A search for obscured sources in the 2nd Palermo BAT catalogue

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Among the 1256 sources included in the 2nd Palermo BAT Catalogue, 735 objects are confidently associated with extragalactic counterparts. We studied the broad-band spectral properties of a large subsample of non-beamed AGNs, combining the Swift-XRT (0.2-10 keV) and Swift-BAT (15-150 keV) spectra. We focused on the obscuration properties of this sample, and we identified some new Compton Thick candidates.

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1. Introduction

While the Cosmic X-ray Background at soft X rays has been almost completely resolved into AGNs ($\sim 80\%$, e.g [1]), its spectrum at energies higher than 10 keV strongly suggests the presence of a large population of AGNs whose emission is (partly) hidden below ~ 10 keV (see e.g. [2],[3]). Therefore, the study of the absorbing properties of AGNs as a class, and in particular of the population of heavily absorbed AGNs, is of great importance to understand the syntesis of the diffuse hard X-ray background.

The hard X-ray regime is the favoured energy range to select and study large AGN samples relatively unbiased with respect to their absorbing column (at least up to $N_H \leq 10^{25}\mathrm{cm}^{-2}$). Only recently, high sensitivity observations with good spatial and spectral resolution have been made possible by Swift-BAT[4] and Integral-IBIS[5], that detected more than 600 AGNs, allowing the creation of a large AGN data archive in this energy band.

The purpose of this work is to investigate the properties of the population of absorbed and Compton Thick AGNs in the large sample of extragalactic sources detected by Swift-BAT after 54 months of observations [6], performing a broad band (0.3-150 keV) spectral study that combines the BAT hard X-ray spectra with the soft X-ray data collected by the Swift X-ray Telescope (XRT, [7]).

2. The sample

We have selected from the 2nd Palermo BAT Catalogue all the extragalactic sources (except clusters of galaxies and blazars) at $|b| > 10^\circ$ for which a Swift-XRT spectrum and a redshift measurement were available. Excluding sources with less than 50 counts in the XRT spectrum, we obtained a sample of 370 sources. According to the classification of the soft X-ray counterpart, as reported from the Simbad and NED databases, the sample is composed by 201 Seyfert 1s, 91 Seyfert 2s, 25 QSO or AGN with uncertain classification, 9 LINERs and 34 normal galaxies. As we do not expect significant hard X-ray emission from normal galaxies, the latter are most probably active galaxies without a proper optical classification. The sample includes 18 Compton Thick sources already known in the literature.

3. Spectral Analysis

For each source in the sample we extracted the 0.2-10 keV spectrum from the available Swift-XRT observations and the 15-150 keV BAT survey spectrum averaged over 54 months. The combined spectra were first analyzed using a simple power-law model absorbed by the Galactic line of sight column density [8] and by an intrinsic column density. Whenever this model was inadequate, we introduced a more complex model that accounts for the reprocessing by an obscuring medium:

$$F(E) = e^{\sigma[E\ (1+z)]N_H} \times AE^{-\Gamma} + A_s E^{-\Gamma} + R_C(E,\Gamma) \tag{3.1}$$

where the first term represents an intrinsically absorbed power-law model (where A is the normalization constant), the second term is a scattered component (a power-law model with the same spectral index as the primary component but without intrinsic absorption, with $A_s < A$) and the

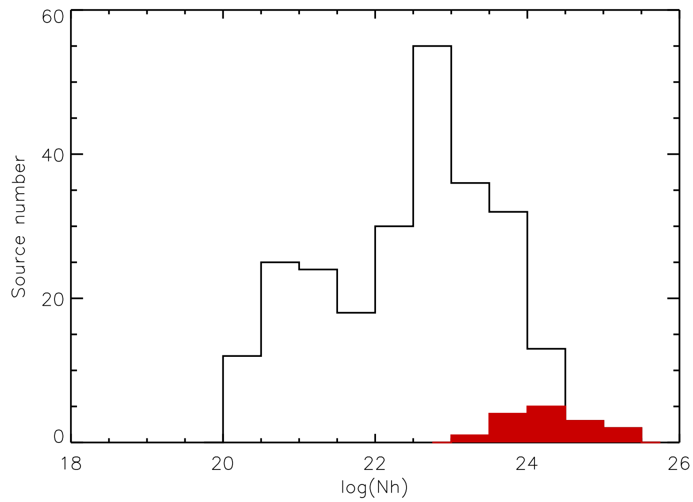

Figure 1: Distribution of best fit absorbing column values in the sample. Sources with best fit NH consistent with zero (127 out of 370) are not included in the histogram. The red area corresponds to already known Compton Thick sources.

third term is the Compton reflection component (`pexrav` model in XSPEC) produced by the obscuring medium. These components are absorbed by a Galactic hydrogen column held fixed to the line of sight value for each source. A line emission at 6.4 keV and/or a thermal component in the form either of a blackbody spectrum or of a line emission spectrum (`mekal` model in XSPEC) were introduced only when needed.

