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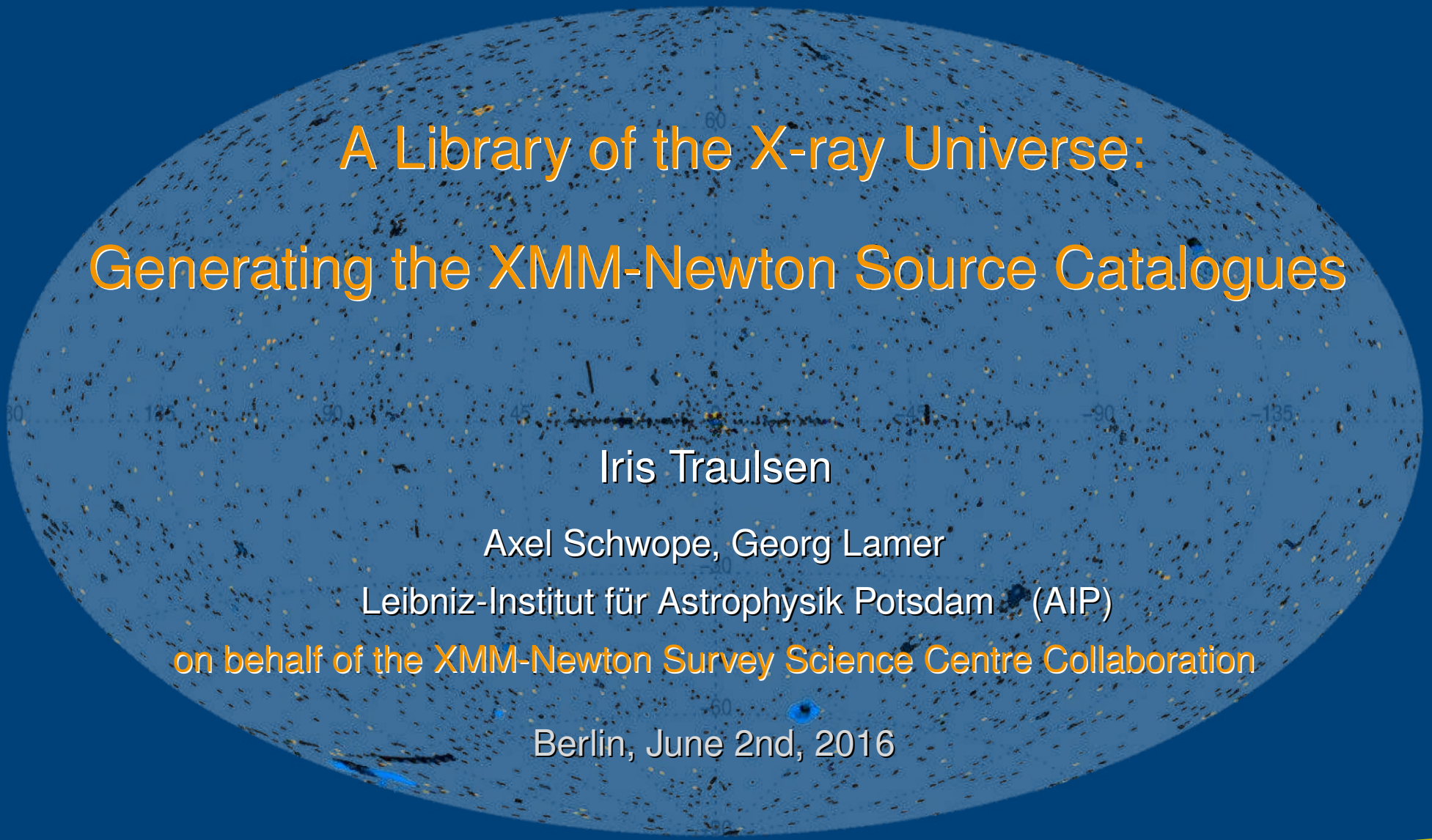

A Library of the X-ray Universe:
Generating the XMM-Newton Source Catalogues

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Axel Schwope, Georg Lamer

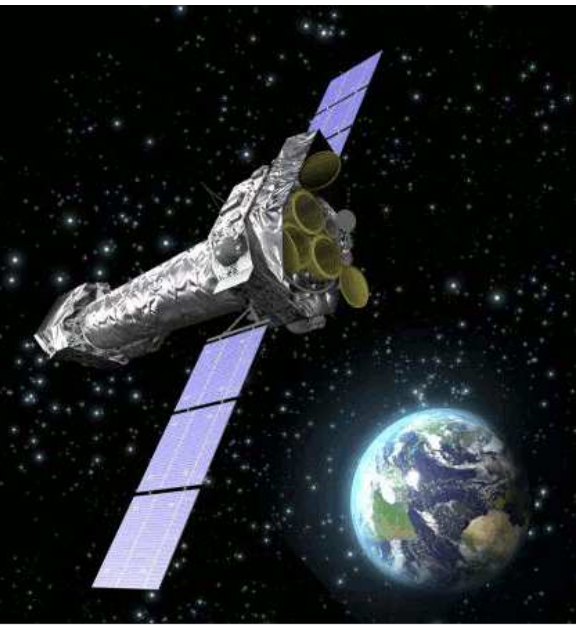
Leibniz-Institut für Astrophysik Potsdam (AIP)

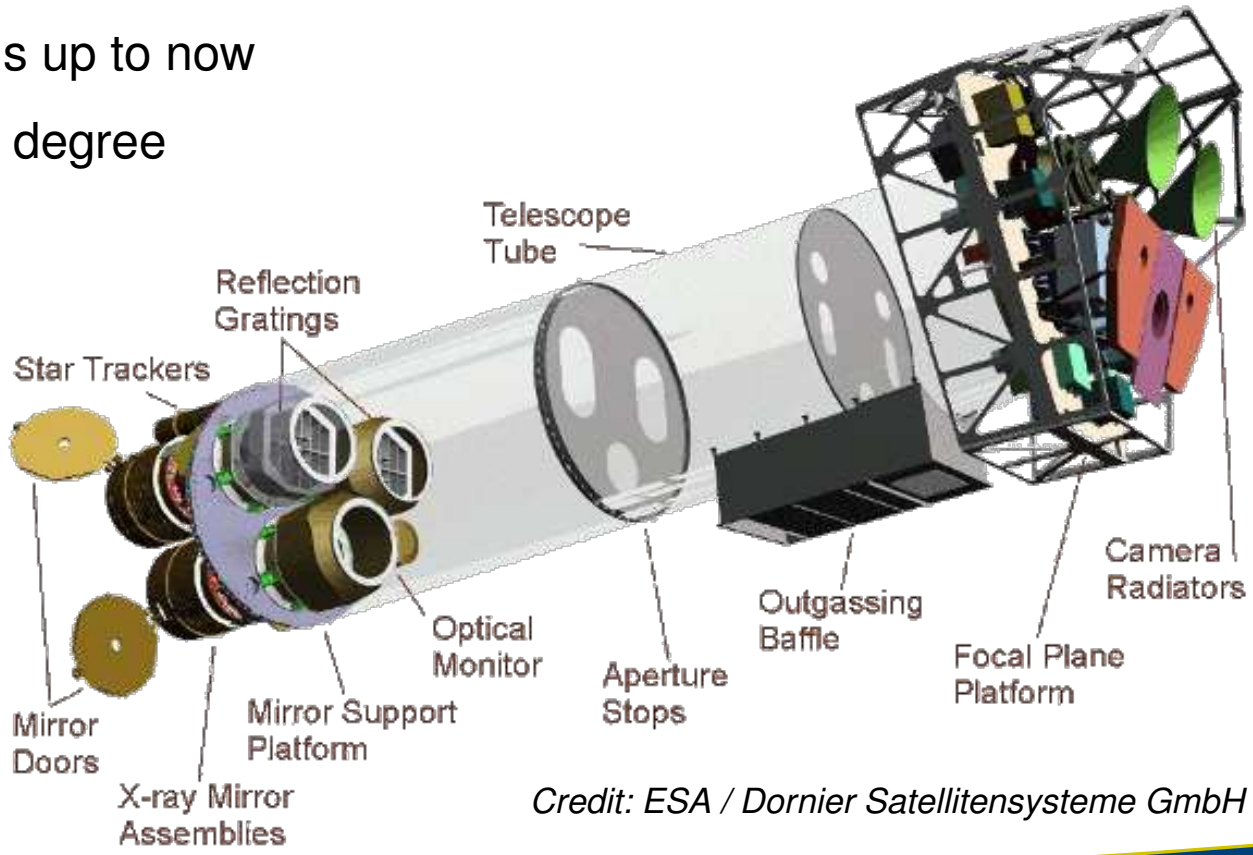
on behalf of the XMM-Newton Survey Science Centre Collaboration

