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ON THE IWASAWA-TANIGUCHI EFFECT OF RADIO-QUIET AGN

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RESUMEN

La existencia de una anticorrelación entre la anchura equivalente (EW) de la línea de emisión de hierro Kα y la luminosidad 2–10 keV (el efecto 'X-ray Baldwin' ó 'Iwasawa-Taniguchi') ha sido debatida en los últimos años. Nuestro objetivo es someter a prueba este resultado, utilizando el mayor catálogo de AGN 'radio callados' con espectros de alta calidad en rayos-X que ha sido publicado hasta la fecha. Nuestro catálogo comprende 157 fuentes. Buscamos una relación entre la EW de la línea de hierro con la luminosidad en rayos X, y también con la masa del agujero negro, el cociente de Eddington y la distancia cosmológica. Los datos aquí presentados han sido analizados homogéneamente, todos los espectros son del mismo instrumento y tienen una relación señal-ruido alta. El ajuste lineal entre la EW y la luminosidad 2–10 keV es muy significativo y produce $\log(EW) = (1.73 \pm 0.03) + (-0.17 \pm 0.03) \log(L_X)$, donde EW es la EW de la línea de hierro neutro Kα en eV y L_X es la luminosidad 2–10 keV en unidades de 10^{44} erg s^{-1}. La anticorrelación con el cociente de Eddington es también muy significativa, pero no hay una clara dependencia de la EW del hierro con la masa del agujero negro.

ABSTRACT

The existence of an anti-correlation between the Equivalent Width (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 aim to test this claim using the largest catalog of radio quiet AGN with high-quality X-ray spectra ever published. Our final sample comprises 157 objects. We search for a relation of the iron line EW with the X-ray luminosity, also with the Black Hole mass, the Eddington ratio and the cosmological distance. The data presented here were analyzed homogeneously, all spectra are from the same instrument and with high Signal-to-Noise Ratio. A linear censored fit of the EW versus 2–10 keV luminosity is highly significant and yields $\log(EW) = (1.73 \pm 0.03) + (-0.17 \pm 0.03) \log(L_X)$, where EW is the EW of the neutral iron Kα line in eV and L_X is the 2–10 keV X-ray luminosity in units of 10^{44} erg s^{-1}. The anti-correlation with the Eddington ratio is also very significant, while no dependence of the iron EW on the BH mass is apparent.

Key Words: galaxies: active — galaxies: Seyfert — quasars: general — X-rays: general

1. INTRODUCTION

In 1993, Iwasawa & Taniguchi presented an anti-correlation between the iron Kα emission line and the 2–10 keV luminosity, according to *Ginga* observations of 37 AGN. This 'Iwasawa-Taniguchi effect' ('IT effect' from now on, also known as 'X-ray Baldwin effect') was then found in a larger sample of objects observed with XMM-*Newton*, giving a relation between luminosity and Equivalent Width (EW) of the narrow core of the Fe Kα as $EW \propto L^{-0.17\pm0.08}$ (Page et al. 2004). 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. Recently, Jiang et al. (2006) combined *Chandra* and XMM-*Newton* data and suggested that, after excluding radio-loud objects, the anti-correlation can be attributed to variations of the continuum, while the iron line stays constant, as expected if the two components are produced on different scales. Nandra et al. (1997) also reported an IT effect in their *ASCA* sample of AGN, but concluded that the effect was entirely due to the relativistically broadened component of the iron line. The presence of an anti-correlation between the iron relativistic line and the luminosity was also recently found by Guainazzi et al. (2006) on a large data set of XMM-*Newton* spectra of AGN.

