# Welcome & Introduction

**Natalie Webb**

**On behalf of the XMM2ATHENA team :**

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*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004168*

# WELCOME TO THE MEETING, PRACTICAL INFORMATION

- Welcome to Toulouse and to the workshop !
- Small constraint, please sign in to the meeting every day – thank you !
- LOC identifiable by the red circle on their badge
- Wifi : Eduroam recommended. Alternatively, individual connections available at welcome desk
- Presentations via central computer where possible – upload pdf of your slides
- Possibility to connect to the zoom and present from your own computer
- Posters, coffee breaks & lunches in the Gervais de Lafond room – next door
- Restricted access to the remainder of IRAP (unless accompanied)
- Hybrid meeting, please use the microphone when asking questions
- For remote participants, please keep microphone muted when not speaking
- For remote participants, please raise hand to ask a question or post in chat
- For all participants, please be respectful to everyone
- For speakers, time slots include 5 minutes for questions, try to stick to time
- Dinner Wednesday, Mas de Dardagna, limited places, require ticket, 55€ drinks included, pay at restaurant


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# WELCOME TO IRAP

- The Research Institute for Astrophysics and Planetary Sciences (IRAP)
- 320 people, ~120 researchers, ~80 engineers, ~50 postdocs, ~50 PhD students
- Three sites, Roche & Belin in Toulouse and at Tarbes (Pic du Midi)
- Situated next to the French Space Agency (CNES) and University of Toulouse III
- Wide range of research : plasma physics, solar system, the Sun, stars, interstellar medium, astro-chemistry, compact objects, astroparticle physics, fundamental physics, galaxies, cosmology, signal processing
- Strong instrumental development, i.e. SPI/integral, radiation monitors/XMM-Newton, ECLAIRs/SVOM and X-IFU/ Athena


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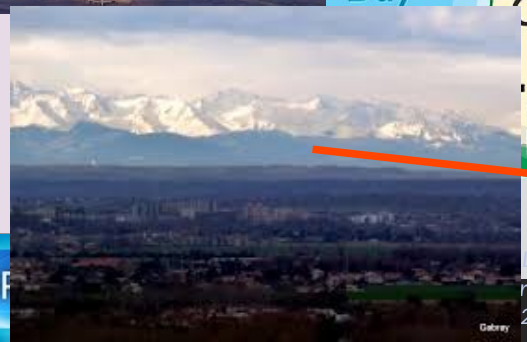
# A BIT ABOUT TOULOUSE







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# THE XMM-NEWTON SURVEY SCIENCE CENTRE

**The XMM-Newton Survey Science Centre (XMM-SSC) was selected by ESA to ensure that the scientific community can exploit XMM-Newton data**


**<u>Responsibilities :</u>**

**Development of much of the science analysis system (SAS)**

**Pipeline processing of all XMM-Newton observations <2012**

**Follow-up/identification of the XMM-Newton serendipitous sky - the XID Programme**

**Compilation of the Serendipitous Source Catalogue.**



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# 4XMM-DR13

983948 detections, 656997 unique sources

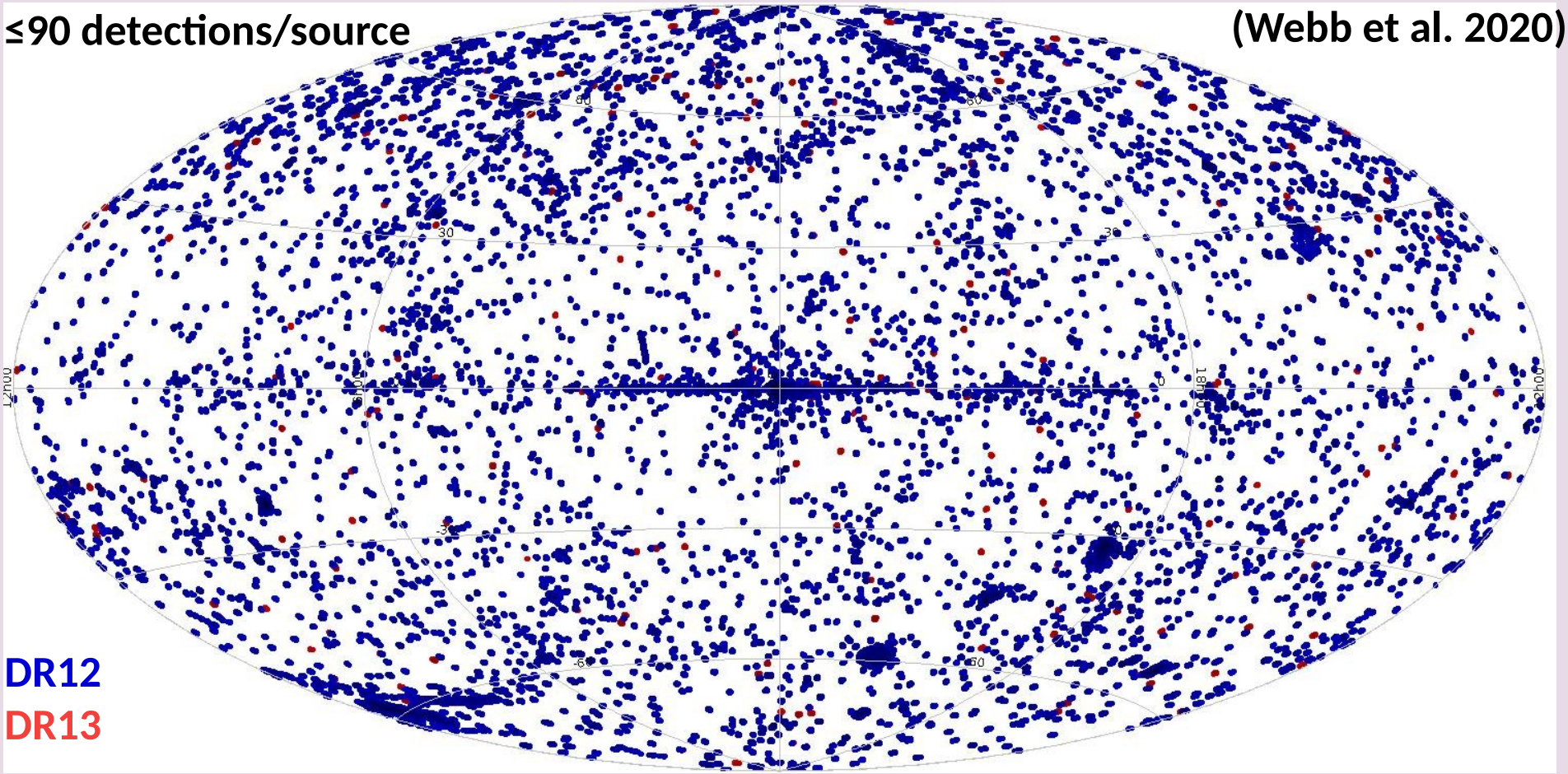
353538 (36%) sources with spectra & lightcurves

