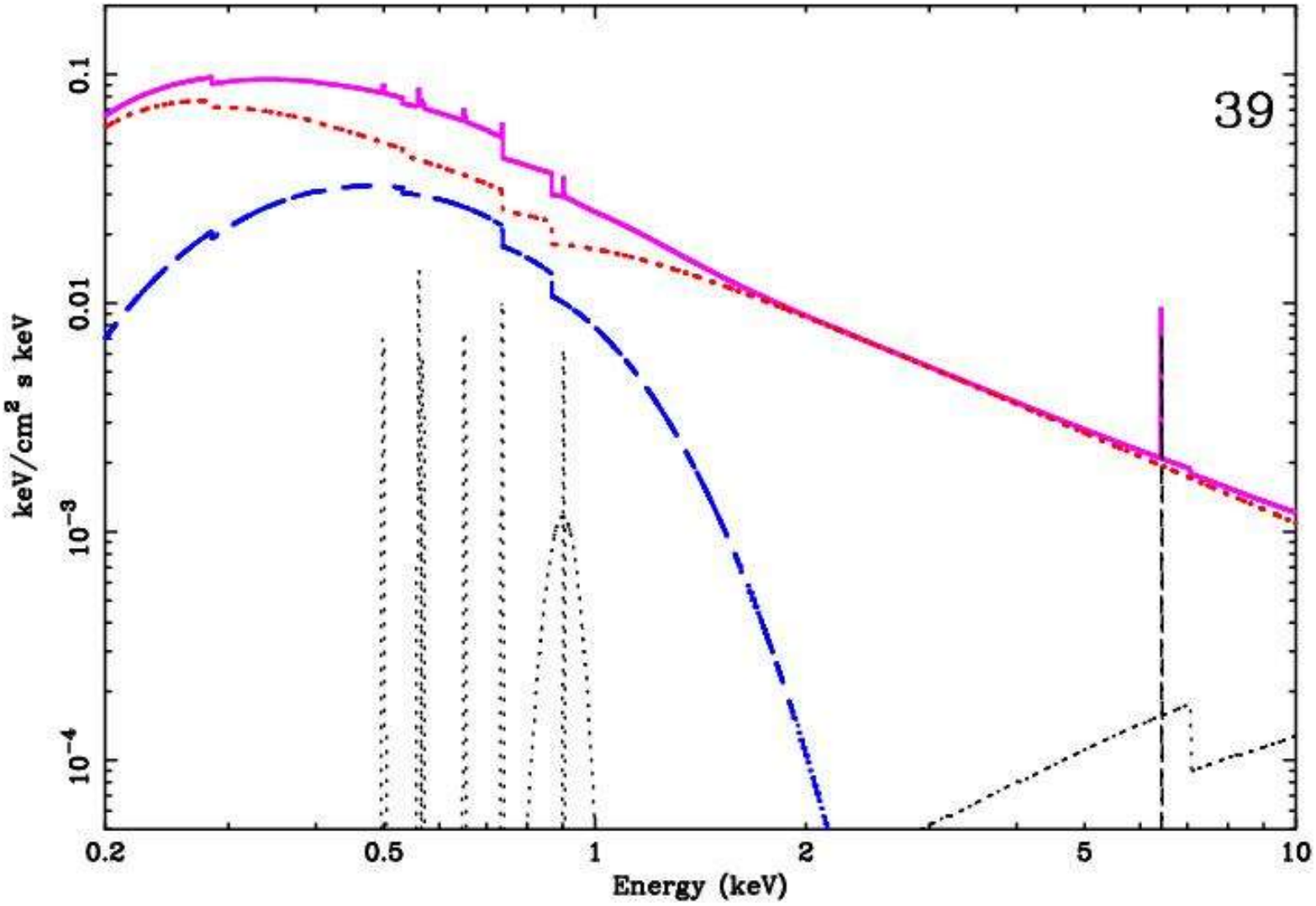
Time resolved spectral variability: “classical picture”



Free parameters: T_{BB} A_{BB} A_{Pl} Γ_{Pl} τ_{E1} τ_{E2}

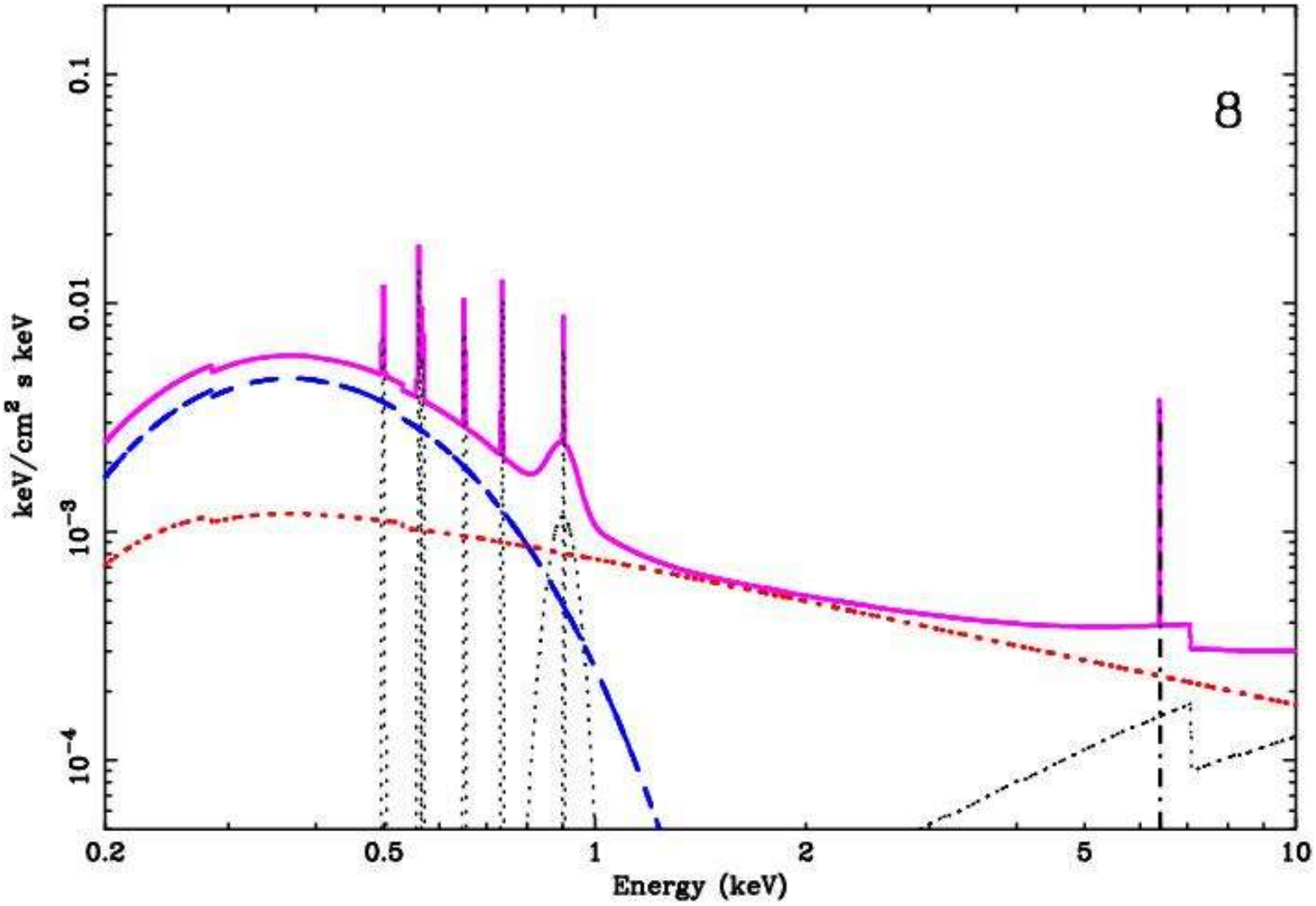
Time resolved spectral variability: “classical picture”

