THE LOG N - LOG S AND THE BROADBAND PROPERTIES OF THE SOURCES IN THE HELLAS2XMM SURVEY

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ABSTRACT

We present the first results from an XMM-Newton serendipitous medium-deep survey, which covers nearly three square degrees. We show the log N - log S distributions for the 0.5-2, 2-10 and 5-10 keV bands, which are found to be in good agreement with previous determinations and with the predictions of XRB models. In the soft band we detect a break at fluxes around 5 \times 10^{-15} cgs. In the harder bands, we fill in the gap at intermediate fluxes between deeper Chandra and XMM-Newton observations and shallower BeppoSAX and ASCA surveys. Moreover, we present an analysis of the broad-band properties of the sources.

Key words: galaxies: active — X-rays: diffuse background — X-rays: galaxies

1. INTRODUCTION

While in the soft band (0.5-2 keV) ROSAT (Hasinger et al. 1998) and especially Chandra (Rosati et al. 2001) has resolved almost all the XRB, in the hard band (2-10 keV) the XRB has been resolved at a 25%-30% level with BeppoSAX and ASCA surveys (Cagnoni et al. 1998, Giommi et al. 2000) and recently at a 90% with Chandra (Rosati et al. 2001). Moreover, in the very hard band (5-10 keV) the fraction resolved by BeppoSAX is around 30% (Fiore et al. 1998) and recently in the XMM-Newton Lockman Hole deep pointing a 60% is reached (Hasinger et al. 2001).

The optical counterparts of the objects making the XRB are predominantly Active Galactic Nuclei (AGN). In the soft band the predominant fraction is made by unabsorbed AGN, with a small fraction of absorbed AGN (Schmidt et al. 1998). The fraction of absorbed type-2 AGN rises if we consider the spectroscopic identifications of hard X-ray sources in BeppoSAX, ASCA and Chandra surveys (Fiore et al. 2001, Della Ceca et al. 2001, Pozzi et al. 2001).

The X-ray and optical observations are consistent with current XRB synthesis models (Comastri et al. 1999, Gill et al. 2001), which explain the hard XRB spectrum with an appropriate mixture of absorbed and unabsorbed AGN, by introducing the corresponding luminosity function and cosmological evolution. However, these models require the presence of a significant population of type-2 QSOs (Norman et al. 2001), not yet detected in sufficient quantities. Type-2 QSOs are rare (so far, only a few are known), luminous and hard (heavily absorbed in the soft band). A good way of finding them is to perform surveys in the hard X-ray bands, covering large solid angles. The large throughput and effective area, particularly in the harder bands, make XMM-Newton currently the best satellite to perform hard X-ray surveys.

In this poster contribution we present results from the HELLAS2XMM survey (Baldi et al. 2002), one of its main goals is to constrain the contribution of absorbed AGN to the XRB.

2. DATA PREPARATION AND CLEANING

We use the XMM-SAS analysis software tasks epproc and emproc to linearize the event files. Before processing, datasets are corrected for the attitude of the satellite in order to have absolute positions in the sky. The Attitude History File(AHF) coordinates are given to the SAS task ofdfix which performs the correction.

The event files produced by epproc and emproc are cleaned from:

- hot pixels; with a procedure (developed at IFC/CNR-Milan by A. De Luca) which uses cosmic ray IRAF tasks to localize the pixels to be rejected in each CCD and XMM-SAS task evselect for removing them from the event files;
- soft proton flares; analysing the light curves at energies greater than 10keV and setting a threshold for good time intervals of 0.15 cts/s for MOS units and of 0.35 cts/s for pn unit.

A complete set of MOS1, MOS2 and pn 600x600 pixel images (1 pixel = 4.35 arcsec) is generated using XMM-SAS task ezxpmmap. The so-created exposure maps are not completely satisfactory, since the evaluation of quantum efficiency, filter transmission, and vignetting is performed
assuming an event energy which corresponds to the mean of the energy boundaries. In the 2-10 keV band, this may lead to inaccuracies in the estimate of these key quantities, thus we create the 2-10 keV band exposure map as a weighted mean of the 2-4.5 keV and the 4.5-10 keV exposure maps (assuming an underlying power-law spectral model with $\Gamma = 1.7$).

XMM-SAS task esplinemap creates a background map by removing all the sources above a fixed maximum likelihood threshold and fitting the remaining with a cubic spline. Even using the maximum number of spline nodes (20), the fit is not enough flexible to take into account the local variations of the background. We correct the background map produced by XMM-SAS, pixel by pixel, comparing the mean value in it with that of the so-called cheesed image produced by XMM-SAS, pixel by pixel, comparing the fit is not enough flexible to take into account the local variations of the background. We correct the background map of the merged image and a model implemented in XMM-SAS task.

Moreover we compute $p$, the poissonian probability that counts originate from a background fluctuation, from the

$$\sum_{n=cts_{src}}^{\infty} e^{-cts_{bkg}} \frac{cts_{bkg}^n}{n!} > p$$

and choose a threshold of $p = 2 \times 10^{-4}$ to decide whether to accept or not a detected source.

4. The survey

The HELLAS2XMM survey (Baldi et al. 2002) currently uses the 15 XMM-Newton calibration and performance verification phase fields shown in table 1. All the fields are at high galactic latitude ($|bI| > 27^\circ$), have low galactic $N_H$ (a few $10^{20}$ cm$^{-2}$) and at least 15 ksec of good observing time. The sky coverage of the sample has been computed using the exposure maps of each instrument, the background map of the merged image and a model for the PSF. We adopt the off-axis angle dependent PSF model implemented in XMM-SAS eboxdetect task.