91763 extended sources

≤90 detections/source

Release: 12th June 2023

Covers 1328 sq. deg of sky (Webb et al. 2020)



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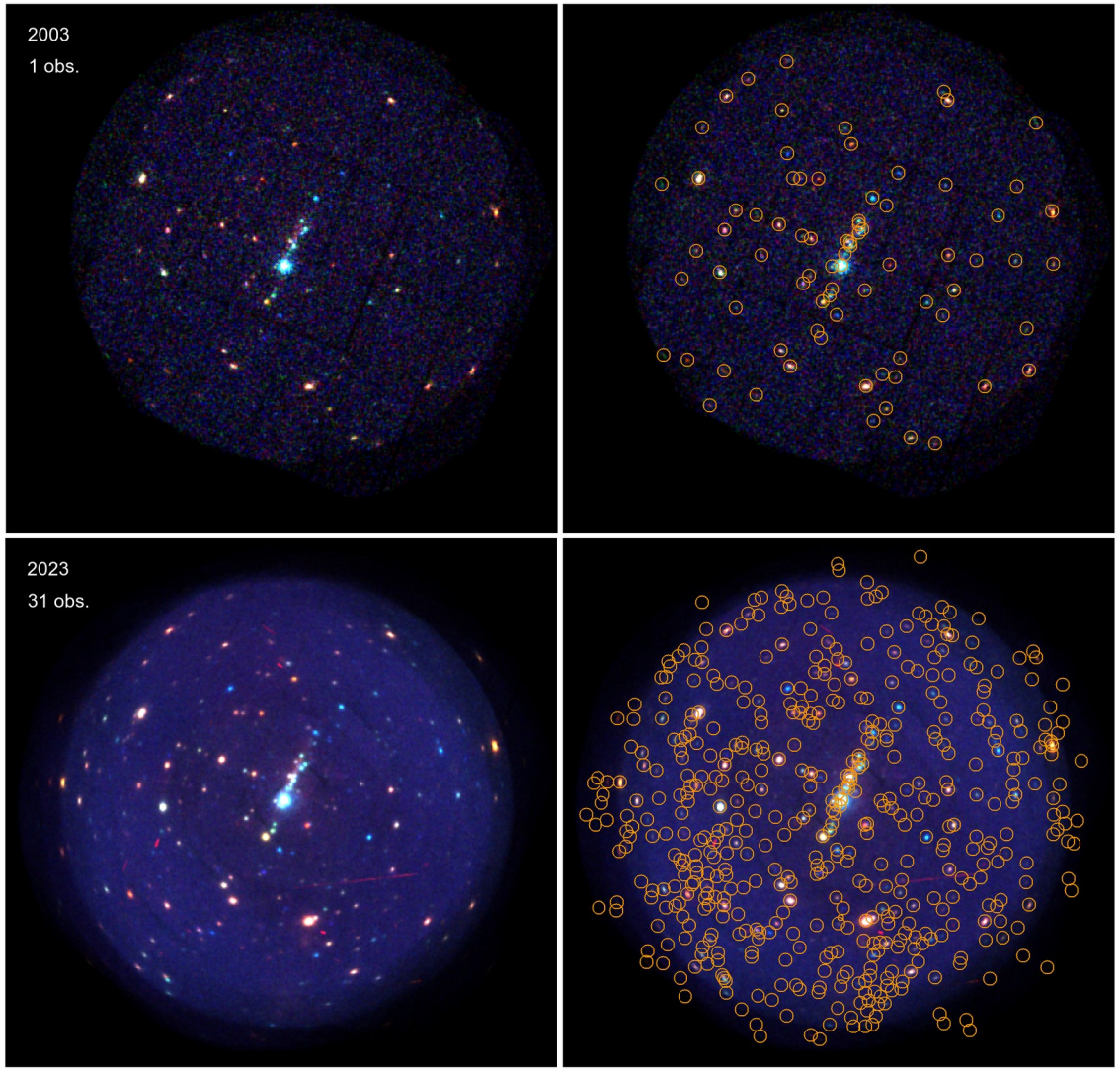
# 4XMM-DR13S




**4XMM-DR13s**
**9796 observations**
**1688 stacks**
**<2.8 Ms per stack**

**(Traulsen et al. 2020)** **401596 sources, ~20% new sources wrt 4XMM-DR13**



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# XMM2ATHENA : APRIL 2021-SEPTEMBER 2024

## XMM-Newton

1999 - .....

## Athena


2037-.....

http://xmm-ssc.irap.omp.eu/xmm2athena/



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# WHY XMM2ATHENA ?

- XMM-Newton observing the X-ray, ultra-violet & optical sky for >24 yrs
- Astronomy has evolved, rarely look at individual sources, but populations
- No longer use a single wavelength, but multi-wavelength and multi-messenger information to help understand the X-ray sources
- Moving into era of time domain astronomy
- Requires operating observatories differently
- New software + methods needed to accompany emerging astronomy
- To be used by next generation X-ray observatory, Athena
- XMM2ATHENA brings together the XMM-Newton SSC, key members of the Athena Science ground segment +members of the X-ray community


