
Transient science with XMM-Newton

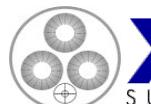
Natalie Webb

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Institut de Recherche en Astrophysique et Planétologie, Toulouse, France



& for the XMM-Newton Survey Science Centre (SSC) & XMM2ATHENA project



XMM-Newton
SURVEY SCIENCE CENTRE

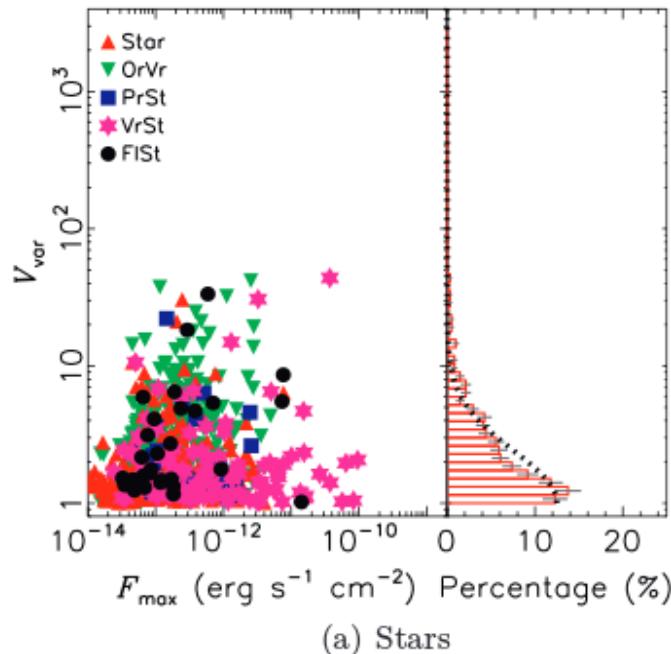


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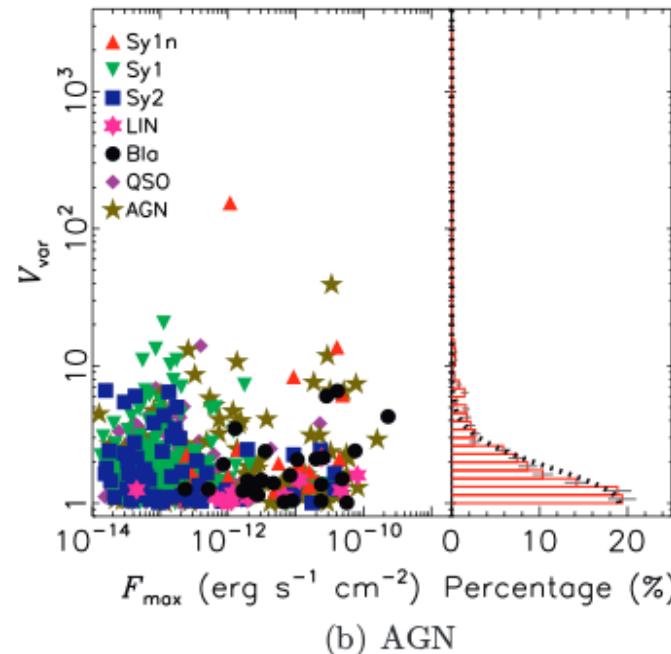
Low latency alerts & data analysis, Jan. 2022

X-ray transients

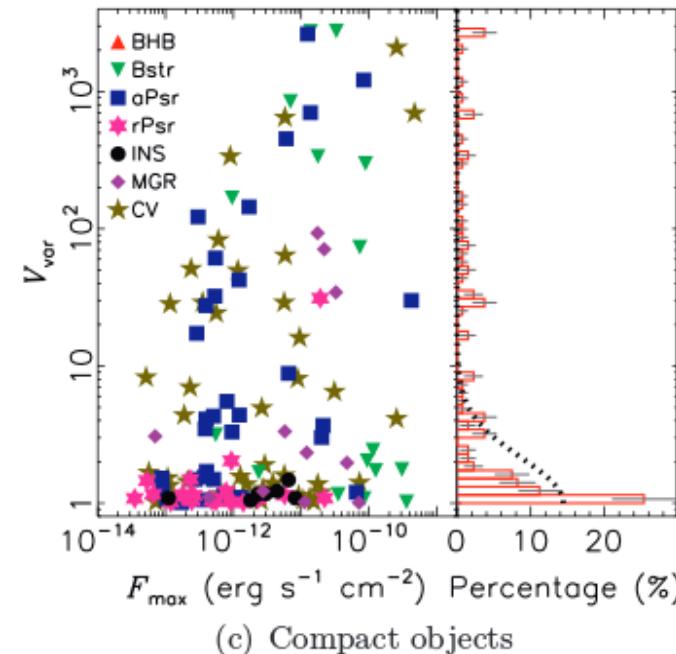
Investigation of 4330 point-like, good signal to noise sources with multiple pointings in 2XMM (Lin, Webb & Barret 2012)