In this paper, we search for the IT effect in the largest cataloger of radio-quiet AGN observed by XMM-*Newton* published so far. Radio-loud ob-

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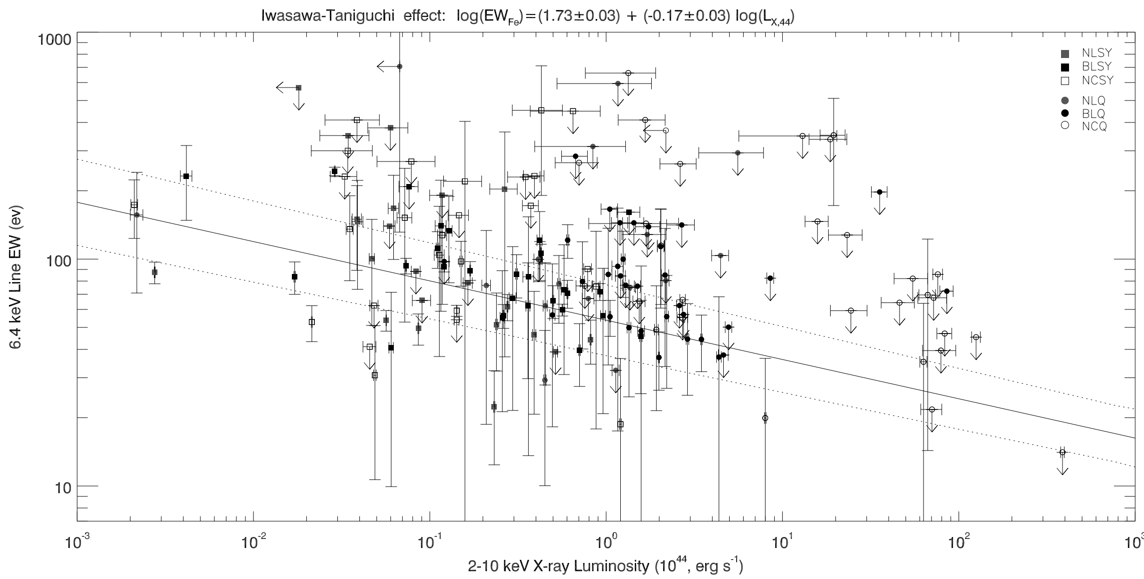

Fig. 1. The 'IT effect': neutral iron EW against 2–10 keV X-ray luminosity of the objects in our catalog. The anti-correlation between the two parameters is shown as the best fitted line, whose analytical expression is reported on the top. The broken lines represent the combined error of the slope and normalization of the best fit. The different symbols refer to the classification of the objects, on the basis of their absolute magnitude and Hβ FWHM: *NLSY*, narrow-line Seyfert 1; *BLSY*, broad-line Seyfert 1; *NCSY*, not-classified Seyfert 1 (no Hβ FWHM measurement available); *NLQ*, narrow-line quasar; *BLQ*, broad-line quasar; *NCQ*, not-classified quasar (no Hβ FWHM measurement available). See text for details.

jects are excluded on the basis of the radio-loudness parameters R and R_X, calculated for each source from data in the literature. The data presented here were analyzed homogeneously, all spectra are from the same instrument and with high Signal-to-Noise Ratio (SNR). Our catalog consists of all radio-quiet Type 1 AGN observed as main targets with XMM-*Newton*, whose data are public since March 2007. At the end of this selection procedure, the total catalog comprises 157 radio quiet AGN, whose X-ray data are complemented with Hβ Full Width Half Maximum (FWHM) and Black Hole (BH) mass measurements, when available in literature (the coverage is 64% and 52%, respectively). We refer the reader to Bianchi et al. (2007) and Bianchi et al., in preparation, for the full presentation of the catalog.

2. THE IT EFFECT

Figure 1 shows the IT effect in our data, along with the best fit:

$$\log(EW) = (1.73 \pm 0.03) + (-0.17 \pm 0.03)\log(L_X),$$

where EW is the EW of the neutral iron Kα line in eV and L_X is the 2–10 keV X-ray luminosity in units of 10^{44} erg s^{-1}. The Spearman's rank coefficient ρ for this correlation is -0.33 for 157 data points, corresponding to a Null Hypothesis Probability P of 4×10^{-5} (see Bianchi et al. 2007, for details on the fitting procedure, which includes errors and upper limits for the EW).

