A&A 365, L51–L59 (2001)
DOI: 10.1051/0004-6361:20000067

Astronomy & Astrophysics

The XMM-Newton Serendipitous Survey*

I. The role of XMM-Newton Survey Science Centre

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Received 2 October 2000 / Accepted 27 October 2000

Abstract. This paper describes the performance of *XMM-Newton* for serendipitous surveys and summarises the scope and potential of the *XMM-Newton* Serendipitous Survey. The role of the Survey Science Centre (SSC) in the *XMM-Newton* project is outlined. The SSC's follow-up and identification programme for the *XMM-Newton* serendipitous survey is described together with the presentation of some of the first results.

Key words. surveys – methods: data analysis – X-rays: general – X-rays: galaxies – X-rays: stars

1. Introduction

In contrast with all-sky X-ray surveys which typically provide relatively shallow coverage, serendipitous surveys provide much deeper observations, albeit restricted to smaller sky areas. Serendipitous X-ray sky surveys, taking advantage of the relatively wide field of view afforded by typical X-ray instrumentation, have been pursued with most X-ray astronomy satellites since the *Einstein* Observatory. The resultant serendipitous source catalogues (e.g. EMSS [835 sources] Gioia et al. 1990, Stocke et al. 1991; WGACAT [$\sim$62 000 unique sources] White et al. 1994; *ROSAT* 2RXP & *ROSAT* 1RXH [$\sim$95 000 & $\sim$11 000 sources respectively] the *ROSAT* Consortium, 2000) have been the basis for numerous studies and have made a significant contribution to our knowledge of the X-ray sky and our understanding of the nature of the various Galactic and extragalactic source populations.

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* Based on observations obtained with *XMM-Newton*, an ESA science mission with instruments and contributions directly funded by ESA Member States and the USA (NASA).