At each image pixel $(x, y)$ we evaluate, within a radius $r_{0.68}$, the total background counts (from the background map). From these we calculate the minimum total counts (source + background) necessary for a source to be detected at a probability $p = 2 \times 10^{-4}$ (defined in Section 3).

The exposure times for MOS1, MOS2 and pn, evaluated from the exposure maps within $r_{0.68}$, are used to compute the count rate $cr$. From the count rate-to-flux conversion factor $cf$ (computed as in Section 3) we build a flux limit map and straightforwardly calculate the sky coverage of a single field.

Summing the contribution from all fields we obtain the

\[
T = \sum_{i=1}^{n} \frac{T_{src}^{MOS1}}{cf_{MOS1}} + \frac{T_{src}^{MOS2}}{cf_{MOS2}} + \frac{T_{src}^{pn}}{cf_{pn}}
\]

where $T$ is the total exposure time.

![Figure 1. Left: XMM-SAS standard background map. Right: corrected background map.](image)

3. Source detection and characterization

A preliminary detection run, using XMM-SAS eboxdetect, is performed in each energy band, in order to create a list of candidate sources. Each source is characterized using a radius corresponding to an EEF of $\alpha=0.68$.

The source counts $S$ and their error $\sigma_S$ are determined as

\[
S = \frac{cts_{src} - cts_{bkg}}{\alpha}
\]

\[
\sigma_S = \frac{\sqrt{cts_{src} + 0.75}}{\alpha}
\]

The countrate is $cr = \frac{S}{T_{tot}}$ where $T_{tot}$ is the sum of MOS1, MOS2 and pn exposure times. The corresponding flux is $F_x = cf \cdot cr$ where $cf$ is calculated from the

\[
\frac{T_{tot}}{cf} = \frac{T_{MOS1}}{cf_{MOS1}} + \frac{T_{MOS2}}{cf_{MOS2}} + \frac{T_{pn}}{cf_{pn}}
\]
total sky coverage of the survey, which is plotted in Figure 2, in three different energy bands.

Figure 2. The total sky coverage of the survey in the 0.5-2 keV (red), 2-10 keV (green) and 4.5-10 keV band (blue).

5. The log N - log S Relation

The log N - log S distributions are plotted in Figure 3 and contain 1022, 495 and 100 sources, for the 0.5-2 keV, 2-10 keV and 5-10 keV band, respectively.

In the 0.5-2 keV band the distribution shows a flattening around $5 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$, similarly to ROSAT data (Hasinger et al. 1998) although with a flatter differential slope index at faint fluxes. We are also in good agreement with Chandra Deep Field South data (Giacconi et al. 2001). In the 2-10 keV band we find that the distribution is significantly sub-euclidean, in contrast to BeppoSAX and ASCA findings (Giommi et al. 2000; Cagnoni et al. 1998; Ueda et al. 1999), indicating that the log N - log S flattens at fainter fluxes. Anyhow it represents a link between Chandra (Giacconi et al. 2001) and BeppoSAX-ASCA observation, sampling an intermediate flux range. The 5-10 keV log N - log S is consistent with an euclidean slope and samples an intermediate flux range between XMM-Newton deeper observations (Hasinger et al. 2001) and BeppoSAX shallower HELAS survey (Fiore et al. 1998).

As shown in Figure 4 and in Table 2, the faint sample shows a tail of hard sources which is not present in the bright sample. The probability of having 84 sources with $HR_1 \geq -0.35$ in the faint sample and no sources with $HR_1 \geq -0.35$ in the bright sample is $\sim 10^{-6}$, so the progressive hardening of the sources towards fainter fluxes seems to be highly significant.

6. Hardness Ratio Analysis

We divided the sample of sources detected both in 0.5-2 keV band and in 2-4.5 keV band in two subsamples containing the brighter ($F_{0.5-2keV} > 2 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$) and the fainter ($F_{0.5-2keV} \leq 2 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$) sources, respectively and we compute for them the hardness ratio:

$$HR_1 = \frac{c_{2-4.5} - c_{0.5-2}}{c_{2-4.5} + c_{0.5-2}}$$

Table 2. $HR_1$ distribution for the faint and the bright sample.

|                | N($HR_1 < -0.35$) | N($HR_1 \geq -0.35$) |
|----------------|-------------------|-----------------------|
| Faint sample   | 654               | 84                    |
| Bright sample  | 107               | 0                     |

As shown in Figure 5 the relation shows a tail of hard sources which is not present in the bright sample. The probability of having 84 sources with $HR_1 \geq -0.35$ in the faint sample and no sources with $HR_1 \geq -0.35$ in the bright sample is $\sim 10^{-6}$, so the progressive hardening of the sources towards fainter fluxes seems to be highly significant.

A further analysis of the hardness ratio has been carried out on the 4.5-10 keV sample. In Figure 6 the relation...
The population of harder sources we detect, probably consists of AGN having substantial absorbing column densities \(N_H > 10^{22} \text{ cm}^{-2}\).

7. **Summary**

We are carrying out a serendipitous XMM-Newton survey. We currently cover nearly three square degrees in 15 fields observed during satellite calibration and performance verification phase. This is, to date, the XMM-Newton survey with the largest solid angle.

The main results can be summarized as follows:

- The log N-log S relations in the 0.5-2 keV, 2-10 keV and 5-10 keV band are in agreement with previous determinations;
- in the hard bands we sample an intermediate flux range: deeper than ASCA and BeppoSAX and shallower than Chandra and XMM-Newton deep surveys
- We find an evidence for hard sources emerging below 0.5-2 keV fluxes of \(2 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}\) and 2-10 keV fluxes of \(10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}\).

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