high flux ~ Seyfert 1 – like spectrum

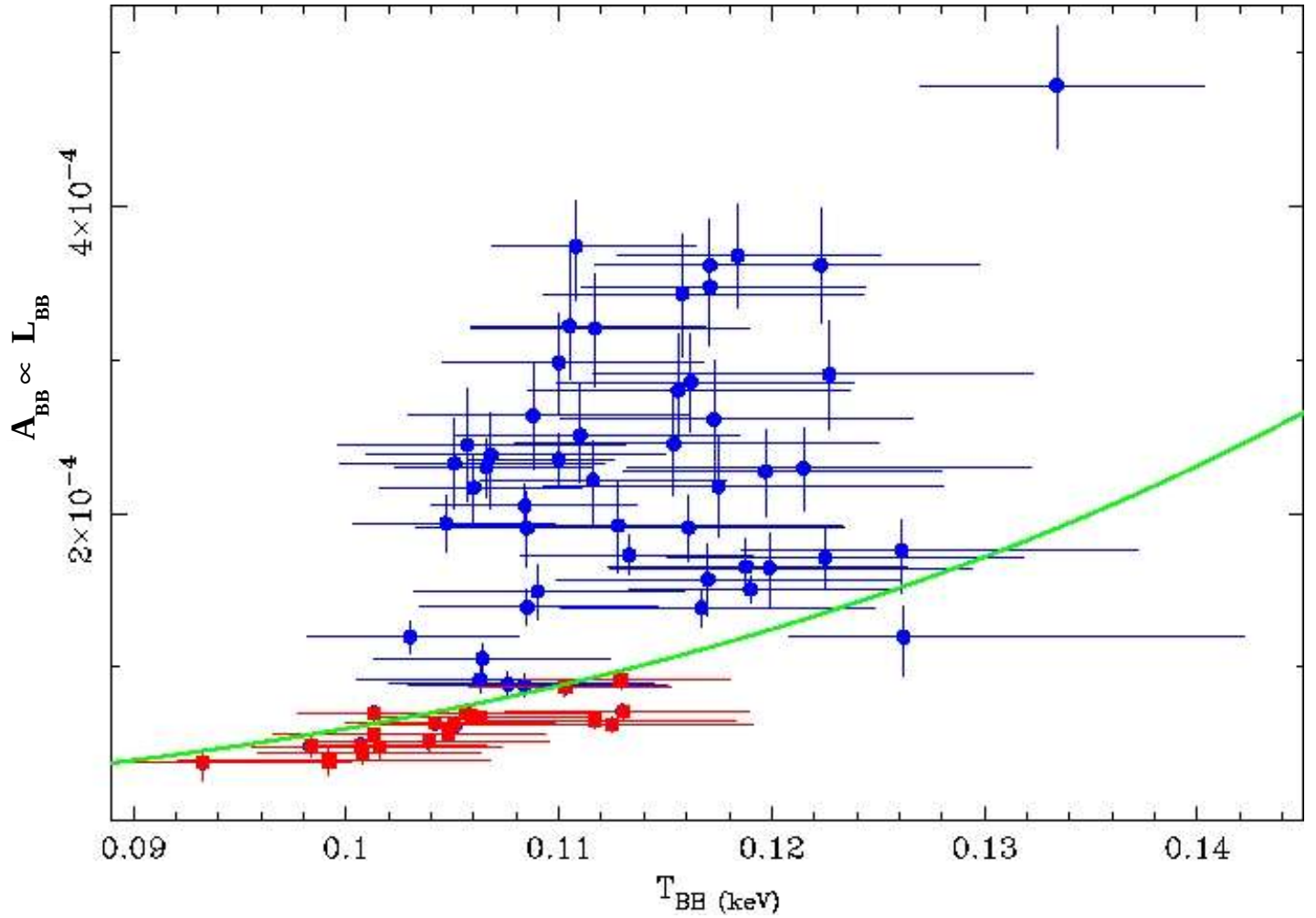


Time resolved spectral variability: “classical picture”

low flux ~ Seyfert 2 – like spectrum



Time resolved spectral variability: “classical picture”