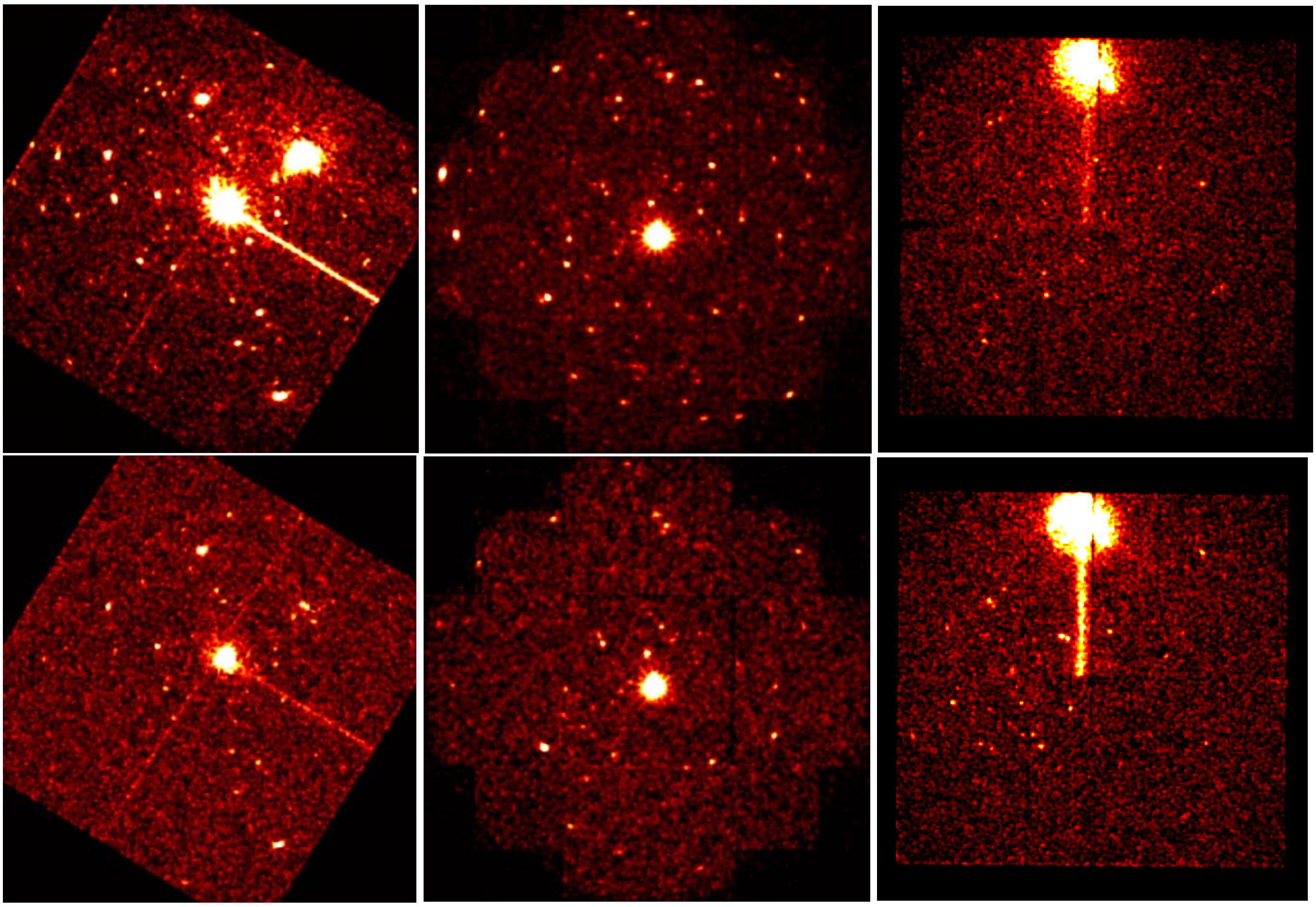

Fig. 1. EPIC images of three fields. Essentially the whole field, 30 arcmin across, is shown in each case. Top row shows the soft band (0.5–2 keV) images and the bottom row the corresponding hard band (2–10 keV) images. *Left*: Mkn 205, EPIC pn image; *Centre*: OY Car, EPIC MOS1+MOS2 image; *Right*: G21.5−0.9 (offset pointing), EPIC pn image. Further details are given in Table 1. The images have been smoothed to aid the visibility of faint sources. The trails associated with bright sources in the pn images are due to 'out-of-time' events which arrive during the read-out cycle of the CCDs and have not been screened out

The *XMM-Newton* Observatory (Jansen et al. 2001), launched in December 1999, provides unrivaled capabilities for serendipitous X-ray surveys by virtue of the large field of view of the X-ray telescopes with the EPIC X-ray cameras (Turner et al. 2001; Strüder et al. 2001), and the high throughput afforded by the heavily nested telescope modules. This capability guarantees that each *XMM-Newton* observation provides a significant harvest of serendipitous X-ray sources in addition to data on the original target. This potential is now starting to be realised, as is described below.

2. The role of the XMM-Newton Survey Science Centre (SSC)

In recognition of the importance of the *XMM-Newton* serendipitous science ESA solicited proposals for an *XMM-Newton Survey Scientist* in 1995. The role of the Survey Scientist centres on providing a coordinated approach to *XMM-Newton* serendipitous data to ensure that the whole scientific community can exploit this valuable resource. In fact the role of the Survey Scientist required by ESA was much wider than this, involving the substantial additional tasks of making a major contribution to the development of the scientific processing and analysis software for *XMM-Newton*, the routine "pipeline" processing of all the observations and the compilation of the *XMM-Newton* Serendipitous Source Catalogue.

The *XMM-Newton* Survey Science Centre (SSC) consortium was selected by ESA in early 1996. The SSC is an international collaboration involving a consortium of 8 institutions in the UK, France and Germany, together with 7 Associate Scientists. The SSC's role in facilitating the exploitation of the *XMM-Newton* serendipitous survey is the main subject of this paper, but here we emphasise the other contributions that the SSC is making to the project. Since 1996 the SSC has been working closely with ESA's Science Operations Centre (SOC) staff in the development of the scientific analysis software required for the *XMM-Newton* project. This is the software that both carries out the initial pre-processing of the *XMM-Newton* scientific data and permits the detailed scientific analysis of the observations: the modules can be used in a fixed configuration for the routine processing of the *XMM-Newton* data, and can be used in an interactive configuration by *XMM-Newton* observers to carry out custom analysis of their data. For documentation of the *XMM-Newton* science analysis software, a collection of software tools now known as the *XMM-Newton* "SAS", see `http://xmm.vilspa.esa.es/sas/`. At the time of writing version 5.0 of the SAS is undergoing final testing with a planned full public release of the system before the end of 2000.

In parallel with the software developments, the SSC has developed the infrastructure required to carry out, on behalf of ESA, the routine "pipeline" processing of all the *XMM-Newton* observations from each of the three instruments. The aim here is to provide a set of data products which will be of immediate value for the *XMM-Newton* observer as well as for the science archive where they will also be stored for eventual public release. The *XMM-Newton* data products include calibrated, "cleaned" event lists which are intended to provide the starting point for most interactive analysis of the data as well as a number of secondary high-level products such as sky images, source lists, cross-correlations with archival catalogues, source spectra and time series. These provide a useful overview of the observation for the *XMM-Newton* observer as well as constituting key archival resources and the starting point for the compilation of the Serendipitous Source Catalogue.

The *XMM-Newton* Serendipitous Source Catalogue will be based on the EPIC source lists[1] from the pipe-line processing, but will also contain comprehensive archival catalogue data, and results from the SSC (and other) follow-up programme(s) described below. The SSC will emphasize the reliability, uniformity and usability of the catalogue paying particular attention to the external catalogue correlations and identification information. The provision of ancillary information such as sky-coverage and sensitivity estimates is planned to ensure the scientific usefulness of the catalogue.

3. Performance of XMM-Newton for serendipitous surveys

Observations obtained in the early phases of the *XMM-Newton* observing programme have been analysed by the project teams in order to establish the in-orbit performance of the Observatory and its instrumentation. Here we concentrate on those aspects of the *XMM-Newton* performance which are important for serendipitous surveys.

