On the Iwasawa-Taniguchi effect of radio-quiet AGN

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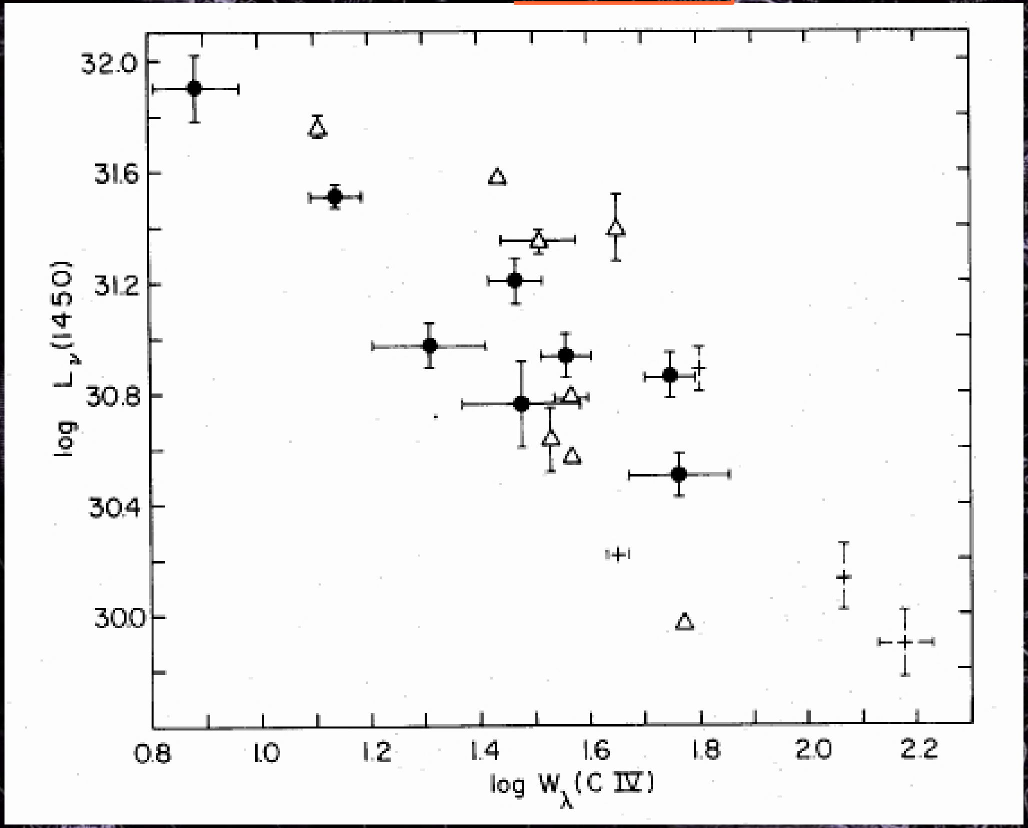
The Baldwin effect

Baldwin (1977) first reported a significant anti-correlation between the EW of the BLR [CIV] λ1549 line and the UV luminosity in quasars (the so-called `Baldwin-effect')