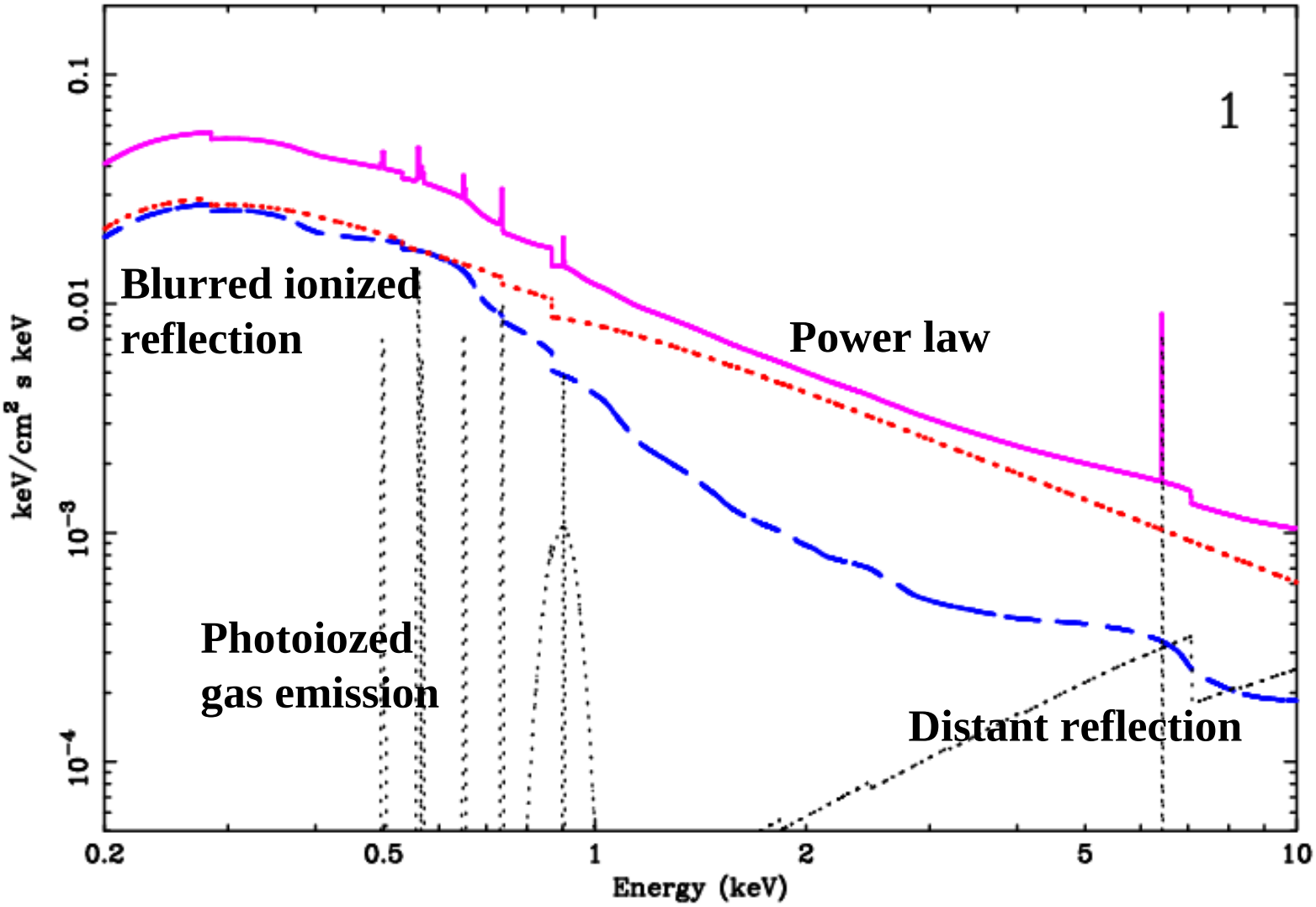
T_{BB} is the same of all PG quasars that have M_{BH} up to 10^5 times higher

Data do not follow the BB relation $L_{BB} \propto T_{BB}^4$ Gierlinski & Done 04; Piconcelli et al. 05; Crummy et al. 06

T_{BB} consistent with constant

$\Rightarrow$ Soft excess tied to atomic process (ionized reflection)?

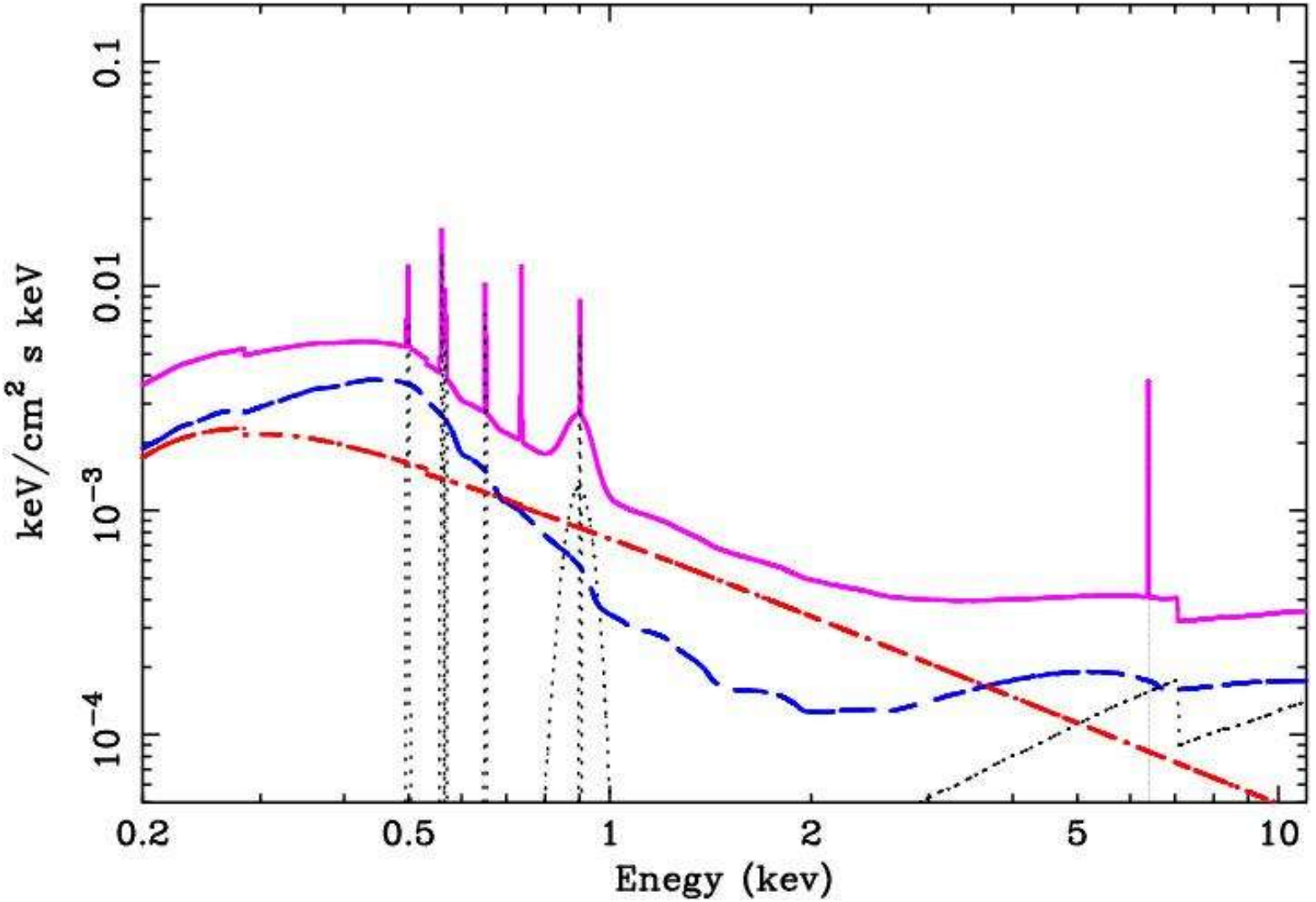
Time resolved spectral variability: Two component model