3.1. Field of view and image quality

The field of view of the *XMM-Newton* X-ray telescopes has a radius of ≈15 arcmin beyond which baffles reduce the out-of-field response to very low levels. The X-ray telescope field of view is completely covered by the EPIC MOS and pn X-ray cameras out to a radius of ≈14 arcmin. The on-axis point spread functions (PSFs) of the X-ray telescopes, confirmed by in-orbit data (Jansen et al. 2001), have FWHM values 5–7 arcsec and HEW values ∼14–15 arcsec. The optical design of the X-ray telescopes produces a PSF which shows only a very slow degradation out to a radius of ∼10 arcmin (Jansen et al. 2001). With appropriate on-board and ground processing (as incorporated into the SAS) to remove hot pixels and noise effects, the EPIC X-ray images are remarkably free from defects with the most noticeable features being the inter-chip gaps in the EPIC pn and EPIC MOS cameras. Figure 1 shows example EPIC images which illustrate these points.

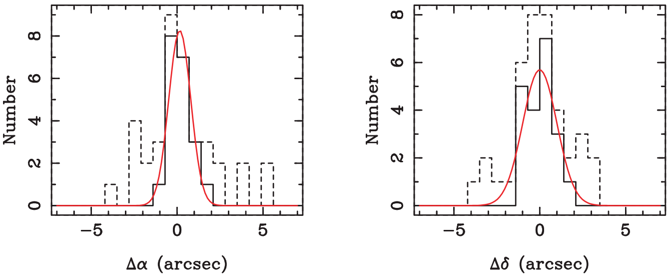

Fig. 2. Residual position differences between X-ray source positions and potential optical counterparts extracted from deep i' CCD images obtained with the INT WFC (see Sect. 5). The solid histogram shows the distribution for counterparts with a high likelihood of being the correct identification. The dashed histogram shows the distribution for all potential candidates. The red curves show the Gaussian fits to the solid histogram data points

3.2. Positional accuracy for EPIC source detections

The accuracy with which EPIC source detections can be measured depends on the accuracy with which the EPIC camera coordinate system can be related to the celestial astrometric reference frame and the statistical accuracy of the individual position determinations in the camera coordinate system. The transformation between the EPIC camera coordinate system and sky coordinates provided by the *XMM-Newton* aspect system has a typical accuracy of ∼4 arcsec. To improve on this, cross-correlation of EPIC X-ray sources with catalogued optical objects (e.g. the USNO A2.0 catalogue) will be used routinely in the processing pipeline to provide an updated transformation between the EPIC and sky frames with an expected accuracy of ≤ 1 arcsec across the whole EPIC field. Using this approach, the EPIC source positions, even for faint sources close to the detection limit, have typical 90% confidence radii of only ≈2–5 arcsec, limited by statistical accuracy of the measurements. An illustration of the positional accuracy already achieved is given in Fig. 2 which shows the X-ray-optical position residuals for a typical *XMM-Newton* observation.

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[1] OM results will also be incorporated.

3.3. Survey sensitivity

The major uncertainty in predicting the EPIC sensitivity pre-launch was the background levels which would be encountered in-orbit. The actual in-orbit background levels measured in the first part of the Lockman Hole observation are $\approx(2.1, 2.9)$ 10^{-3} ct s^{-1} arcmin^{-2} for the EPIC pn camera in the soft (0.5–2 keV) and hard (2–10 keV) bands respectively. Very similar values: $\approx(2.0, 2.6)$ 10^{-3} ct s^{-1} arcmin^{-2} are found for the two EPIC MOS cameras combined. A significant fraction of this background, particularly at hard X-ray energies, is due to residual particle background with contributions from both high energy particles interacting with the body of the EPIC detectors and from soft protons scattered into the focal plane by the X-ray mirrors. These background levels correspond to the nominal quiescent background detected outside of background flares at high galactic latitudes and appear to be relatively stable and reproducible over the first 9 months of science operations[2]. During background flares the background can increase by large factors ($>$ 10 is not uncommon) and portions of these data are of limited use for faint source detection or the mapping of low surface brightness emission.

Using the nominal quiescent background values together with the measured *XMM-Newton* PSF we have computed an updated EPIC point source sensitivity based on a simple 5σ source detection criterion against assumed purely Poissonian background fluctuations, as shown in Fig. 3[3]. Empirical data from analysis of several *XMM-Newton* fields using the source detection software developed by the SSC for the SAS are broadly consistent with these plots. The actual background in an observation depends critically on the fraction of background flares removed, i.e. the trade-off between net background levels and net exposure time. An investigation of a few example fields demonstrates that the effective sensitivity of typical observations is within a factor 2 of the values plotted in Fig. 3. A few observations are affected by enhanced background throughout; here the average background can be several times higher than the nominal values even after the removal of the largest flares.