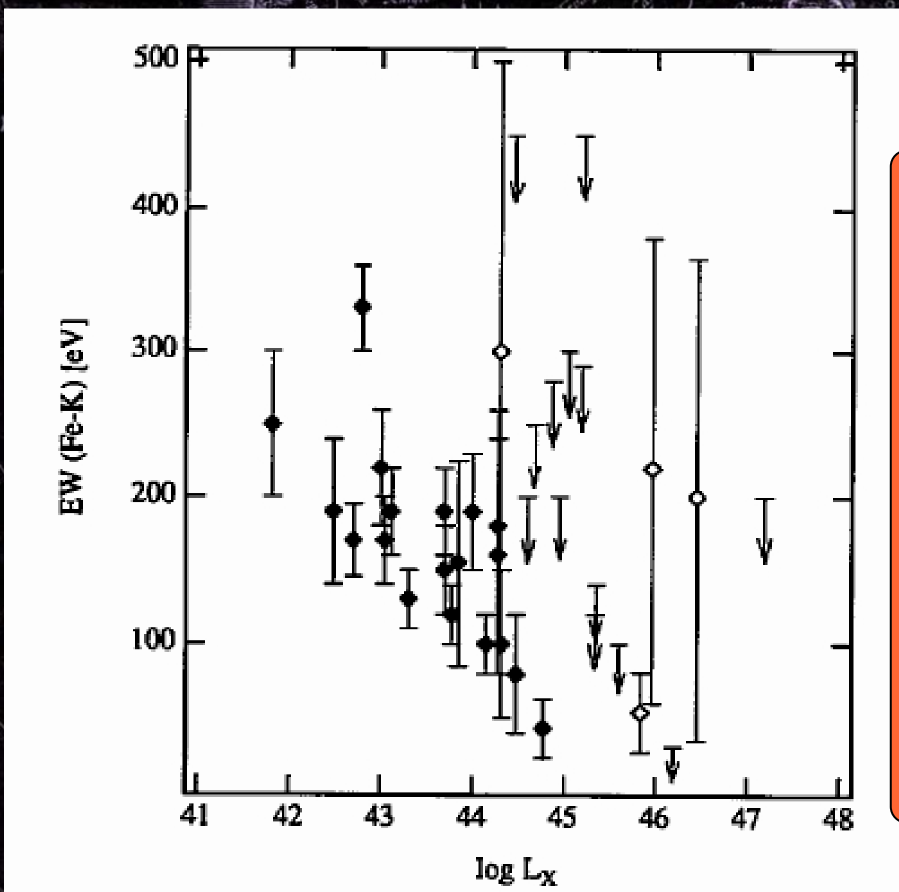


- Change of the ionizing continuum and gas metallicity with luminosity
- Luminosity-dependent covering factor and ionization parameter of the BLR

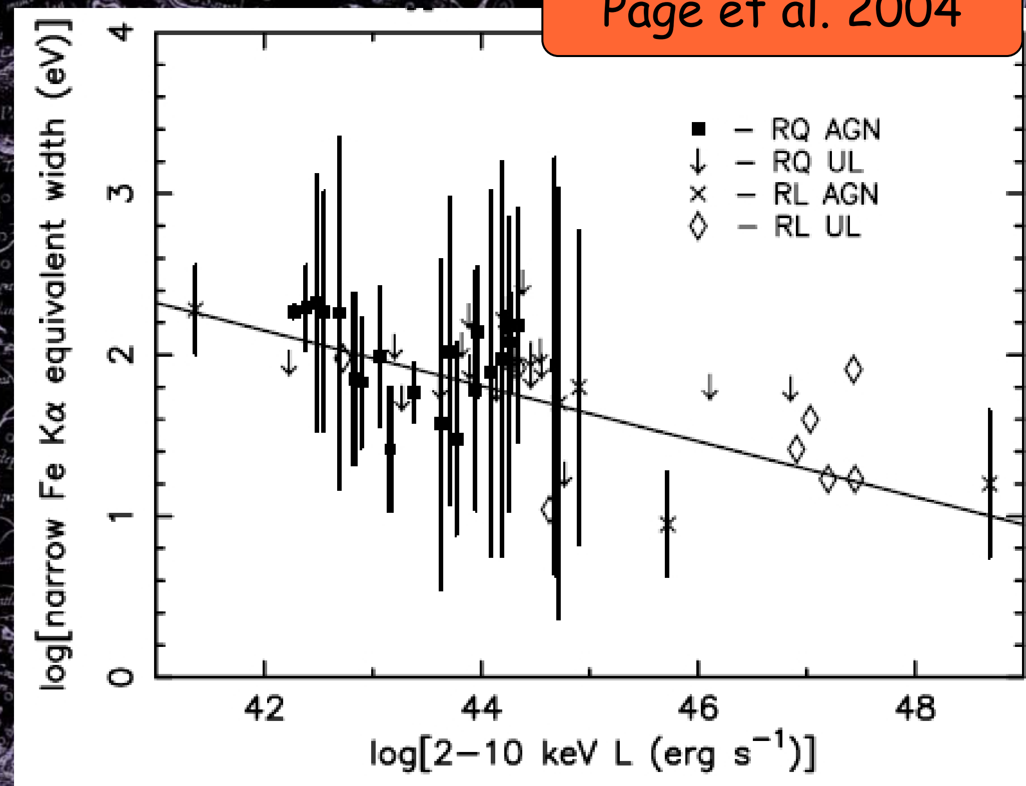
Is the primary physical parameter which drives the Baldwin effect the accretion rate, instead of the luminosity?

The X-ray Baldwin effect
(Iwasawa-Taniguchi effect)

In 1993, Iwasawa & Taniguchi presented a similar anti-correlation between the iron Ka emission line and the 2-10 keV luminosity, according to *Ginga* observations of 37 AGN. This 'Iwasawa-Taniguchi effect' (IT effect) was then found in a larger sample of objects observed by XMM-*Newton*, giving a relation between luminosity and EW) of the narrow core of the Fe Ka as EW$\propto$ L$^{-0.17\pm0.08}$ (Page et al. 2004).