(a) Stars



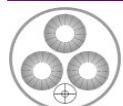
(b) AGN



(c) Compact objects

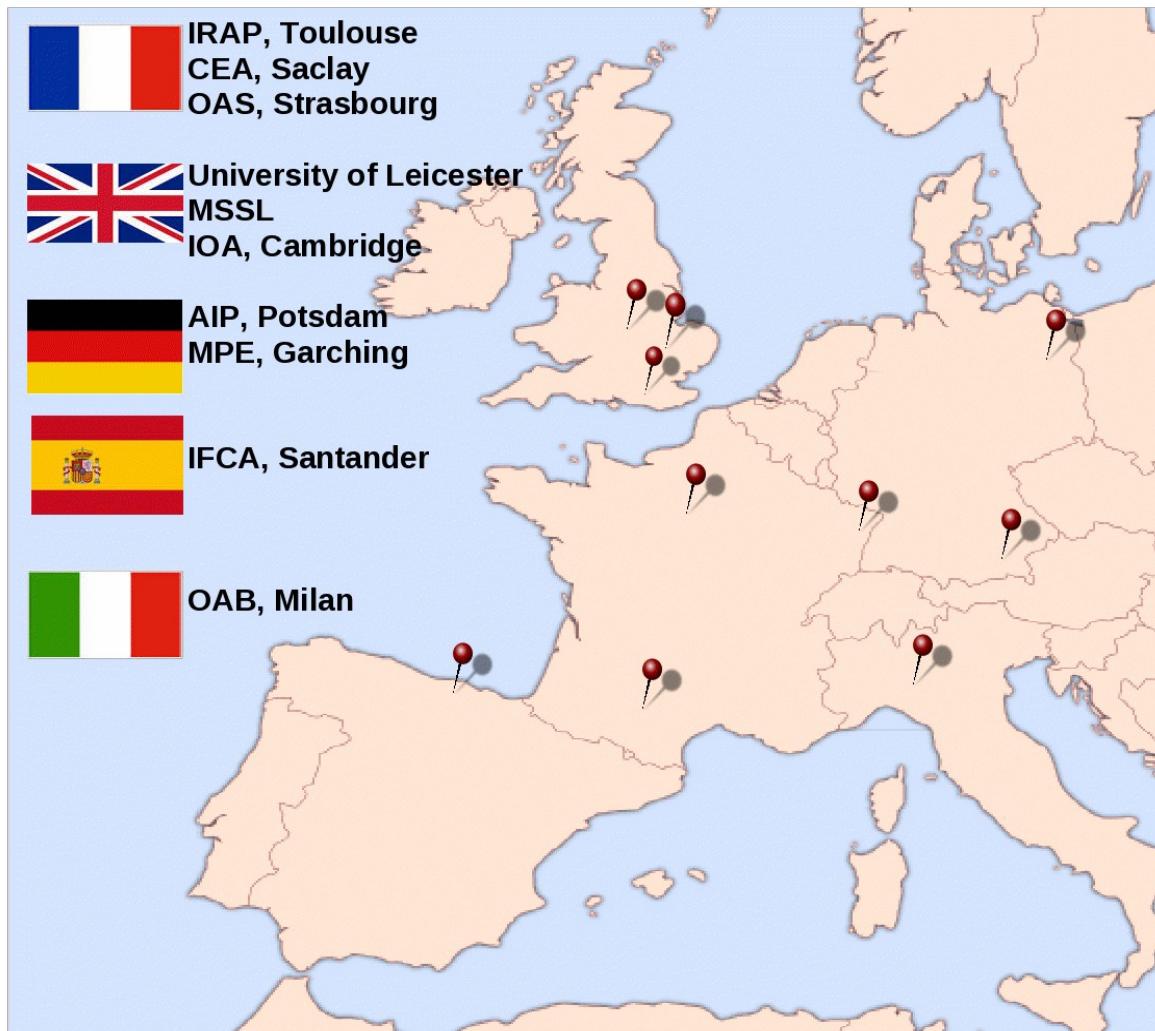
Transient X-ray sources are :

- gravitational wave events
- tidal disruption events
- X-ray binary outbursts
- γ -ray bursts
- supernovae
- magnetars
- cataclysmic variables
-



XMM-Newton Survey Science Centre (SSC)

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



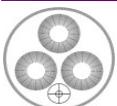
Responsibilities :

Development of science analysis system (SAS)

Pipeline processing of all XMM-Newton observations.

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

Compilation of the Serendipitous Source Catalogue.



