Evolution of X-Ray Selected AGN

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Abstract. Deep X–ray surveys have shown that the cosmic X–ray background (XRB) is largely due to the accretion onto supermassive black holes, integrated over the cosmic time. These surveys have resolved more than 90% of the X–ray background at ~ 1 keV and about 50% at 10 keV into discrete sources. Optical spectroscopic identifications show that the sources producing the bulk of the X–ray background are a mixture of unobscured (type-1) and obscured (type-2) AGNs, as predicted by the XRB population synthesis models. A class of highly luminous type-2 AGN, so called QSO-2s, has been detected in the deepest Chandra and XMM-Newton surveys. The fraction of type-2 AGN among all AGN, however, decreases significantly with luminosity. The new Chandra AGN redshift distribution peaks at much lower redshifts (z $\sim$ 0.7) than that based on ROSAT data. The low redshift peak applies both to absorbed and unabsorbed AGN and is also seen in the 0.5-2 keV band alone. The new, preliminary X-ray luminosity function changes shape between low and high redshifts, confirming the luminosity-dependent density evolution model. The space density of Seyfert galaxies evolves much slower than that of QSOs.

1 Introduction

In recent years the bulk of the extragalactic X–ray background in the 0.1-10 keV band has been resolved into discrete sources with the deepest *ROSAT*, *Chandra* and *XMM-Newton* observations [1–4]. Optical identification programmes with Keck [5–8]) and VLT [9,10] find predominantly unobscured AGN-1 at X-ray fluxes $S_X > 10^{-14}$ erg cm^{-2} s^{-1}, and a mixture of unobscured and obscured AGN-2 at fluxes $10^{-14} > S_X > 10^{-15.5}$ erg cm^{-2} s^{-1} with ever fainter and redder optical counterparts, while at even lower X-ray fluxes a new population of star forming galaxies emerges [11–13]. At optical magnitudes R>24 all these surveys suffer, however, from spectroscopic incompleteness, so that photometric redshift techniques have to be applied [14].

After having understood the basic contributions to the X-ray background, the interest is now focusing on understanding the physical nature of these sources, the cosmological evolution of their properties, and their role in models of galaxy evolution. The X-ray observations have been roughly consistent with X-ray background population synthesis assuming a mixture of absorbed and unabsorbed AGN, folded with the corresponding luminosity function and cosmological evolution, e.g.[15–17]. However, inputs to these models are still rather uncertain, like e.g. the cosmological evolution of low-luminosity AGN or the fraction of type-1

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to type-2 AGN as a function of redshift and intrinsic luminosity, and a wide range of different assumptions has been invoked for these parameters [18,19], see also [20]. Finally, the source statistics and optical incompleteness are rather poor at high redshifts.

The deep Chandra and XMM surveys, but also wider ASCA surveys have already provided important new constraints. Several examples of the long-sought class of high redshift, radio quiet type-2 QSO have been detected in deep fields [21,22,8,9]. These allow for the first time to constrain the fraction of type-2 AGN as a function of X–ray luminosity. At low luminosities a type-2 fraction of 75-80% is found, consistent with local optically selected Seyfert galaxies, while at high luminosities the type-2 fraction is significantly smaller [23,9]. The redshift distribution of Chandra deep survey sources peaks at $z \approx 0.7$. This is related to the finding of a much slower cosmic evolution for Seyferts compared to QSOs [23–26,10]. And finally, significant spikes are found in the redshift distributions [27,28], indicating that AGN prefer to live in sheets of large-scale structure.

2 Deep XMM-Newton Survey in the Lockman Hole

The Lockman Hole is the region on the sky having the lowest interstellar hydrogen column density and thus provides an excellent window to the distant Universe. It had been chosen as the location of the deepest ROSAT survey, which resolved the majority of the diffuse soft X-ray background into discrete sources [1]. It has also been selected for the first XMM-Newton deep survey in the PV phase [3]. Recently we have been awarded a very long XMM-Newton survey exposure in this field, bringing the net exposure to about 800 ksec, corresponding to almost 20 days of XMM-Newton exposure [29,30]. Figure 1 shows an X-ray image of this observation. The spacecraft pointing directions have been dithered between successive exposures in order to smooth out the effects of the gaps between the CCD chips.

This data has been used to determine the redshift and temperature of one of the most distant clusters of galaxies known [31,32], as well as to determine the distribution of spectral properties of the X-ray sources [33,34]. The fraction of the background resolved into discrete sources decreases from more than 90% at energies below 2 keV to about 50% at energies of 10 keV [35], leaving a significant population of hard sources still to be resolved. Spectroscopic follow-up observations have been performed at the Keck telescope in spring 2003 and 2004 in collaboration with Pat Henry and Maarten Schmidt, using the Deimos wide field spectrograph. Together with the already existing ROSAT sources we now have 125 spectroscopic identifications in this field. For a subsample of sources with X-ray fluxes $> 10^{-15}$ erg cm^{-2} s^{-1} we reach a spectroscopic completeness of $\sim 80\%$ in the inner field with 10 arcmin radius.