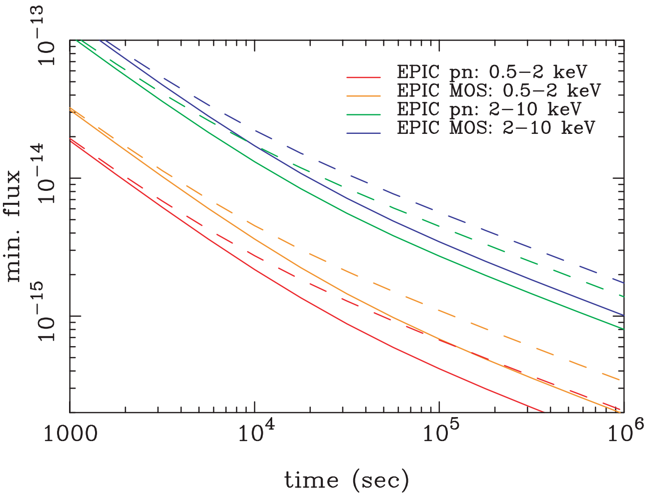

Fig. 3. EPIC sensitivity (5σ minimum detectable flux in erg cm^{-2} s^{-1} in respective bands) as a function of exposure time. Sensitivity is computed for an assumed $\alpha = 1.7$ power-law spectrum with a column density $N_{\rm H} = 3\ 10^{20}$ cm^{-2}. Solid curves are for the nominal background rates quoted in the text. Dashed curves are for background levels enhanced by a factor 3. The EPIC MOS curves correspond to the combination of the two cameras

At very faint fluxes the effective sensitivity is limited by confusion effects. Although a detailed study of source confusion has not yet been carried out, the long *XMM-Newton* observations of the Lockman Hole (Hasinger et al. 2001) demonstrate that source confusion is not a significant problem in either the soft (0.5–2 keV) or hard (2–10 keV) X-ray bands for an observation duration of ≈100 ksec which reaches flux limits $f_{\rm X} \approx 0.31$ and $\approx 1.4\ 10^{-15}$ erg cm^{-2} s^{-1} in the soft and hard bands respectively.

4. The XMM-Newton Serendipitous Survey

4.1. Scope and scientific potential

The high throughput, large field of view and good imaging capabilities of *XMM-Newton* mean that it detects significant numbers of serendipitous X-ray sources in each pointing, as is illustrated in Fig. 1. To quantify the serendipitous source numbers expected from *XMM-Newton* observations we note that for the typical exposure time of 20 ksec, *XMM-Newton* will detect sources down to $\approx 10^{-15}$ erg cm^{-2} s^{-1} in the 0.5–2 keV band, and $\approx 10^{-14}$ erg cm^{-2} s^{-1} in the 2–10 keV band, these values referring to a 5σ detection in the combined EPIC pn and MOS cameras (cf. Fig. 3). The X-ray source density at these flux levels in the high latitude sky is already established from *ROSAT* studies in the soft band (Hasinger et al. 1998) and has now been extended to harder energies by recent *Chandra* and *XMM-Newton* studies (Mushotzky et al. 2000; Giacconi et al. 2000; Hasinger et al. 2001). Taking into account the telescope vignetting which reduces the sensitivity off-axis and the distribution of exposure times yields an expected ∼50–100 sources per typical EPIC field (over the whole field, i.e. in a sky area ≈0.2 sq. deg.). Around 30–40% of these are expected to be detected in the hard band, smaller than might have

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[2] The soft band (0.5–2 keV) background levels of course show a factor of few change over the sky due to intrinsic variations in the Galactic foreground, cf. *ROSAT* studies. The hard band background shows much smaller variation, except at very low Galactic latitudes.

[3] The 5σ value represents a relatively conservative limit which crudely takes into account the fact that there are additional systematic background effects which have yet to be characterised in detail. For the effective beam area of *XMM-Newton*, the appropriate limit for purely Poissonian background fluctuations to yield ≤ 1 spurious source per field is $\approx 3.5 - 4\sigma$.

Table 1. Source content of *XMM-Newton* fields

Field	Exposure time (ksec)	Galactic. latitude	Source numbers[a] soft-band[b] obs	pred	hard-band[b] obs	pred
Mkn 205 (EPIC pn data)[c]	17	+42°	39	45	22	20
OY Car (EPIC MOS1+MOS2 data)	50	−12°	64	55	25	30
G21.5−0.9 (EPIC pn data)[d]	30	−1°	15	(0)[e]	19	(∼10)[e]

a: Approximate observed and predicted source numbers ($> 5\sigma$) for off-axis angle ≤ 12 arcmin.
b: Soft-band: 0.5–2 keV; hard-band: 2–10 keV.
c: First exposure in orbit 75 only.
d: Offset pointing (cf. Fig. 1).
e: Background extragalactic sources only, note that source count predictions depend sensitively on the Galactic column density for this field.

been expected from the higher sky density at higher energies, this fraction reflecting the lower effective hard-band sensitivity in flux terms.