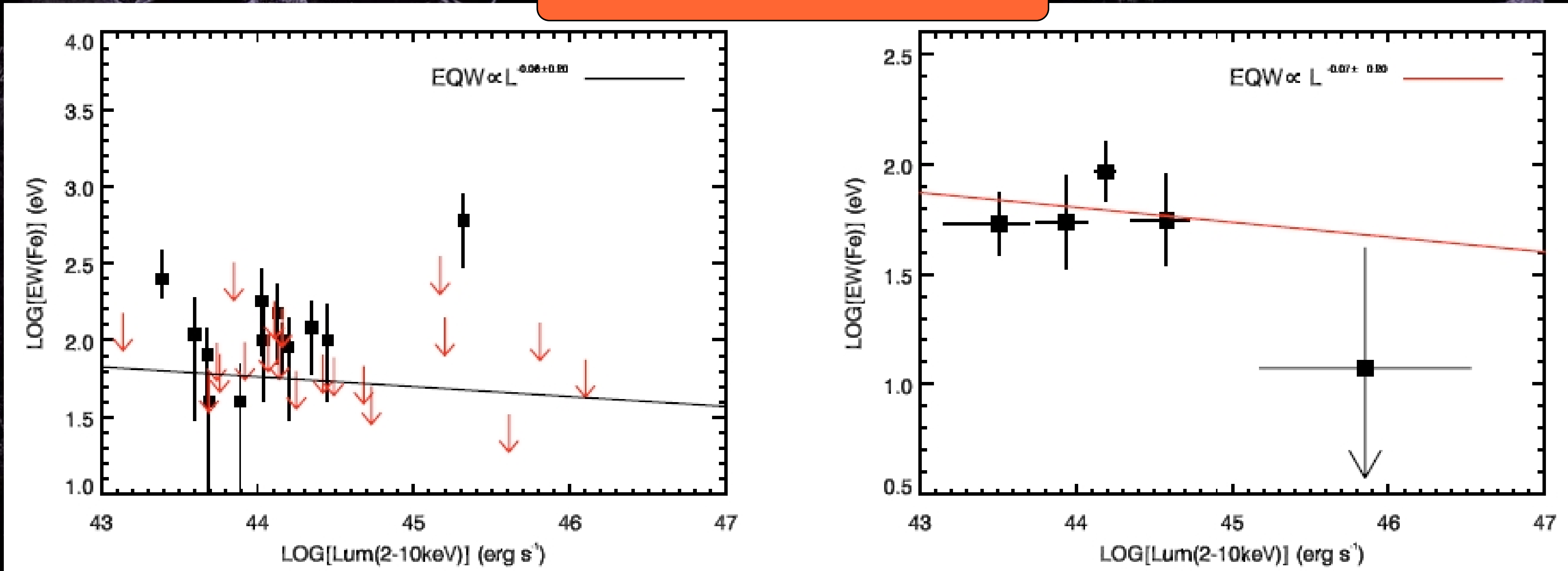


Iwasawa & Taniguchi 1993



Page et al. 2004

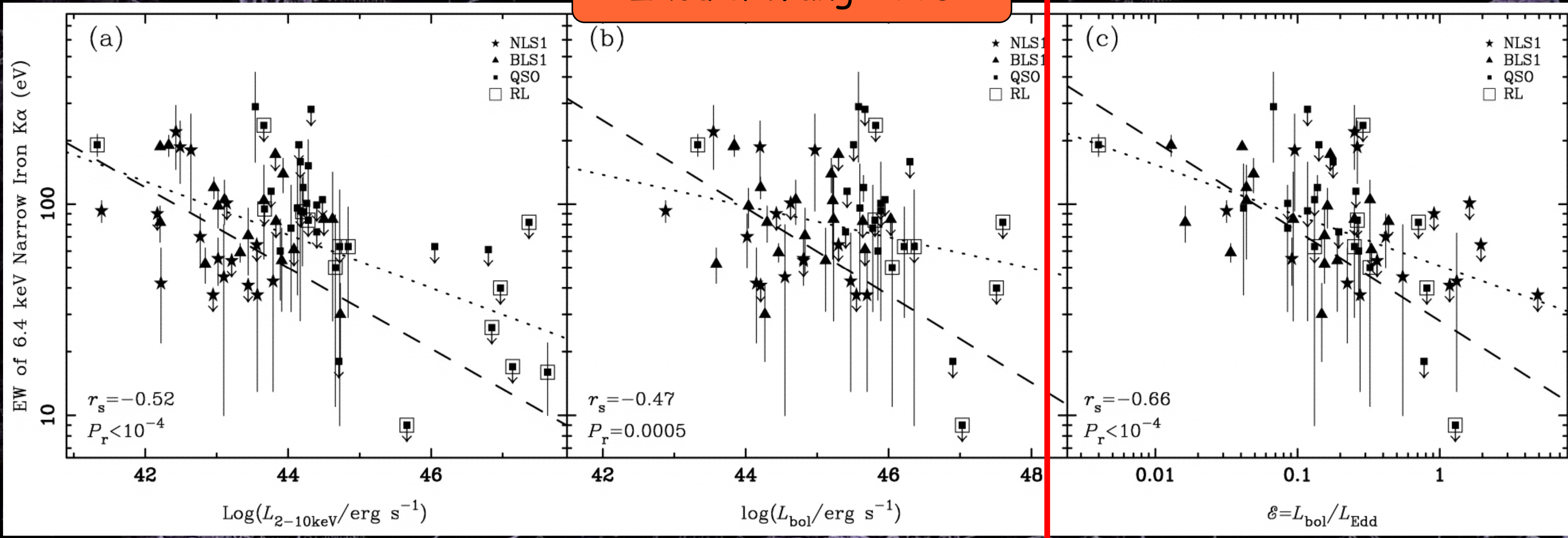
Jiménez-Bailón et al. 2005



The significance of this effect was questioned by Jiménez-Bailón et al. (2005) in their analysis of XMM-*Newton* data of PG quasars, pointing out the importance of **contamination from radio-loud objects**