Free parameters: $\alpha_{discemissivity}$ ξ_{Refl} A_{Refl} A_{Pl} τ_{E1} τ_{E2}

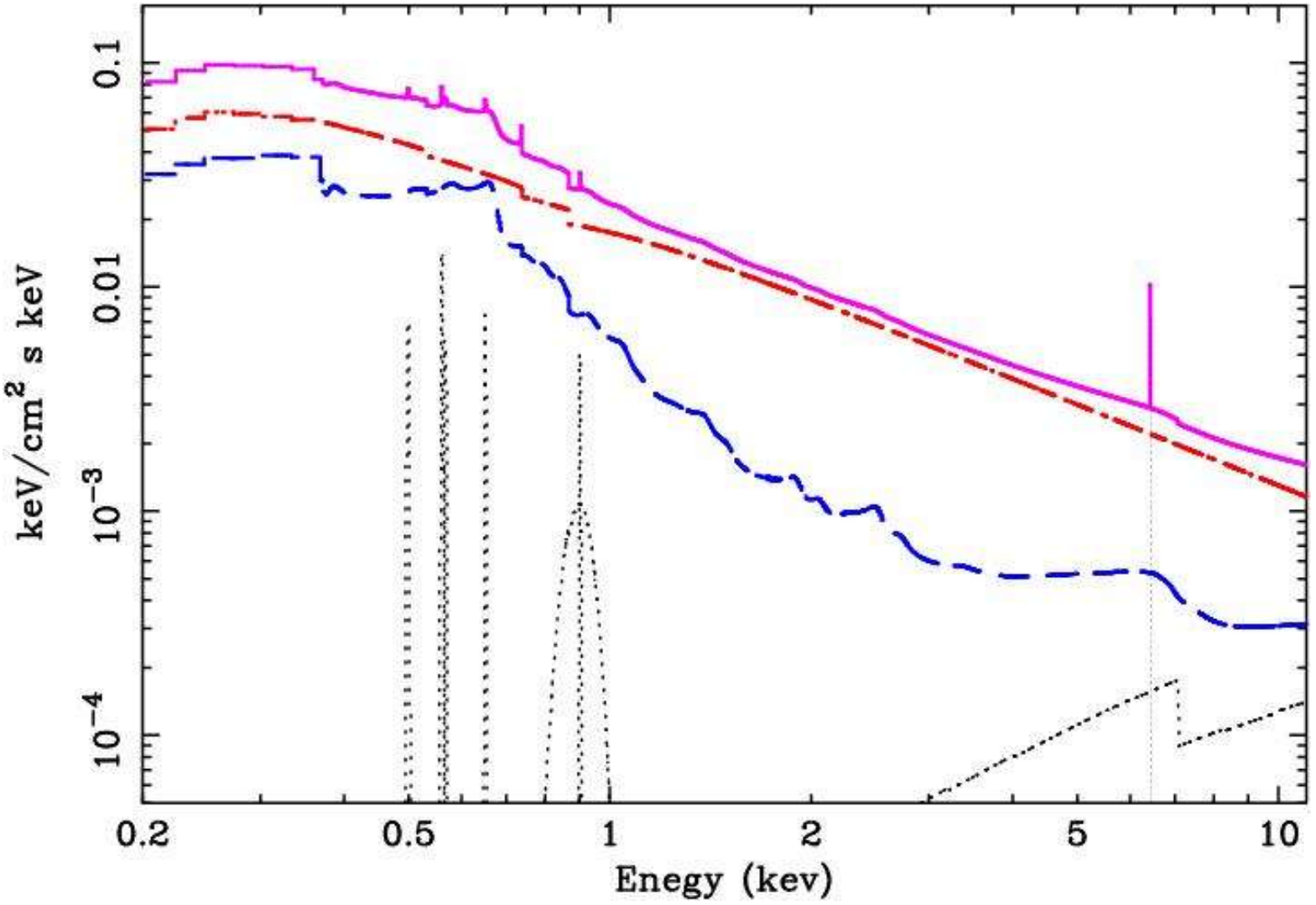
Time resolved spectral variability: Two component model