4XMM-DR11



3 February 2000 – 17 December 2020

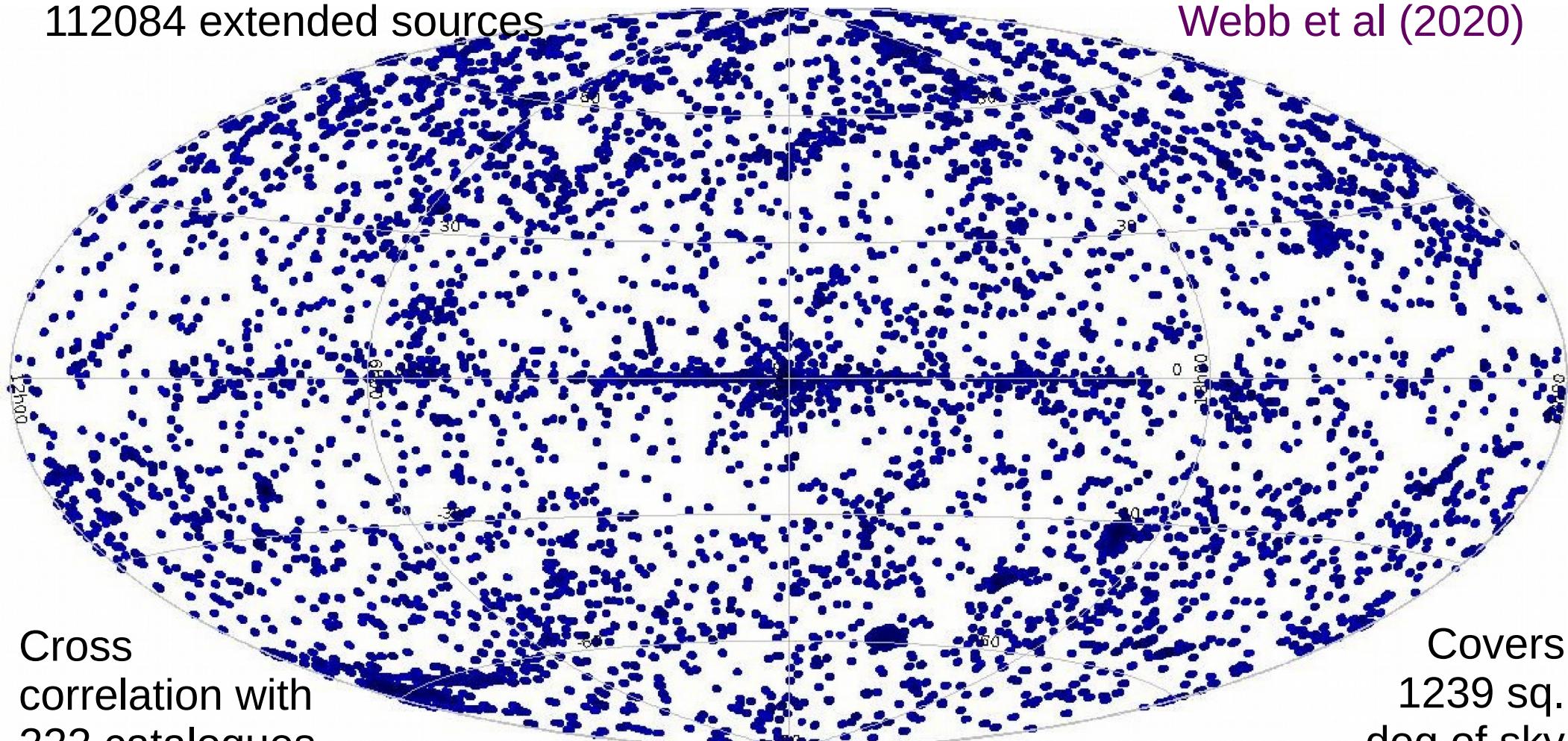
Released : 18th August 2021

895415 detections, 602543 unique sources - detected up to 80 times

319292 (36%) sources with spectra and lightcurves

112084 extended sources

Webb et al (2020)



Cross
correlation with
222 catalogues

Covers
1239 sq.
deg of sky



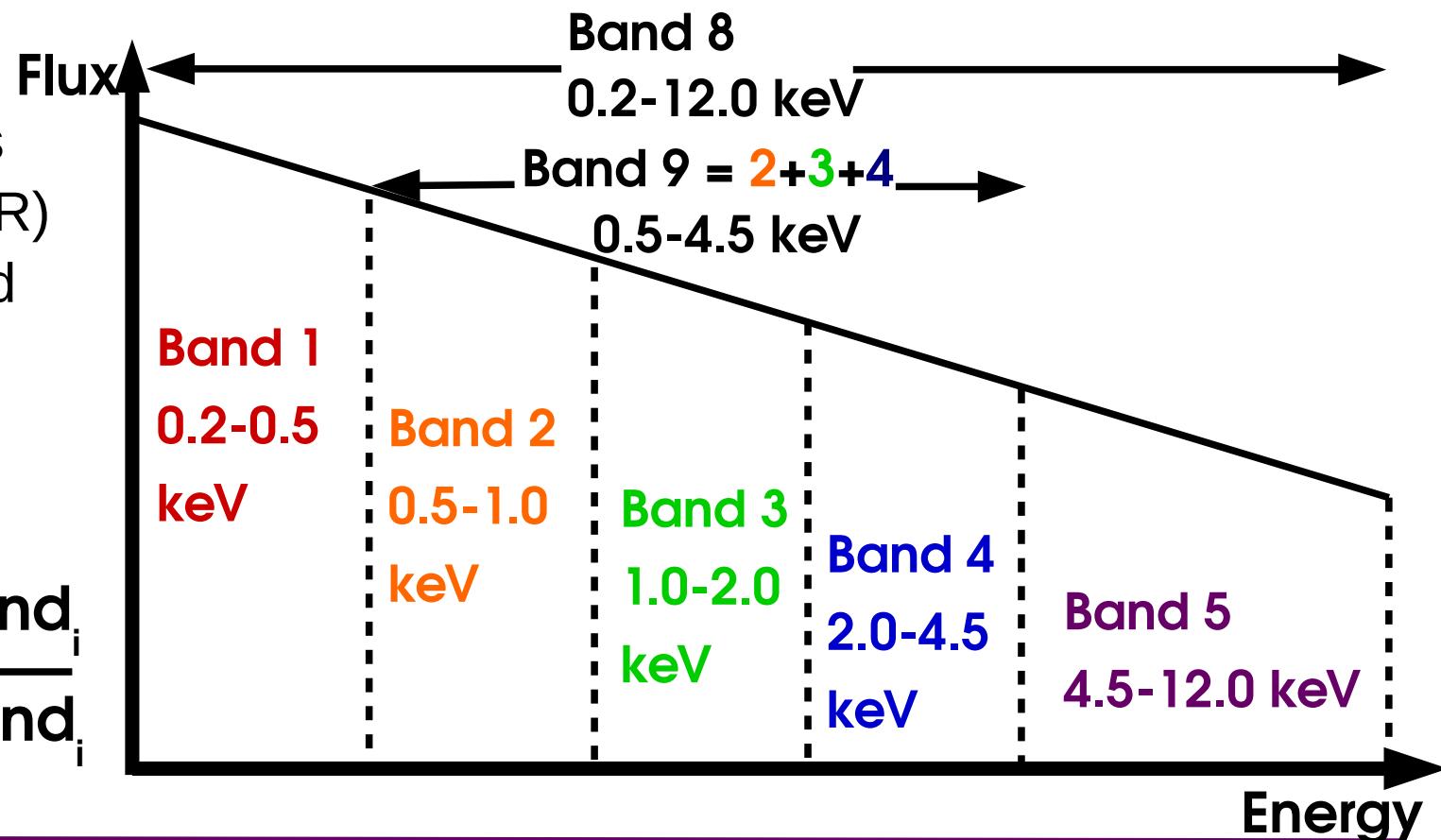
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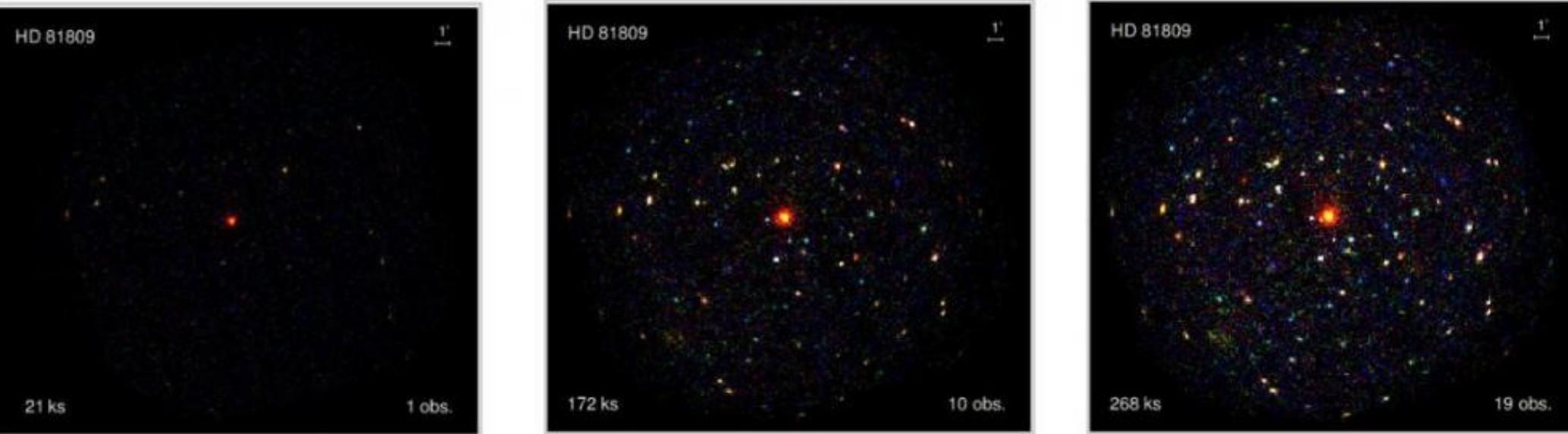
336 columns of information including :

