A shallow XMM survey of AAT 2-degree fields

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ABSTRACT

We briefly describe our wide-area (3 deg^2) shallow XMM survey (5 ksec exposure). Our survey consists of contiguous EPIC pointings in areas previously observed with the Anglo-Australian Telescope (AAT) 2-degree field (2df) multi-fibre spectroscopy system. We will make 14 pointings in total in two AAT fields (70 ksec total) reaching a flux level of $\sim 5 \times 10^{-15}$ erg cm^{-2} s^{-1}in the 0.5-2 keV band and detecting at least 500 QSOs and few hundreds other sources *per* AAT *field* in this band alone. The great advantage of these pointings is that spectroscopic information already exists down to B$\sim$21 for QSOs and B$\sim$20 for galaxies and hence we will immediately have spectroscopic identifications for a significant fraction of our sources. The sample will provide an excellent database for the study of a) the QSO X-ray luminosity function in soft and hard X-rays b) the average typical QSO spectrum c) the nature of the flat-spectrum population implied by the hard X-ray ASCA number counts d) the contribution of galaxies to the X-ray background e) detect clusters at high redshifts (z>0.5).

1. Introduction

The ROSAT mission was very successful in resolving a large fraction of the XRB (X-ray background) at soft energies. Deep ROSAT surveys found a surface density of 1000deg^{-2} to a flux limit of $\sim 2 \times 10^{-15}$ergs^{-1}cm^{-2}(Hasinger et al. 1997). Optical identifications of shallower surveys (eg Shanks et al. 1991, Georgantopoulos et al. 1996) have shown that the majority of sources are broad-line AGN (QSOs) at a mean redshift z=1.5. Some highly luminous ($L_x > 10^{42}$erg s^{-1}) narrow-line galaxies were also detected at faint fluxes ($< 10^{-14}$ erg cm^{-2} s^{-1}). However, due to the large error box of the ROSAT PSPC and the high sky density of field galaxies presenting emission lines, up to half of the NLXGs could be due to chance coincidences. Roche et al. (1995) found a strong correlation between the X-ray source positions and galaxies on deep AAT plates.

This established that optical galaxies form a substantial fraction of the XRB at soft energies. The nature of these galaxies remained unclear. However, the high X-ray luminosities of these objects (orders of magnitude higher than the luminosities of nearby galaxies with the same optical luminosity) immediately suggests that these harbour low luminosity AGN (type-II AGNs similar to the Seyfert 2 locally). The discovery of a type-II AGN at a redshift of z=2.2 (Almaini et al. 1995) with a flat X-ray spectrum ($\alpha = 0.5$), lent some weight to the above hypothesis. The AGN nature of the NLXGs is further corroborated by the follow-up observations (Schmidt et al. 1998) of 50 PSPC sources ($> 5 \times 10^{-15}$ erg cm^{-2} s^{-1}) in the Lockman hole. These sources were also followed up by ROSAT HRI and hence they have accurate X-ray positions excluding the possibility of misidentifications. Schmidt et al. (1998) identify 31 broad-line AGN and 8 NLXGs which show strong [NeV] and [NeIII] emission lines and hence these are most probably type-II AGN. However, the statistics is still very poor and the unambiguous identification of large numbers of this new population remains elusive.

The situation in hard X-rays is less clear. ASCA deep surveys probed fluxes (5×10^{-14} erg cm^{-2} s^{-1}) two orders of magnitude below HEAO-1 but still an order of magnitude above the deep ROSAT surveys flux limit. The hard number count distribution, logN-logS, is a factor of two above the ROSAT logN-logS (converted in the 2-10 keV band using a spectral index of $\alpha = 1$, the mean spectral index of ROSAT sources). This suggests the presence of a new population of sources, apart from the broad line AGN which dominate the ROSAT counts at bright fluxes. This population has either a flat or an absorbed spectrum ($N_H > 3 \times 10^{21}$). Optical IDs of the ASCA sources show indeed some fraction of the sources to be associated with Seyfert-2 type nuclei (eg Ohta et al. 1996, Boyle et al. 1998, Georgantopoulos et al. 1998), and therefore these galaxies may be associated with the NLXGs detected in deep ROSAT surveys. However, the large error box of ASCA (typically 1 arcmin), the very poor number statistics (with only a few NLXGS detected in hard X-rays) together with the very poor photon statistics (40-50 photons per source) significantly hamper the study of these objects in hard X-rays. A large number of the ASCA sources in our deep ASCA survey are broad-line AGN. Surprisingly the coadded ASCA GIS hardness ratio of these sources appears to be relatively flat ($\alpha = 0.55 \pm 0.15$, Georgantopoulos et al. 1998b) similar to the spectrum of the XRB (Gendreau et al. 1995), and therefore broad-line AGN could make a substantial contribution to the XRB together with the NLXGs. Again with less than 20 broad-line AGN and fewer than 1000 photons in our deep ASCA surveys it is difficult to obtain statistically significant results using ASCA alone.