low flux

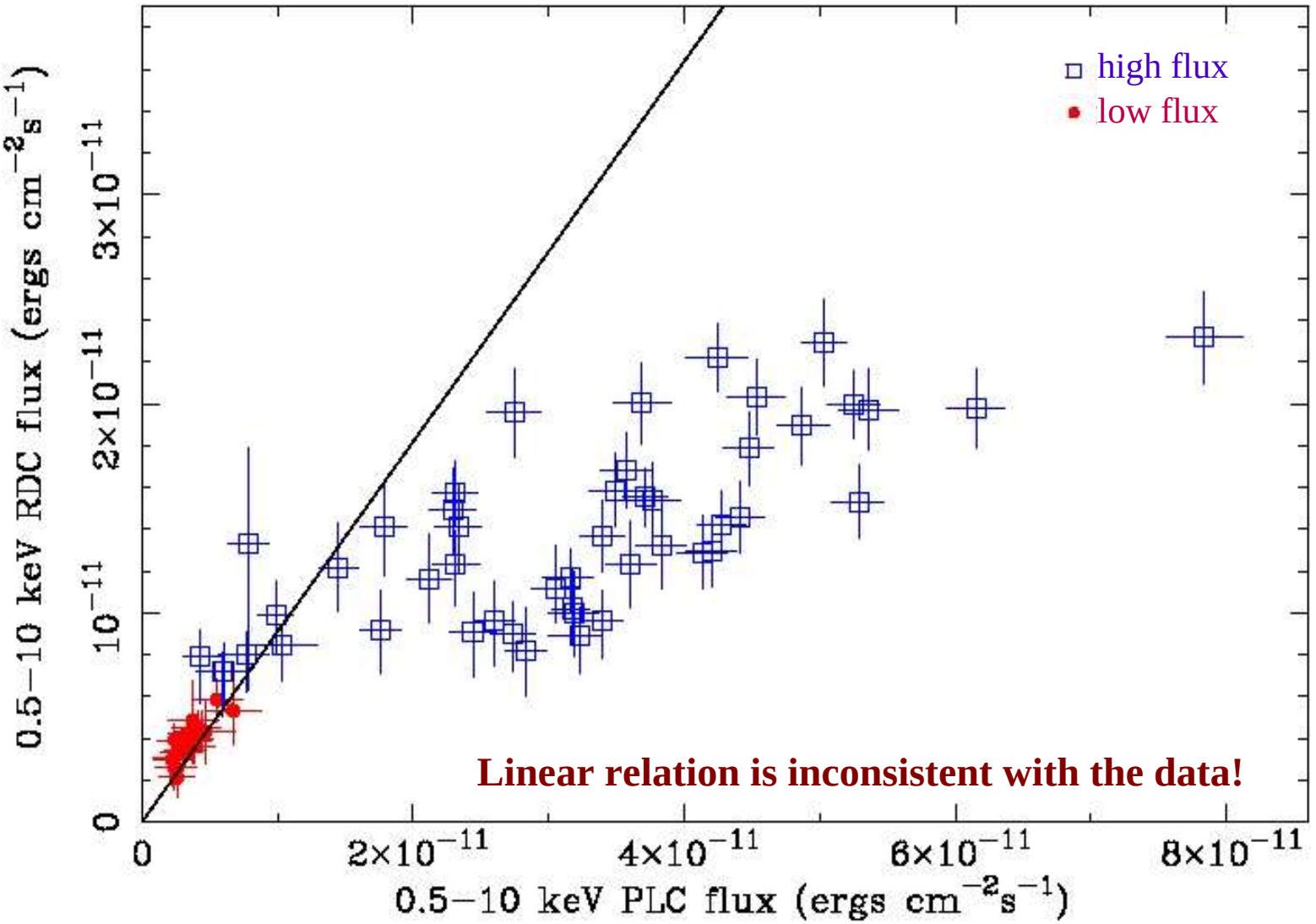


Time resolved spectral variability: Two component model

high flux



Two component model

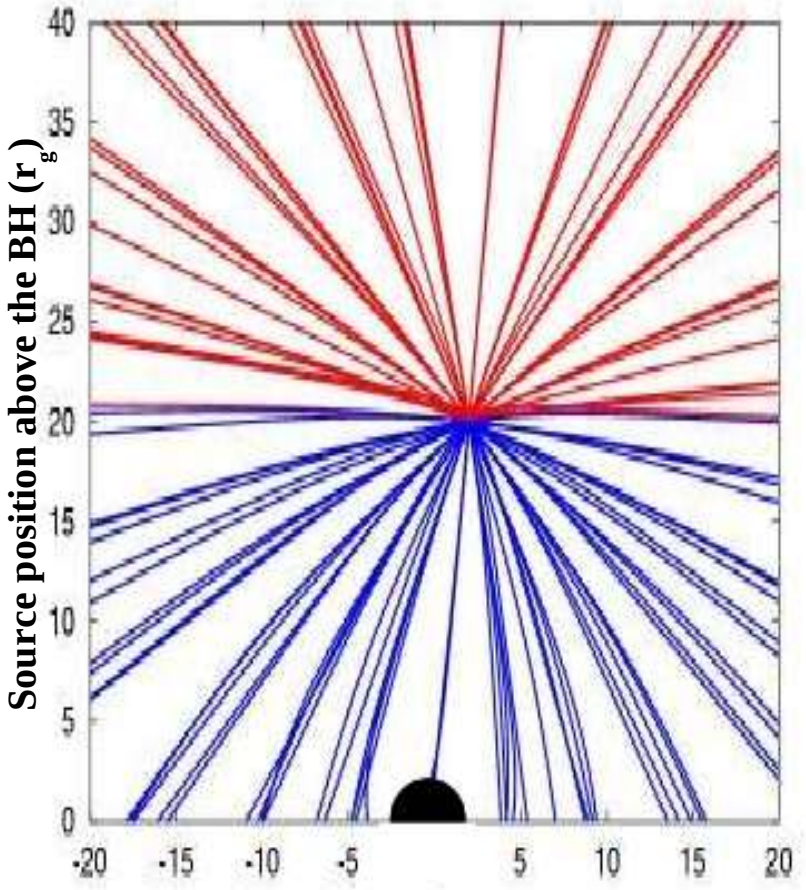


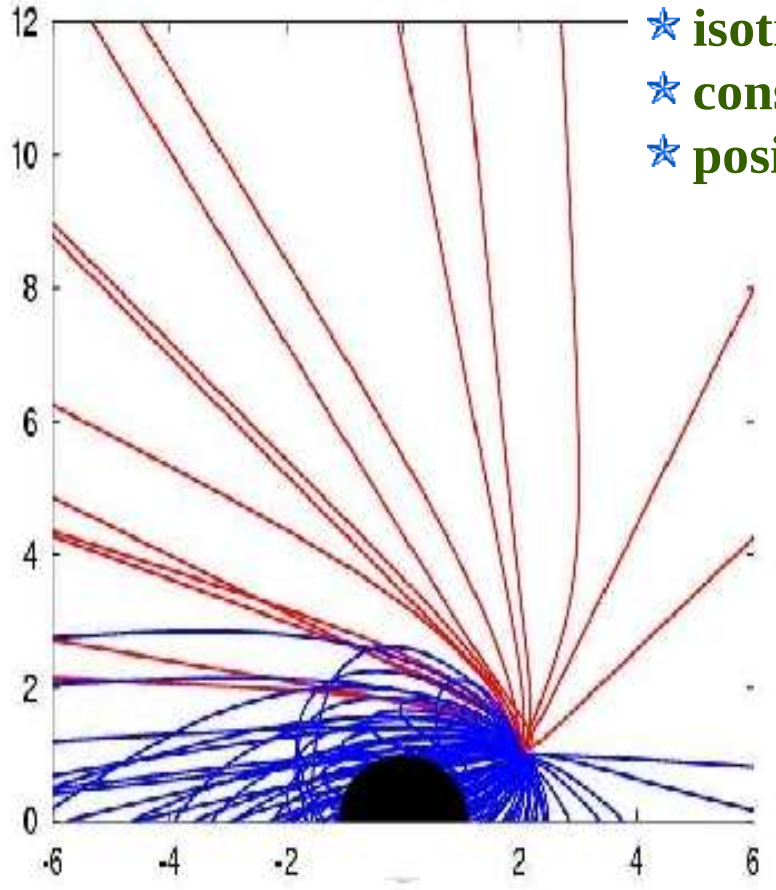
- **The reflection explains the observed constancy of the soft excess "temperature" and its similarity to PG quasars**

- **The observed relation is predicted by the light bending model Miniutti and Fabian 2004**