The extent to which these expectations are matched by the real data is illustrated by the images in Fig. 1 which show three typical *XMM-Newton* EPIC observations of calibration and performance verification fields covering a range of Galactic latitudes and exposure times. The source content of these fields is summarised in Table 1 (note that the numbers are given for off-axis angles ≤ 12 arcmin, i.e. an area of ≈0.125 sq. deg.; the full field numbers are 25–30% higher). The source numbers in the high latitude and mid-latitude fields are in general accord with our expectations (predicted numbers in Table 1 are for the Hasinger et al. 1998; Giacconi et al. 2000 source counts and the sensitivities given in Fig. 3 with an approximate correction for the sensitivity decrease off-axis due to telescope vignetting; these predicted numbers are only accurate to 10–20%). The G21.5−0.9 field, at low Galactic latitude and with a high column density ($N_{\rm HI}+N_{\rm HII} \approx 10^{23}$ cm^{-2}), samples a rather different source population as shown by the somewhat lower source density and the fact that there is little correspondence between the soft and hard band detections. In the soft band the detections in this field are likely to be dominated by foreground objects, most of which will be active stars (see Sect. 5). In the hard band the faint source population revealed is likely to be dominated by a mixture of background extragalactic sources seen through the Galactic disk and distant (and hence similarly absorbed) luminous Galactic objects which may include cataclysmic variables and other low luminosity accreting systems. The approximate calculation of the expected extragalactic source numbers in the G21.5−0.9 field given in Table 1 (sensitive to the column density distribution) indicates that a significant fraction, but not all, of the hard band sources maybe background objects.

With the current operational efficiency, *XMM-Newton* makes of the order 500–800 observations per year, covering ∼100 sq. deg. of the sky. The XMM-Newton *serendipitous X-ray catalogue* will thus grow at a rate of ∼50 000 sources per year, i.e. the annual rate will be comparable in size to the complete *ROSAT* All Sky Survey, but will go to fluxes 2–3 orders of magnitude fainter. The catalogue will thus constitute a deep, large area sky survey which will represent a major resource for a wide range of programmes. The extended energy range of *XMM-Newton*, compared with previous imaging X-ray missions such as *ROSAT* and the *Einstein* Observatory, will mean that *XMM-Newton* is expected to detect significant numbers of obscured and hard-spectrum objects (e.g. obscured AGNs, heavily absorbed Galactic binaries) which are absent from earlier studies. This will provide an important extra dimension to the serendipitous catalogue.

Chandra observations will also provide a serendipitous sky survey comparable in many ways to what *XMM-Newton* can offer. Nevertheless a number of factors, in particular the smaller field of view with good imaging quality and the fact that the full ACIS array is not always selected by the observer, contribute to producing a significantly smaller sky coverage (by a factor 5–10) for the *Chandra* serendipitous sky survey. *XMM-Newton* also has a very significant advantage at photon energies above 4–5 keV: at low energies the ratio of EPIC/ACIS effective areas is 3–4 but this increases to ∼6 at 5 keV and > 10 at 7 keV. The *XMM-Newton* serendipitous sky survey is thus likely to contain much larger samples of highly obscured sources, an important factor for the study of the objects currently believed to make up the bulk of the X-ray background (cf. Lockman Hole study of the 5–10 keV source counts, Hasinger et al. 2001).

X-ray selection of samples provides a well-proven and extremely efficient means of finding some of the most astrophysically interesting objects, many of which have their peak luminosity in the X-ray band. *XMM-Newton*, with its broad-band and high sensitivity will provide less biased samples than those based on previous soft X-ray missions. It is clear that the *XMM-Newton* serendipitous source catalogue will prove to be a major resource in many areas of scientific investigation. Examples include:

- the importance of obscuration in the faint AGN population;

- the evolution of the quasar luminosity function with redshift;
- the nature of faint X-ray galaxies - their contribution to the X-ray background;
- the evolution and luminosity function of clusters of galaxies and the nature of density fluctuations in the early Universe;
- the coronal activity in stars and its dependence on luminosity, spectral type, stellar rotation and age;
- the space density of accreting binary systems.

4.2. Need for follow-up studies

In order to exploit the full potential of the *XMM-Newton* serendipitous survey in the context of a wide range of scientific programmes, the key initial step will be the "identification" of the X-ray sources, i.e. a knowledge of the likely classification into different object types. For the *XMM-Newton* serendipitous sources, the X-ray observations themselves will provide the basic parameters of each object: the celestial position, X-ray flux for all sources and information on the X-ray spectrum, spatial extent and temporal variability for the brighter objects detected. This information alone may, in some cases, be sufficient to provide a clear indication of the type of object, but for the vast majority of sources, additional information will be required before a confident classification of the object can be made. Some of this information will come from existing astronomical catalogues, or from existing or planned large-scale optical, IR and radio surveys (e.g. SDSS, 2MASS, Denis, FIRST/NVSS), but it is clear that the full exploitation of the *XMM-Newton* serendipitous survey will require a substantial programme of new observations, primarily in the optical and IR using ground-based facilities.

4.3. The SSC Follow-up (XID) Programme

The overall aim of the SSC Follow-up Programme, for simplicity the "XID Programme", is to ensure that the potential of the *XMM-Newton* serendipitous survey can be fully exploited by the astronomical community. The XID Programme is thus designed to maximise its value for a wide range of potential scientific uses of the serendipitous data. In order to ensure the optimum utility of the programme, the results from the SSC XID Programme will enter the public *XMM-Newton* Science Archive[4]. The value of building a "statistically" identified catalogue of EPIC sources and delivering it to the community is that it will provide large homogeneous samples for studying class properties and to search for rare objects.