2. The XMM shallow survey

The large effective area of XMM provides us with the opportunity to increase dramatically (especially in hard energies) the size of our samples as well as our photon statistics. Moreover, the good spatial resolution of XMM (and hence accurate X-ray positions) guarantee that the number of misidentifications will be negligible. Although deep X-ray surveys will provide excellent spectra of faint sources like the narrow-line AGNs, shallow surveys are complementary as they cover large areas and hence they provide good statistics for eg the derivation of luminosity functions, and the detection of high redshift clusters.

Our shallow XMM survey (5 ksec) consists of contiguous EPIC pointings in areas previously observed spectroscopically by the Anglo-Australian Telescope (AAT) 2-degree diameter field (2df). The 2df gives up to 400 spectra simultaneously. We will make 14 pointings in total in two AAT fields (70 ksec total time requested). Our survey will reach a flux level of $\sim 5 \times 10^{-15}$ erg cm^{-2} s^{-1}in the 0.5-2 keV band and will detect at least 500 QSOs and few hundred other sources in this band alone, on the basis of the ROSAT logN-logS (e.g. Georgantopoulos et al. 1996). In the hard band (2-10 keV) we will reach a flux limit of 5×10^{-14} erg cm^{-2} s^{-1}comparable to the deepest ASCA survey. The ASCA logN-logS (Georgantopoulos et al. 1997) yields a surface density of 60deg^{-2} or at least 100 hard sources in all XMM fields according to our simulations.

3. The scientific goals

3.1. The QSO luminosity function

Our experience with ROSAT (Boyle et al. 1994) has shown that ∼100 QSOs could provide a good estimate of the luminosity function and its evolution. With 500 QSOs we will be able to derive the best estimate yet of the QSO luminosity function in soft X-rays and derive for the first time an accurate estimate of the QSO luminosity function in hard X-rays at redshifts out to ~ 1.5 or greater. The latter is of particular importance as it is unaffected by absorption. When coupled with measurements of the local luminosity function estimates of the rate of luminosity evolution in this band will also be derived. The physical basis for luminosity evolution in the optical and soft X-ray may well be different from that in the 2-10 keV band as the former is strongly affected by the properties of the accretion disc while the latter may be more directly a measure of the central engine.

3.2. The average QSO spectrum

We estimate that a 10^{-14} erg cm^{-2} s^{-1}QSO will yield 70 counts in the 0.1-10 keV band, in the EPIC pn alone, sufficient for a '3-color' estimate of the spectrum, allowing crude determinations of both absorbing column and spectral index to be made. Additionally by coadding the counts in the fashion of e.g. Schartel et al. (1996), we will study the average QSO spectrum as a function of luminosity and redshift. We expect over 80,000 QSO counts from all three XMM modules in the 14 fields. This allows the derivation of excellent signal-to-noise spectra in several redshift and/or luminosity bins. More importantly, we will probe the typical QSO spectrum in the 2-10 keV band that presently is not well determined.

3.3. The nature of the hard population

The ASCA logN-logS is a factor of two above the ROSAT counts (Georgantopoulos et al. 1997). This suggest the presence of a population with flat or absorbed spectra. However, the poor spatial resolution of ASCA (1 arcmin rms) makes the optical follow-up very difficult. For example, due to the high surface density of galaxies at faint magnitudes, there are several Narrow-Line galaxies in each ASCA error box. With XMM's superior spatial resolution we will be able to immediately determine the optical counterparts of the X-ray sources.

3.4. The X-ray emission of galaxies

Roche et al. (1995) and Almaini et al. (1997) established that galaxies make a substantial contribution (at least 18%) to the soft XRB by cross-correlating the optical positions on AAT plates with the XRB sources and fluctuations in three ROSAT PSPC fields. However, the nature of these galaxies remains unclear as they could host active nuclei. Here, we will extend their results to harder energies using a large sample of 14 fields and hence improving the statistics. The good positional errors of the XMM EPIC will also help to improve the signal of the cross-correlation. More importantly, we will know the identification of the cross-correlated galaxies through their optical spectra (at least those with B<21).

3.5. High-redshift clusters

Clusters will appear as extended objects up to a redshift of at least z=1-1.5 (and thus should be detected with Voronoi tesselation techniques eg Scharf et al. 1997). For the brightest clusters we may be able to estimate redshifts from the Fe line at 6.7 keV. According to the Rosati et al. (1998) logN-logS of ROSAT clusters we expect to detect ~ 20 clusters in our survey. The above estimate may be only a lower limit as it includes only clusters detectable by ROSAT ie only up to $z \sim 0.8$. The number density of luminous clusters detected at high redshift is expected to have profound implications for various cosmological models.

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