Mem. S.A.It. Suppl. Vol. 17, 112

Memorie della
Supplementi

X-ray spectroscopy of bright AGN

G. Matt and S. Bianchi

Dipartimento di Fisica, Università degli Studi Roma Tre, Via della Vasca Navale 84, I-00146 Roma, Italy
e-mail: `matt@fis.uniroma3.it; bianchi@fis.uniroma3.it`

Abstract. WFXT will observe tens of thousands of AGN with at least a few thousands counts each, so allowing for a detailed spectral analysis and providing a great leap forward in population studies. In this paper we review the present status of spectroscopic studies of samples of AGN, and discuss a few open issues, to the solution of which WFXT will contribute significantly.

Key words. X-rays: Active Galactic Nuclei

1. Introduction

In this paper we will try to assess the relevance of WFXT to the study of “bright” AGN. First of all, let us clarify what we mean with “bright” in this context. We mean a source detected with enough counts to permit a decent spectral analysis. Based on experience, one can (conservatively) put the number of counts needed to characterize and model the main spectral components to 5000, even if about 1000 counts may be sufficient if the spectrum is not too complex. Figure 1 shows the logN-log (Counts) in the 0.5-2 keV energy range for the three surveys (wide, medium and deep) which are the backbone of the WFXT observational program. All together, about 60000 (300000) AGN with more than 5000 (1000) counts are expected. This is a really impressive number when compared with what we have today (hundreds of sources, see below).

With so many sources available for a detailed spectral analysis, and even if WFXT has been mainly conceived and designed for cosmological purposes, studies of bright AGN - with the main emphasis to population studies - promise to be extremely rewarding.

2. Where we are now

Spectroscopic studies of AGN populations are largely based on XMM-Newton observations. The largest sample is that derived from the BSS (Bright Serendipitous Survey: Della Ceca et al. 2004, Caccianiga et al 2008). It is a flux limited sample (flux limit of 7×10^{-14} erg cm^{-2} s^{-1} in the 0.5-4.5 keV energy range), extracted from the XMM Serendipitous Survey based on sources found serendipitously in the field of pointed targets. The sample comprises 400 sources, 80% of which are AGN. The X-ray selection guarantees the detection of sources like e.g. elusive AGN (Maiolino et al. 2003) which are very difficult to find at longer wavelengths.

A different approach to population studies is to collect all the pointing observations of AGN which have a sufficient number of counts for a detailed spectral analysis. We built