Table 2. XID Core Programme sample parameters

Sample	Flux range[a]	Sky dens.[b]	# EPIC[c]	R mag.[d]
FAINT	$\geq 10^{-15}$	2200	5–10	23–25
MEDIUM	$\geq 10^{-14}$	340	30–50	21–23
BRIGHT	$\geq 10^{-13}$	10	1000	17–21
GALACTIC	$\geq 5\ 10^{-15}$	$\sim$300	40	wide range

a: X-ray flux in erg cm^{-2} s^{-1} in the 0.5–4.5 keV band.
b: Source density (deg^{-2}).
c: No. of EPIC fields required.
d: Expected R-magnitude range of counterparts.

The approach planned by the SSC is a programme which brings together the *XMM-Newton* data themselves, existing catalogue and archival material and new ground-based observational data in an integrated fashion. The main new observational elements, the "Core Programme" and the "Imaging Programme", are outlined below.

4.4. The XID Core Programme

The aim of the Core Programme is to obtain the identifications for a well-defined sample of X-ray sources drawn from selected *XMM-Newton* fields, primarily using optical/IR imaging and spectroscopy. Imaging is required both to locate potential candidates accurately and reveal their morphology, whilst the optical spectroscopy provides the diagnostics needed both for object classification and for determining basic object parameters such as redshift and spectral slope. The principal objective is to obtain a completely identified sample which can be used to characterise the *XMM-Newton* source population overall sufficiently well that we can use the basic X-ray and optical parameters to assign a "statistical" identification for a large fraction of all the sources in the *XMM-Newton* serendipitous source catalogue.

The strategy involves two samples: one for the high and one for the low galactic latitude sky. The high galactic latitude sample consists of three subsamples, each containing $\approx$1000 X-ray sources in three broad flux ranges: $f_x > 10^{-15}$; $f_x > 10^{-14}$; $f_x > 10^{-13}$ erg cm^{-2} s^{-1} in the 0.5–4.5 keV band (see Table 2). The size of the subsamples is dictated by the need to identify enough objects to reveal minority populations. Studying sources at a range of X-ray fluxes is necessary because we already know that the importance of different source populations changes with X-ray flux level. A parallel study is planned for the low galactic latitude sample. Taking into account the difficulty of obtaining completely identified samples close to the Galactic plane, here we aim to identify a sample of $\sim$1000 sources above a flux level of $\approx$5 10^{-15} erg cm^{-2} s^{-1}(0.5–4.5 keV), from target fields covering a range of galactic latitudes and longitudes (Table 2). In our programme we also need to minimise bias against any particular X-ray spectral form by recognising flux limits in different X-ray

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[4] The SSC XID Programme is restricted to *XMM-Newton* data which is in the public domain, i.e. outside the 1-year proprietary period, except for observations where the *XMM-Newton* observer has given explicit permission for the SSC to commence follow-up work in the proposal for *XMM-Newton* observations.

bands. To achieve this, additional soft and hard X-ray selected samples will be included in the programme.

The requirements for the Core Programme are summarised in Table 2. The median optical magnitudes in Table 2 (and the size of the subsamples) illustrate that this is a very demanding programme. For example spectroscopy of the counterparts to the faintest X-ray sources will require access to multi-object spectrographs on 8–10 m class telescopes, and indeed a substantial fraction of counterparts will be inaccessible, whilst even for the sources in the "medium" flux sample access to 4–8 m class telescopes will be needed. For the "bright" sample the situation will be somewhat different in that a large fraction of counterparts will be on existing optical sky survey material (e.g. POSS), and a significant fraction may have likely identifications with catalogued objects, leading to reduced requirements for spectroscopic follow-up.

Taking into account the fact that reaching the faint sample depth requires long *XMM-Newton* exposures, and that most of these observations are being pursued for surveys by the observation PIs, the current emphasis in the SSC XID programme is on the medium flux sample (and later as the observations become available, on the bright sample) which, although ambitious, is feasible provided access to the necessary ground-based observing facilities is possible.

4.5. The Imaging Programme

Whilst the Core Programme focuses on the identification of a selected subsample of *XMM-Newton* serendipitous sources, the complementary Imaging Programme aims to obtain optical/IR photometry and colours for a large number of *XMM-Newton* fields. The programme rationale is based on the fact that a combination of X-ray flux and X-ray colours (from the *XMM-Newton* data) and optical magnitude and optical colours (e.g. from new ground-based observations) will provide the key parameters which make possible an accurate "statistical" identification of the *XMM-Newton* sources. This will be possible using the results from the Core Programme which characterise the *XMM-Newton* source populations, thus providing the link, in a statistical sense, between the source identification and these basic parameters.

Multi-colour optical imaging provides good discrimination between object types (e.g. AGN-star separation) as well as photometric redshifts, whilst IR imaging has an important role to play as the counterparts to obscured X-ray sources are expected to also show significant reddening.

