**TITLE**

ASP Conference Series, Vol. **VOLUME**, **PUBLICATION YEAR**

**EDITORS**

SHEEP: the ASCA 5-10 keV survey

I. Georgantopoulos

*Institute of Astronomy & Astrophysics, National Observatory of Athens, Greece*

K. Nandra

*Goddard Space Flight Center, NASA, Greenbelt, Maryland, USA*

A. Ptak

*Physics Department, Carnegie Mellon University, Pittsburgh, USA*

**Abstract.** We present the first results of the hard (5-10 keV) ASCA GIS survey SHEEP (Search for the High Energy Extragalactic Population). We have analysed 149 fields covering an area of 39 deg$^2$ detecting 69 sources. Several of these appear to be associated with QSOs and Seyfert-1 galaxies but with hard X-ray spectra, probably due to high absorption ($N_H > 10^{22}$ cm$^{-2}$). Indeed, the hardness ratio analysis shows that the spectra of the majority of our sources can be represented with a “scatterer” model similar to obscured Seyfert galaxies locally. According to this model, our sources present high intrinsic absorption ($N_H \sim 10^{23}$) but also significant amounts of soft X-ray emission coming from scattered light.

1. Introduction

The X-ray background (XRB) is made up of emission by discrete sources. Previous soft (0.1-2 keV) ROSAT X-ray surveys demonstrated that a large fraction of the XRB constitutes of QSOs (Shanks et al. 1991, Hasinger et al. 1998). Harder X-ray surveys in the 2-10 keV band with ASCA and BeppoSAX suggested that obscured AGN also contribute a large fraction of the XRB (Georgantopoulos et al. 1997, Cagnoni et al. 1998, Ueda et al. 1998, Akiyama et al. 2000, Giommi et al. 2000). These obscured AGN are associated with either Seyfert type galaxies locally, or with broad-line AGN (QSOs) at high redshift (Georgantopoulos et al. 1999, Fiore et al. 1999). Recently, Chandra observations (eg Mushotzky et al. 2000, Giacconi et al. 2000) have almost resolved the XRB in the 2-10 keV band in a small area of the sky and hence with very small number statistics. Surprisingly, the Chandra observations have increased the mystery of the X-ray background even further. Mushotzky et al. find two new populations: one is associated with anonymous early-type galaxies while the other one has no or extremely faint (B$>$25) optical counterparts. Both present very hard X-ray spectra harder than the spectrum of the XRB.
In order to identify the nature of these enigmatic hard sources one needs to find brighter examples for spectroscopic follow-up in both optical and X-ray wavelengths. Unfortunately, the Chandra surveys contain sources with typically only a few tens of photons and they do not cover sufficient area to reveal rare, bright examples of the above populations. We have therefore begun a large area (40 deg$^2$) hard (5-10 keV) X-ray survey with the ASCA GIS to find such examples in the nearby Universe. Our ASCA survey SHEEP (Search for the High Energy Extragalactic Populations) is very similar to the BeppoSAX HELLAS survey (Fiore et al. 1999). We believe that both the SHEEP and the HELLAS surveys are timely complements for the deep Chandra surveys which will pin down the brightest examples of the long sought high redshift AGN population and the new classes of Chandra objects.

2. The SHEEP survey

We have chosen to use the GIS instrument onboard ASCA due to its large FOV (0.33 deg$^2$) and high sensitivity in the 5-10 keV band. We are using fields from the TARTARUS AGN database (Turner et al. 2000). We reject fields with a) exposure less than 30 ksec (combined GIS2+GIS3) b) Galactic latitude $|b| < 20$ and c) target brighter than 0.02 ct s$^{-1}$ (as a bright target could contaminate the whole field due to the extended wings of the PSF). Our survey consists of 149 fields covering an area of 39deg$^2$. We find candidate sources in the coadded GIS2 and GIS3 images by simply eyeballing the images (on average there are about 0 or 1 sources per image). We then use a circular detection cell to determine the significance of the detection. We have detected 69 sources with a significance above a Poisson probability threshold of $3 \times 10^{-5}$ or (equivalently $4.5\sigma$) in a “detection” cell of $\sim 4$ arcmin$^2$. Our faintest source has a count rate of $\sim 7 \times 10^{-4}$cts s$^{-1}$ corresponding to a flux of $9 \sim 10^{-14}$ (5-10 keV) ($\Gamma = 1.6$).