The light bending model

Martocchia Matt 96 Reynolds Begelman 97 Miniutti Fabian 03 04





Miniutti Fabian 03 04

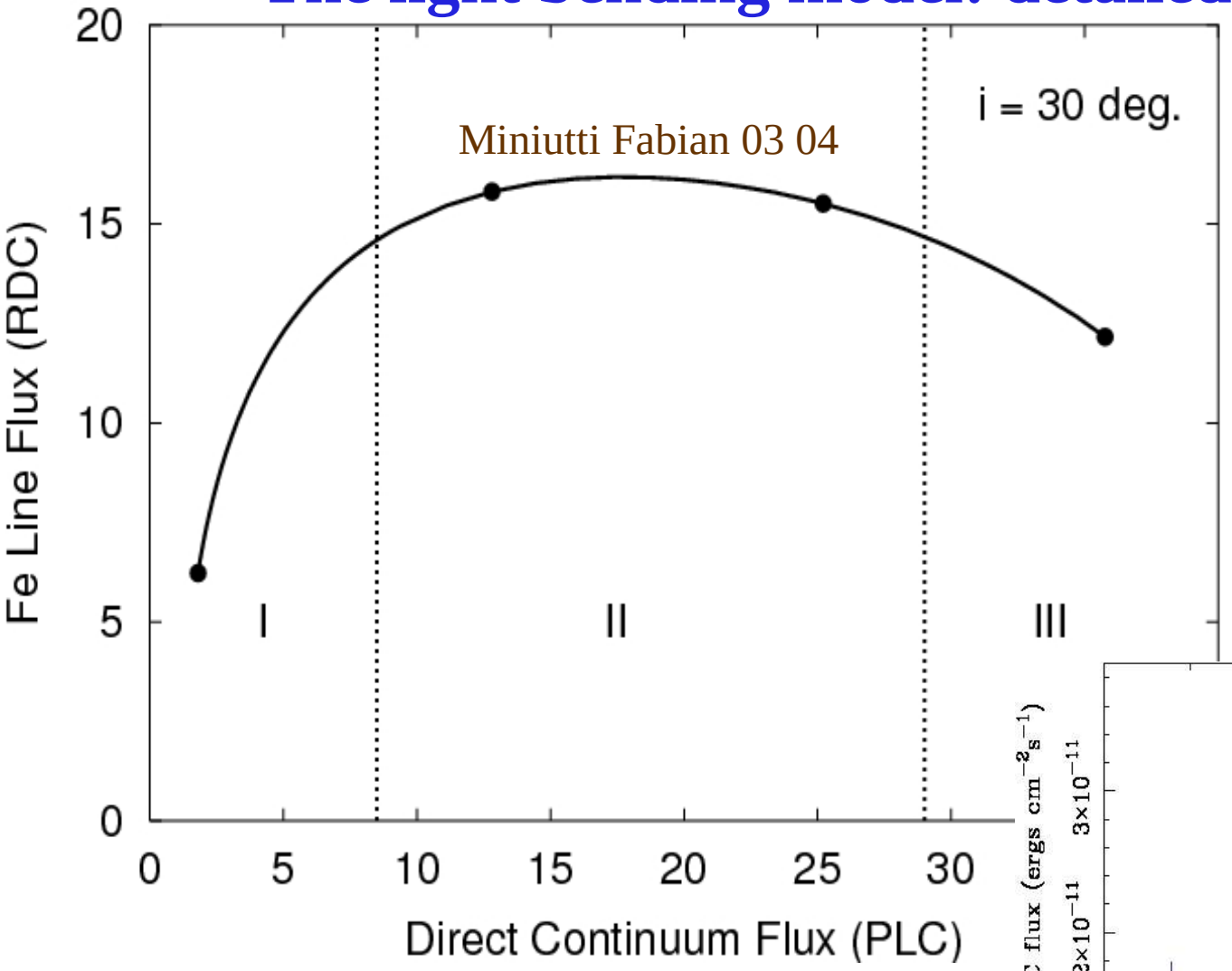
Primary source of X-rays

- **isotropic emission**
- **constant luminosity**
- **position specified by h**

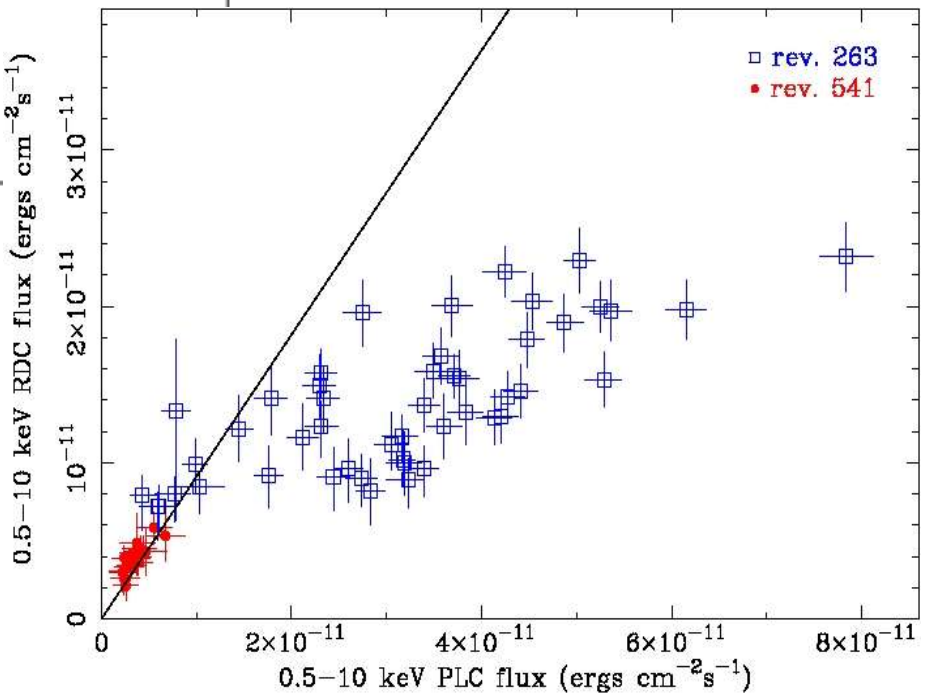
- **source almost isotropic at h> 20 r_g**
- **source flux lower with lower h**

The main idea is thus that changes in the height of the source induce the observed variability via gravitational light bending