Berlin, June 2nd, 2016

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



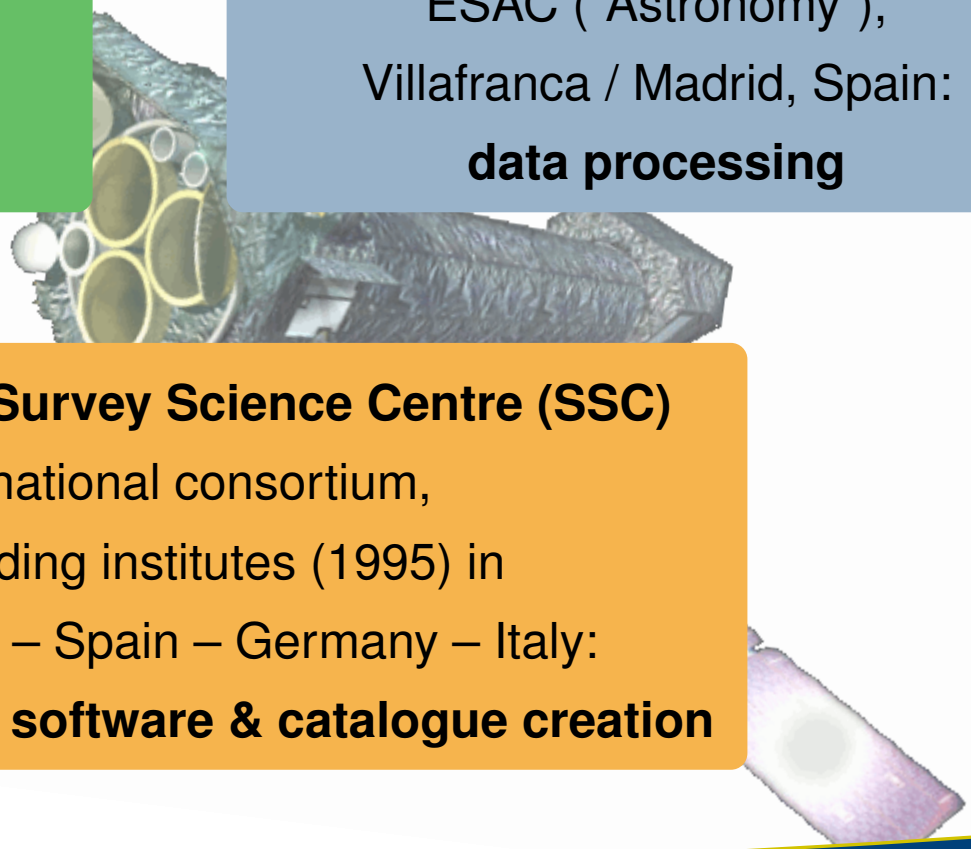


Credit: ESA / Dornier Satellitensysteme GmbH

The XMM-Newton Consortium

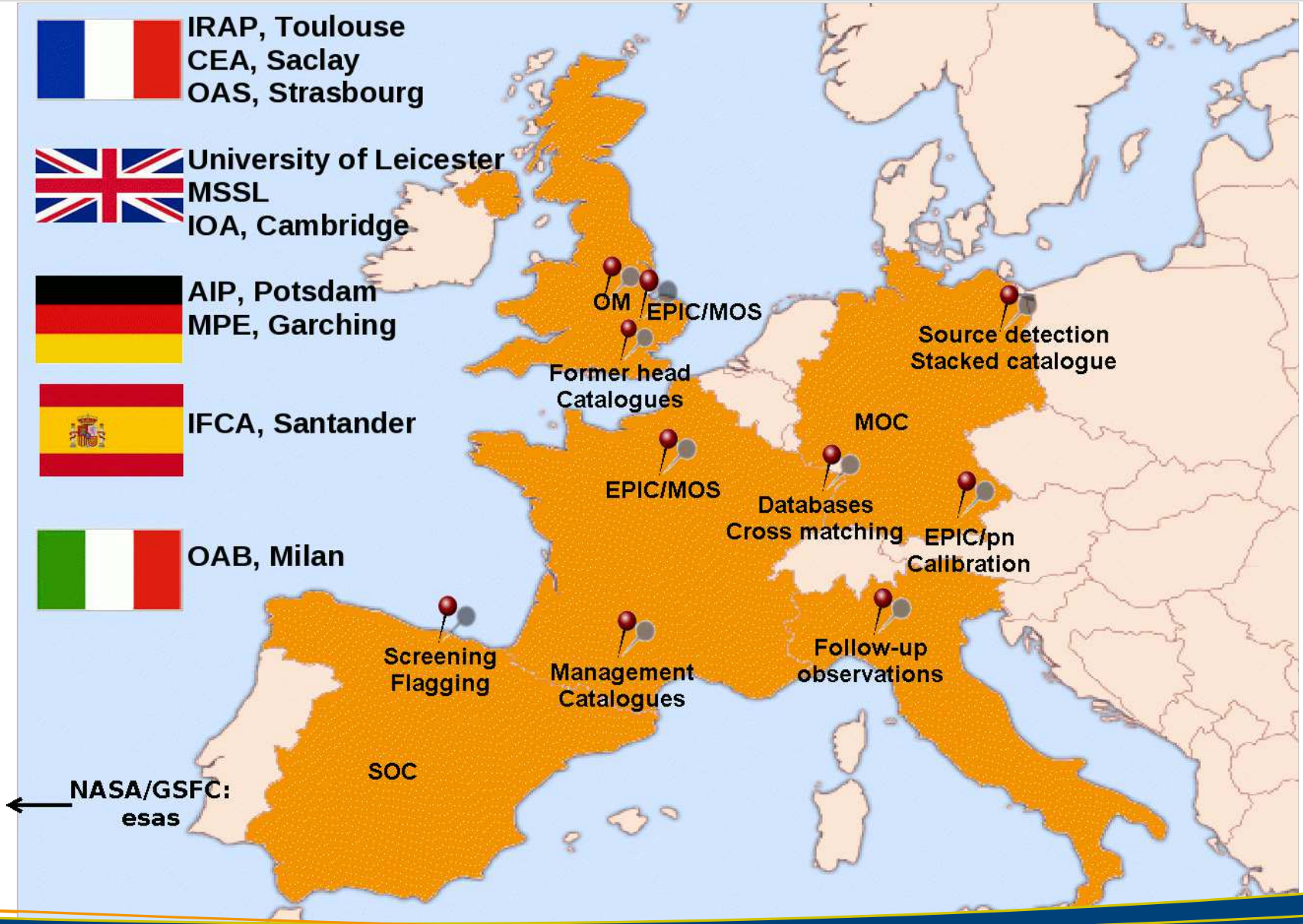
XMM-Newton
Mission Operations Centre (MOC)
ESOC (“Operations”),
Darmstadt, Germany:
flight control