The Imaging Programme will primarily be pursued using new optical/IR imaging. To reach $R \sim 23-25^{\rm m}$, and $K \sim 20^{\rm m}$, the typical values required for the serendipitous survey follow-up, is within the range of 2–4 m class telescopes[5].

5. XID Programme implementation and first results

The SSC XID Programme started in April 2000 with initial optical and IR imaging and the first spectroscopic data were taken in June 2000. As noted above, the current emphasis of the programme is on the medium flux sample (cf. Table 2). A substantial fraction of the observing time for the current programme was awarded within the Canary Islands International Time Programme (ITP) to a project, known as "AXIS" (*An XMM-Newton International Survey*, `http://www.ifca.unican.es/~xray/AXIS`) which focuses on the follow-up of the medium flux XID sample and the nature of the hard X-ray source population.

Optical imaging has been obtained for more than 30 *XMM-Newton* fields using the INT Wide Field Camera and the ESO-MPG 2.2 m Wide Field Imager. The Sloan u, g, r, i, z bands have been chosen for optical imaging as these provide significant advantages for the determination of spectroscopic redshifts. Near-IR imaging of a few fields has already been obtained with the INT 2.5 m and the CIRSI IR camera in the H band (CIRSI does not offer the K band). For spectroscopy, three short runs have already been completed using the WHT 4.2 m with the WYFFOS multi-object spectrograph, the WHT with the ISIS dual-beam spectrograph and with the NOT 2.5 m with the ALFOSC spectrograph. The WHT spectroscopy with WYFFOS can reach $R \sim 21^{\rm m}$ and $\sim 22^{\rm m}$ with ISIS. The NOT/ALFOSC spectroscopy concentrated on objects with $R < 18^{\rm m}$.

We have already obtained spectroscopic identifications for ~40 *XMM-Newton* sources in the first few fields studied. These fields include the Mkn 205 field (cf. Fig. 1 and Table 1, we used detections from the combined data of the two exposures), three of the five G21.5−0.9 calibration observations (these cover ~0.5 sq. deg; cf. Fig. 1 and Table 1 which relate to one of the five observations), and two Guaranteed Time (GT) fields at high galactic latitude. Figure 4 shows the finding charts and optical spectra of three example identifications made in these fields:

- A $z = 0.33$ galaxy in the Mkn 205 field showing Hβ and [OIII] narrow emission lines at $\lambda\lambda 6466, 5803, 6595$ Å. Judging by its X-ray luminosity ($L_{\rm X} \approx 10^{43}$ erg s^{-1}) and line ratios this galaxy probably hosts an active nucleus;
- An object at $z = 1.82$ in a GT field[6] which shows broad emission lines (notably Si IV, C IV, CIII] & Mg II at $\lambda\lambda 3939, 4365, 5381, 7890$ Å) with broad blue-shifted absorption troughs to the CIV & CIII] lines (arrowed in Fig. 4). This thus appears to be a broad absorption line (BAL) quasar. If confirmed this would

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[5] Imaging from the *XMM-Newton* OM (Mason et al. 2001) will in many cases provide valuable data for the Imaging Programme, in particular by extending the coverage to the UV. Availability of appropriate OM data cannot be guaranteed however, because the choice of OM readout modes, filters etc. are selected by the observation PI.

[6] A field for which SSC follow-up permission was granted by the observation PI.

