The XMM-Newton Slew Survey: XMMSL1

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Issues at last CAL meeting

- Initial processing of slew data was finished
- Found attitude/astrometry problem of ~30 arcsecs
- Weren’t sure whether to limit search to DET_ML=8 or 10
- Needed to identify and reject spurious sources
Attitude Problem

Two types of positional error

(1) Real error of ~7

(2) Error of 0-60 (mean 30) but only in slew direction

Reason: AHF times rounded to nearest 1 second. Hence error of $\leq 0.5s = 45$ arcsecs (at slew rate of 90 degs/hour)

Solution: Use the RAF (full time resolution)
- Initially gave consistent offset error of 60 arcsecs

Solution 2: Remove 0.75s CCD integration time from all RAF entries
- Positional error finally ~8” (1 sigma)
  (17” for 90%)
**RE-Processing with RAF**

- Analysed 219 EPIC-pn (FF,eFF,LW) slews from revs 314 to 978

- Sky coverage = 15% (6200 deg\(^2\))

- Made: soft (0.2-2 keV), hard (2-12 keV) and total (0.2-12 keV) images, source search to produce 3 independent source lists

- Combined lists to produce catalogue of 5200 detections with DET_ML>8
XMMSL1: The Catalogue

- Full Catalogue: 5200 detections (DET_ML>8), 845 hard band (2-12 keV) detections

Check for and flag spurious detections
Spurious detections

Optical loading: NO! - only apparent for $m_v<2$

Extended source: mainly due to SNR

Halo of bright source: mainly LMXB

High Background: indistinguishable from extended source, 30s flare = 45’ diameter “remnant”.

Total flagged sources = 470
Large/Bright Extended Sources

Sources found in Puppis-A

XMM slew

ROSAT HRI
Halo of bright source

12 sources with >100 c/s
High background

Many sources due to background flare
XMMSL1: The Catalogue

- Full Catalogue: 5200 detections, 470 flagged as spurious (DET_ML>8)
- 694 hard band (2-12 keV) detections flagged as good

Simulate to estimate the spurious fraction due to background fluctuations
Simulations/Spurious fraction

Find dependence of spurious sources on number of photons in image
Randomise the position of every photon in all 11400 slew images and run
the standard source search
Tabulate number of false sources

Real sources and fluctuations for different selections

<table>
<thead>
<tr>
<th>Band</th>
<th>DET_ML&gt;8</th>
<th>DET_ML&gt;8, rate&lt;3</th>
<th>DET_ML&gt;10</th>
<th>DET_ML&gt;10, rate&lt;3</th>
<th>DML&gt;14+(DML&gt;10,rate&lt;3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>4730 (929)</td>
<td>3471 (456)</td>
<td>3015 (195)</td>
<td>2436 (106)</td>
<td>2713 (109)</td>
</tr>
<tr>
<td>0</td>
<td>3882 (580)</td>
<td>3037 (348)</td>
<td>2596 (118)</td>
<td>2171 (86)</td>
<td>2384 (89)</td>
</tr>
<tr>
<td>4</td>
<td>694  (272)</td>
<td>429  (93)</td>
<td>314  (61)</td>
<td>241  (24)</td>
<td>261  (25)</td>
</tr>
<tr>
<td>5</td>
<td>2619 (186)</td>
<td>1994 (69)</td>
<td>2042 (46)</td>
<td>1649 (13)</td>
<td>1888 (13)</td>
</tr>
</tbody>
</table>

Detection Likelihood
XMMSL1: The Catalogues

- Full Catalogue: 5200 detections, 470 flagged as spurious (DET_ML>8)
  - Simulations suggest a further 930 due to background fluctuations
  - 694 hard band (2-12 keV) detections, 270 due to background from sims

- Clean catalogue: 2713 sources flagged as good
  DET_ML>10 for low bckgnd images
  DET_ML>14 for higher bckgnd images
  - 4% expected to be false, 261 hard band sources (9% false from simulations)

Released on 3rd May via XSA
Survey Characteristics

Source Count Distribution

Exposure Time Distribution

Minimum @ 4 counts

Maximum @ ~10 seconds

- Can calculate flux limits for the XMM-Slew survey
Hard Band

Total band (0.2-12 keV): 1.1x10^{-12} ergs/s/cm^2
Hard band (2-12 keV): 3.7x10^{-12} ergs/s/cm^2
Soft band (0.2-2 keV): 5.7x10^{-13} ergs/s/cm^2

Piccinotti sample from HEAO-1 A-2 has 85 2-10 keV sources in 65% of high latitude sky, excluding LMC, SMC.

Slew clean sample has 148 hard band sources in 8% of the high latitude sky.

Ratio=14, gives 6x deeper than HEAO-1 for Log-N/Log-S slope of -3/2

Work to do on Eddington bias, completeness etc.
Survey Characteristics – Hard Band

![Graph showing survey characteristics in the hard band with flux limits and sample surveys highlighted.](image)
Identifications

Cross-correlated source list with Simbad, NED, HEASARC.

Also working with the GAVO cross-matching tool to find the most likely optical/2MASS/radio counterparts.