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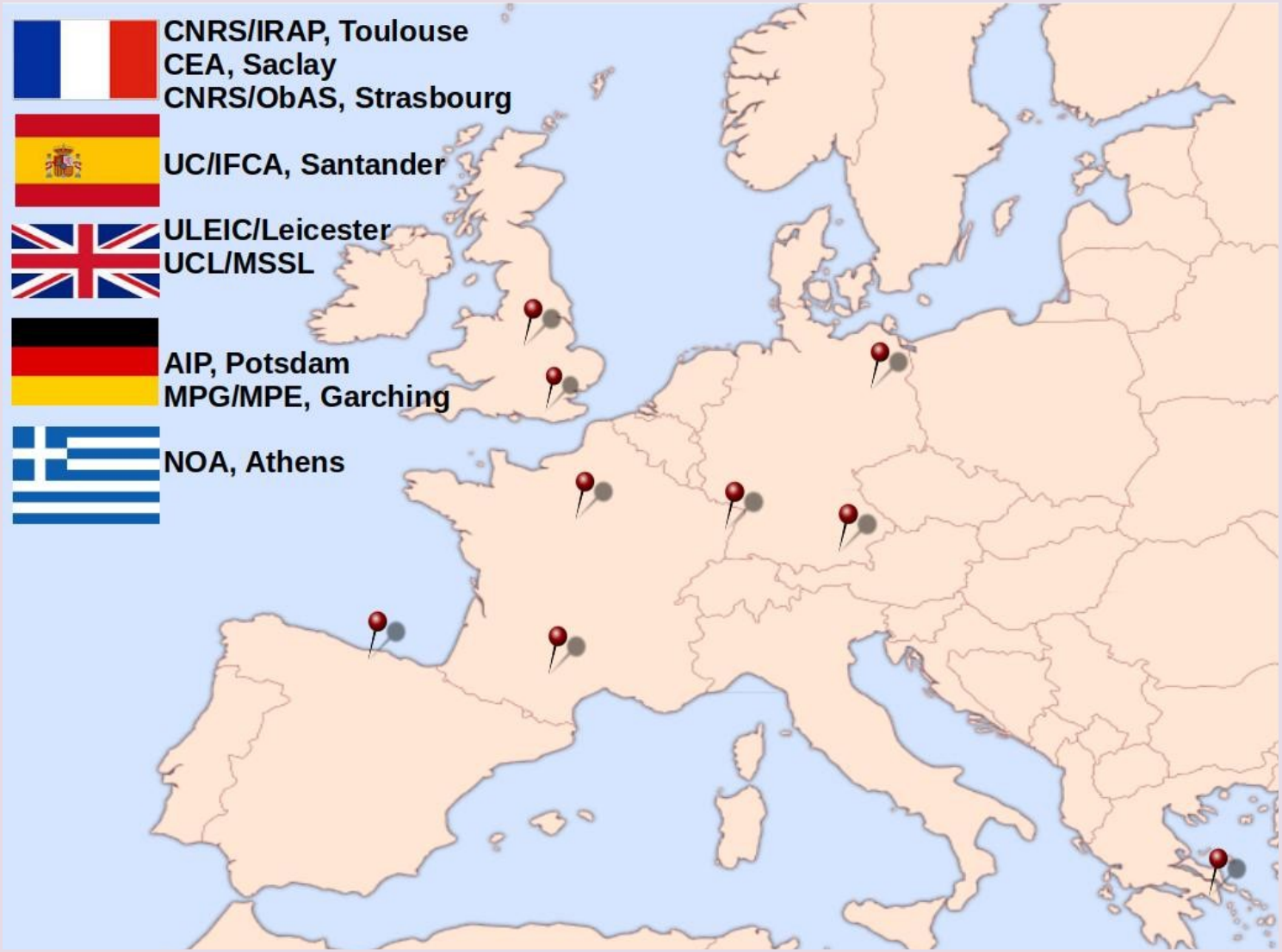
# CONSORTIUM







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# OUTCOMES

- New classification software (naive Bayes classifier)
- Improved software for source detection in stacked data
- Machine learning algorithm to determine photometric redshifts
- Software to detect (very) short term and long term variability
- XMM-Newton alerts
- Improved sensitivity estimator
- New outreach material
- Train the next generation of X-ray astronomers
- Methodology and software ready for Athena


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# AN IMPROVED VERSION OF THE CATALOGUE : 5XMM

## New XMM-Newton catalogue, 5XMM-DR15 in 2025 containing :

- Re-reduction of all data with improved software and calibration
- Single stacked catalogue using source detection reaching deeper fluxes
- Upper limits
- Identifications of all XMM-Newton X-ray, UV and optical sources
- Other multi-wavelength/messenger counterparts to X-ray sources
- Photometric redshifts
- Fits to spectra, including sources with just 5 flux bands
- Physically motivated (type/z) spectral fits for best spectra
- (Very) short term and long term variability
- Methodology and software ready for Athena


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# SCOPE OF THE MEETING

- Discuss the format and accessibility of X-ray and multi-wavelength catalogues
- Understand the uses of the catalogues and the needs of the user
- Adapting to time domain astronomy
- Investigating new source classification and machine learning techniques
- Learn about new software and methods
- Discuss upcoming missions, software and tools
- Reflect on the importance of outreach/diversity in astronomy

Aim to provide better catalogues and software in the future


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# SUMMARY

- XMM2ATHENA will allow XMM-Newton archival data to be fully exploited
- XMM2ATHENA is providing additional functionality & more complete catalogues
- New version of sensitivity estimator, FLIX
- New catalogues of spectral fits for all sources, classifications, etc already out
- 4XMM-DR14 currently being prepared, 5XMM expected for 2025
- XMM2ATHENA will prepare the X-ray community for future X-ray missions
- XMM2ATHENA is helping to make astronomy more accessible to the public
- Knowledge of XMM-Newton & X-ray observatories passed on to next generation


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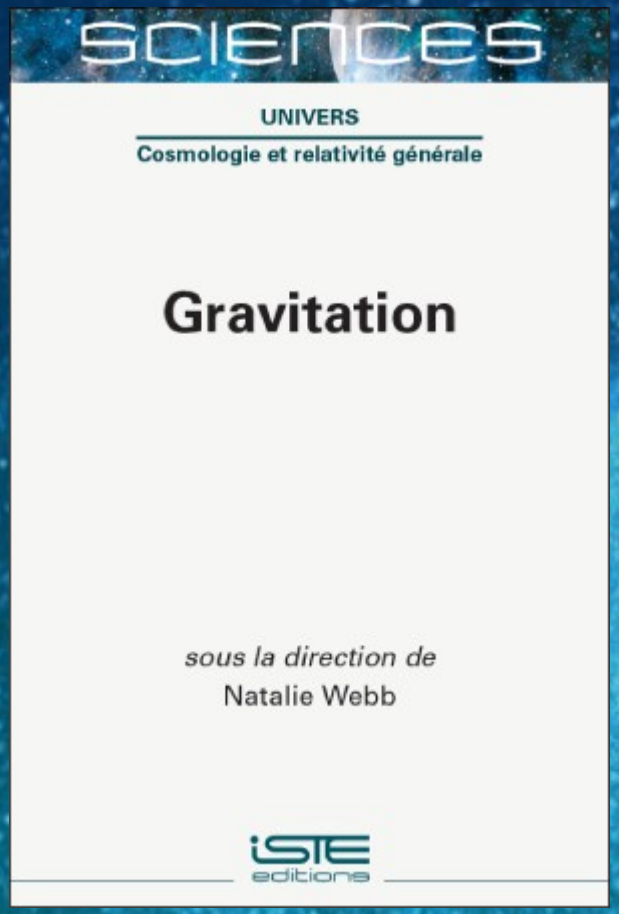
# TEACHING SUPPORT




Field : Universe

Subject : Cosmology and General Relativity

## Gravitation

Edited by

**Natalie Webb**, Université Toulouse III, France

- **Aimed at final year under-graduate/post-graduate students**
- **General relativity**
- **Compact objects**
- **Gravitational waves**
- **Friedman-Lemaître-Robertson-Walker metric & cosmology**
- **Currently available in French, soon in English & Spanish**
- **Printed and electronic versions available**
- **https://www.istegroup.com/en/produit/gravitation/**