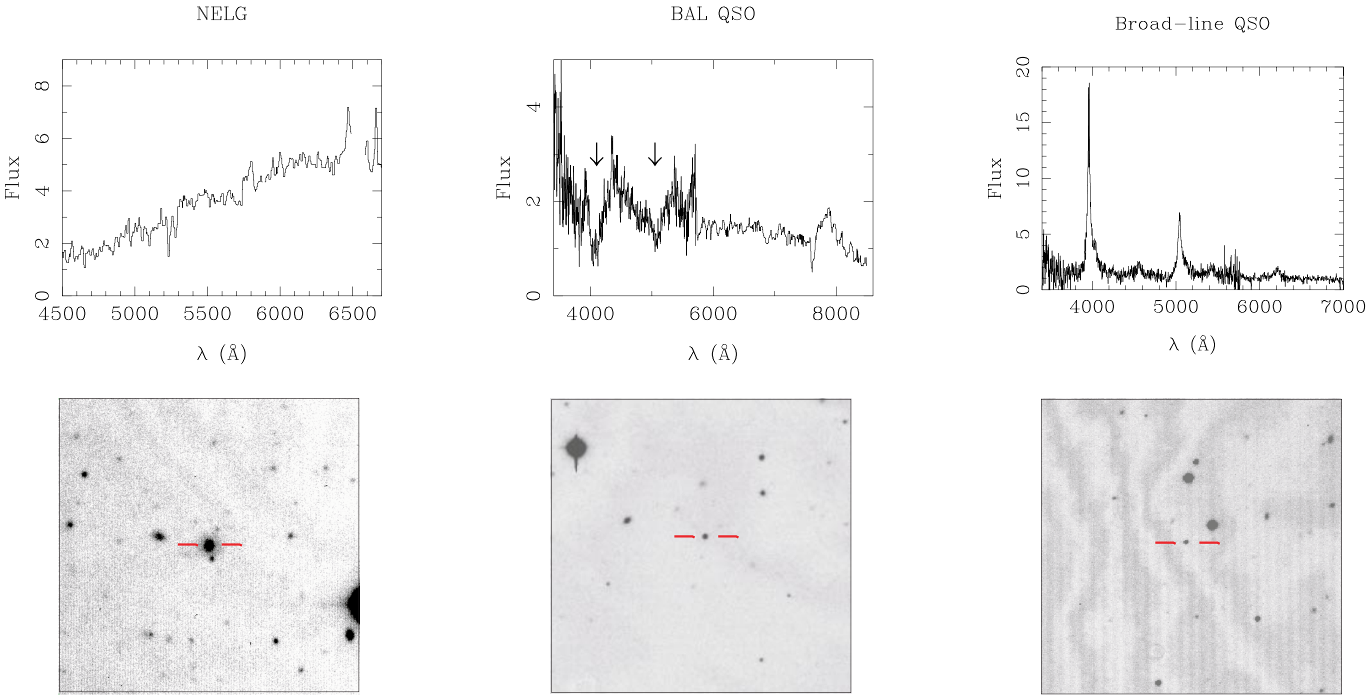

Fig. 4. Optical spectra and finding charts of the counterparts for three serendipitous *XMM-Newton* sources. *Left panels*: an object in the Mkn 205 field identified with a $z = 0.33$ galaxy. *Centre panels*: an object in a GT field identified with a BAL quasar at $z = 1.82$. *Right panels*: an object in the same field identified with a quasar at $z = 2.26$. The NELG spectrum is from the WHT + WYFFOS (gaps due to poor sky subtraction) and the lower two from WHT + ISIS (both arms shown). Optical fluxes are in units of 10^{-17} erg cm^{-2} s^{-1} Å^{-1}. Finding charts are $\approx 2 \times 2$ arcmin in size and are taken from INT WFC i'-band imaging

be one of the first X-ray selected BAL objects so far, such objects being extremely faint at soft X-ray energies (Green & Mathur 1996);

- An object at $z = 2.26$, in the same field, showing the typical broad emission lines of a quasar. The strongest lines are Lyα, CIV & CIII] at $\lambda\lambda 3959, 5040, 6212$ Å.

Although it is premature to discuss the results in any detail at this stage, as our programme has yet to accumulate statistically useful samples of identifications, we can nevertheless make some general remarks. In the high galactic latitude fields for which we have spectroscopic data so far, broad-line AGN (15 objects) dominate the total number of identified sources. The other identified objects include 4 narrow emission line galaxies (NELGs; in this context this means extragalactic objects with no obviously broad lines), 1 "normal" galaxy and 3 stars (2 of which are dMe).

As found in previous *ROSAT* surveys, e.g. Lehmann et al. (2000), all the NELGs are at $z < 0.5$. Some of these NELGs may actually be obscured AGN, but more thorough analysis and better quality spectra are required to confirm this. Our programme has not yet found an example of a high redshift type II AGN, but this is as expected because we have concentrated on the X-ray and optically brighter objects so far.

In the one low latitude region for which we have spectroscopy so far (the three overlapping G21.5−0.9 fields), initial problems in establishing good astrometry for the field led to poorer X-ray source positions. Because of the high star density at low latitudes, this exacerbated the difficulty of selecting optical counterparts. Accordingly our observations to date have concentrated on the brighter optical counterparts. Of the 27 sources observed to date, 11 show clear stellar spectra. Only 3 of these show clear spectroscopic evidence of being active at the current spectroscopic resolution; this highlights the fact that *XMM-Newton* can detect stars with lower activity. Analysis of the data for the other objects observed is still in progress. Given the current emphasis on the brighter counterparts, it is not surprising that our study has not yet revealed other classes of object, e.g. distant, faint cataclysmic variables or even background AGN which will be both faint and highly reddened.

The XID programme is in the early stages of what is a long-term project. We look forward to realising the potential of the *XMM-Newton* serendipitous survey over the coming years in what seems likely to be a rich and rewarding programme.

Acknowledgements. It is a pleasure to acknowledge the efforts and dedication of the large team of people who have been essential in developing the SSC, not all of whom are represented as co-authors of this paper. We gratefully acknowledge allocations of telescope time for the public XID programme by ESO, PATT and the CCI for the AXIS project. Mat Page and Ismael Perez-Fournon are thanked for their contribution to the AXIS programme observing. The INT and the WHT are operated on the island of La Palma by the Isaac Newton Group in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofisíca de Canarias.

Support for the SSC project provided by the following agencies: Deutsches Zentrum für Luft- und Raumfahrt (DLR) under grant numbers 50 OR 9908 0 & 50 OX 9701 5; PPARC (UK); CNES (France) and NASA (via the HEASARC). TM thanks the Italian Space Agency (ASI) for financial support.

The referee, Thierry Courvoisier, is thanked for his constructive suggestions for improvements to this paper.

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