- Identifiers/coordinates
- Observation date/time and observing mode
- Exposure
- /background info
- Extent
- Counts/fluxes/rates
- Hardness ratios (HR)
- Maximum likelihood
- Quality flags
- Variability

$$HR_i = \frac{\text{Band}_{i+1} - \text{Band}_i}{\text{Band}_{i+1} + \text{Band}_i}$$

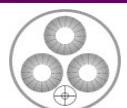


4XMM-DR11s



- 1475 stacks
- 8292 observations
- 335 812 sources
- ~20% new sources with respect to 4XMM-DR11
- Long term variability

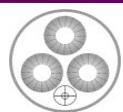
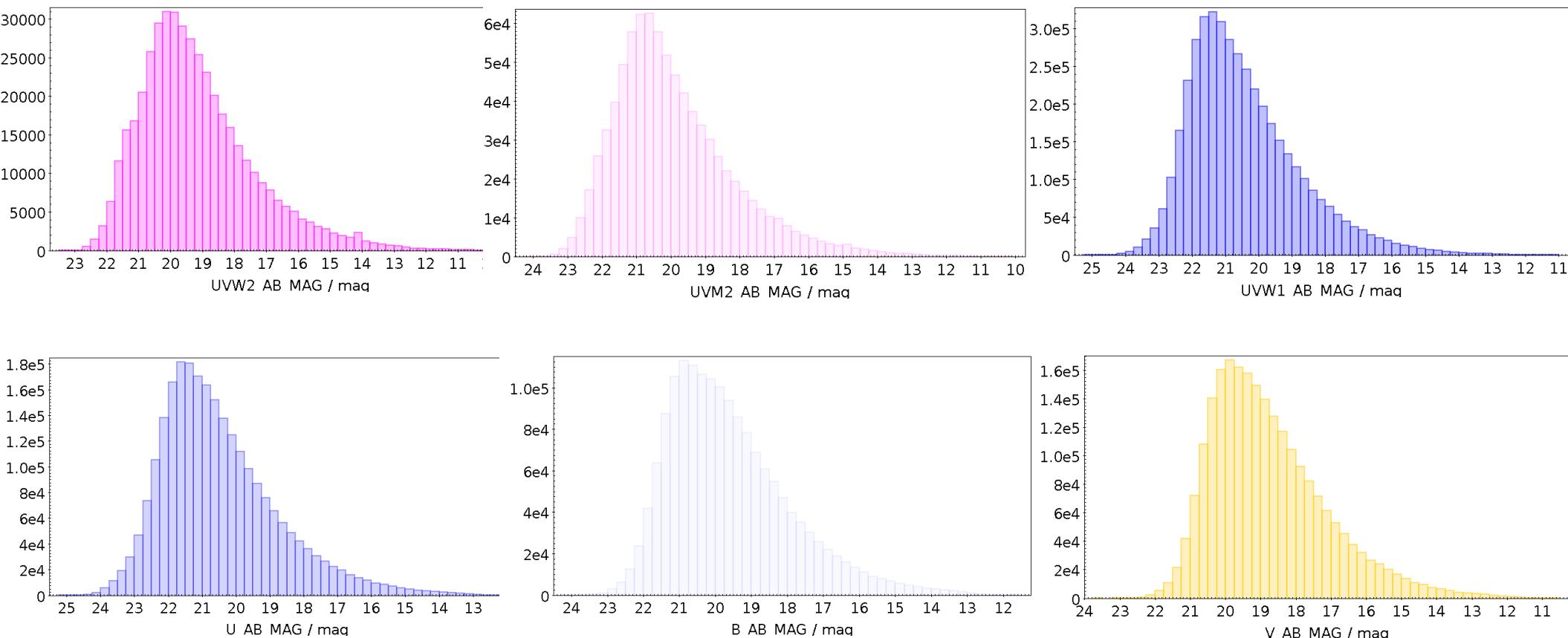
Traulsen et al., 2020