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



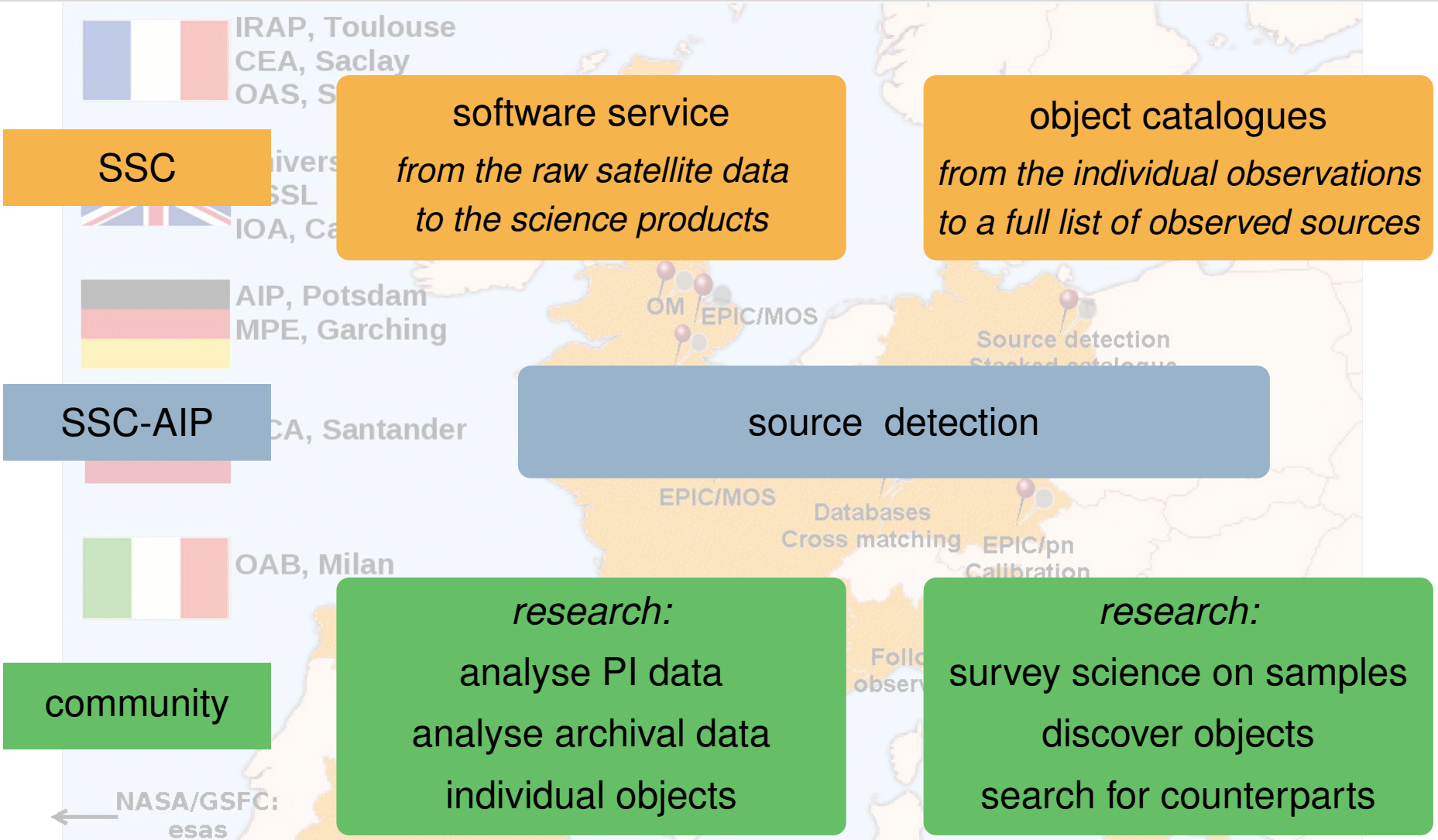
XMM-Newton Survey Science Centre (SSC)
international consortium,
ten founding institutes (1995) in
UK – France – Spain – Germany – Italy:
science analysis software & catalogue creation

The XMM-Newton Survey Science Centre (SSC)



Map adapted from IRAP Toulouse & U. Leicester

The XMM-Newton Survey Science Centre (SSC)



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

SSC-AIP

source detection

community

research:

analyse PI data

analyse archival data

individual objects

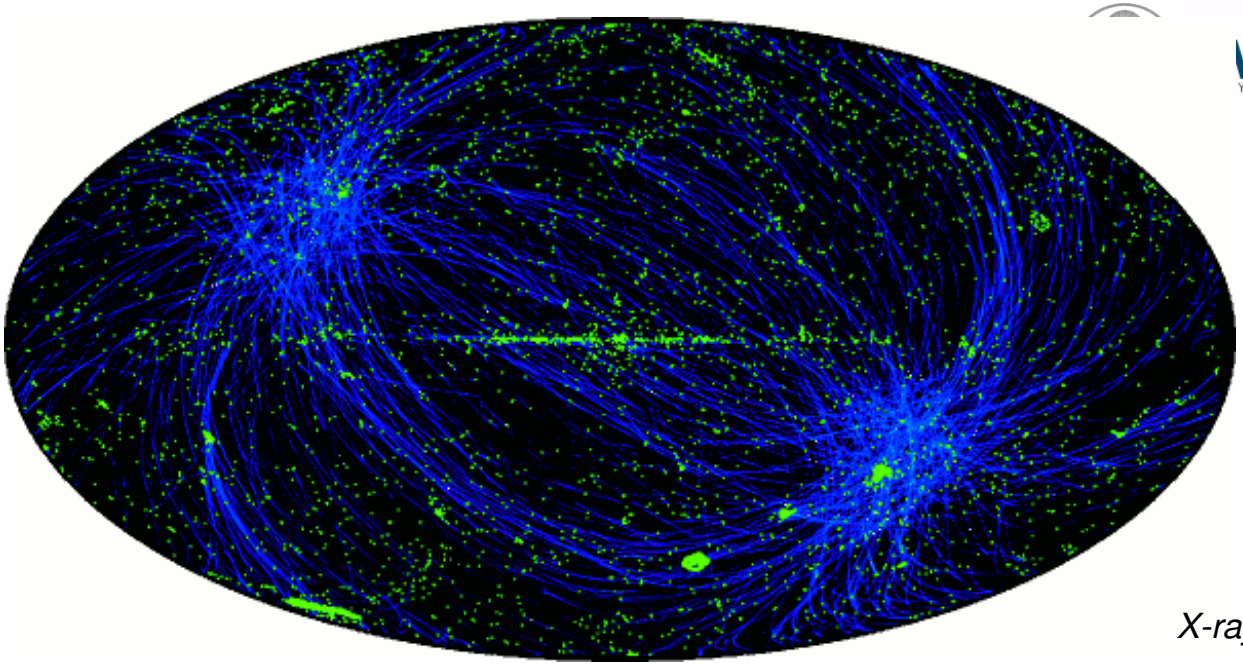
research:

survey science on samples

discover objects

search for counterparts

I. Catalogue creation



Sky map:
X-ray group U. Leicester

3XMM	&	XMMSL1
pointed observations:		slews:
almost 680 000 detections /		about 40 000 detections
469 000 unique sources		about 70% sky coverage
more than 900 square degrees		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