# IMPORTANCE OF DATA EXPLOITATION

## Estimate of the carbon footprint of astronomical research infrastructures

2022, Nature Astronomy, Volume 6, p. 503-513

Jürgen Knödlseder[1], Sylvie Brau-Nogué[1], Mickael Coriat[1], Philippe Garnier[1], Annie Hughes[1], Pierrick Martin[1] & Luigi Tibaldo[1]

worldwide active astronomical research infrastructures currently have a carbon footprint of 20.3±3.3 $MtCO_2$ equivalent ($CO_2e$) and an annual emission of 1,169±249 $ktCO_2e\ yr^{-1}$ corresponding to a footprint of 36.6±14.0 $tCO_2e$ per year per astronomer. Compared with contributions from other aspects of astronomy research activity, our results suggest that research infrastructures make the single largest contribution to the carbon footprint of an as-

Note : average carbon footprint / European / year : ~8 $tCO_2$

**Findings include :**

**- Operations are ~1-2 % of carbon footprint of typical space based mission**

**- More comprehensive exploitation of data limits carbon footprint**

**=> Longevity of XMM-Newton coupled with intense archive exploitation reduces carbon footprint of X-ray astronomy in Europe**



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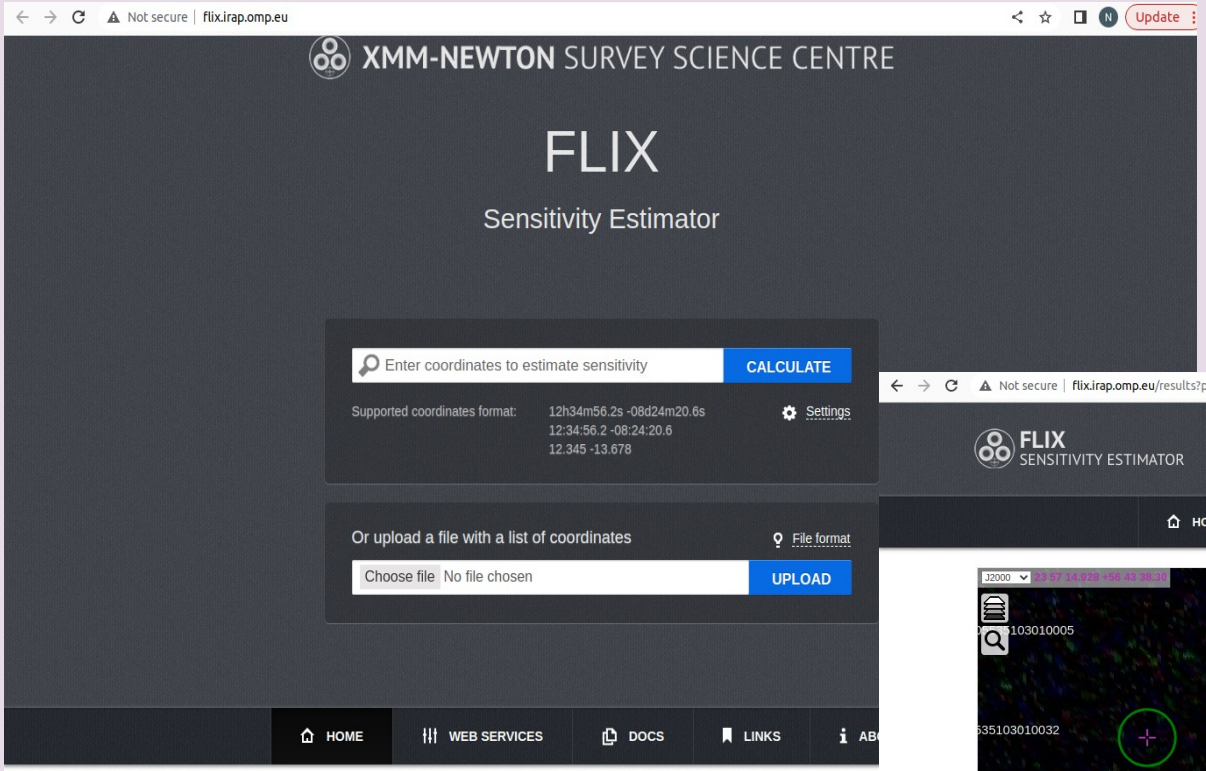
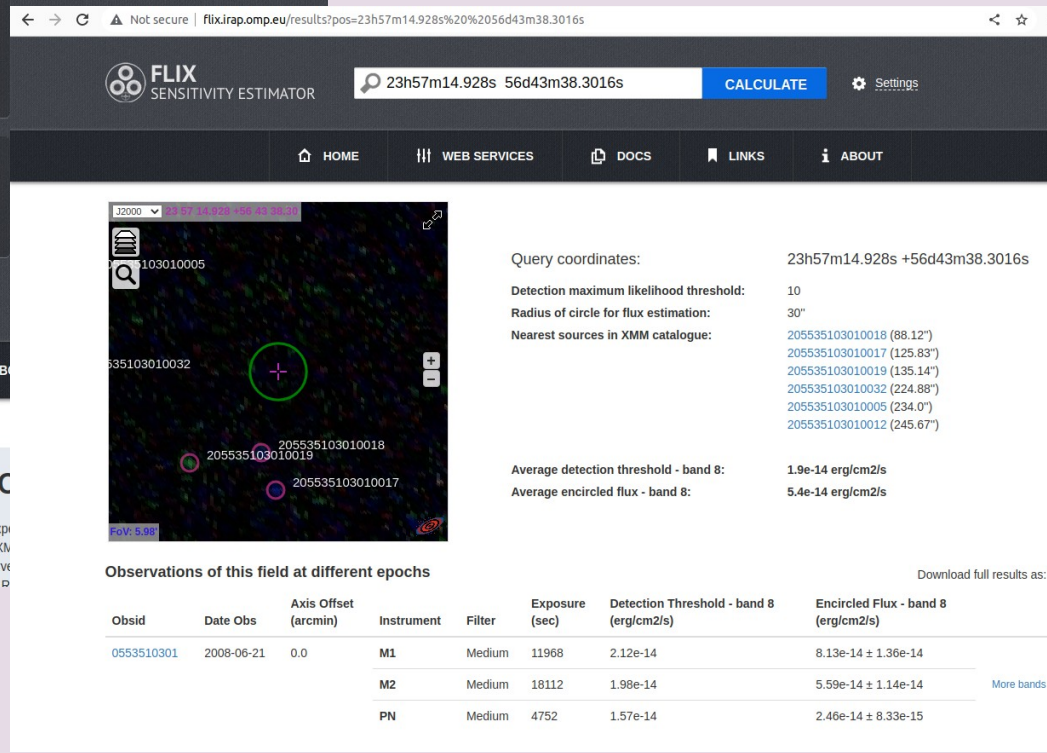
# FLIX SENSITIVITY ESTIMATOR