Jiang et al. (2006) suggested that the anti-correlation can be attributed to variations of the continuum, while the iron line stays constant

Zhou & Wang 2005



The anti-correlation of the EW with the Eddington ratio may be stronger than with luminosity
(Zhou & Wang 2005)

The XMM-*Newton* Catalogue of Radio-Quiet AGN

<u>157 sources</u>

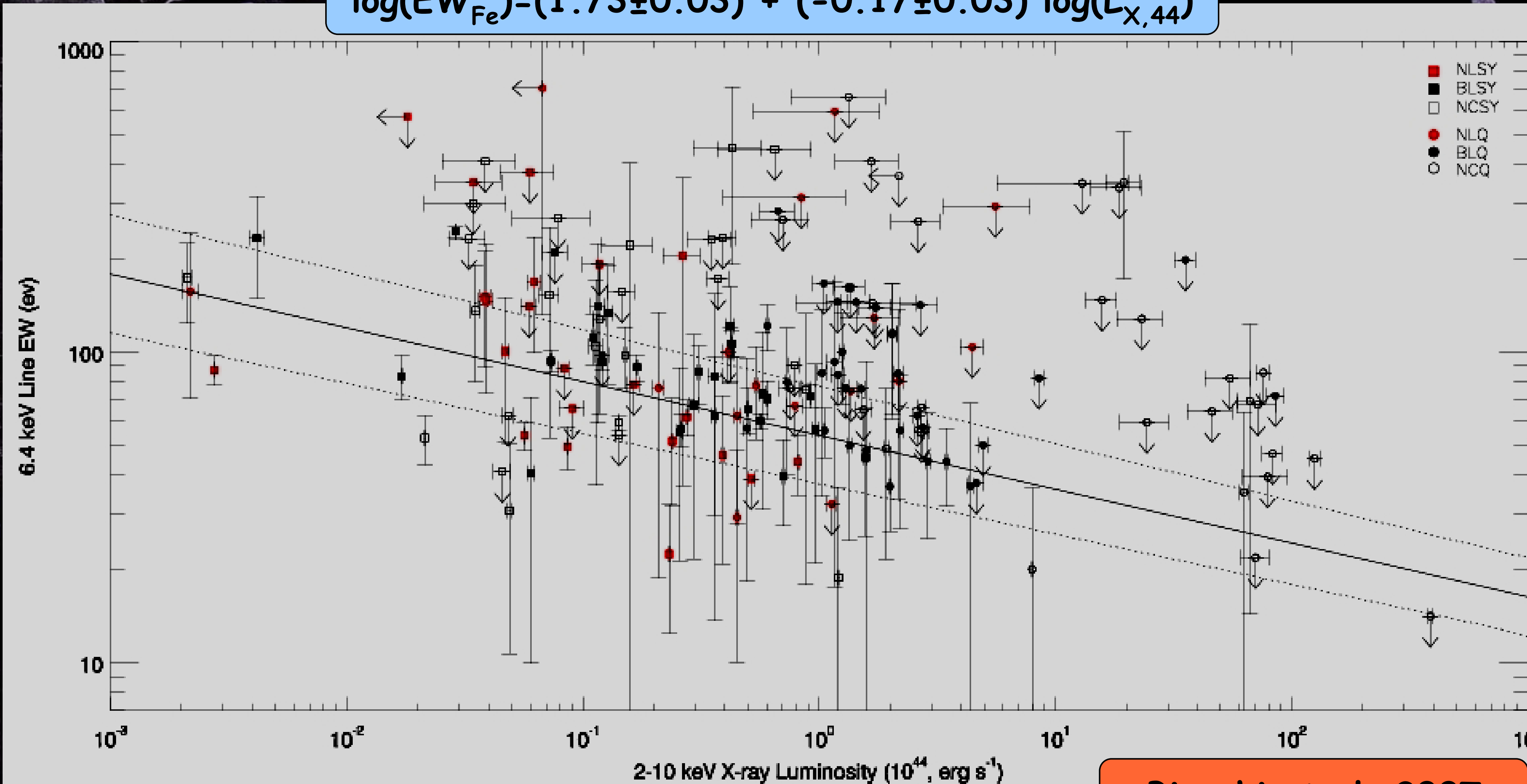
All <u>radio-quiet</u> AGN in targeted XMM-*Newton* pn observations:

- >200 counts in either of the (rest-frame) bands of 0.5-2 and 2-10 keV
- <1% pileup
- log(R)<1 (quasar) – log(R)<2.4 and $\log(R_X)<-2.755$ (Seyfert)
- $N_H<2\times10^{22}$ cm^{-2}

- 6 and 20 cm fluxes (~100% of the catalog)
- Hβ FWHM (64% of the catalog)
- BH mass (52% of the mass)

Luminosity dependent bolometric correction (Marconi et al. 2004)

$\log(EW_{Fe})=(1.73\pm0.03) + (-0.17\pm0.03)\log(L_{X,44})$



Bianchi et al. 2007

<u>The IT effect is highly significant</u>

157 data points (81 measures, 76 upper limits)

$\rho=-0.33$ - $P=4\times10^{-5}$

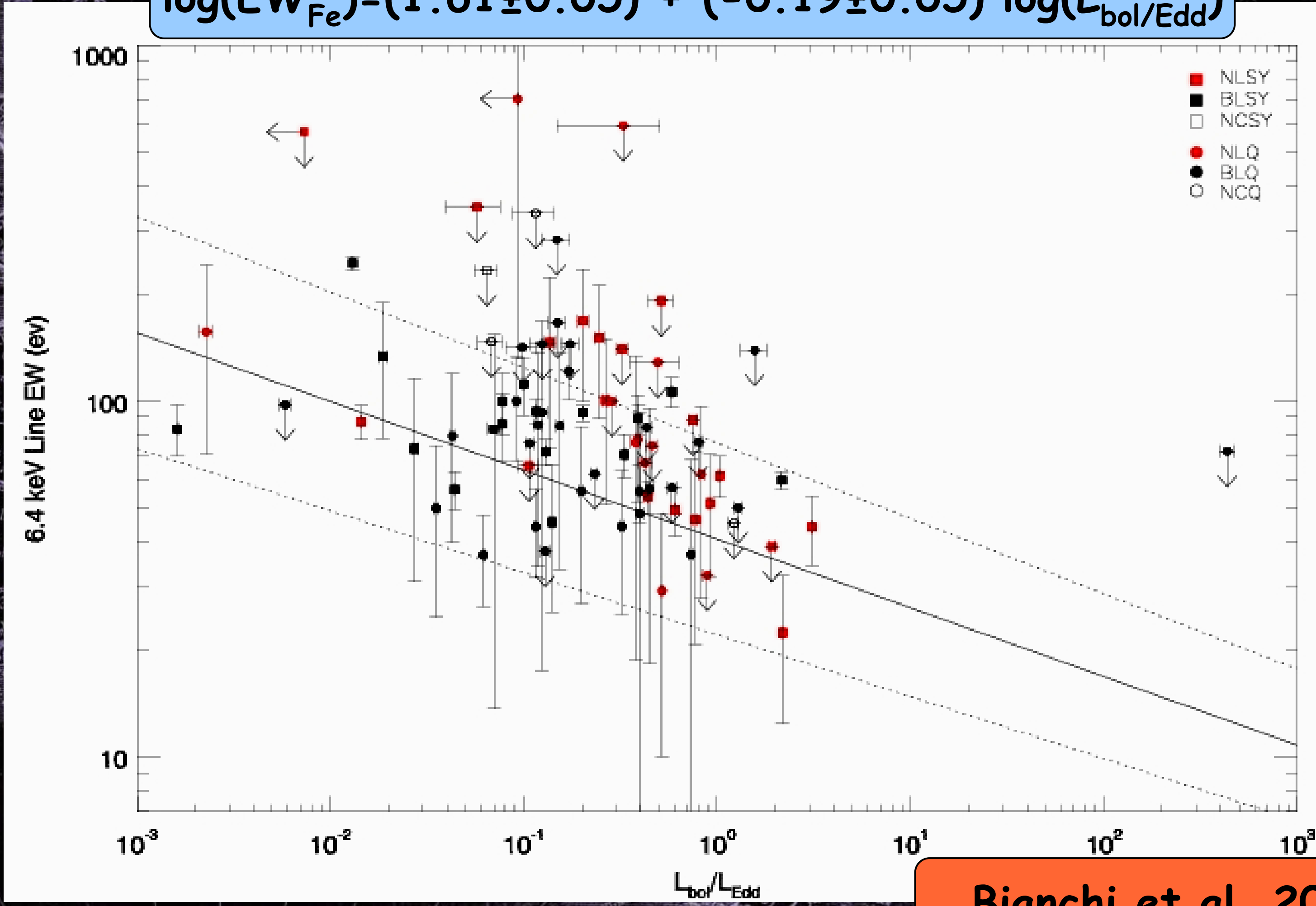
The anti-correlation of the EW with the Eddington ratio is highly significant

82 data points (50 measures, 32 upper limits)