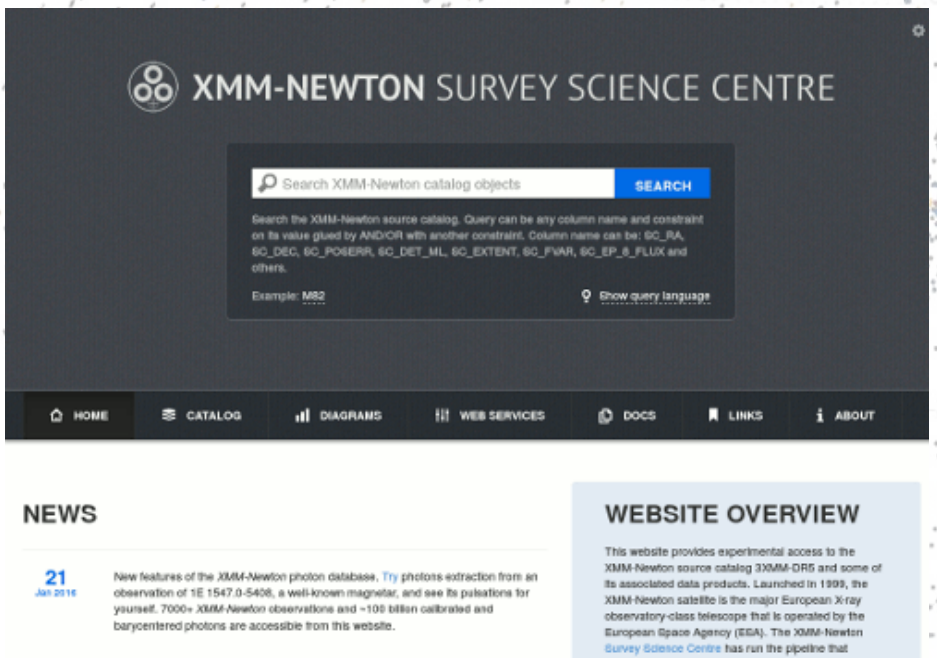
Rosen et al. 2016, A&A 590, A1 (highlight)

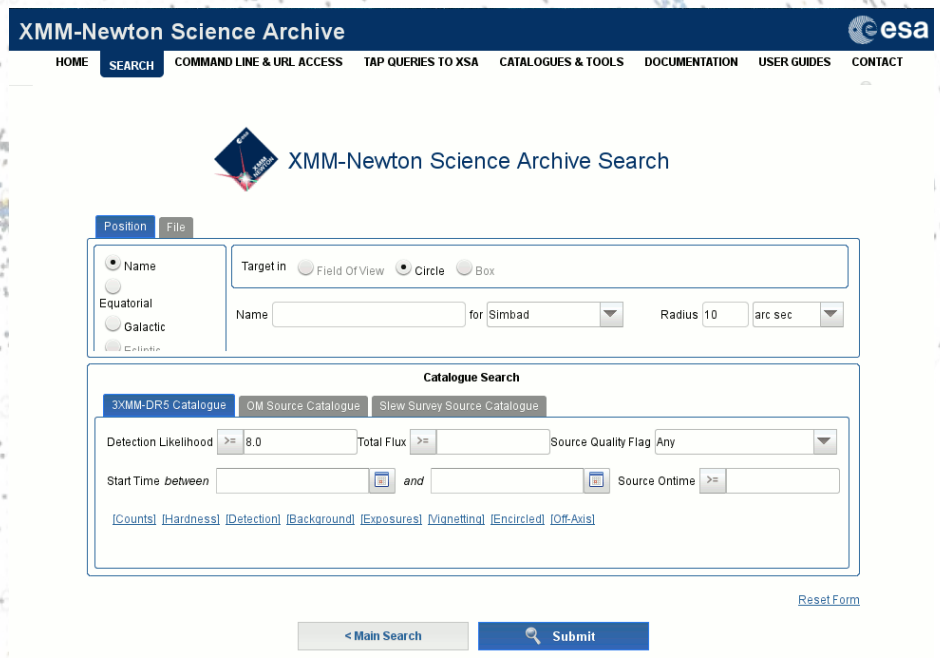
The 3XMM catalogues: some interfaces

several web interfaces, in particular:

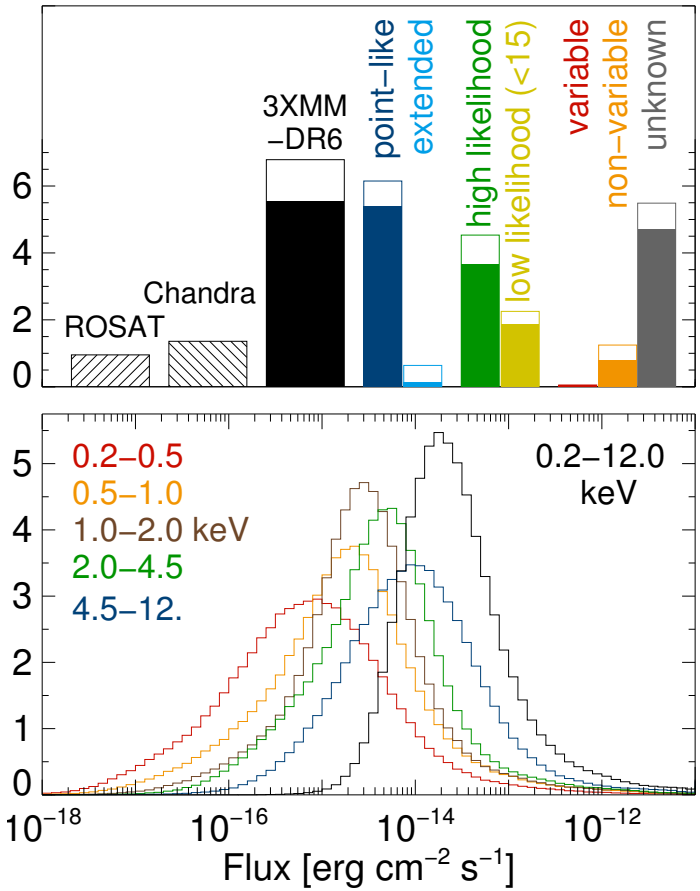
`http://xmm-catalog.irap.omp.eu`

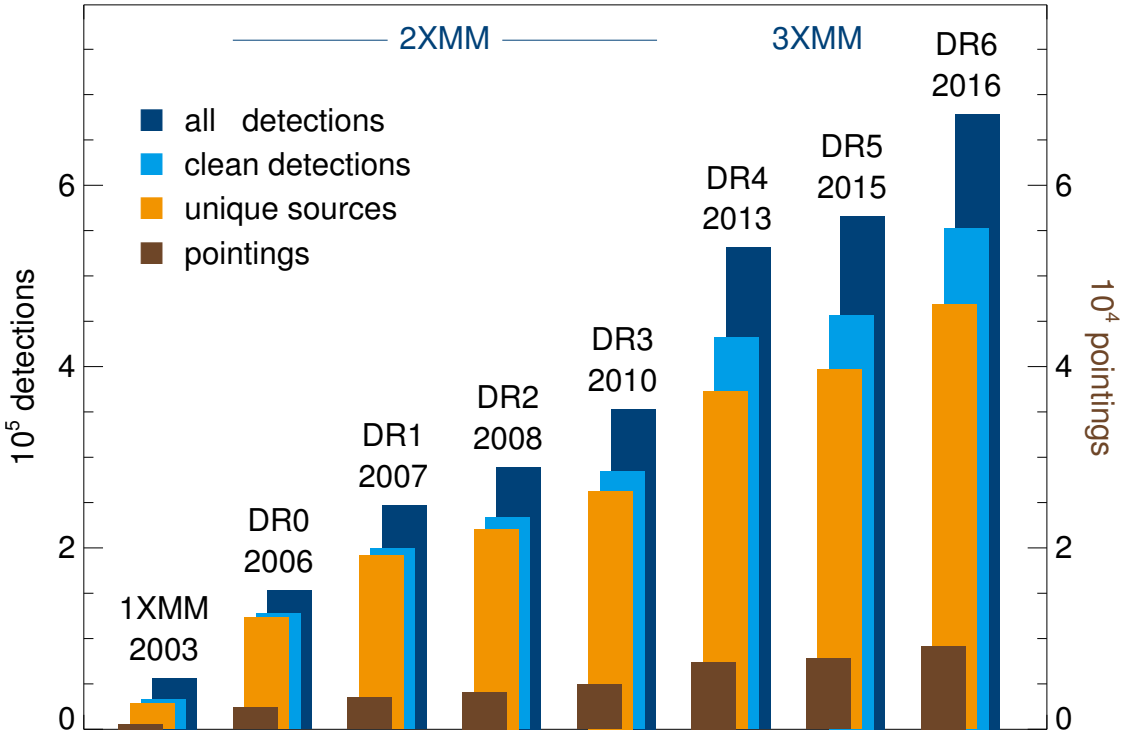
`http://nxsa.esac.esa.int/nxsa-web`





The 3XMM catalogues: some numbers





3XMM-DR6: release planned for June 2016

Scientific impact of the 3XMM catalogues: some examples

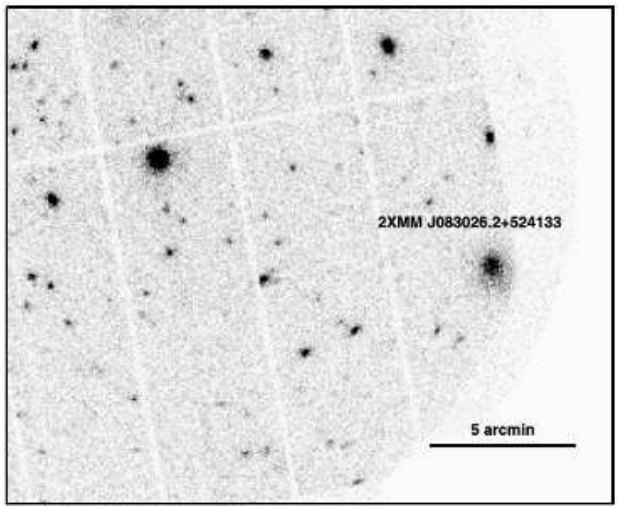
- discoveries ("serendipitous" detections) of new objects

  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

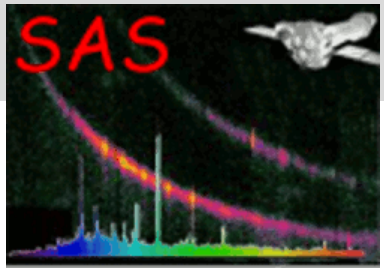


Lamer et al. (2008)

- 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

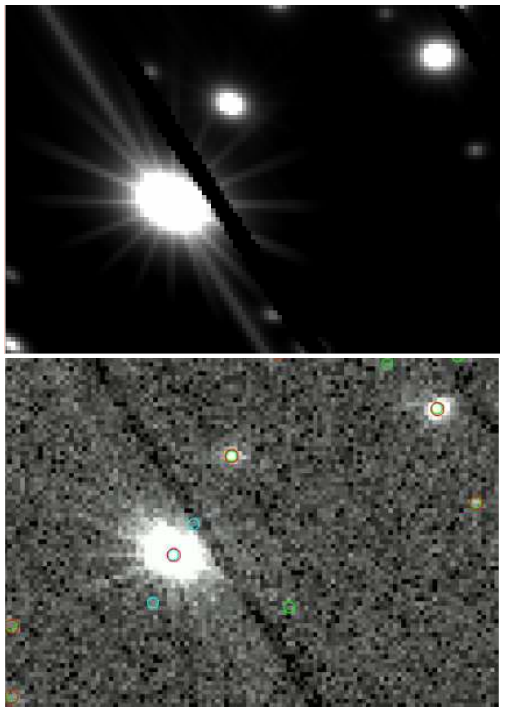


- suite of more than 250 extraction & analysis tasks
- used by every observer to process the data

  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



source image and fitted PSF

[+]SSC-AIP is funded via the DLR

My current project: Source detection in overlapping observations

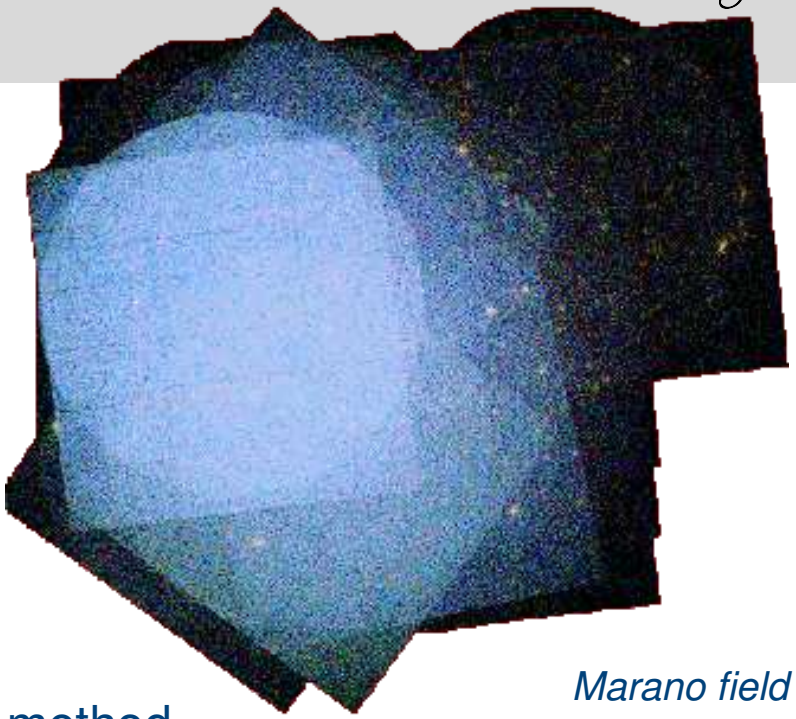
repeatedly observed point sources
(e.g. calibration objects)