Figure 1 shows the distribution of best fit absorbing column density values in the sample. 127 out of the 370 sources in the sample have NH values consistent with zero: these values (mostly corresponding to Seyfert 1s, with a few QSOs and "normal" galaxies) are not included in the histogram. The red area corresponds to the Compton Thick sources already known in the literature. One of them, NGC 1365, shows NH of the order of 10^{23}cm^{-2}, but this source is known to be surrounded by a highly variable absorber (e.g [9]); the few others with NH best fit values below 10^{24}cm^{-2}, are consistent within errors with being in the Compton Thick regime. Seven more sources are found with NH higher than 10^{24}cm^{-2}: five of them are optically classified as Seyfert 2 and two as Seyfert 1; in three cases no measurement of NH was available in the literature, while in the other cases an absorbing column value was reported of the order of a few $\times 10^{23}$cm^{-2}.

4. The fraction of obscured AGNs

The distribution of observed absorbing column values suffers from a strong observational bias, caused by the fact that the effect of absorption in the BAT energy band starts to be significant above NH $\sim 5 \times 10^{23}$cm^{-2}, preventing the detection of obscured sources with extreme NH values (NH $> 10^{25}$cm^{-2}). This bias shall be taken into account if we want to evaluate correctly the fraction of

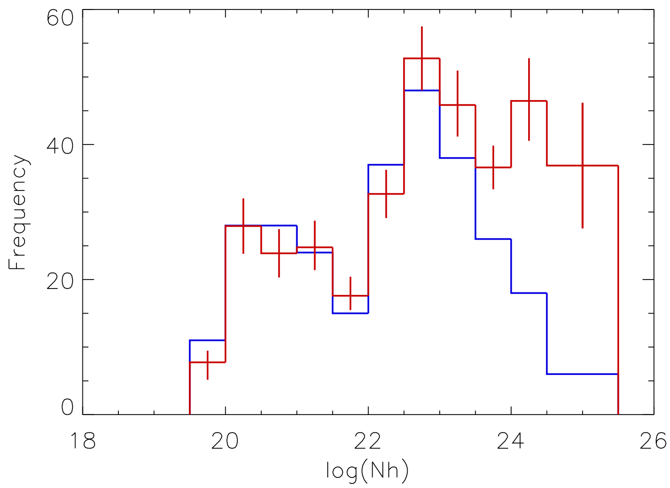

Figure 2: Distribution of observed NH in the sample (black histogram) and correction for absorption.

absorbed (NH $> 10^{22}$cm^{-2}) and Compton Thick (NH $> 10^{24}$cm^{-2}) sources in the Universe. We have therefore corrected this effect using the two methods described below.

Renormalization of the logN-logS of NH selected samples. Similarly to the procedure used by [10], we have split the sample into logarithmic bins of NH (0.5 dex wide) and built the observed logN-logS of each of the subsamples. Heavy absorption causes the observed logN-logS to be shifted toward lower fluxes: we have then computed the ratio between observed and intrinsic flux in the 15–150 keV band for each NH bin (assuming a power-law model with photon index $\Gamma = 1.9$ for the direct component and including the Compton-reflected component in a self-consisting way, using the `Mytorus` model [11]) and used these values to derive the number of sources needed to produce the observed logN-logS when accounting for absorption. The result is reported in Figure 2, with the black histogram representing the observed distribution of NH values and the red histogram representing the distribution after correcting for the absorption bias. This correction leads to 72 ± 7% of absorbed sources and 24 ± 8% of Compton Thick sources.

Selection of the subsample at z<0.015. Figure 3 shows the distribution of redshift values in our sample. It is apparent that most obscured sources (NH$> 10^{24}$cm^{-2}) are located, on average, closer to the observer than sources with lower absorption, with the farthest one at z=0.053. We have thus applied a correction for the local sample as described in [12], using only the subsample with z$<$ 0.015. We found that this subsample includes 63 ± 14% of absorbed sources and 19 ± 8% of Compton Thick sources.

The results of both methods compare well with those reported by [3] that predict ~ 70% of absorbed sources and ~ 15% of Compton Thick sources. The work is still in progress, with the detailed spectral analysis of the candidate obscured sources on-going.

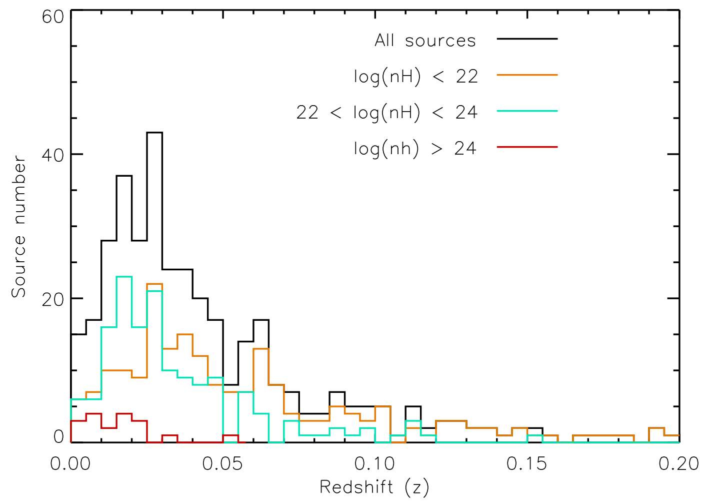

Figure 3: Distribution of redshift in the sample.

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