The light bending model: detailed calculations



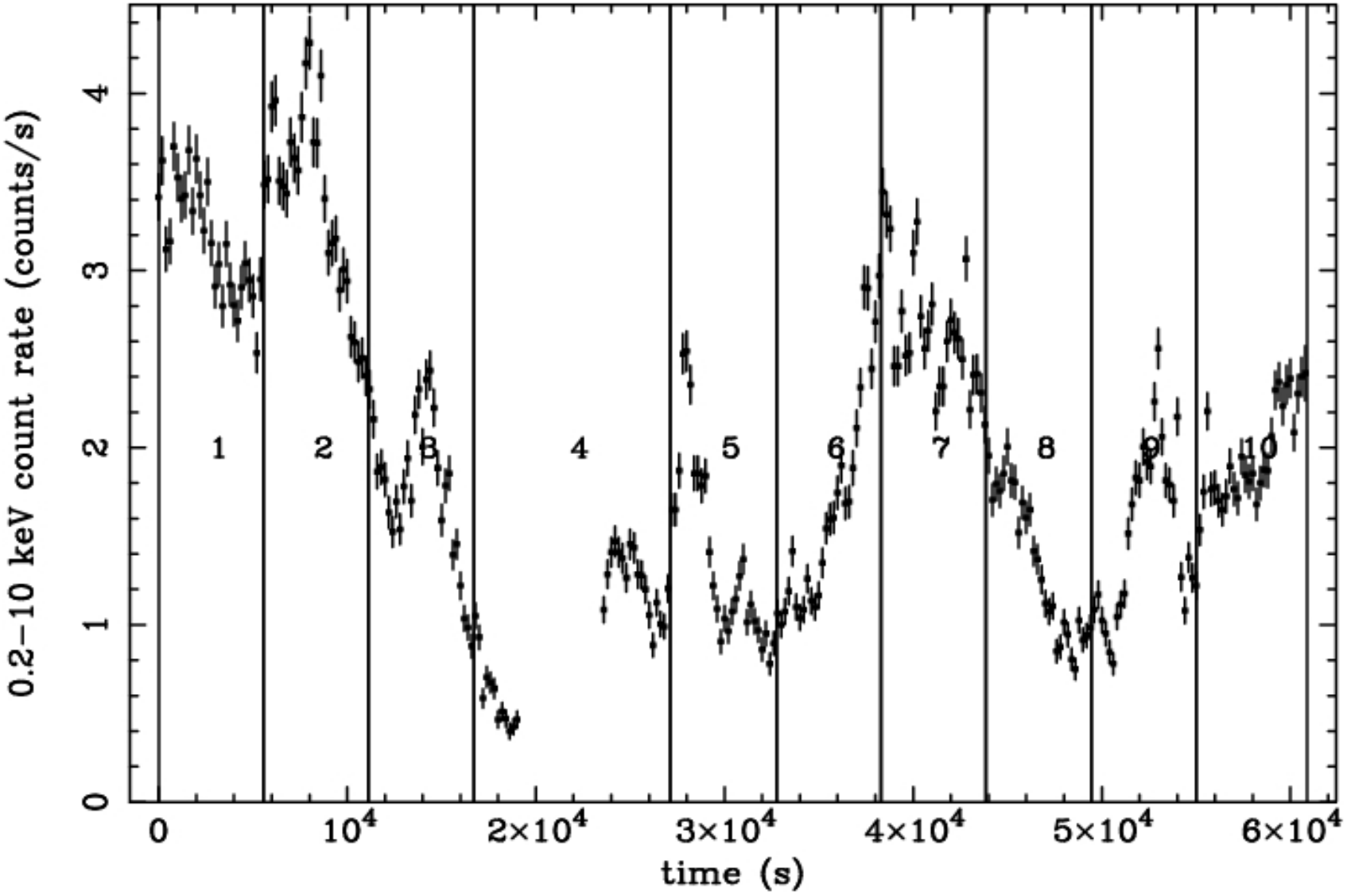
- correlation between RDC and PLC at low flux
- constant RDC at medium high flux



NGC 4051 ⇒ height X-ray source < 20 r_g

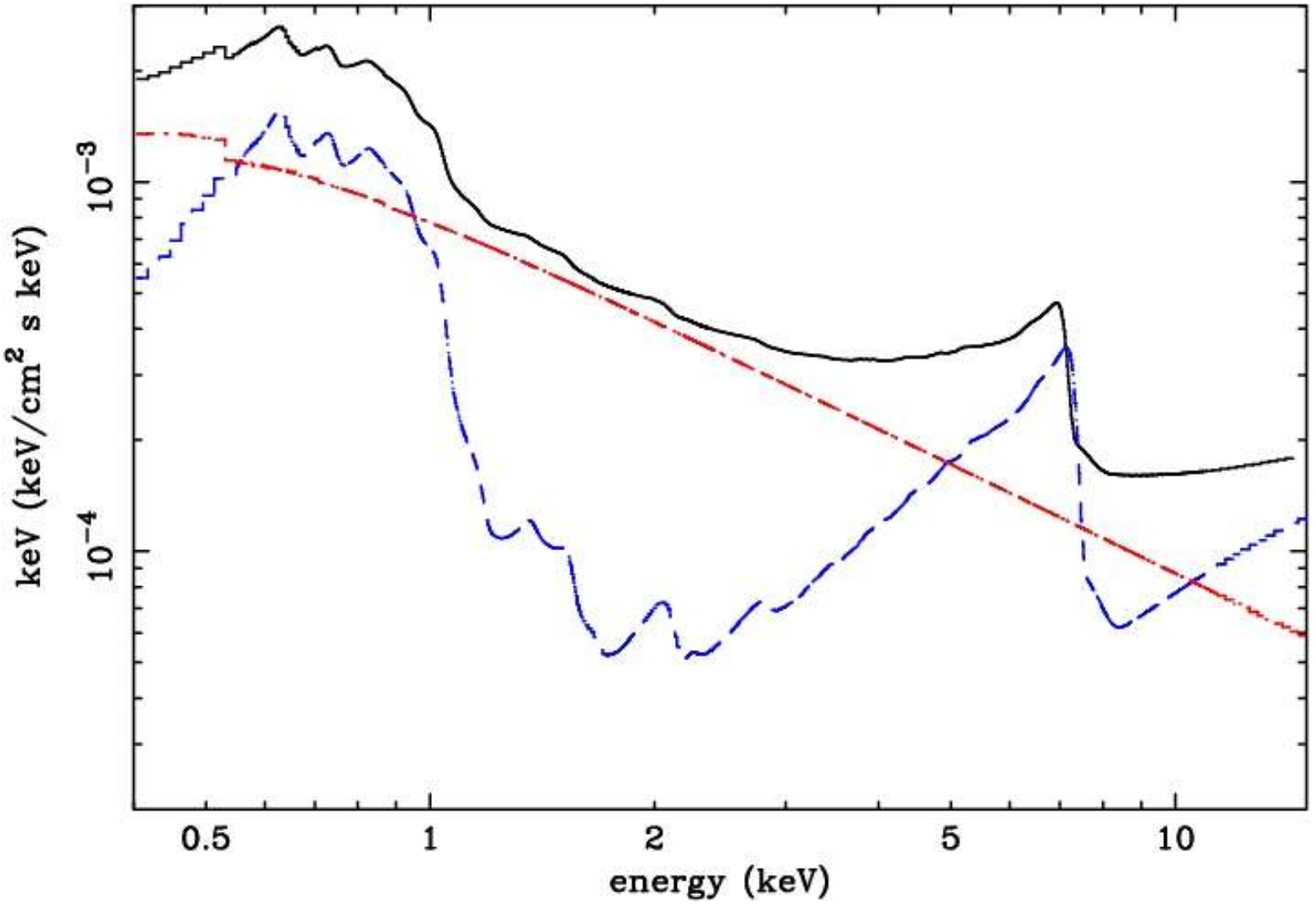
IRAS 13224-3809: Another light bending dominated source?