ρ=-0.38 – P=6×10^{-4}

Still significant if a costant bolometric correction is used

$$\log(EW_{Fe})=(1.61\pm0.05) + (-0.19\pm0.05)\ \log(L_{bol/Edd})$$



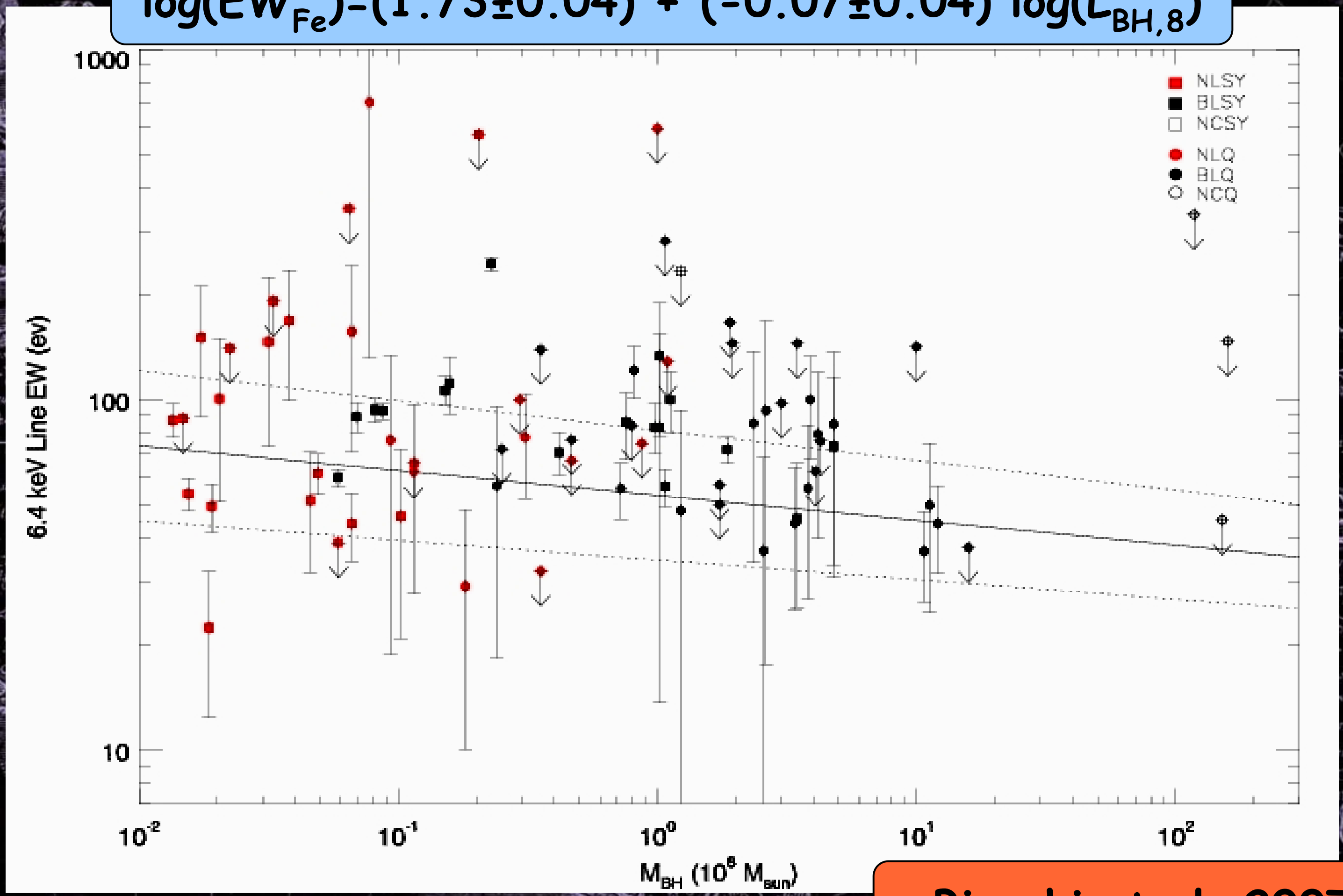
Bianchi et al. 2007

No significant dependence of the iron EW on the BH mass is apparent

82 data points (50 measures, 32 upper limits)

ρ=-0.15 – P=0.3

$\log(EW_{Fe})=(1.73\pm0.04) + (-0.07\pm0.04)\log(L_{BH,8})$



Bianchi et al. 2007

Luminosity-dependent covering factor of the torus?

- Most of the iron line flux comes from the torus, not the BLR (e.g. Bianchi et al. 2004, Nandra 2006)
- The IT effect is mainly driven by the X-ray luminosity (or Eddington ratio), NOT the BH mass

The most likely explanation is in terms of
a luminosity-dependent covering factor of the torus
This is in agreement with models which predict an increase of the opening angle of the torus with luminosity due to disc-driven winds
(Konigl & Kartje 1994)

Interestingly, this implies a decrease of the fraction of obscured AGN with luminosity
as observed (Ueda et al. 2003; La Franca et al. 2005),
albeit in Compton-thin sources

Variability effects?

