A Library of the X-ray Universe:
Generating the XMM-Newton Source Catalogues

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XMM-Newton: ESA’s large X-ray space telescope

- built and operated by a consortium of 14 European countries
- three X-ray (0.1−12 nm / 0.15−12 keV) and one UV/optical telescope(s)
- observing the “hot” processes in the Universe since Dec. 1999
- more than 12,400 pointings up to now
- large field of view of half a degree
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The XMM-Newton Consortium

XMM-Newton Mission Operations Centre (MOC)
ESOC (“Operations”),
Darmstadt, Germany:
flight control

XMM-Newton Science Operations Centre (SOC)
ESAC (“Astronomy”),
Villafranca / Madrid, Spain:
data processing

XMM-Newton Survey Science Centre (SSC)
international consortium,
ten founding institutes (1995) in
UK – France – Spain – Germany – Italy:
science analysis software & catalogue creation
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The XMM-Newton Survey Science Centre (SSC)

IRAP, Toulouse
CEA, Saclay
OAS, Strasbourg

University of Leicester
MSSL
IOA, Cambridge

AIP, Potsdam
MPE, Garching

IFCA, Santander

OAB, Milan

Map adapted from IRAP Toulouse & U. Leicester

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The role of the XMM-Newton SSC
Software service from the raw satellite data to the science products

Object catalogues from the individual observations to a full list of observed sources

Source detection

Research:
- Analyse PI data
- Analyse archival data
- Individual objects

Research:
- Survey science on samples
- Discover objects
- Search for counterparts

Community

Iris Traulsen (AIP) The role of the XMM-Newton SSC
I. Catalogue creation

Sky map:
X-ray group U. Leicester

3XMM & XMMSL1

pointed observations:
almost 680 000 detections /
469 000 unique sources
more than 900 square degrees

slews:
about 40 000 detections
about 70% sky coverage
sensitivity similar to ROSAT
The 3XMM catalogues: some facts

- standardized reduction pipeline
- including e.g. thorough treatment of X-ray and instrumental background
- variety of source parameters like coordinates, fluxes, hardness ratios, extent, detection likelihood, variability, ...
- fluxes in five narrow and two broad energy bands
- flagging of potentially spurious detections
- spectra and time series of bright sources
- matching of multiply observed detections into unique sources
- cross-correlation with external catalogues
- full reprocessing after substantial software upgrades, increments inbetween

several web interfaces, in particular:

http://xmm-catalog.irap.omp.eu  
http://nxsa.esac.esa.int/nxsa-web
The 3XMM catalogues: some numbers

3XMM-DR6: release planned for June 2016
Scientific impact of the 3XMM catalogues: some examples

* discoveries ("serendipitous" detections) of new objects
galaxy clusters, active galactic nuclei, ultraluminous X-ray sources, interacting binaries, ...
example: discovery of an isolated neutron star candidate, Pires et al.
example: discovery of the most X-ray luminous galaxy cluster at redshift 1, Lamer et al.

* comprehensive database for
  ▶ statistical studies of object classes
  ▶ finding counterparts of IR – GeV sources
  ▶ timing and variability studies

* basis of international projects like
  ▶ The XMM-Newton spectral-fit database
  ▶ EXTraS: Exploring the X-ray Transient and variable Sky
  ▶ ARCHES: Astronomical Resource Cross-matching for High Energy Studies

(→ hundreds of citations to the 2XMM/3XMM papers)
II. Science Analysis Software

* suite of more than 250 extraction & analysis tasks
* used by every observer to process the data

**thousands of users, more than 4500 refereed XMM-Newton papers**

* development & maintenance: Spain, Germany, France; online HelpDesk offered by SOC/ESAC in Spain
* 12 packages under AIP responsibility$^+$:

**maximum-likelihood source detection**

- highest possible detection sensitivity & lowest possible number of false ("spurious") detections
- part of many individual proposals
- central part of the catalogue pipeline

$^+$SSC-AIP is funded via the DLR

source image and fitted PSF
My current project: Source detection in overlapping observations

repeatedly observed point sources (e.g. calibration objects)

repeatedly observed fields (e.g. deep fields, LMC)

arbitrarily overlapping pointings

repeatedly observed fields in the XMM-Newton sky (blue)
Aims of stacked source detection

Overlapping observations, intentionally or arbitrarily:

* in 3XMM: processed individually
* stacked processing:
  longer effective exposure time

Aims:

▸ provide a standardized source-detection method for overlapping observations
▸ more convenient handling of multiple pointings for the users
▸ optimize stacked source parameters
▸ basis of a future “stacked catalogue” of repeatedly observed sources
▸ cf. other surveys
Example Marano field – single vs nine observations

→ more detections, higher likelihoods, consistent fluxes
Spectral energy distribution of magnetic cataclysmic variables:

- accretion column
- accretion region
- unheated white dwarf
- M-star
- accretion stream
- curtain

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Spectral energy distribution of magnetic cataclysmic variables:

- Optical
- Hard X-rays / cyclotron
- EUV - soft X-rays
- Optical - ultraviolet
- Infrared - optical

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My scientific interest in XMM-Newton: Interacting binaries

Spectral energy distribution of magnetic cataclysmic variables:

multi-wavelength observations + spectral models = first physically consistent SED model

(Traulsen+ 2014)
The future of space-based X-ray astronomy

**Spektr-RG** (Russia – Germany) planned launch in 2017: *era of object statistics*

**Athena** (ESA large mission) proposed launch in 2028–2032: *carrying a calorimeter era of X-ray line diagnostics*

![Graph showing orbital phase vs. energy](Credit: AIP / MPE)

- Local radial velocities
- Mass determination

*(Traulsen+ 2014)*
3XMM — The largest library of the X-ray universe

* currently the largest catalogue of X-ray sources
* fund of new detections and counterparts to other observations
* built by the international XMM-Newton Survey Science Centre Consortium
* example for the potential of future multi-national efforts
* yearly increments, next one to be released soon
* new: stacked source detection in multiply observed fields
* looking forward to the upcoming opportunities like Spektr-RG carrying ART-XC & eROSITA