Send offprint requests to: G. Matt

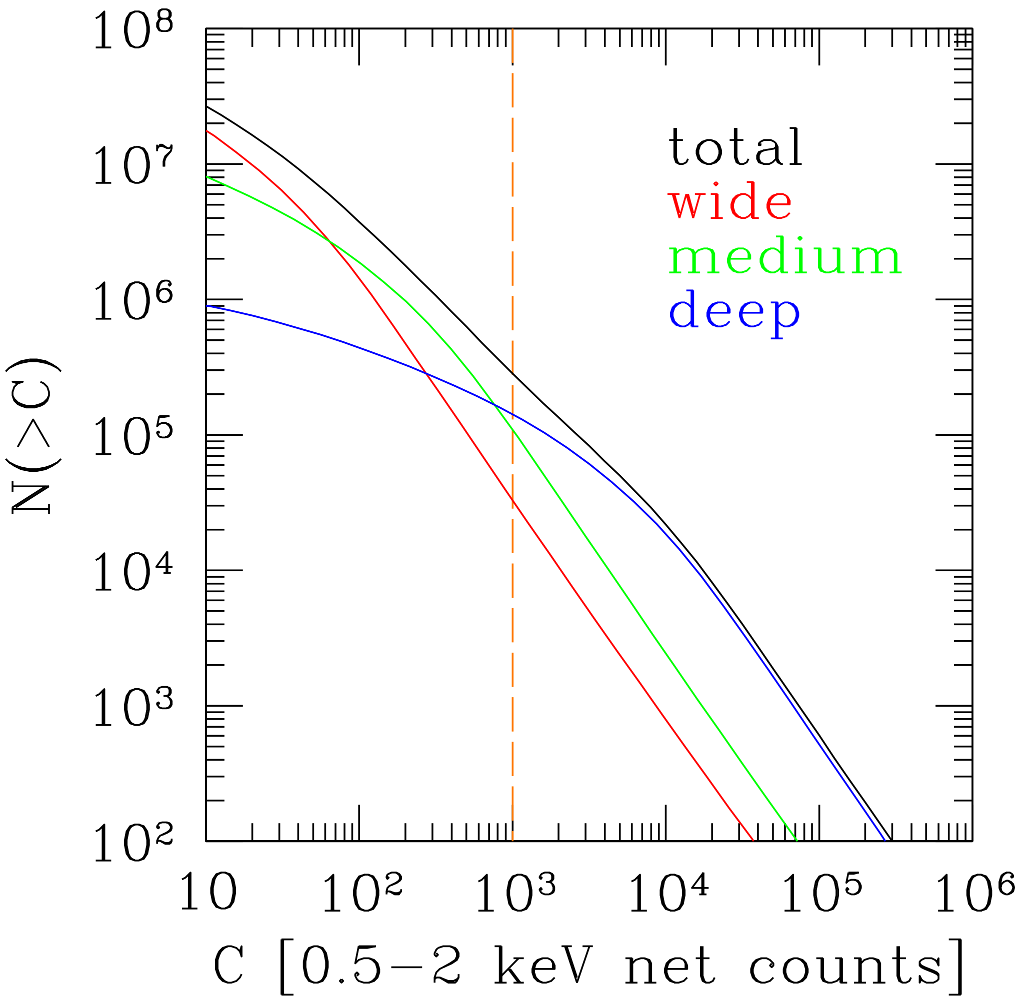

Fig. 1. The logN-log(Counts) in the 0.5-2 keV energy range for the three WFXT surveys (wide, medium and deep). The dashed vertical line indicates the number of sources with more than 1000 counts. Courtesy of Roberto Gilli.

such a sample by requiring at least 200 counts in both the 0.5-2 keV and 2-10 keV energy bands (most sources actually have more than a thousand counts). Further constraints are pile-up less than 1% and absorbing column density less than 10^{22} cm^{-2}. We selected only radio-quiet sources. The resulting sample of Seyfert 1/QSO, called CAIXA (Catalogue of AGN in the XMM-Newton Archive; Bianchi et al 2009a,b) is composed of 156 objects. All sources have 6 and 20 cm fluxes measured, while for 64% of them the Hβ FWHM from the Broad Line Region is known. The mass of the black hole is known for 52% of the sample.

The main results from CAIXA can be summarized as follows.

– The 2-10 keV power law index is harder in Broad Lines Seyfert 1s (BLS1; Γ=1.62±0.04) than in Narrow Lines Seyfert 1s, (NLS1; Γ=1.94±0.07) as shown in Figure 2. The two populations