- New interface
- Improved code
- Processing time halved
- No further time-outs
- Accepts large requests




**http://flix.irap.omp.eu/**

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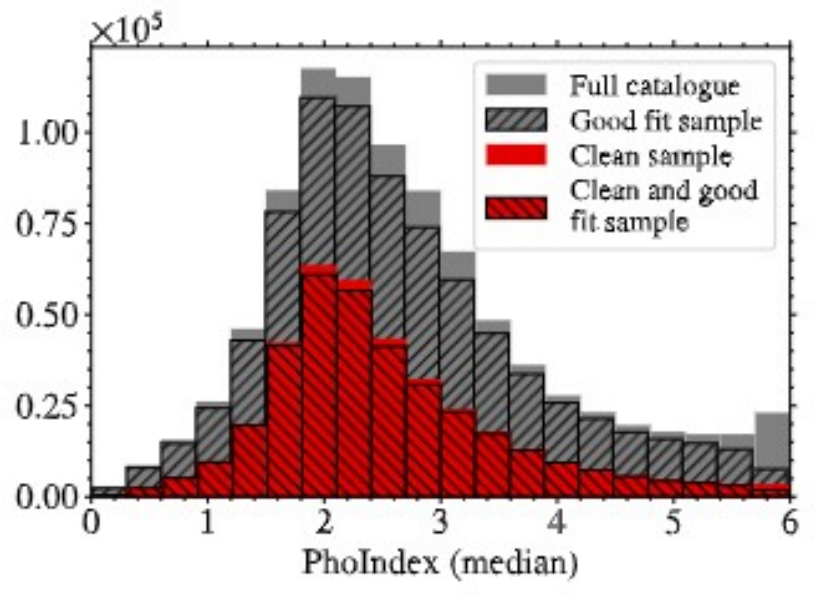
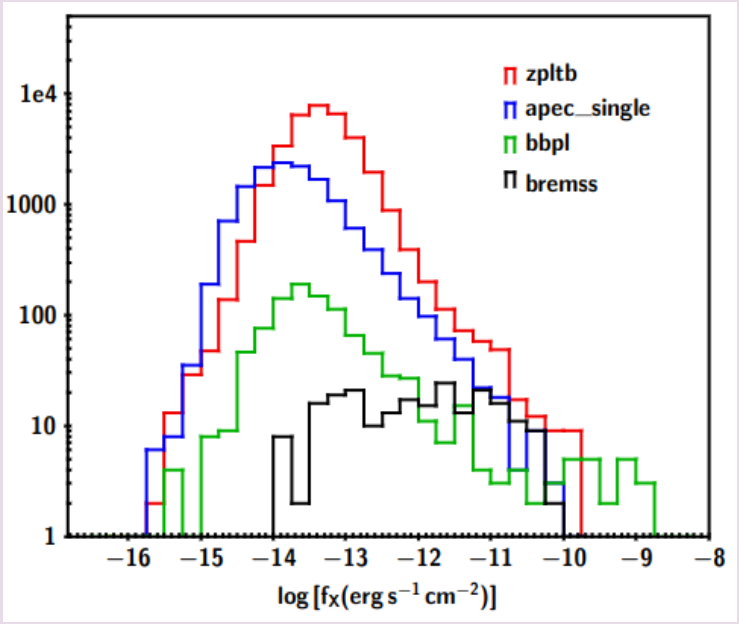
# SPECTRAL FITS

- Bayesian fitting (BXA, Buchner+14)
- Simple fit to all extracted spectra
- Fit to stacked spectra
- Fit to all sources, even without extracted spectra
- Classified sources with photometric redshifts: physically motivated fits
- All catalogues available: http://xmm-ssc.irap.omp.eu/xmm2athena/

| Class | Model name |
|---|---|
| AGNs | redshifted powerlaw |
| Stars | one-temperature apec |
| XRBs | blackbody powerlaw |
| CVs | bremsstrahlung |





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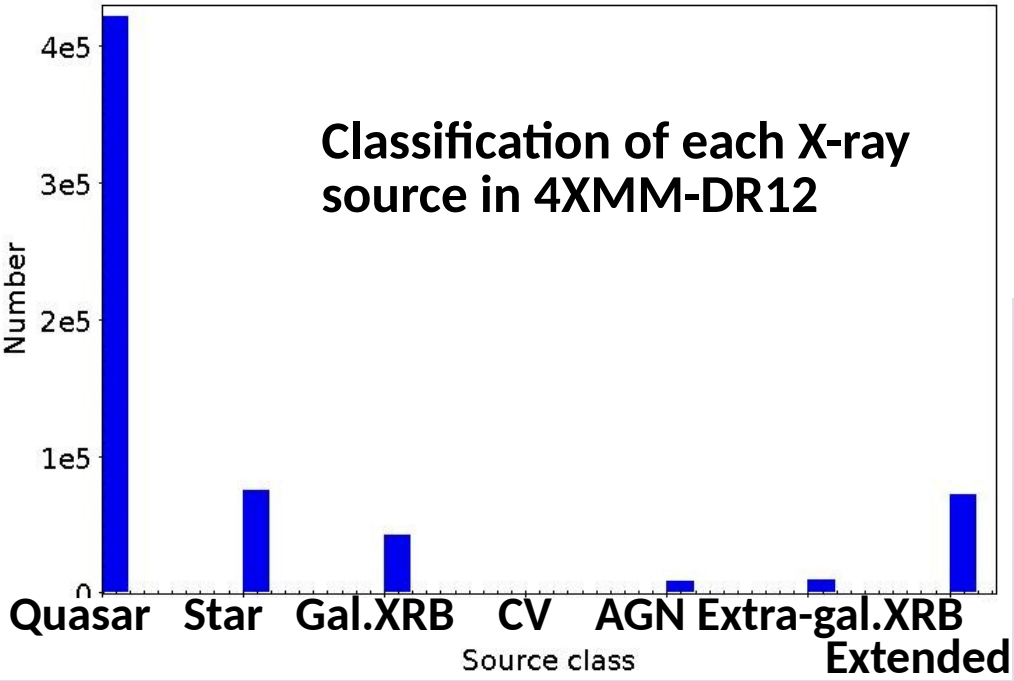
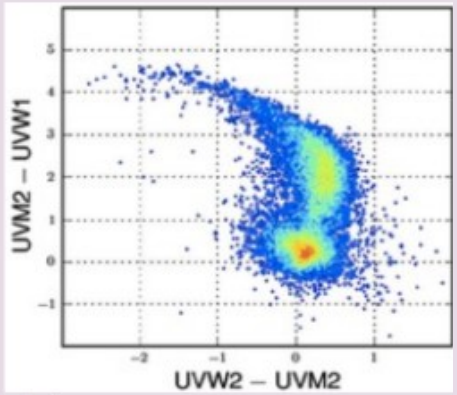
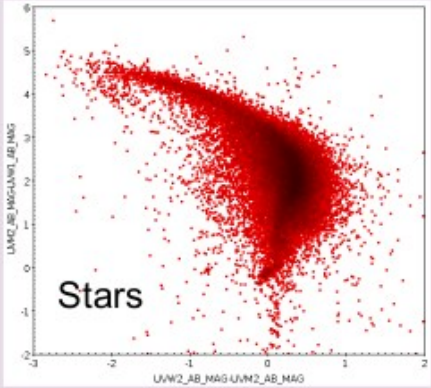
# CLASSIFICATIONS