- Narrow Line Seyfert 1
- z=0.0667

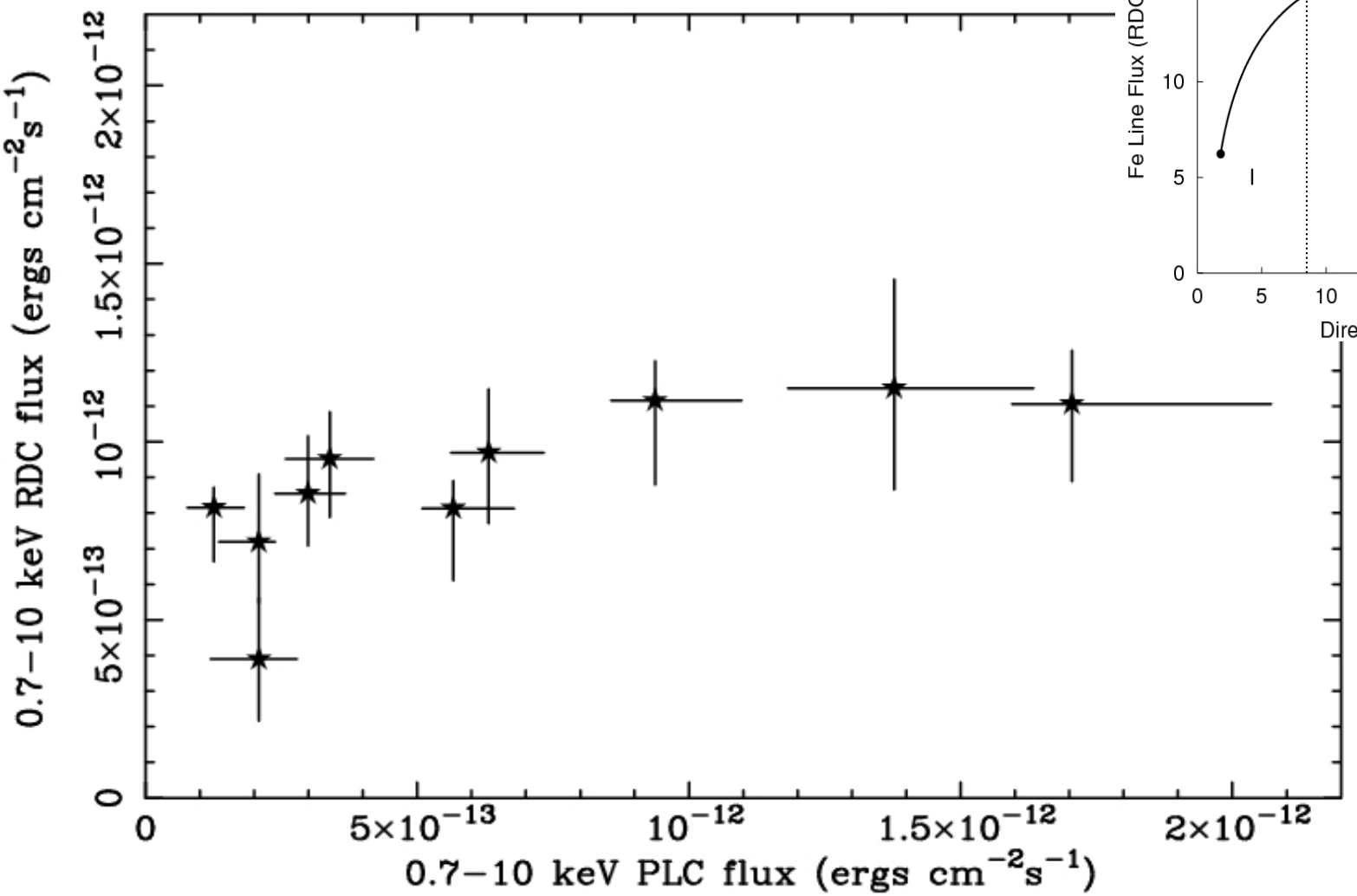


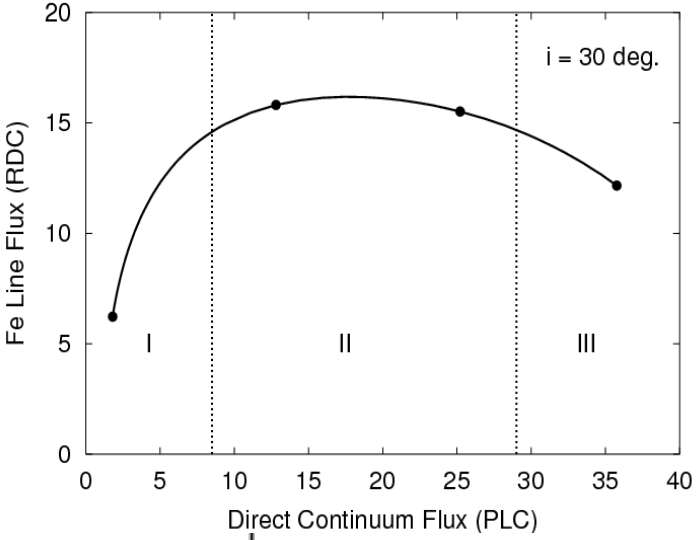
Boller et al. 2003

Time resolved spectral variability: The new interpretation



Two component model





- The RDC is correlated with the PLC at low flux and saturates at medium-high flux
- The observed relation is predicted by the light bending model Miniutti and Fabian 2004
- The reflection explain the observed constancy of the soft excess "temperature" and its similarity to PG quasars

Conclusions

- The XMM-Newton data of NGC 4051 and IRAS 13224-3809 are in agreement with the light bending model
  - relation flux PLC vs flux RDC
  - constancy of T_{BB} and Gamma flux

- These imply that the nuclear emission comes from a few gravitational radii ($h < 20\ r_g$) and Kerr black hole

- The soft excess emission and variability is consistent with being due to relativistic ionized reflection

- NGC 4051: Constant emission from photo-ionized gas and constant neutral reflection from distant material $\Rightarrow$ Seyfert 2 like