Found counterparts for 55% of sources.

Represented categories:

AGN: 583
Galaxies: 467
Clusters/groups: 85
Stars: 362
Variable stars: 208
SNR: 14
LMXB: 16
HMXB: 5
WD: 2

HB89 0642+449 (QSO)
z=3.4 (1.2 ct/s)
- LMXRBs (hardest sources) congregating in Galactic plane
- Very few soft sources in the Galactic plane (none extragalactic)
Correlations with ROSAT

- 55% of sources correlate with ROSAT (non-extended, DET_ML>10)
- 1% show variability by > factor of ten

Mean rate:
XMM-slew/ROSAT~10
NGC 3599 – Slew/RASS count rate ratio $\sim 500!$
(RASS upper limit $< 2 \times 10^{39} \text{ erg s}^{-1}$)

Very soft!
$L_x \sim 3 \times 10^{41} \text{ erg s}^{-1}$!
Extremely Bright Sources

Galactic Plane
RX J173143.6-165736
LMXRB
2600 cts in 8 sec
Extended sources

15% of sources extended

Associations with 81 Zwicky/Abell clusters
Sensitive to relatively faint clusters and extended sources in general thanks to wide band-pass, tight PSF and low background.
Supernova Remnants

Puppis A

ROSAT HRI

XMM slew

Also a cause of ‘spurious’ sources
SNRs in the SMC

Raw slew image
Vela Supernova Remnant
Vela Supernova Remnant

- ROSAT
- XMM-Newton Slew

~\frac{1}{2} \text{ hour observing time} !
Survey Characteristics – Soft Band

XMM-Slew

0.5-2 keV flux limit (erg cm$^{-2}$ s$^{-1}$)

$10^{-13}$

$10^{-14}$

$10^{-15}$

$10^{-16}$

$10^{-17}$

$\Omega$ (degrees$^2$)
Survey Characteristics – Hard Band

2-10 keV flux limit (erg cm$^{-2}$ s$^{-1}$)

- Exosat
- HEAO-1
- RXTE (only <4 keV)
- EMSS (only <4 keV)
- XMM-Slew

$\Omega$ (degrees$^2$)
The XMMSL1 Catalogue

<table>
<thead>
<tr>
<th></th>
<th>Total Band (0.2-12 keV)</th>
<th>Soft Band (0.2-2 keV)</th>
<th>Hard Band (2-12 keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full Catalogue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5200</td>
<td>4179 (ID 52%)</td>
<td>2752 (ID 66%)</td>
<td>845 (ID 27%)</td>
</tr>
<tr>
<td>(ID 47%) (RASS 32%)</td>
<td>(RASS 36%)</td>
<td>(RASS 49%)</td>
<td>(RASS 17%)</td>
</tr>
<tr>
<td><strong>Clean * Catalogue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2713</td>
<td>2595 (ID 72%)</td>
<td>1981 (ID 79%)</td>
<td>307 (ID 61%)</td>
</tr>
<tr>
<td>(ID 71%) (RASS 51%)</td>
<td>(RASS 53%)</td>
<td>(RASS 60%)</td>
<td>(RASS 45%)</td>
</tr>
</tbody>
</table>

* The full catalogue is set at a threshold of DET_ML>8
* Simulations show that the full hard band sample is likely contaminated with spurious sources at a level >10%.
* The clean catalogue (DET_ML>14 + (DET_ML>10 + BG_RATE<3) has a hard band spurious fraction <10%

* Note that the full soft band catalogue is not so affected and has a spurious fraction <10%
## Completeness

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<tbody>
<tr>
<td>Fraction of Sky Covered</td>
<td>20 % (25%)*</td>
<td>40 % (50%)</td>
<td>60 % (75%)</td>
<td>80 % (100%)</td>
</tr>
<tr>
<td>Number of sources (full)</td>
<td>5200 (6500)</td>
<td>10400 (13000)</td>
<td>15600 (19500)</td>
<td>20800 (26000)</td>
</tr>
<tr>
<td>Number of sources (clean)</td>
<td>2700 (3375)</td>
<td>5400 (6750)</td>
<td>8100 (10125)</td>
<td>10800 (13500)</td>
</tr>
</tbody>
</table>

* Including high background slews
Correlations with ROSAT

XMM–Newton slew sources in RASS
Pilot Studies

Source extended into a 4 arcmin streak due to 2.6 second frame time.

Full frame (73ms) mode streak = 6 arcsecs – not a problem.

Extra pn sensitivity + additional MOS background means little to be gained from analysing MOS slews.

New operations strategy (now in place):

- MOS slews used for calibration
- All PN slews larger than 15 minutes down-linked and processed
- Medium filter if FF,eFF,LW and Closed for other modes
Future Plans

- Release scripts to allow general users to duplicate this work with next SAS release
- Issue an update to XMMSL1 consisting of slews processed since rev 978, slews which failed to process and the cleanest bits of high background slews (4000 deg²)
- Then implement system to keep catalogue updated with new data once a month.
- Maybe work on co-adding slew data
- Write upper limits server for XSA or VO