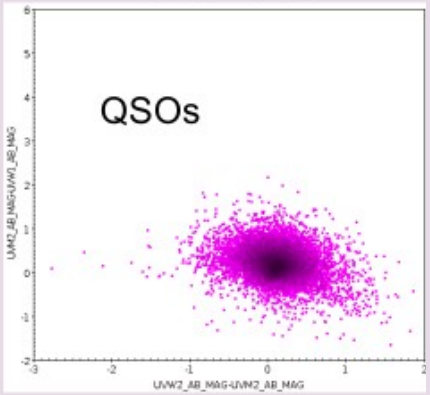


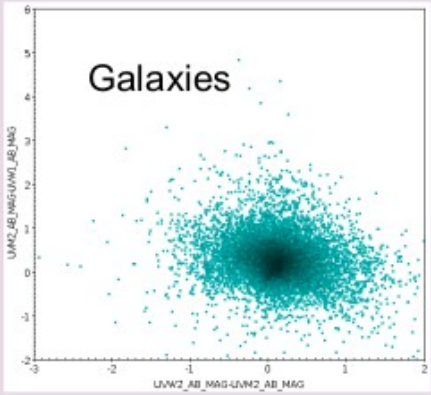

Tranin et al. (2022 & 2023)

Classification of OM sources




- Revisited naive Bayes classification
- Based on 15 criteria pertaining to spatial, spectral, and timing properties + multiwavelength counterparts
- Outlier measure used to identify objects of other nature



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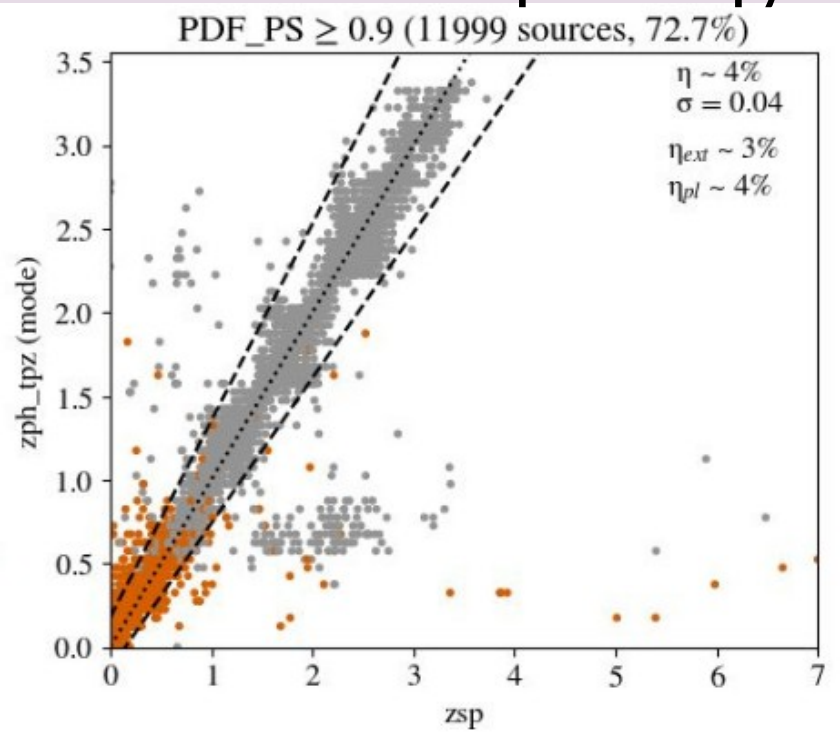
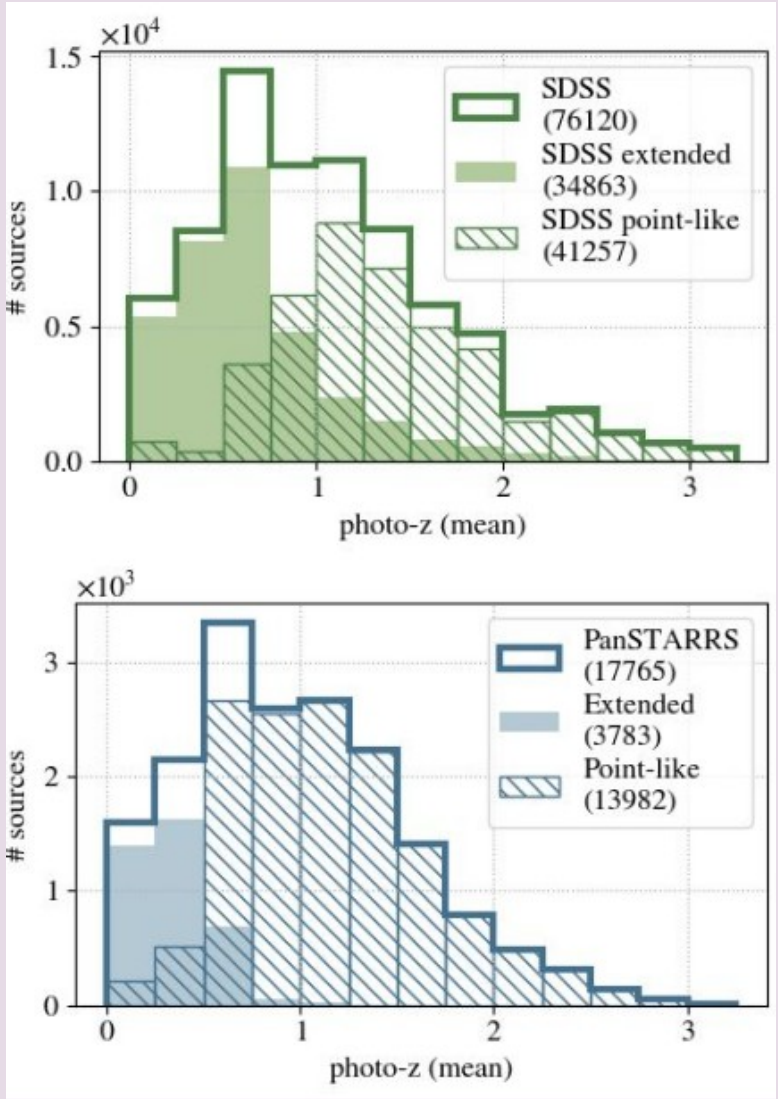
# PHOTOMETRIC REDSHIFTS