We have cross-correlated our catalogue with existing X-ray and optical catalogues. 59 SHEEP sources are located within the 2-degree diameter FOV of a pointed ROSAT PSPC observation. However, only 32 have ROSAT counterparts within 2 arcmin (2 $\sigma$ GIS position error). 5 of them have a ROSAT all-sky survey Bright Source Catalogue (RASSBSC) counterpart. By offsetting the positions of the SHEEP sources, we find that the number of ROSAT (WGACAT) and ASCA source chance coincidences is less than 3 (it is practically nil for the RASSBSC sources). A large number of the sources with ROSAT counterpart have already spectroscopic classification in the literature. In table 1 we give the optical -IDs of these sources. It is evident that the dominant population is type-1 AGN ie QSOs and Seyfert-1 galaxies. Our highest redshift source is the QSO RXJ125827+3528.0 at $z=1.88$.

In Fig. 1 we are plotting the number count distribution, logN-logS, in the 5-10 keV band for our sample. We have used a spectrum of $\Gamma = 1.6$ to convert count rates to flux. We are comparing with the logN-logS derived from the BeppoSAX HELLAS survey (Comastri et al. 2000). We are also comparing with the ASCA 2-10 keV logN-logS (Cagnoni et al. 1998) converted in the 5-10 keV band again assuming a mean source spectrum of $\Gamma = 1.6$. We see that the Cagnoni et al. logN-logS, $N(> S) \approx 10^{-21}S^{-1.67}$ (in the 5-10 keV band) provides a good fit to both the SHEEP and HELLAS data. At the faintest flux
Table 1. The ROSAT subsample: optical IDs from the literature

| Classification    | Count |
|-------------------|-------|
| QSOs/Sy1          | 10    |
| Sy2/LINER         | 3     |
| Radio Gal.        | 1     |
| Cluster           | 1     |
| No-ID             | 16    |

probed by our survey we are resolving about 15% of the 5-10 keV XRB (using the HEAO-1 XRB normalization of Marshall et al. 1980).

3. The spectral properties

In Fig. 2 we plot the hardness ratio versus the count rate in the 5-10 keV band for our 69 sources. The hardness ratio is defined as h-m/h+m where h and m are the counts in the 2-5 and 5-10 keV band respectively (corrected for vignetting and light falling outside the detection cell). The solid line denotes a spectrum with $\Gamma = 1.4$ ie the spectrum of the XRB in the ASCA band (Gendreau et al. 1995). We see that large fraction of our sources have spectra harder than that of the XRB. There is also a separation between the sources detected by ROSAT (solid circles) and the sources with ASCA detections only (open circles) with the former being in general softer than the latter. Interestingly, some of the ROSAT sources with hard X-ray spectra ($\Gamma < 1.4$ ) are high redshift QSOs (eg CCRS 1429.7+4240) We note that the 2-10 keV spectrum does not get harder with decreasing flux. This is in contrast to previous X-ray spectral studies of sources detected in the 2-10 keV band (Della Ceca et al. 1999, Giommi et al. 2000).