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



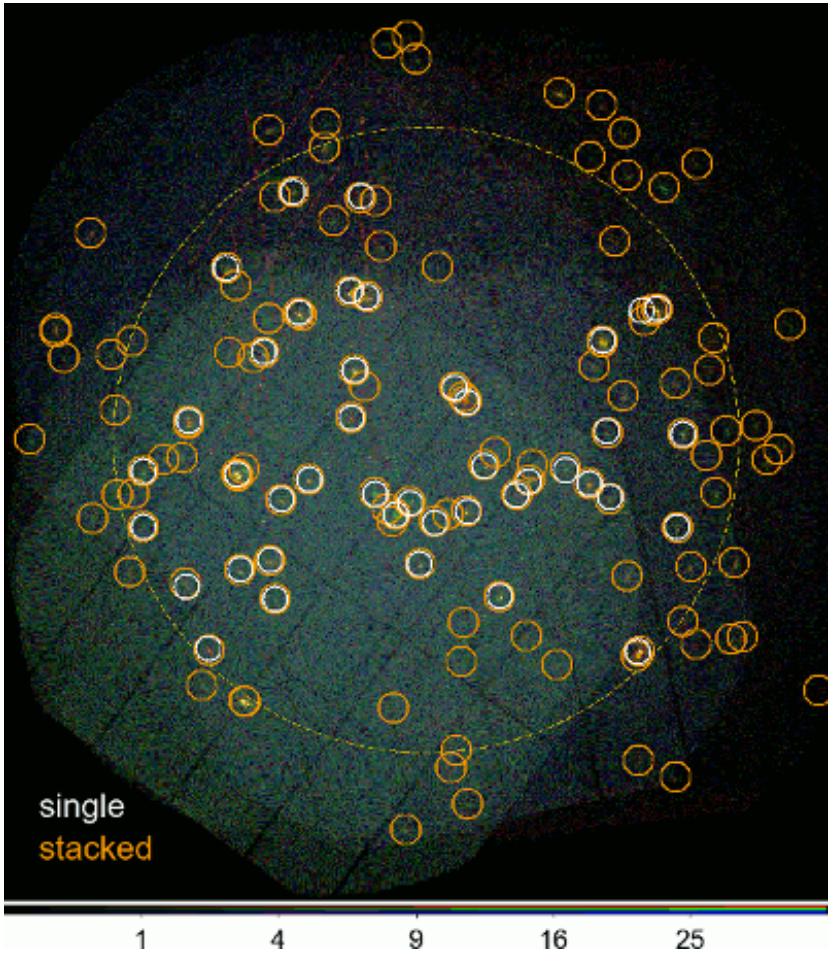
Marano field

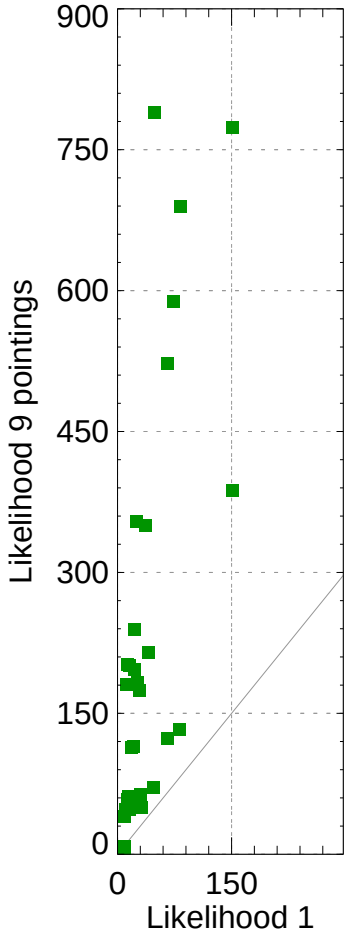
Overlapping observations,
intentionally or arbitrarily:

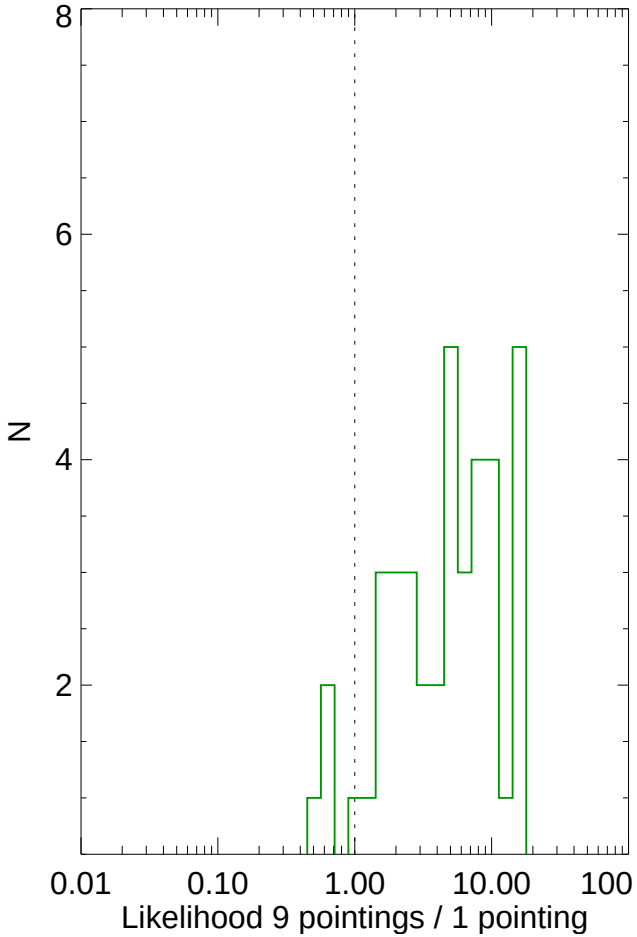
- in 3XMM: processed individually
- stacked processing:
  longer effective exposure time