- Will provide photometric redshifts for all extra-galactic sources
- Pipeline based on MLZ-TPZ (Carrasco Kind & Brunner, 2013)
- SDSS, PanSTARRS & DES photometry
- Compared to redshifts from spectroscopy





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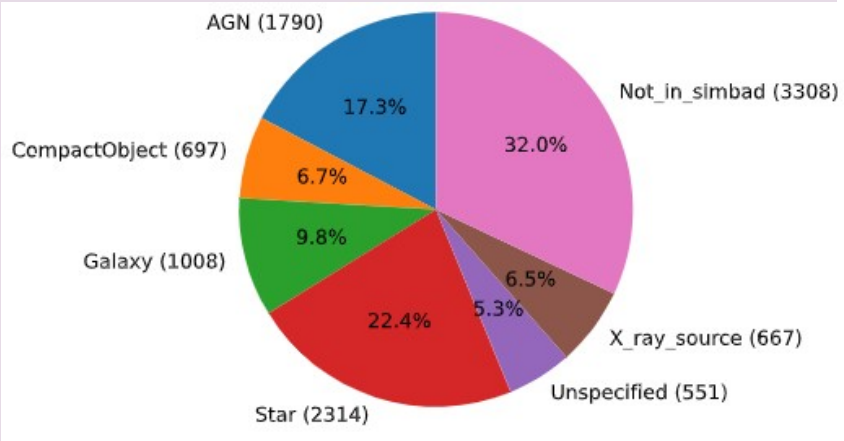
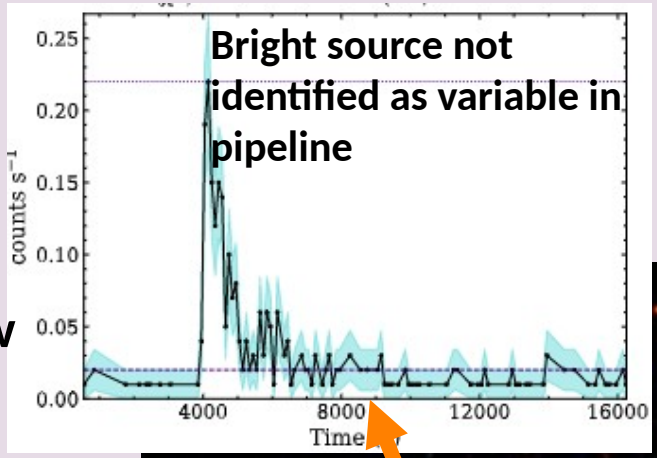
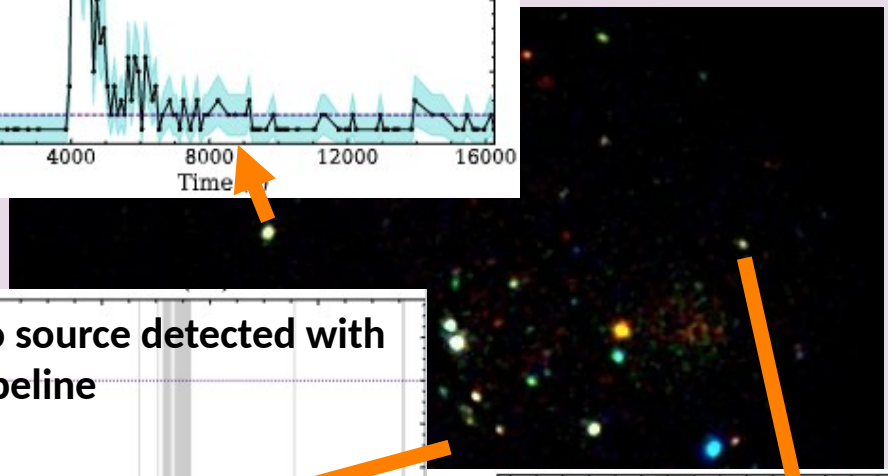
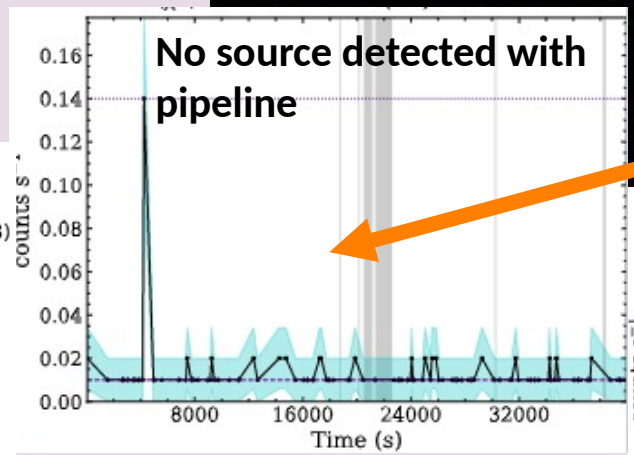
# SHORT, FAINT BURSTING TRANSIENTS

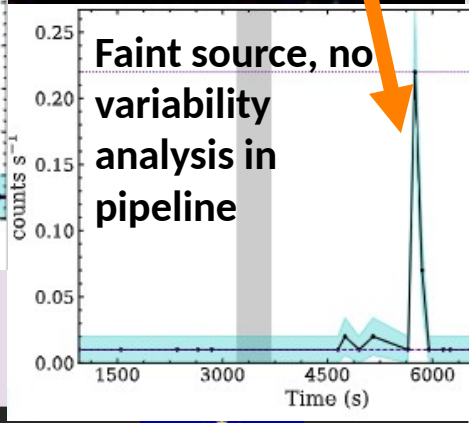
- Code developed to find very rapid, faint transients
- Good at finding variability in sources where no lightcurve extracted (thus no variability evaluation – 64% of 4XMM)
- 7529 previously detected sources now shown to be variable
- A few tens of new sources discovered (neutron star candidates, stars, ...)
- Gupta et al. (to be sub.), Pastor Marazuela et al. (2020)