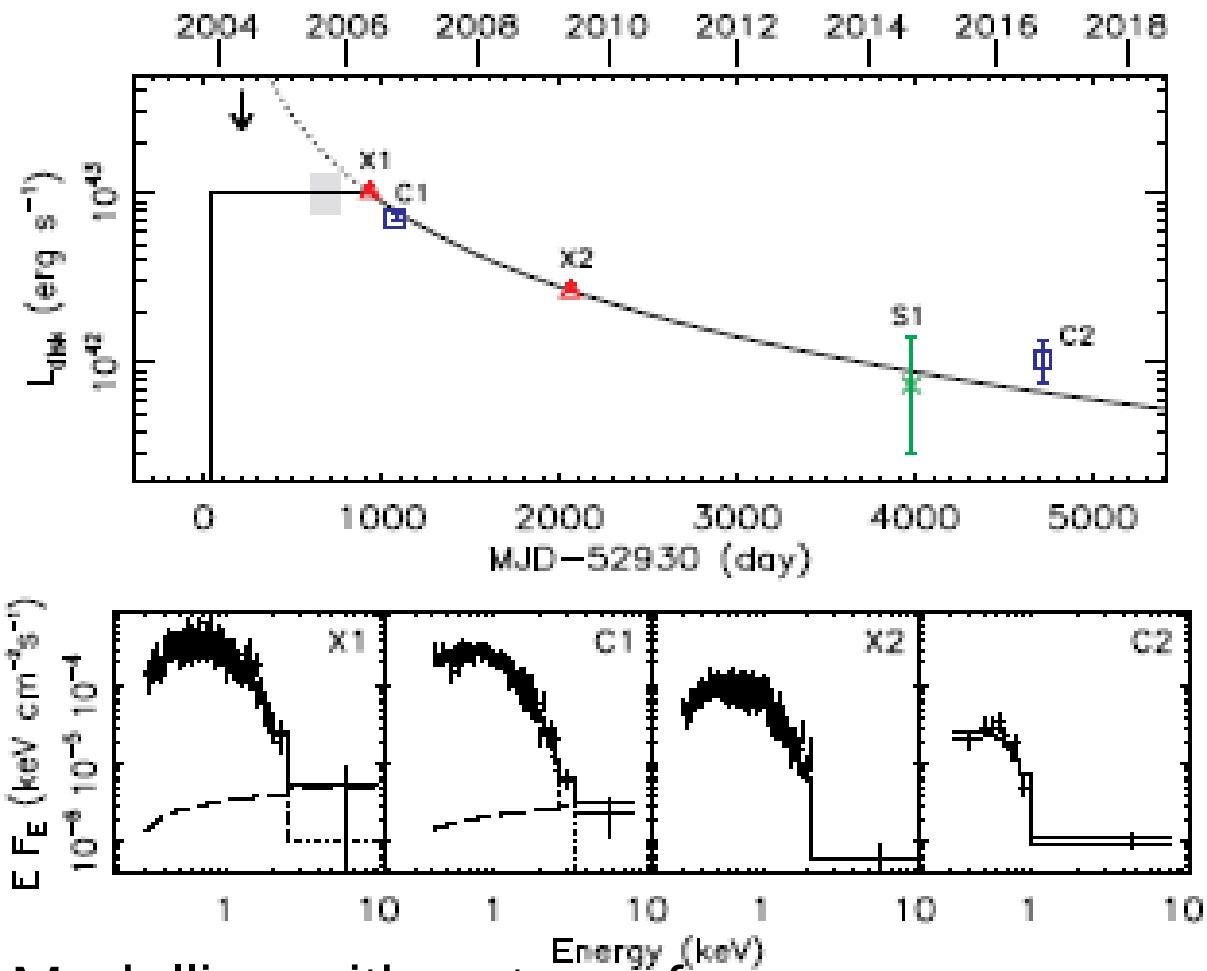
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SUSS-5.0

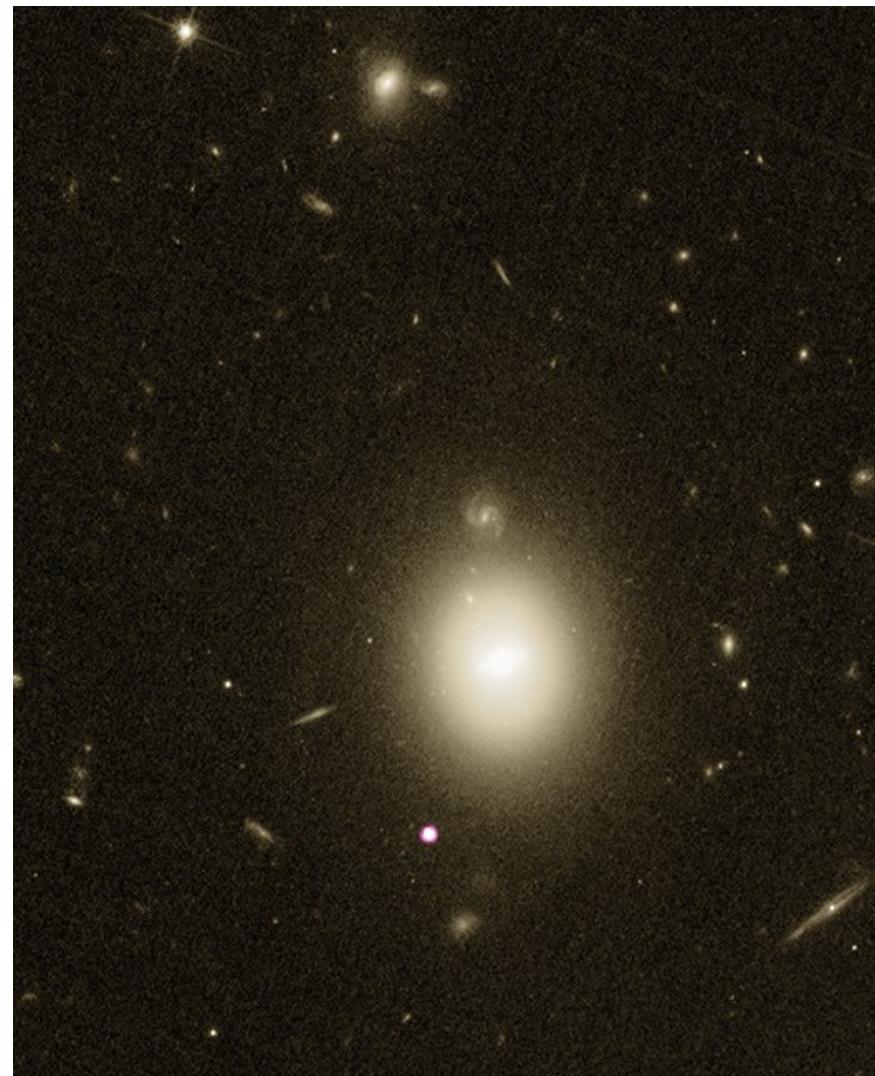
- ◆ 10th December 2020
- ◆ 10628 observations
- ◆ 8863922 detections, 5965434 sources, 1120754 with multiple entries
- ◆ 114 columns



Low mass tidal disruption events



Lin, ..., NW, et al. Nature Astronomy (2018)



Modelling with *optxagnf*:

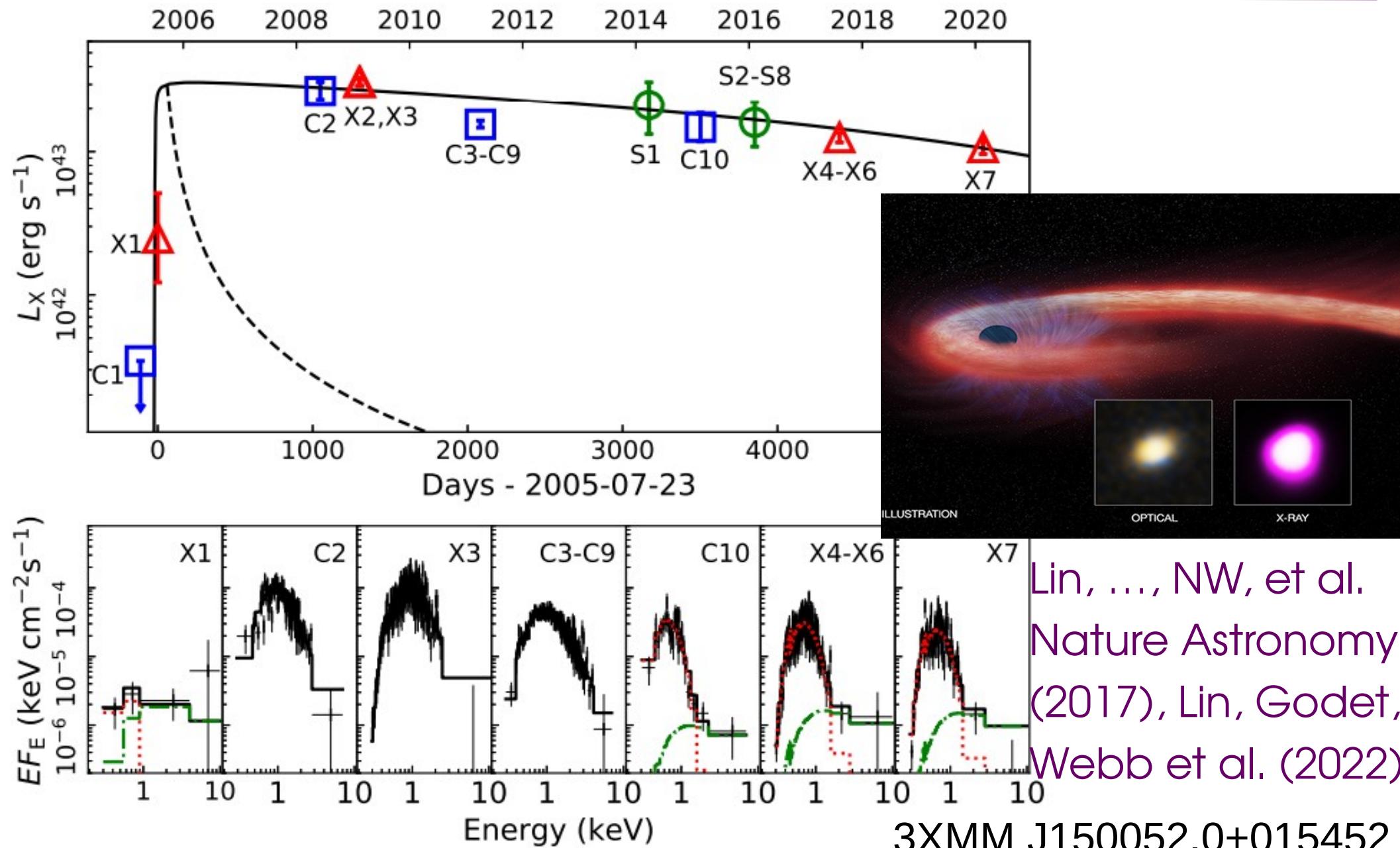
$$0.92 < a_* \text{ (spin)} < 1.0 \quad (D_L = 247 \text{ Mpc})$$

$$5.3 \times 10^4 M_\odot < \text{mass} < 1.2 \times 10^5 M_\odot$$

$$7.1 \times 10^4 M_\odot \text{ (Chen \& Shen 2018)}$$



Extreme tidal disruption event



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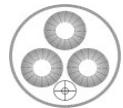
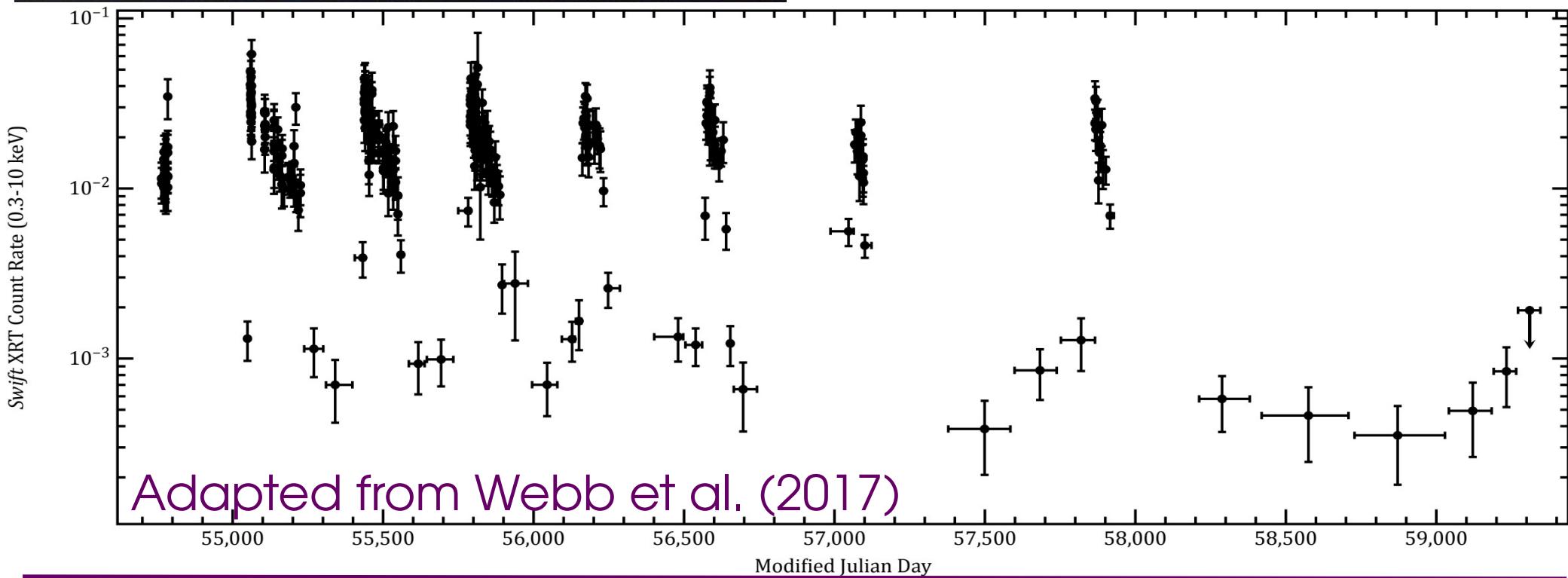
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A very bright ULX (HLX-1)