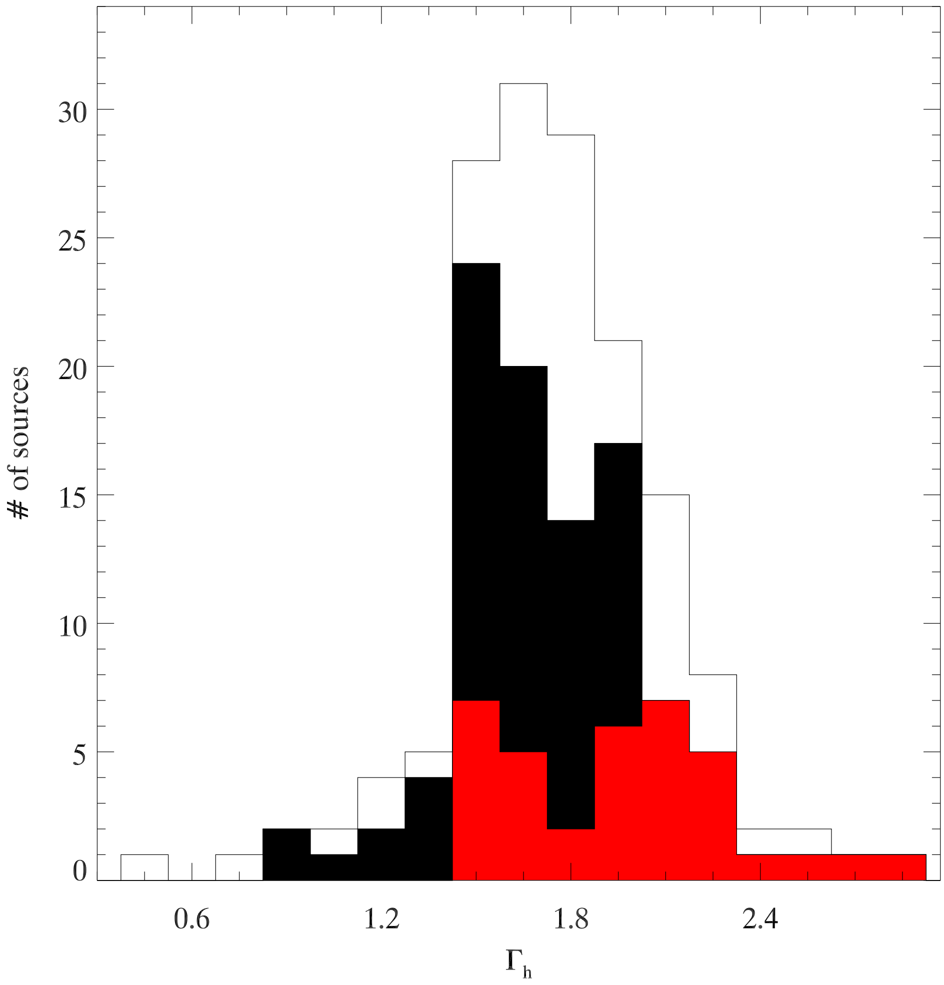

Fig. 2. The histogram of the 2-10 keV power law indices for NLS1 (red), BLS1 (black) and unclassified objects (white). From Bianchi et al. (2009a).

are different at more than 99.99% confidence level. (Here BLS1/NLS1 are defined as having the FWHM of the Hβ line larger/smaller than 2000 ks/s). This result confirms previous findings (Brandt et al. 1997).

- The Hβ FWHM is anticorrelated with the ratio between the soft and hard X-ray luminosities, and with the ratio between the optical and the X-ray flux. NLS1 seem to be X-ray weaker than BLS1.
- 123 out of 156 sources need a second and steeper power law to model the soft X-ray emission. If the second power law is replaced by a thermal model, the soft excess is characterized by a temperature which is constant across the range of luminosities and black hole masses, as already found by several authors (Gierlinski & Done 2004; Crummy et al. 2006). More on the soft excess issue in the next section.

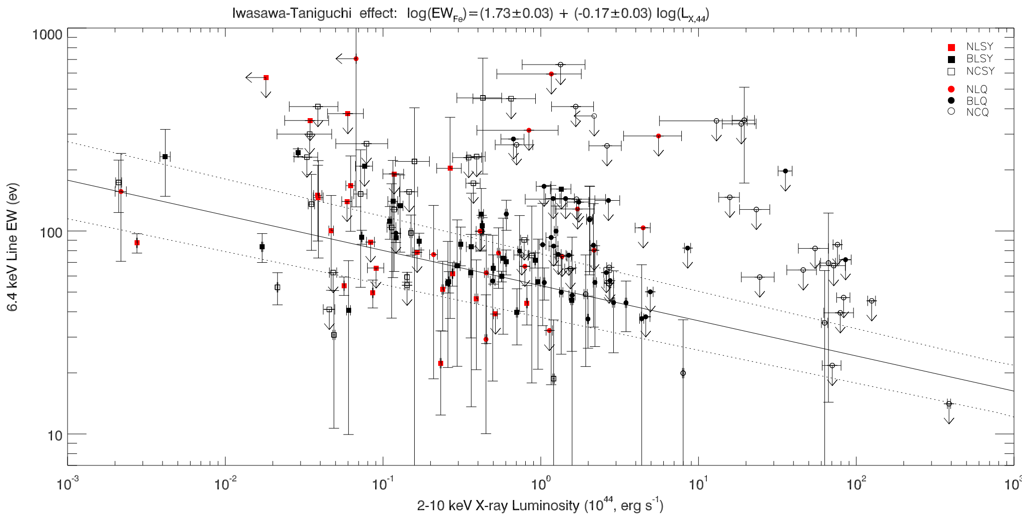

Fig. 3. The IT effect: the neutral iron line EW against 2-10 keV X-ray luminosity. See Bianchi et al. (2007) for details.