Our result is consistent with previous claim for the IT effect, whether radio-loud objects were included or not. In the original paper by Iwasawa & Taniguchi (1993), the slope of their anti-correlation was -0.20 ± 0.03. The following results are all consistent with each other: -0.17 ± 0.08 (Page et al. 2004), -0.06 ± 0.20 (Jiménez-Bailón et al. 2005). As for Jiang et al. (2006), they quote -0.20 ± 0.04 for their whole sample and -0.10 ± 0.05 for a sub-sample without radio-loud objects.

In order to understand which is the main driver for the IT effect, we checked the behavior of the iron Kα EW with respect to the Eddington ratio, the BH mass and the redshift (see Figure 2 for the first two relations). The anti-correlation with the Eddington ratio is highly significant ($\rho = -0.38$ for 84 data points, $P = 5 \times 10^{-4}$). On the other hand, the correlation with z is weaker and, quite interestingly, no significant dependence of the iron EW on the BH mass is apparent ($\rho = -0.17$ for 84 data points, $P = 0.2$). In this respect, it seems that the lack of dependence on the BH mass is mainly driven by

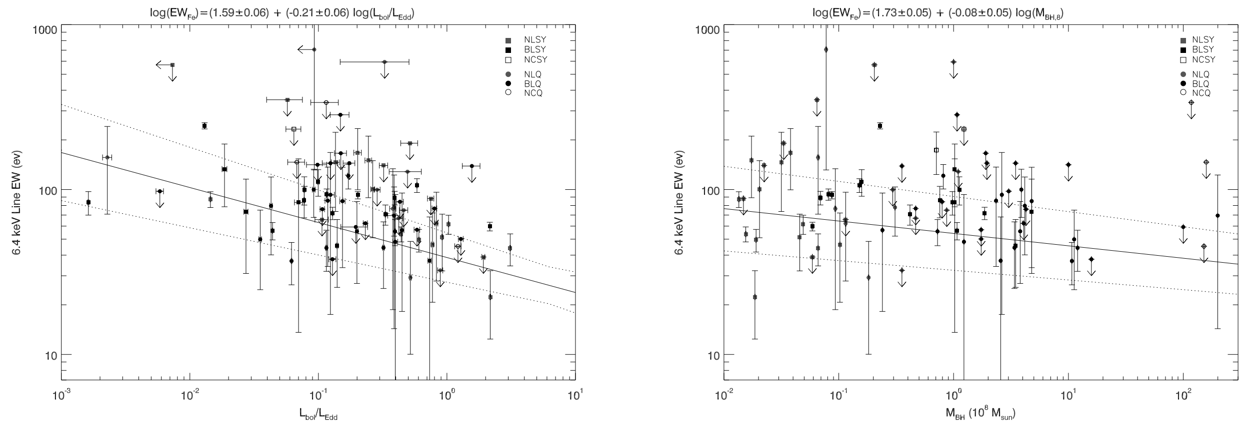

Fig. 2. *Left panel*: Neutral iron EW against the Eddington ratio L_{bol}/L_{edd}, adopting a luminosity-dependent X-ray bolometric correction (after Marconi et al. 2004). *Right panel*: The same as above, but against the BH mass. See caption of Figure 1 for details.

narrow-line objects, which populate the lower range of masses. The statistics involved in the subclasses of our catalog prevents us from drawing firm conclusions.

3. DISCUSSION

The most likely explanation for the IT effect is in terms of a luminosity-dependent covering factor of a compact Compton-thick torus. Such a possibility could be related to disk-driven hydromagnetic wind models, which predict an increase of the opening angle of the torus with luminosity (Königl & Kartje 1994). This, in turns, would lead to a reduction of the covering factor of the torus, which could explain the observed iron line-luminosity anticorrelation. This is in agreement with the recent discovery of a non-linear relation between thermal emission from dust and optical luminosity in AGN, which implies a decrease of the covering factor of dust with luminosity, with a slope of $\simeq -0.18$ (Maiolino et al. 2007). A side implication of this luminosity-dependent covering factor for the torus is a decrease of the fraction of obscured AGN with luminosity, as it was indeed recently observed (Ueda et al. 2003; La Franca et al. 2005). It must be noted, however, that the latter observational result is based on Compton-thin sources only, while the torus is likely Compton-thick.

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