Continuum variability effects naturally produce an anti-correlation between X-ray luminosity and iron EW, which may contribute to the overall IT effect. However, the simulated anti-correlation has a slope of -0.05±0.05 (Jiang et al. 2006), much weaker than the observed IT effect

The amplitude of variability in radio-quiet AGN is generally <u>smaller than one order of magnitude</u>, while the IT effect is observed on <u>six orders of magnitude</u> in luminosity, making this explanation unlikely

Ionization state of the torus rises with luminosity?

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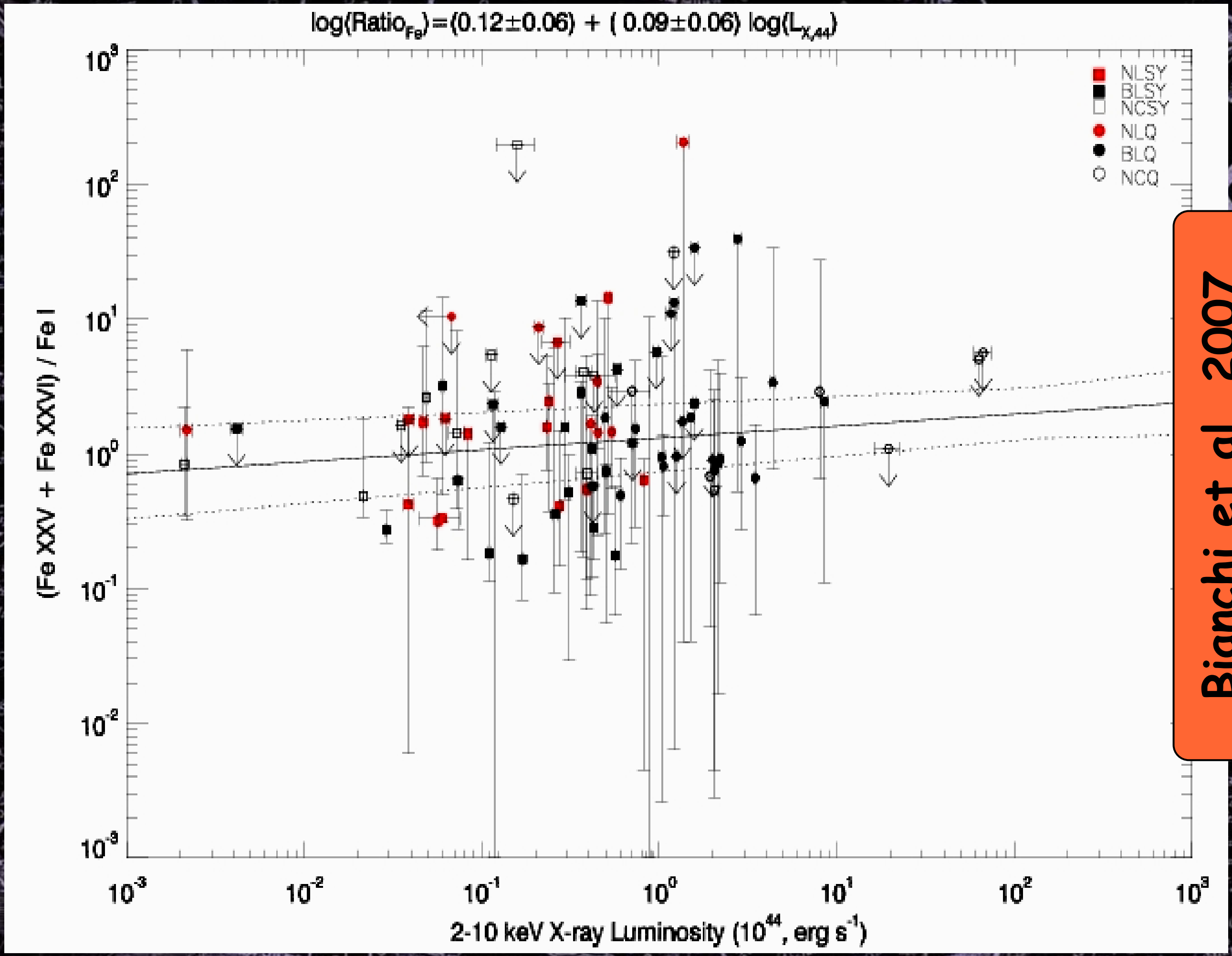
Larger contribution from He- and H-like iron with higher luminosity

The correlation between the ratio of highly ionized iron to neutral iron with luminosity is rather weak

