X-ray source populations from the XMM-Newton Medium Survey

Francisco J. Carrera, X. Barcons, M. Ceballos (IFCA, CSIC-UC, Spain)
J. Bussons (U. Murcia, Spain)
&
XMM-Newton Survey Science Centre
(J. Ebrero, A. Corral, S. Mateos, M. J. Page, M.G. Watson, J. Tedds, R. Della Ceca ...)

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Why bother with Medium surveys?

- The maximum of the contribution of sources to the X-ray background happens at “medium” fluxes ($\sim 10^{-14}$ cgs, Carrera+07)
- 2XMM (Watson+08) is a Medium Survey
  - Huge resource, barely tapped
  - Need pathfinder/reference
- Many (most?) XMM-Newton observations at $|b|>20^\circ$ would qualify
  - Periodical updates to 2XMM?
  - 1000000s of sources end of XMM-Newton life ($\sim 2020?$)
Definition of the surveys

- **AXIS (Carrera+07):**
  - 36 XMM-Newton target fields:
  - Galactic latitude $|b|>20$ deg
  - Good quality: source screening
  - Solid angle $\sim 4.8$ deg$^2$
  - Total of 1434 distinct X-ray sources with detection likelihood $>15$

- **XMS: subset of AXIS (Barcons+07)**
  - 25 fields chosen for follow-up: 3.3 deg$^2$
  - Flux limited in Soft, Hard and XID: total of 319 sourceS
  - Optical imaging: g,r,i (INT/WFC) to $r \sim 23$-24
  - Reliable & unique candidate counterpart in r/i for virtually all sources ($< 5''$ or $< 5\sigma$): only 8 “empties”
  - Optical spectroscopy
    - 5m and 8m-class longslit spectra
The XMS samples

<table>
<thead>
<tr>
<th>Name</th>
<th>Band (keV)</th>
<th>Flux limit $10^{-14}$ cgs</th>
<th># sources (unique)</th>
<th># identified (fraction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft XMS-S</td>
<td>0.5-2</td>
<td>1.5</td>
<td>211 (1)</td>
<td>202 (96%)</td>
</tr>
<tr>
<td>Hard XMS-H</td>
<td>2-10</td>
<td>3.3</td>
<td>160 (20)</td>
<td>134 (84%)</td>
</tr>
<tr>
<td>XID XMS-X</td>
<td>0.5-4.5</td>
<td>2.0</td>
<td>285 (56)</td>
<td>264 (93%)</td>
</tr>
<tr>
<td>Ultrahard XMS-U</td>
<td>4.5-7.5</td>
<td>-</td>
<td>71 (2)</td>
<td>61 (86%)</td>
</tr>
</tbody>
</table>
Breakdown of identified sources

+2 BL Lacs

<table>
<thead>
<tr>
<th>Source</th>
<th>XMS-S Soft</th>
<th>XMS-H Hard</th>
<th>XMS-X XID</th>
<th>XMS-U Ultrahard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad-line AGN</td>
<td>75% (152/202)</td>
<td>65% (87/134)</td>
<td>74% (195/264)</td>
<td>69% (42/61)</td>
</tr>
<tr>
<td>Narrow-line galaxies (AGN)</td>
<td>13% (26/202)</td>
<td>25% (35/134)</td>
<td>14% (38/264)</td>
<td>25% (15/61)</td>
</tr>
<tr>
<td>Absorption line galaxies + clusters</td>
<td>3% (7/202)</td>
<td>6% (8/134)</td>
<td>3% (9/264)</td>
<td>3% (3/61)</td>
</tr>
<tr>
<td>Stars</td>
<td>7% (15/202)</td>
<td>2% (3/134)</td>
<td>8% (20/264)</td>
<td>0% (0/61)</td>
</tr>
</tbody>
</table>

Clear differences between Soft/XID and Hard/Ultrahard – selected samples
All galaxies consistent with hosting AGN $L_X > 10^{42}$ erg/s: obscured AGN

$\sim 1/3$ NELGs have optical line ratios $\sim$ STB (Barcons+)

All UnIDed Hard sources are optically extended: galaxies too
Peak of QSO distribution ($z \sim 1.5$) well sampled.

Obscured population out to $z \sim 1$ in Hard sample.
X-ray spectral analysis
X-ray spectral analysis Corral+08, Bussons+08

- Extracted X-ray spectra (pn+MOS) for all 319 sources
  - Fitted Gal. abs. * power law
  - Fitted Gal. abs. * Intrinsic abs. * power law
- $N_H - \Delta N_H(90\%) > 4 \times 10^{21}\text{cm}^{-2}$: X-ray absorbed 35 ⇒ Filled symbols
  - 8 BLAGN: 4%  – 2 BLAGN: 1%
  - 15 NELG: 31%  – 10 NELG: 11%  $N_H - \Delta N_H(90\%) > 10^{22}\text{cm}^{-2}$: 14
  - 3 Gal: 27%  – 1 Gal: 9%
X-ray spectral analysis Corral+08, Bussons+08

6 (18%) UnIDed X-ray absorbed

⇒ UnID obscured/unobscured AGN?
$L_{X,\text{hard}}$ vs. $N_H$: QSO2s
X-ray absorption
and
optical obscuration
in AGN
X-ray colours: $\log(F_{X,\text{hard}}/F_{\text{opt}})$ vs. $HR_2$

- Full sample
- Obscured AGN?
- Unobscured AGN?
- Stars?
- X-ray loud
- X-ray hard
Optical colours

10% of QSOs are red

Optically red
Now, let’s mix them up

Full sample

X-ray hard

Optically red

X-ray loud
Now in 3D
Increasing the sample: brighter sources
BSS: brighter cousins

- ~400 XMM-Newton/MOS2-selected objects down to $7 \times 10^{-14}$ cgs in the XID band (DellaCeca+04)
- Subsample of 350 fully identified (Caccianiga+08):
  - More sophisticated classification scheme than XMS
  - In the end, ~AGN1/2 dividing line is ~HR$_2$(MOS2)=-0.4
    - “Our” Absorbed/unAbsorbed AGN classification
- X-correlated with SDSS DR6:
  - 112 sources with UgriZ magnitudes
  - Same average XID flux as parent sample
- Shallower in X-ray and optical than XMS:
  - Good for comparison/completeness?
X-ray colours: $\log(\frac{F_{X,\text{XID}}}{F_{\text{opt}}})$ vs. HR2
X-ray colours: $\log(F_{X, XID}/F_{opt})$ vs. HR2
Optical colours

XBS bluer in g than XMS?

Full sample

Optically red

Optically red

$g - r$

$r - i$
Optical colours

XBS bluer in g than XMS?

Full sample

Optically red
Conclusions
• Unobscured accretion dominates, but increasingly important contribution from obscured objects.
• X-ray absorption and optical obscuration not equivalent:
  – 4% of type 1 AGN are X-ray absorbed
  – 79% of type 2 AGN are not X-ray absorbed
  – 10% of X-ray selected type 1 AGN have red colours
• “Clustering” of AGN1/2 in X/opt col space
• Even at medium fluxes, an important fraction of the X-ray sources have optically faint and red optical counterparts:
  – Need 10m class observing time
• Most unIDed objects faint (r/i>21.5), ext. (and Xabs): NELGs?
• On-going work:
  – Comparing to XBS to increase sample/see difference from lower flux?