A key question is whether our sources present hard spectra due to large amount of intrinsic absorption or whether they are intrinsically hard. For example, bremsstrahlung emission from an ADAF would produce a spectrum with $\Gamma = 1.4$ in our band (Narayan 1999). A pure reflection spectrum eg in the case of a Compton-thick Seyfert galaxy could produce an even flatter spectrum. In order to investigate, in more detail, the spetral properties of our sources and in particular the role of absorption, we plot the X-ray colour-colour diagram (Fig. 3). Here we compare the softness ratio (h-s/h+s) versus the hardness ratio (h-m/h+m) where s,m and h are the counts in the 0.7-2, 2-5 and 5-10 keV band respectively. A wide range of spectral properties is evident on Fig. 3. Absorbed model spectra consisting of a power-law of $\Gamma = 1.9$ (the typical AGN spectrum) and a column $N_H = 10^{24}$ and $N_H = 10^{23}$ cm$^{-2}$ are denoted with a long and a short dash respectively; the above model spectra are evolved from redshift $z=0$ to redshift $z=2$ progressively getting softer as the K-correction moves the absorption to softer energies outside the ASCA band. The solid line represents a power-law spectrum with no absorption; the softest end of the line corresponds to $\Gamma = 1.9$ while the hardest point to $\Gamma = 1.0$. Finally, the dotted line corresponds to a scattering model. Here, we assume that the hard X-ray emission is covered by an obscuring screen of $N_H = 10^{23}$. 10% of the X-ray emission...
is scattered along the line of sight due to an electron scattering medium. This model is typical of intermediate Seyfert galaxies (e.g., Seyfert 1.8 -1.9) in the local Universe (e.g., Turner et al. 1997). Again we evolve our model from redshift $z=0$ to $z=2$. We see that the scatterer model provides an excellent description for a large number of our sources. Della Ceca et al. (1999) have reached similar conclusions studying the spectral properties of a sample of ASCA sources detected in the softer 2-10 keV band.

4. Conclusions

We report the first results from the hard (5-10 keV) ASCA GIS survey SHEEP. The purpose of our survey is to detect bright, nearby examples of the hard populations which contribute the largest fraction of the XRB. We have detected 69 sources in 39 deg$^2$. 32 of these sources have ROSAT counterparts and therefore have a rather secure optical counterpart. Already existing literature classifications show that 12 of the ROSAT sources are associated with type-1 AGN (i.e., Seyfert-1 and QSOs). Some of the above sources present very hard X-ray colours
Figure 2. The hardness ratio in the 2-10 keV band. \( h \) and \( m \) denote the counts in the 2-5 and the 5-10 keV band respectively. Filled circles correspond to sources with ROSAT detections while open circles to those with ASCA detections only. Triangles denote sources (3\( \sigma \) upper limits) with no significant detection in the 2-5 keV band.

in the 2-10 keV band, comparable or even harder than the spectrum of the XRB. Such obscured QSOs at high redshift have been also found in the BeppoSAX HELLAS survey. Furthermore, the X-ray colour-colour analysis shows that the majority of our sources can be described with obscured AGN models with large amounts of absorption (> \( 10^{22}\text{cm}^{-2} \)) but where small amounts of soft X-ray emission are also present. The soft X-rays are possibly arising from scattering of the primary X-ray continuum along the line of sight on a warm medium. This "scatterer" model is in line with the Seyfert unification scheme scenario.

References

Akiyama et al. 2000, ApJ, 532, 700
Cagnoni, I., Della Ceca, R., Maccacaro, T., 1998, ApJ, 493, 54
Comastri, A. et al., 2000, in proc. “Large Scale Structure in the X-ray Universe”, Santorini, eds. M. Plionis & I. Georgantopoulos, AtlantiSciences, Paris
Figure 3. The X-ray colour-colour diagram. The s, m and h bands correspond to 0.7-2, 2-5 and 5-10 keV respectively. Open and filled circles denote sources with detections in ASCA and ROSAT respectively. Sources with no detection in the 0.7-2 and 2-5 keV bands have been omitted for simplicity.

Della Ceca, R., et al., 1999, ApJ, 524, 674
Fiore et al. 1999, MNRAS, 306, L55
Georgantopoulos, I. et al. 1997, MNRAS, 291, 203
Georgantopoulos, I. et al. 1999, MNRAS, 305, 125
Giacconi, R., et al., 2000, ApJ, in press, astro-ph/0007240
Giommi, P., et al., 2000, A&A, 362, 799
Hasinger, G. et al. 1998, A&A, 329, 482
Mushotzky, R.F., Cowie, L.L, Barger, A.J., Arnaud, K.A., Nature, 404, 459
Shanks, T., Georgantopoulos, I., Stewart, G.C., Pounds, K.A., Boyle, B.J.,
Griffiths, R.E. 1991, Nature, 353, 315
Turner, T.J., George, I., Nandra, K., Mushotzky, R.F., 1997, ApJS, 133, 23
Turner, T.J., Nandra, K., Turcan, D., George, I.M., 2000, Astroph. Letters &
Comm., in press
Ueda et al., 1998, Nature, 391, 866