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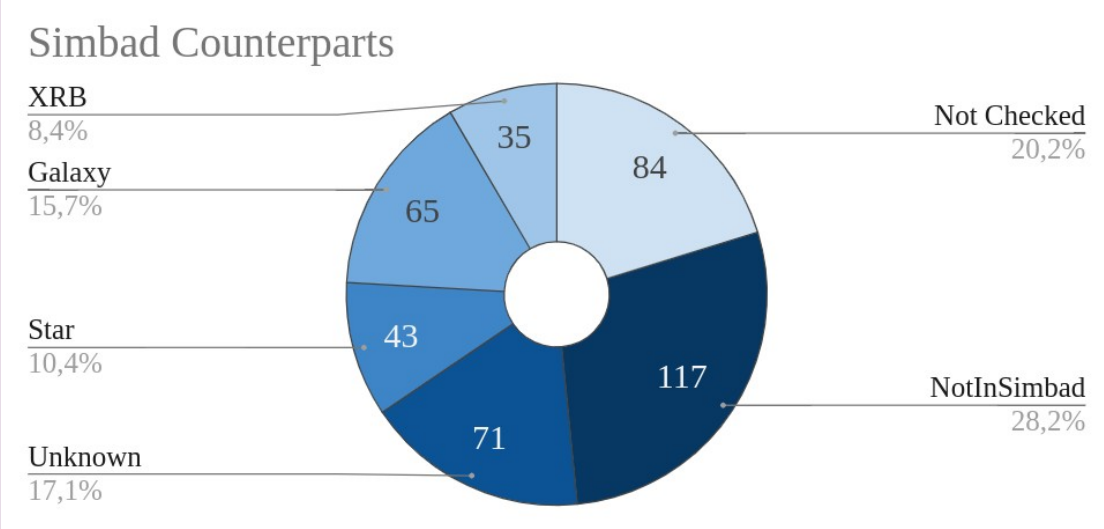
# LONG-TERM TRANSIENTS & ALERTS

- Many objects vary on months to years timescales (supernovae, ULXs, TDEs, changing look AGN, gravitational wave events, X-ray & CV outbursts)
- Code developed to find long term transients (baseline 30 years)
- Uses 6 additional X-ray catalogues+XMM upper limits
- 0.5 long-term transients (> factor 5) detected per day
- Majority are unknown sources
- Of known objects, the majority are from galaxy centres (TDEs, Changing look, etc)
- Rare objects found (Quintin et al. 2021 & 2023)
- Quasi-real time alerts could be provided



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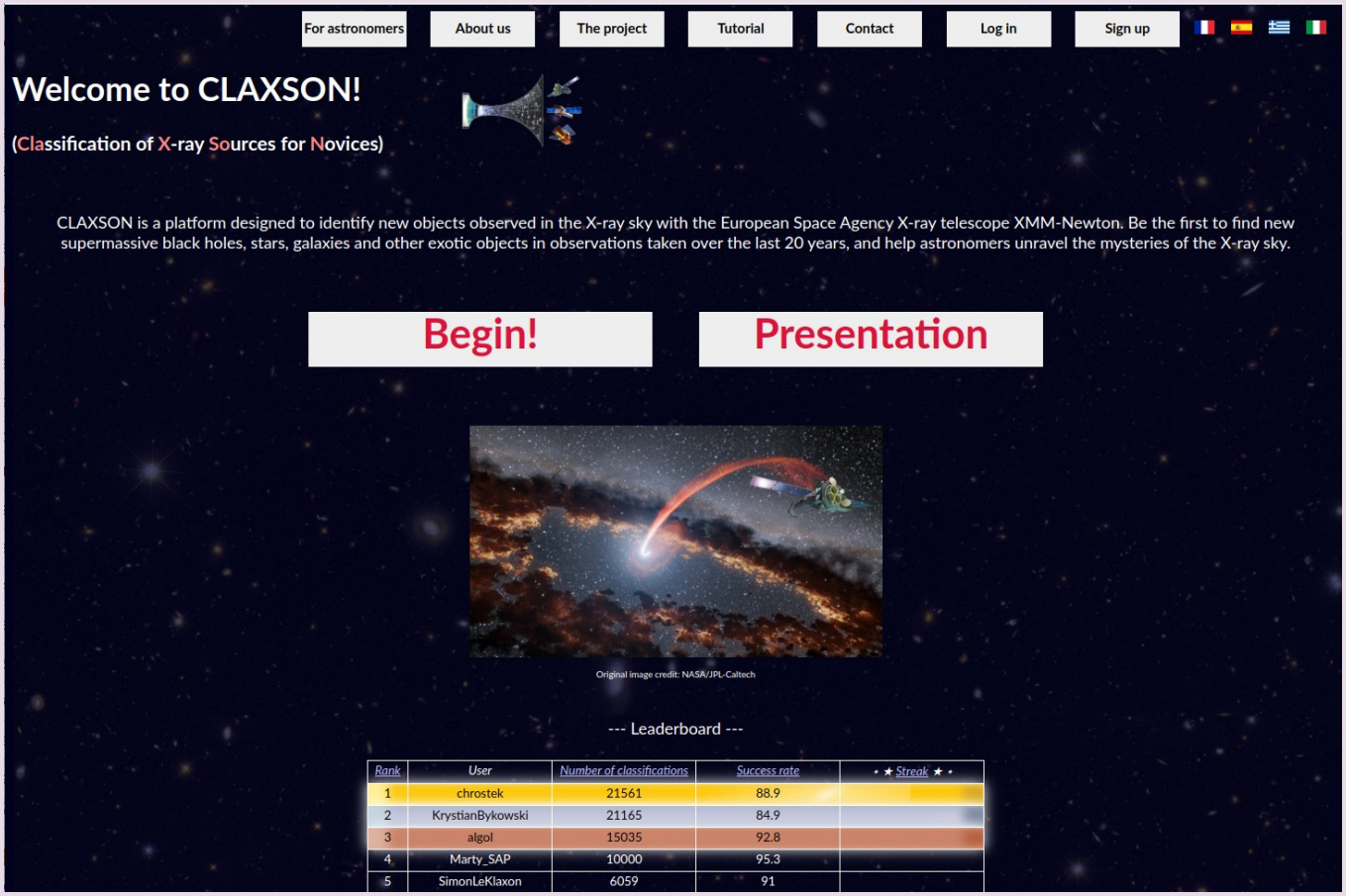
# COMMUNICATION




- Many talks and events at local, national and international level
- Numerous outreach activities in different participant's countries
- Papers published
- Follow us on

**Aim: use identified sample for better classification using Tranin et al. (2022) method**
**Teaches about objects and how to identify them**
**Uses wisdom of crowds (20 IDs to identify source)**
**http://xmm-ssc.irap.omp.eu/claxson/index.php?**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