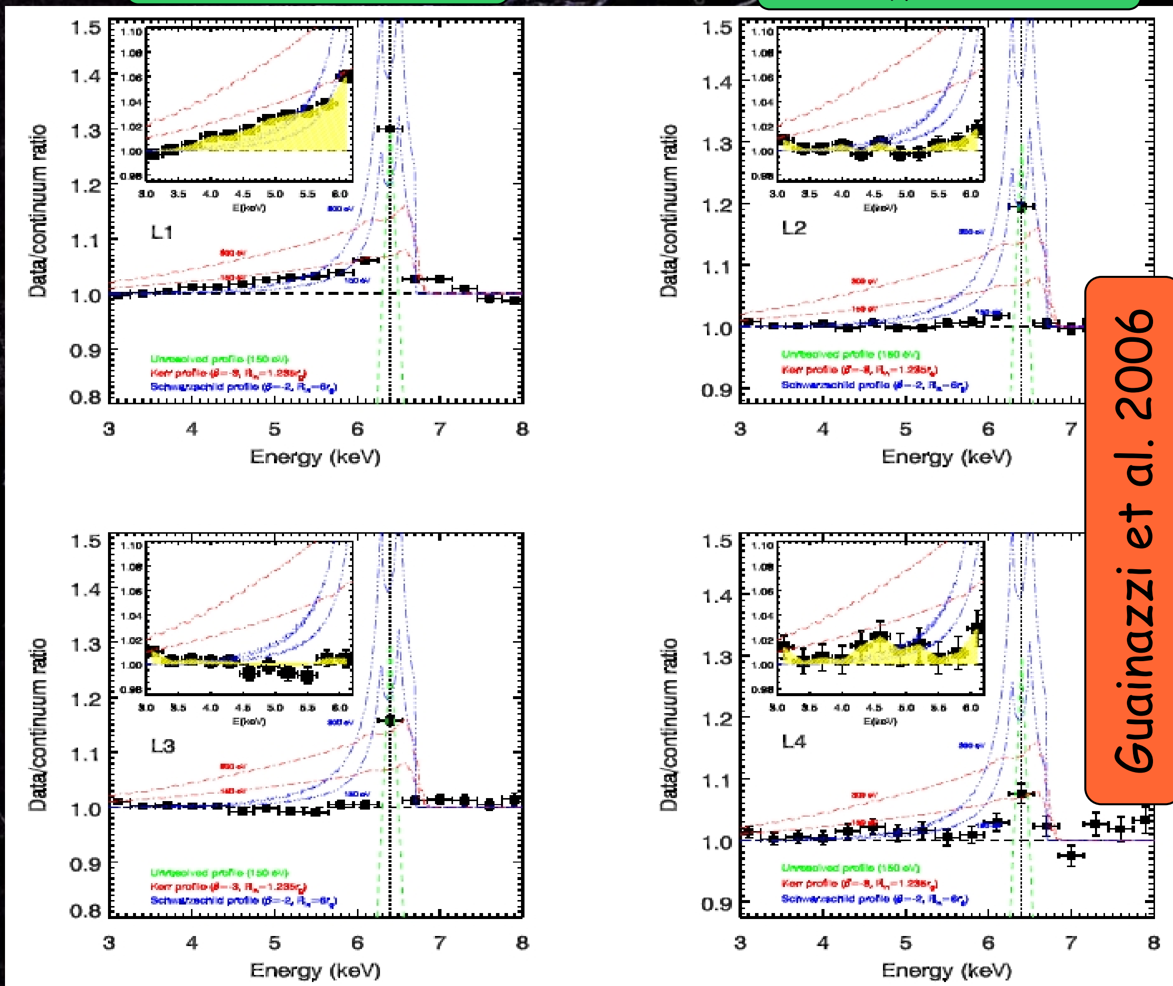


Bianchi et al. 2007

Relativistic iron line component?

$L_X < 5 \times 10^{43}$ cgs

$10^{43} < L_X < 5 \times 10^{43}$ cgs



Guainazzi et al. 2006

$5 \times 10^{43} < L_X < 1.5 \times 10^{44}$ cgs

$L_X < 10^{44}$ cgs

<u>Guainazzi et al. (2006) showed that a broad profile is significantly more common in low luminosity AGN</u>

The EWs in our fits are dominated by the narrow core
=>
The relativistic iron line can possibly contribute to the overall anti-correlation, but <u>cannot account for most of the observed IT effect</u>, which implies an 80% decrease of the iron EW in four orders of magnitude in X-ray luminosity

<u>See also Longinotti's talk</u>

Conclusions

The existence of an anti-correlation between the EW of the neutral narrow core of the iron Kα emission line and the 2-10 keV luminosity (the so-called 'X-ray Baldwin' or 'Iwasawa-Taniguchi' effect) has been debated in the last years. We tested this claim on the largest catalogue of radio quiet AGN high-quality X-ray spectra ever published (157 objects)

A linear censored fit on the EW vs 2-10 keV luminosity is highly significant:

$$\log(EW_{Fe})=(1.73\pm0.03) + (-0.17\pm0.03)\log(L_{X,44})$$

The anti-correlation with the Eddington ratio is also very significant

No dependence of the iron EW on the BH mass is apparent

The most likely explanation is in terms of a luminosity-dependent covering factor of the torus