- A strong correlation between the X-ray luminosity and the BH mass is found. The slope is flatter than 1, suggesting that high-luminosity objects may be X-ray weak. A luminosity dependent bolometric correction could explain this result, but the one proposed by Marconi et al. (2004) leads to a more-than-linear relation. A linear relation is instead recovered using a bolometric correction based on the accretion rate (Vasudevan & Fabian 2007) or using the radio luminosity.
- The Iwasawa-Taniguchi effect is definitely confirmed (see next section).
- Fe XXV and Fe XXVI lines are detected in 24 sources, indicating that the presence of highly ionized matter is not uncommon. Their absolute and relative EWs are consistent with a production in distant matter which is photoionised by the AGN, with large ionization parameters and large column densities (up to 10^{23} cm^{-2} for Fe XXV, even larger for FeXXVI).

3. The WFXT contribution

A number of currently open problems (part of them already mentioned in the previous section) may be addressed - and hopefully solved - by WFXT thanks to the very large number of AGN which will be characterized spectroscopically.

- The nature of the soft X-ray emission in type 1 AGN. Soft X-ray emission in excess to the extrapolation of the hard X-ray power law was first discovered by EXOSAT in the Seyfert 1 galaxy Mkn 841 (Arnaud et al. 1985), and then observed to be common in type 1 AGN. Its origin, however, is still unknown. An interpretation in term of thermal disc emission - possibly Comptonized by a scattering layer - was first suggested, and remained the most popular one for many years. However, it was recently realized that the temperature which results from fitting the spectrum with a thermal emission is always around 0.1-0.2 keV, independently of the mass of the black hole. In the standard accretion disc model, instead, the temperature should scale with $M_{BH}^{-\frac{1}{4}}$. Alternative models have been proposed, which assume that the almost constant temperature is actually an artifact due to emission related to atomic physics transitions. The two most popular models are the relativistically broadened wind (Gierlinski & Done 2004, Middleton

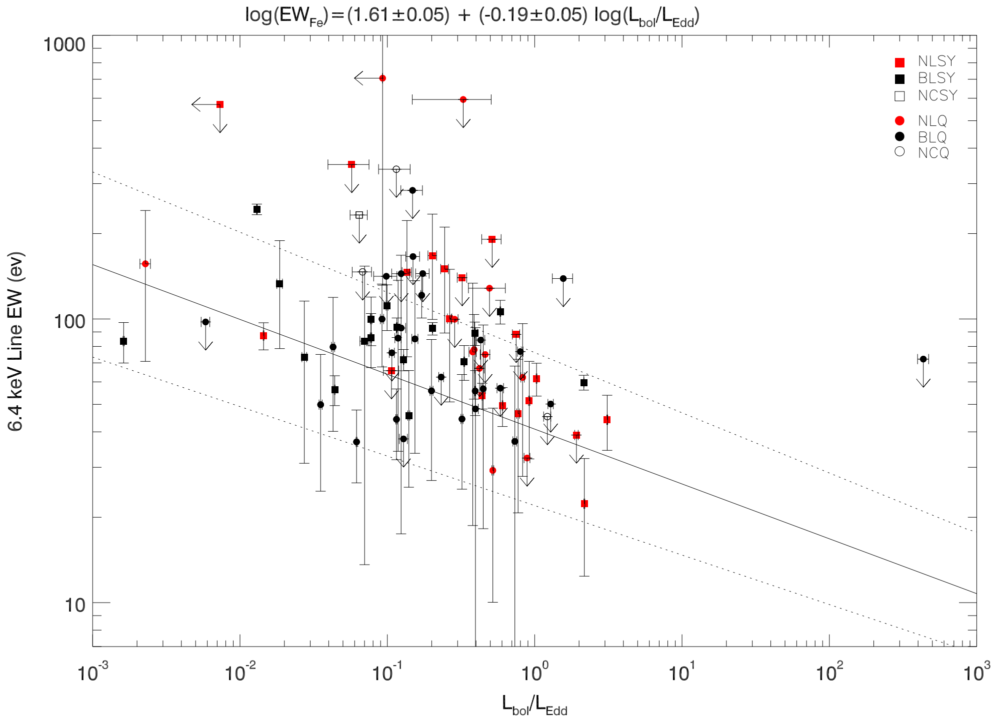

Fig. 4. The IT effect as a function of the Eddington ratio. See Bianchi et al. (2007) for details.

et al 2007) and the reflection model (Ross & Fabian 1993, Crummy et al. 2006). Both models, however, have serious problems. The wind model requires very large outflow velocities, while the reflection model requires - at least in some sources - very large reflection components.
WFXT will enlarge tremendously the number of sources where the soft X-ray excess can be studied, in so doing stretching considerably the range of masses probed. Its soft X-ray response is very well suited to this purpose. While at the moment no clear-cut measurement to solve the soft X-ray problem has been proposed, it is very likely that WFXT will contribute significantly to the understanding of the soft X-ray excess.

