Rubies in the XMM-Newton Slew Survey

Richard Saxton (ESAC)

Andy Read, Rhaana Starling (LU)
Stefanie Komossa (MPiFR)
Jan Robrade, Jurgen Schmitt (Hamburg)
Beate Stelzer (Tuebingen)
Michael Freyberg (MPE),
Dongyue Li, Weimin Yuan (NAOC),
Achille Nucita (INAF),
Nora Strotjohann (DESY)
Slews are on average, 70 degs long and 0.5 degs wide.

Data is taken with the EPIC-pn camera, Medium filter and the observing mode of the previous observation

Produce sub-images of ~1 deg$^2$ in 0.2-2, 2-12 and 0.2-12 keV bands (soft, hard and full bands)

Positional error: 7.3” (1-sig), 11.3” (90%)
XMMSL2 sky coverage

XMMSL2 – released March 2017 (2114 slews up until end of 2014)
65000 deg^2, 29393 detections and 23000 individual sources

85% of sky covered at least once

0.2 – 2 keV band : $F_{0.2-2} > 6 \times 10^{-13}$ cgs
2 – 12 keV band : $F_{2-12} > 4 \times 10^{-12}$ cgs
Cygnus Loop

0.5-2.0 keV
1 Degree

ROSAT

XMM slew

~1/2 hour observing time!
Coverage / Depth

Brandt et al. 2015

Soft X surveys

\[ F_{0.2-2} \geq 6 \times 10^{-13} \text{ ergs/s/cm}^2 \]

Hard X surveys

\[ F_{2-10} \geq 4 \times 10^{-12} \text{ ergs/s/cm}^2 \]
Circle size ≡ source flux

75% of sources are identified
Clusters of galaxies

>500 clusters of galaxies detected
The XMMSL2 catalog contains ~25% stars. Most of the stellar XMMSL2 sources are late-type dwarfs with an outer convection zone. Only about 75% of the XMMSL2 sources have a RASS identification. Hence, a substantial portion of the stellar XMMSL2 sources are previously unknown X-ray sources caught in an active or flaring state.
A puzzling M dwarf among the XMMSL transients

An M dwarf seen as transient XMM-slew source → probably a flare
But: M dwarf has age > 7 Gyr → very low activity expected

EXCEPTIONALLY STRONG ACTIVITY DISCOVERED IN A VERY OLD M DWARF
Form sample of 318 objects with XMM_slew / RASS flux ratio > 10
And > 5 counts in XMM slew.

~5% of sources have > 10 variability
Population of transients

Li et al. in prep
Transient population stars

On average variable stellar population consists of lower mass, cooler stars, usually K or M dwarves

Li et al. in prep

On average variable stellar population consists of lower mass, cooler stars, usually K or M dwarves
**Novae**

**V598 Pup** – 50 c/s, Oct 2007

**XMMSL1 J060636.2-694932**
25 c/s, July 2006

Nova detected in LMC

*Read et al. 2008*

*Read et al. 2009*
XMMSL1 J063045.9-603110 – 32 c/s (Dec 2011) with very faint optical counterpart

Mainetti et al. 2016 suggested it as a TDE based on subsequent X-ray LC and soft spectrum

Oliviera et al. 2017 – optical spectrum showing Nova in nebula phase.
Supernovae

Some SN exploding into dense environments show delayed high-L, X-ray emission relative to Optical.

L_x \sim 5 \times 10^{41} \text{ ergs/s}

SN 2015J - Type IIn

L_x \sim 2 \times 10^{40} \text{ ergs/s}

Also SN2010jl, SN2006jd similar luminosity but much harder X-ray spectrum, lasted for several years

L_x \sim 5 \times 10^{41} \text{ ergs/s, } kT \sim 200 \text{ eV}

Nucita et al. 2017
Probing principally $10^{42} < L_x < 10^{46}$
$0.03 < z < 2.0$
Slew number counts fit well with extension from 2XMM

Clusters under-represented – due to insensitivity of current detection algorithm?
Seyfert 2 - line widths are <200 km/s – z=0.01816
July 2010 - XMM slew source found with

\[ F_{0.2-2\text{keV}} = 3 \times 10^{-12} \text{ ergs/s/cm}^2 \]

Very soft spectrum (15 photons)
\[ kT \sim 70 \text{ eV} \]
AGN – high variability

Strotjohann et al. 2016

M_BH from K luminosity

Sample of 24 galaxies with >10 variability from RASS
Tidal Disruption Events

NGC 3599

Optical Image

Slew – total band

Slew – soft band

Slew – hard band

- Distance = 65 million light years
- Closest tidal disruption candidate to date

(Esquej et al, 2007, 2008)
TDE – fast follow-up

2MASS 0740-85
Saxton et al. 2017

XMMSL1 1446+68
Saxton et al. in prep.
Fast variability in early phase. SDSS 1201+30, factor 50 drop in flux within 1 week

What causes the flux drop?
Dip can be reproduced by a binary with $M_{BH}=10^7$, a secondary with $M_{BH}=8\times10^5$ and separation of 6 mpc, orbital period $T_b \leq$ few 100 days
Pericentre of secondary black hole

Liu, Li and Chen 2009
Binary black-hole TDE model

Vigneron et al. 2018

Light curve of TDE occurring in plane of binary orbit

perpendicular to BBH orbit
Raw slew data made available after 8-12 days. Since 2009, processed automatically, compared with RASS and results made available on web page.
Future prospects

- Release of XMMSL2 – delta 1 with data from 2015-2018 by end of this year.