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



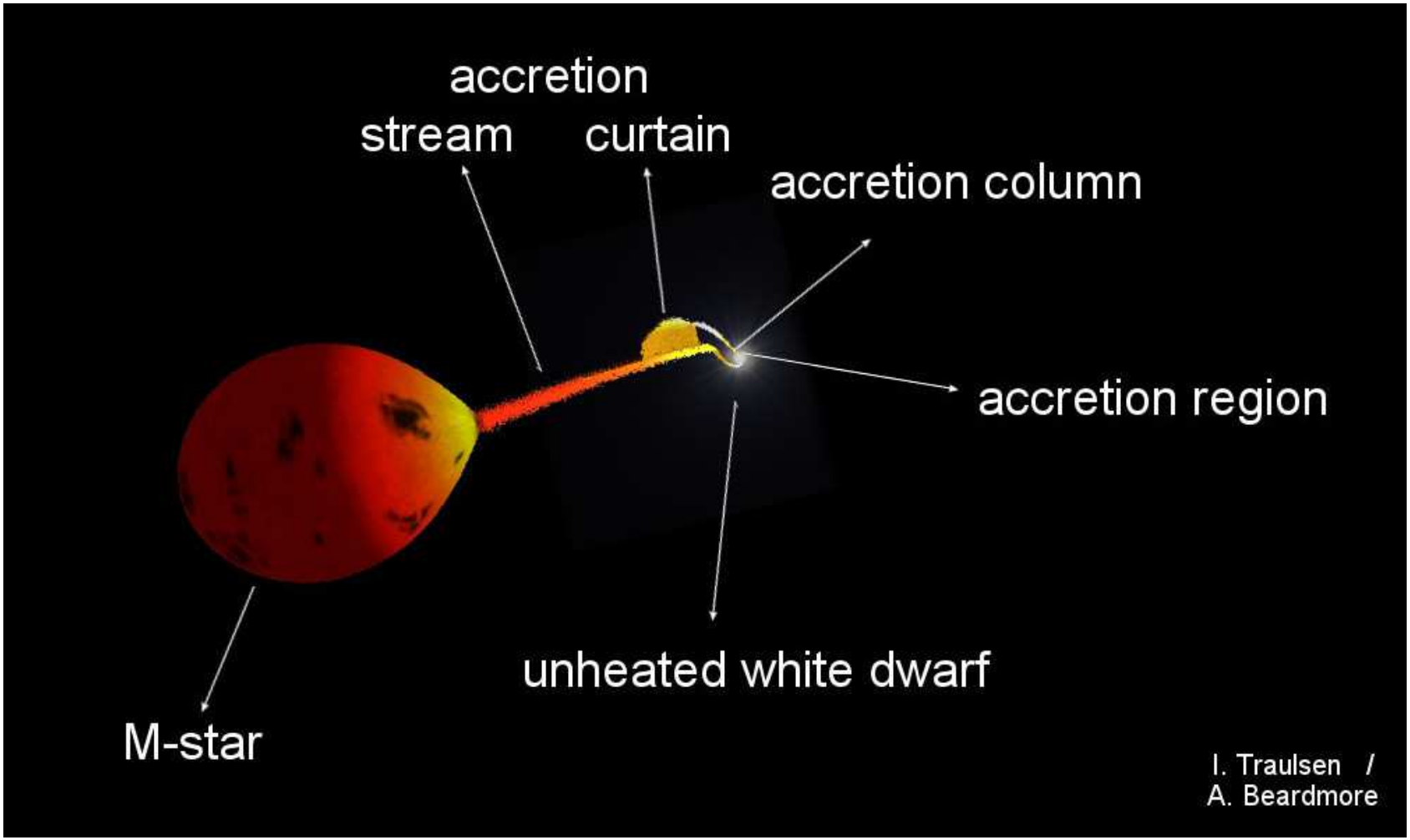




→ more detections, higher likelihoods, consistent fluxes

My scientific interest in XMM-Newton: Interacting binaries

Spectral energy distribution of magnetic cataclysmic variables:



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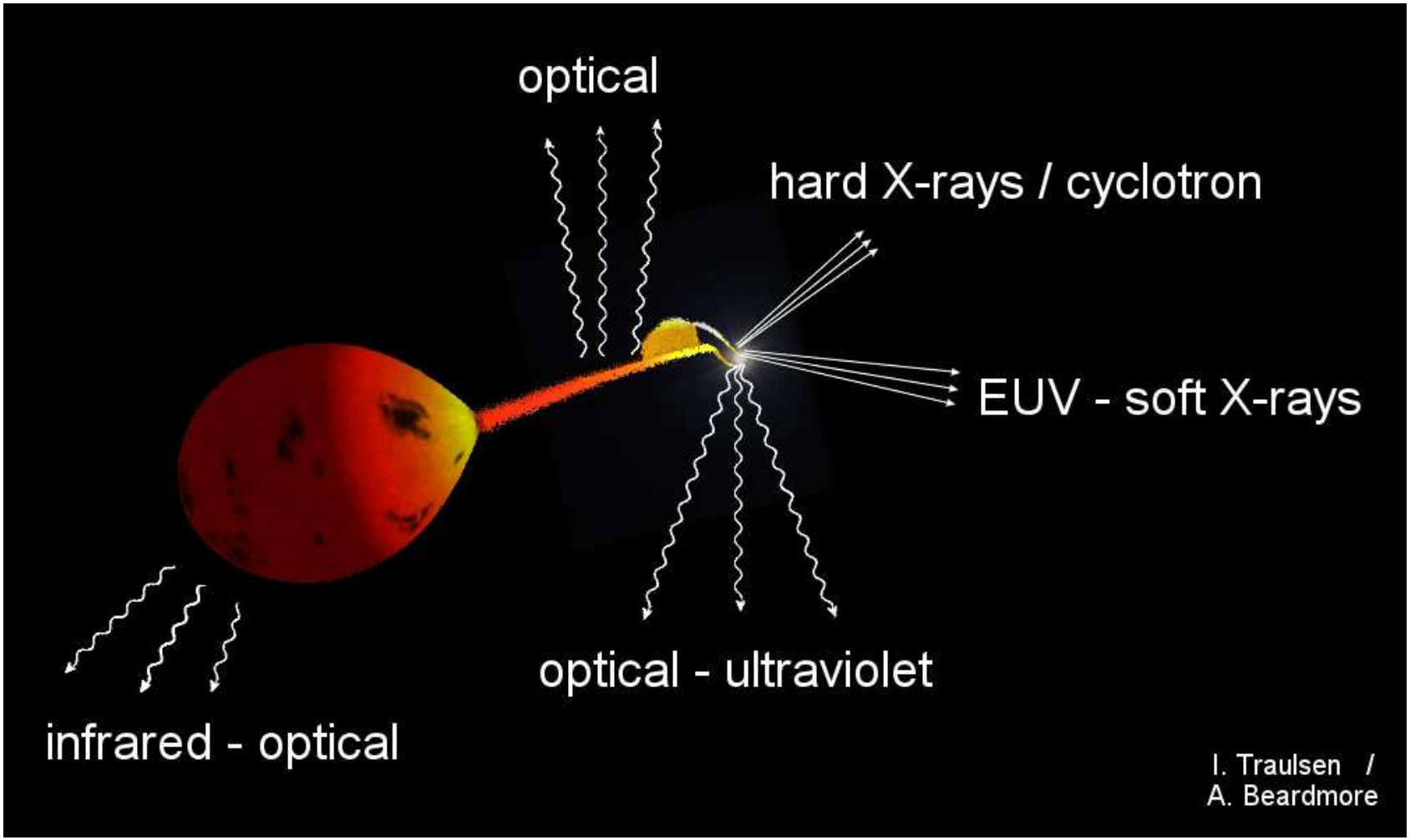