HLX-1 associated with ESO 243-49 at 95 Mpc (Farrell, NW et al. 2009, Nature; Wiersema, Farrell, NW et al. 2010)

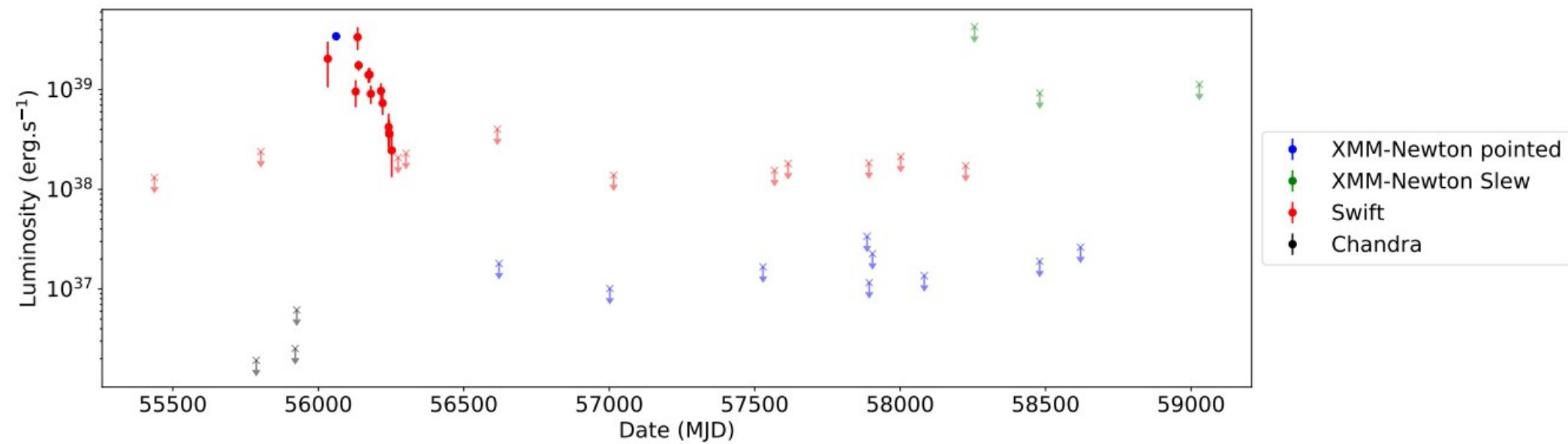
$L_{x(\text{max})} = 1.2 \times 10^{42} \text{ erg s}^{-1}$ (Godet, Barret, NW et al. 2009)



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A second neutron star ULX in NGC 7793



Quintin, Webb et al. (2021)

A new pulsating (0.397 s, 3.4 σ) ULX in NGC 7793 (two confirmed in galaxy)

Two other ULXs also highly transient – may also contain neutron stars



Transient Alerts

Plan to provide transient alerts to community, when PI is in agreement

Developed task to be inserted into pipeline

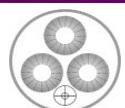
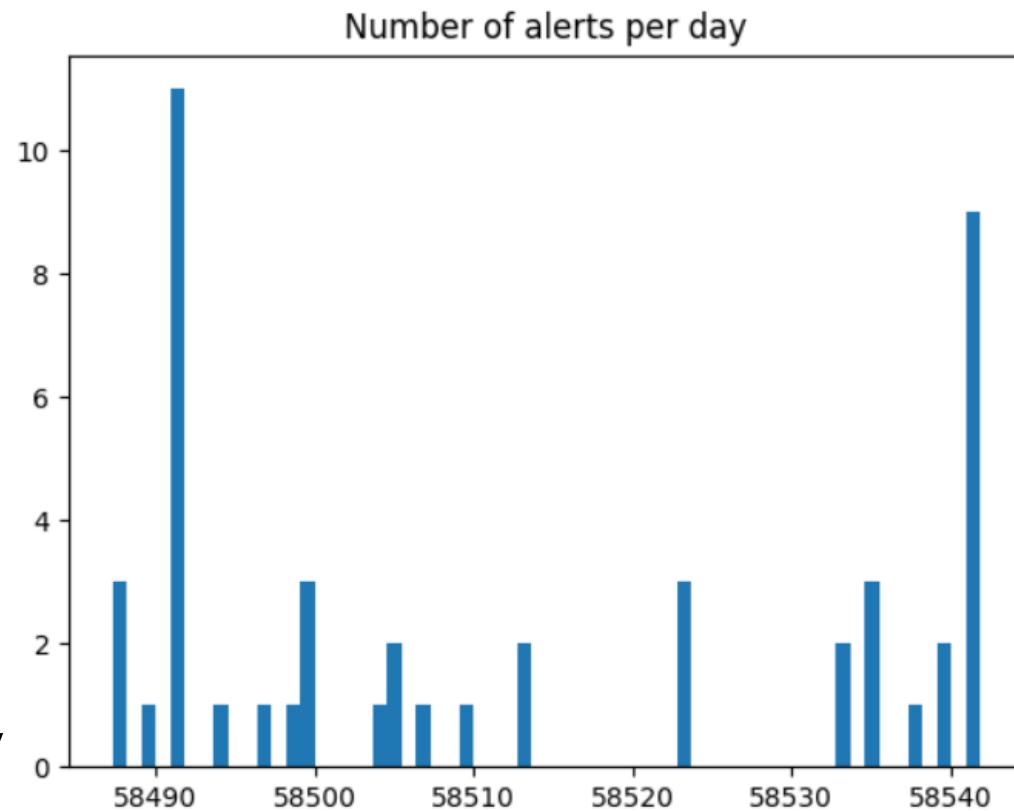
>30 yrs of XMM-Newton, Swift, Chandra, ROSAT etc data + upper limits