– The properties of the Warm Absorber beyond the local Universe. In about half of Seyfert 1s in the local Universe, absorption by moderately ionized matter (the so-called "Warm Absorber") is present (e.g. Reynolds 1997). The absorbing matter is usually outflowing with velocities of the order of hundreds of km/s, even if higher velocities have also been found, but in more ionized matter (Risaliti et al. 2005). The location of the Warm Absorber is still uncertain, even if Blustin et al. (2005) suggest that this matter is related to the obscuring pc-scale torus required in unification models. Mass and energetics are consequently also largely unknown.
Possible dependencies of the presence of the Warm Absorber and its physical properties on luminosity and redshift are basically unexplored. WFXT will provide such an exploration, helping to understand the nature and the physical and morphological properties of the Warm Absorber.

– The IT effect at high redshifts and luminosities. The Iwasawa-Taniguchi (IT) effect (Iwasawa & Taniguchi 1993) is the anticorrelation between the equivalent width

(EW) of the narrow core of the iron line and the X-ray luminosity, and for this reason it is also known as “X-ray Baldwin effect”. The reality of this effect has been disputed for a long time, but now it is established beyond doubt (Bianchi et al. 2007; see Figure 3). While part of this effect may be due to variability (Jiang et al. 2006) - if the line is emitted in distant matter, and is therefore not variable on short time scale, an increase in the primary flux results inevitably in a decrease of the line EW - the presence of the anticorrelation over several decades in luminosity indicates a different, more fundamentale cause. The anticorrelation seems to be driven by the Eddington ratio (see Figure 4), rather than the mass of the black hole.
The most likely explanation of the IT effect is an anticorrelation between the covering factor of the line emitting matter (possibly the torus) and the X-ray luminosity, as also suggested by IR observations (Maiolino et al. 2007). Unfortunately, the limited energy band of WFXT prevents a study of the IT effect in the local Universe; a much larger sample, to confirm the relation with the Eddington ratio and to search for the effect in separate subclasses would be highly desirable. On the other hand, WFXT will offer the opportunity to search for this effect beyond the local Universe, in so doing significantly populating the - now severely underpopulated - high luminosity part of the anticorrelation.

4. Conclusions

Samples based on XMM-Newton consist of a few hundreds of sources with enough counts for a detailed spectral analysis. WFXT will increase this number by 2-3 orders of magnitude, providing an analogue in the X-ray domain of the SDSS in the optical band. Extensive population studies over a large range of luminosities and redshifts will then become, for the first time in X-rays, a reality.

References

Arnaud, K. A., Branduardi-Raymont, G., Culhane, J. L., et al., 1985, MNRAS, 217, 105
Bianchi, S., Guainazzi, M., Matt, G., Bonilla, N.F., 2007, A&A, 467, L19
Bianchi, S., Guainazzi, M., Matt, G., Bonilla, N.F., Ponti, G., 2009a, A&A, 495, 421
Bianchi, S., Bonilla, N.F., Guainazzi, M., Matt, G., Ponti, G., 2009b, A&A, 501, 915
Blustin, A.J., et al., 2005, A&A, 431, 111
Brandt, W.N., Mathur, S., Elvis M., 1997, MNRAS, 285, L25
Caccianiga, A., et al., 2008, A&A, 477, 735
Crummy, J., Fabian, A. C., Gallo, L., Ross, R. R., 2006, MNRAS, 365, 1067
Della Ceca, R., et al., 2004, A&A, 428, 383
Gierlinski, M., Done C., 2004, MNRAS, 349, L7
Iwasawa, K., Taniguchi, Y., 1993, ApJ, 413, L15
Jiang, P., Wang, J.X., Wang, T.G., 2006, ApJ, 644, 725
Maiolino, R., et al., 2003, MNRAS, 344, L59
Maiolino, R., et al., 2007, A&A, 468, 979
Marconi, A., et al., 2004, MNRAS, 351, 169
Middleton, M., Done, C., Gierlinski, M., 2007, MNRAS, 381, 1426
Reynolds, C.S., 1997, MNRAS, 286, 51
Risaliti, G., et al., 2005, ApJ, 630, L129
Ross, R.R., Fabian, A.C., 1993, MNRAS, 261, 74
Vasudevan, R.V., Fabian, A.C, 2007, MNRAS, 381, 1235