- Is the slew survey worth continuing in the eRosita / Einstein Probe era?

- Maybe not, but we will always have HILIGT (see poster)
HILIGT – multi-mission flux/upper limit server

**TARGET NAME**

NGC 3599

**PARAMETERS**

- **keV Range**
  - XMM-Newton: 0.2 - 2, 2 - 12, 0.2 - 12
  - ROSAT: 0.2 - 2, 0.2 - 2
  - EXOSAT: 0.2 - 2
  - INTEGRAL: 20 - 40, 40 - 60, 60 - 100

- **Upper limit significance**
  - 1σ, 2σ, 3σ

- **Spectral model**
  - Power law
  - Slope: 2
  - NH: $3 \times 10^{20}$
## XMM-NEWTON SLEW

<table>
<thead>
<tr>
<th>Observation Date</th>
<th>Count rate 0.2 - 2</th>
<th>Count rate 2 - 12</th>
<th>Count rate 0.2 - 12</th>
<th>Exp. time(s)</th>
<th>Flux 0.2 - 2</th>
<th>Flux 2 - 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002/05/27 04:32:50</td>
<td>5.8109 ± 1.1722</td>
<td>&lt;1.1450</td>
<td>6.7256 ± 1.3813</td>
<td>4.3216</td>
<td>(8.3444 ± 1.6833) e-12</td>
<td>&lt;1.0470e-11</td>
</tr>
<tr>
<td>2003/11/22 17:38:28</td>
<td>4.7725 ± 0.7293</td>
<td>&lt;0.4806</td>
<td>5.1788 ± 0.7957</td>
<td>9.0814</td>
<td>(6.8533 ± 1.0473) e-12</td>
<td>&lt;4.3954e-12</td>
</tr>
<tr>
<td>2006/06/23 14:23:12</td>
<td>&lt;0.3618</td>
<td>&lt;0.4984</td>
<td>&lt;0.4324</td>
<td>10.0753</td>
<td>&lt;5.1950e-13</td>
<td>&lt;4.5574e-12</td>
</tr>
<tr>
<td>2008/12/02 23:38:16</td>
<td>&lt;0.3211</td>
<td>&lt;0.4417</td>
<td>&lt;0.3841</td>
<td>11.3529</td>
<td>&lt;4.0104e-13</td>
<td>&lt;4.0392e-12</td>
</tr>
<tr>
<td>2015/06/14 06:14:33</td>
<td>&lt;0.4872</td>
<td>&lt;0.5795</td>
<td>&lt;0.5332</td>
<td>7.4816</td>
<td>&lt;6.9589e-13</td>
<td>&lt;5.2991e-12</td>
</tr>
<tr>
<td>2017/06/13 12:33:16</td>
<td>&lt;0.6699</td>
<td>&lt;0.4847</td>
<td>&lt;0.7203</td>
<td>8.5947</td>
<td>&lt;9.0194e-13</td>
<td>&lt;4.4326e-12</td>
</tr>
</tbody>
</table>

## XMM-NEWTON POINTED

<table>
<thead>
<tr>
<th>Observation Date</th>
<th>Count rate 0.2 - 2</th>
<th>Count rate 2 - 12</th>
<th>Count rate 0.2 - 12</th>
<th>Exp. time(s)</th>
<th>Flux 0.2 - 2</th>
<th>Flux 2 - 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006/06/23 12:24:00</td>
<td>0.1224 ± 0.0066</td>
<td>0.0079 ± 0.0018</td>
<td>0.1303 ± 0.0068</td>
<td>5917</td>
<td>(1.7579 ± 0.0949) e-13</td>
<td>(7.2828 ± 1.0680) e-14</td>
</tr>
<tr>
<td>2008/12/02 11:27:05</td>
<td>0.0343 ± 0.0011</td>
<td>0.0030 ± 0.0003</td>
<td>0.0373 ± 0.0011</td>
<td>41734</td>
<td>(4.9253 ± 0.1581) e-14</td>
<td>(2.7566 ± 0.3561) e-14</td>
</tr>
</tbody>
</table>

## INTEGRAL

<table>
<thead>
<tr>
<th>Observation Date</th>
<th>Count rate 20 - 40</th>
<th>Count rate 40 - 60</th>
<th>Count rate 60 - 100</th>
<th>Exp. time(s)</th>
<th>Flux 20 - 40</th>
<th>Flux 40 - 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>No data found</td>
<td>No data found</td>
<td>No data found</td>
<td>No data found</td>
<td>No data found</td>
<td>No data found</td>
<td>No data found</td>
</tr>
</tbody>
</table>
Multi-mission – fluxes and upper limits

3C 273

NGC 3599