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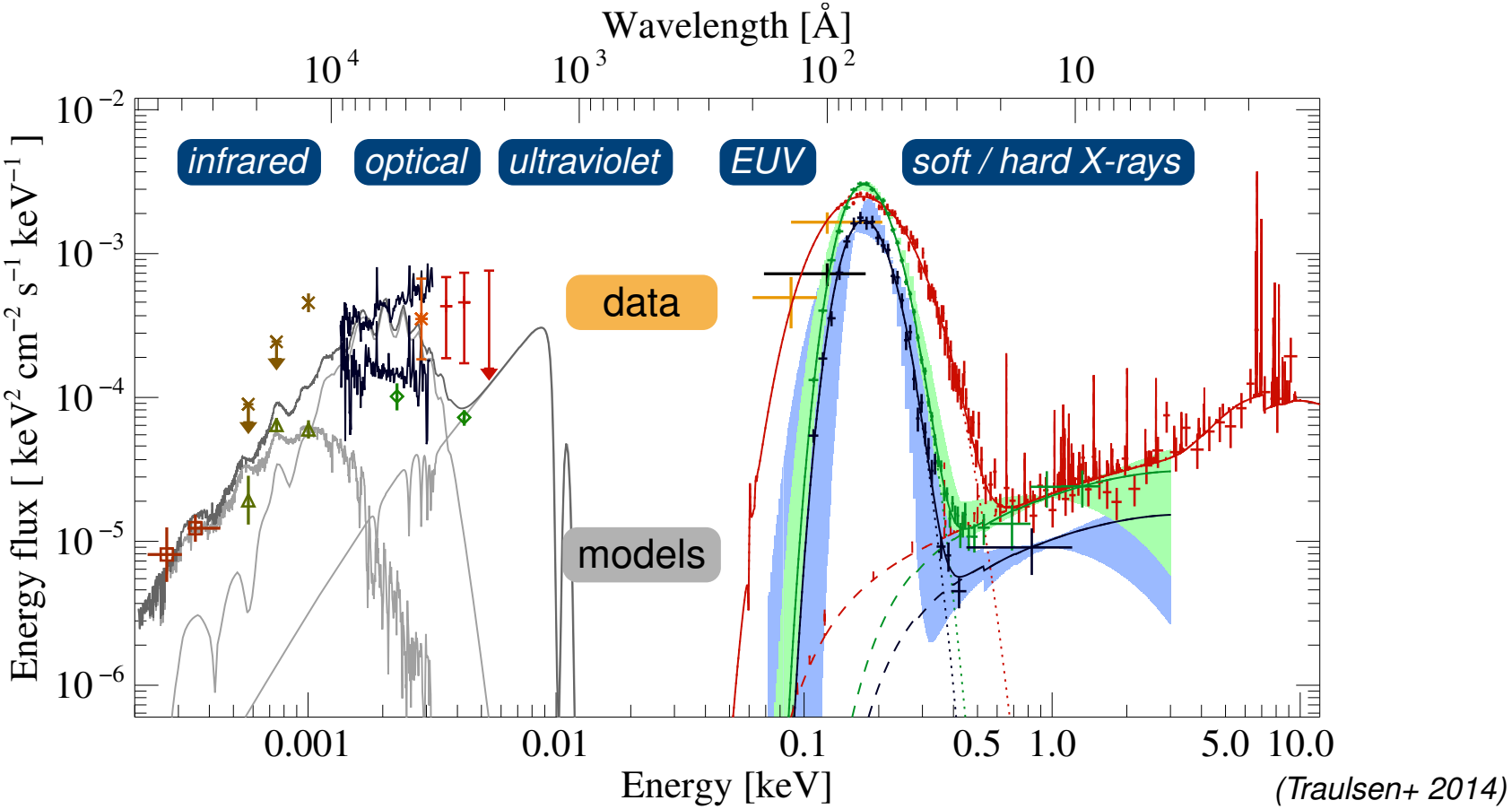


(Traulsen+ 2014)

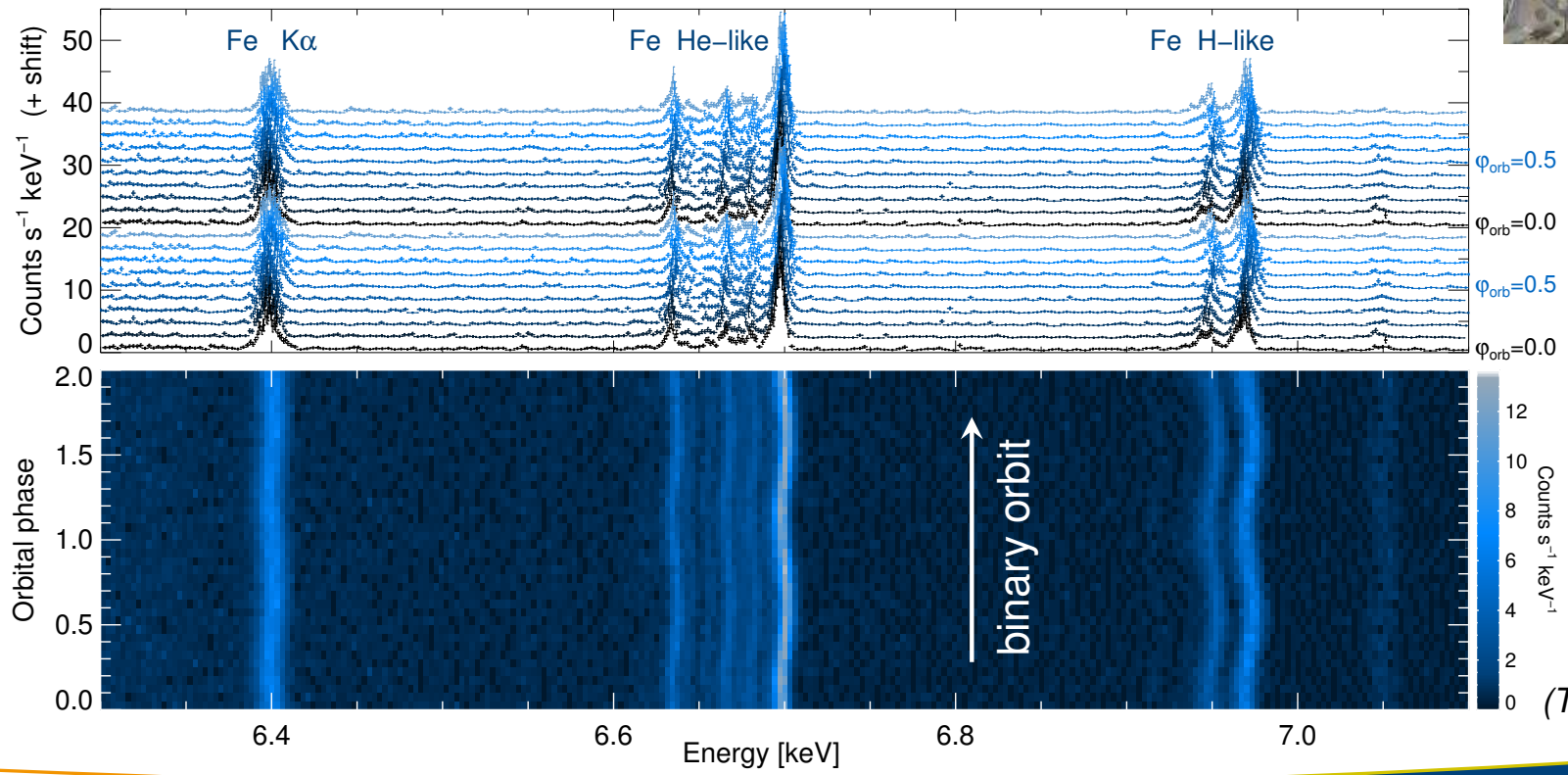
multi-wavelength observations + spectral models = first physically consistent SED model

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*

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