Also exploits the OM data

Test on two months of DR10 data to determine alert rate

Chosen (example) variability of factor 3 (data bars 90%)

Consider sources rising, falling, generally variable + short term variability

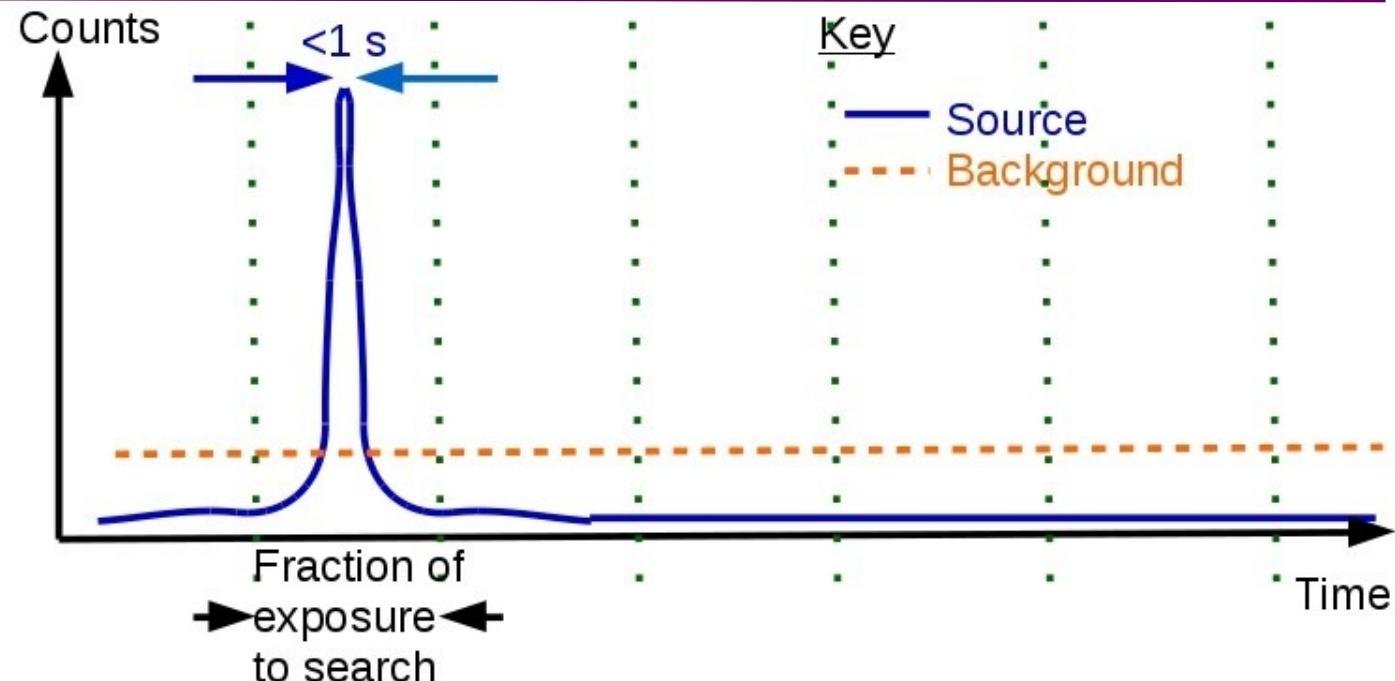


Transient Alerts

4XMM time
resolution poor

Faint burst drowned
out by background in
long observation

Require new way to find
short bursts



Pastor Marazuela, Webb et al (2020) devised new methodology to search for sudden bursts and searched whole field of view in short time windows

5751 pn full frame obs. searched, 2536 rapidly varying sources discovered

4 new extra-galactic type I X-ray bursts discovered, only 2 previously known

Recent improvements include using MOS data (confirm bursts) and other observing modes to search all 15000 observations in DR11





1st April 2021 – 31st March 2024

- ◆ Classified X-ray sources (Tranin et al. 2021)
- ◆ Improved upper limit server
- ◆ Identification + classification of OM sources
- ◆ Multi-wavelength/messenger counterparts to X-ray sources
- ◆ Improved source detection in the stacked catalogue
- ◆ 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 (+alerts)
- ◆ New outreach material
- ◆ A single 5XMM catalogue with all the above information

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

Future & Catalogue Access

New incremental version planned for 2022 (DR12)

Alerts to the community of variable sources in nearly real time

Other XMM2ATHENA products coming



Catalogue access: XMM-SSC webpages :<http://xmmsc.irap.omp.eu>

But also at :

XSA at ESA's XMM-Newton SOC : <http://xmm.esac.esa.int/xsa/>

XCAT-DB at : <http://xcatdb.unistra.fr/4xmmdr11>

The IRAP catalogue server XSA : <http://xmm-catalog.irap.omp.eu/>

Browse at HEASARC NASA GSFC :

<http://heasarc.gsfc.nasa.gov/db-perl/W3Browse/w3browse.pl>

ESA sky : <http://sky.esa.int/>

And complimentary optical/UV catalogue using OM data (8.9 million detections, 6 million sources, 6 bands down to 23-25 mag.)

HLX-1 – a failed tidal disruption event

Orbital evolution of a companion, polytrope $n=1.5$, $\Gamma=5/3$ and initial periapsis separation from the IMBH (relative to the tidal radius) of 2.3 (red), 2.4 (magenta), 2.5 (blue), 2.7 (black), $\lambda = R/0.01R_\odot$ and $M_4 = M_{\text{BH}}/10^4 M_\odot$

