LSXPS: The Living Swift-XRT Point Source catalogue

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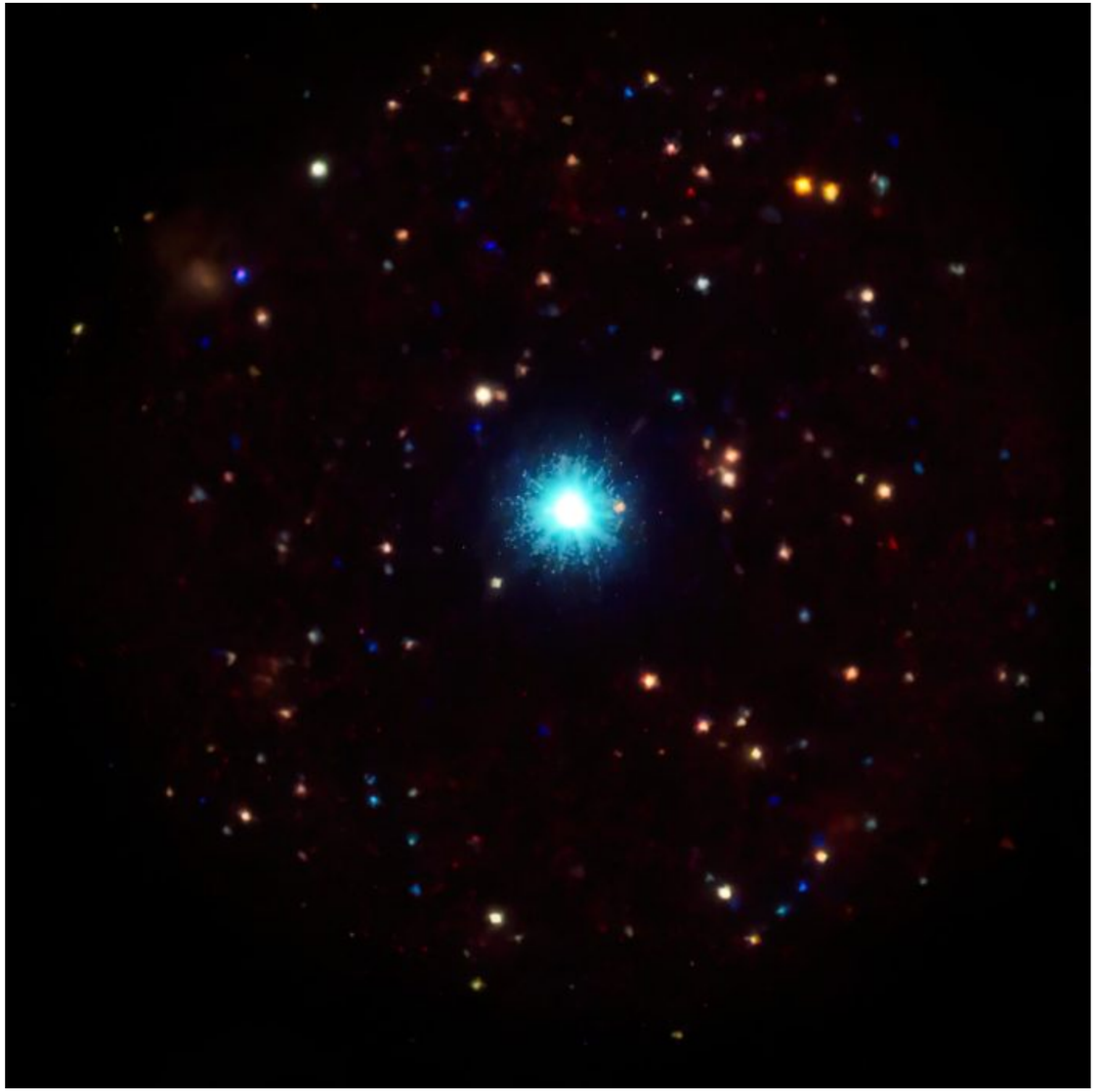
Why do we make catalogues?

- Because there's so much more serendipitous science that "planned" science.
- Serendipitous science is discovery space.
  - Including for transients — see for example the "Fast X-ray Transients" from Chandra data, or QPEs from XMM (and other) data.



Catalogues and transients.

- X-ray catalogues are always out of date!
  - 2SXPS: Published 2019 November; last dataset: 2018 August
    - 15 month delay.
  - 4XMM-DR13: Published 2023 June; last dataset: 2022 December
    - 6 month delay!
- Not so great for transient follow up…!
  - Of course, MAXI and eRosita have low-latency transient pipelines.
- Catalogues are also important references, e.g. for multi-messenger response.
  - **Upper limit calculators are really valuable.**

Swift-XRT Daily Statistics

- Daily average of ~45 fields/day in “PC mode”.
- Median exposure: ~900 s
  - Sensitivity: 2×10^{-13} erg cm^{-2} s^{-1}.
- How often do we expect to find transients?

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- Median exposure: ~900 s
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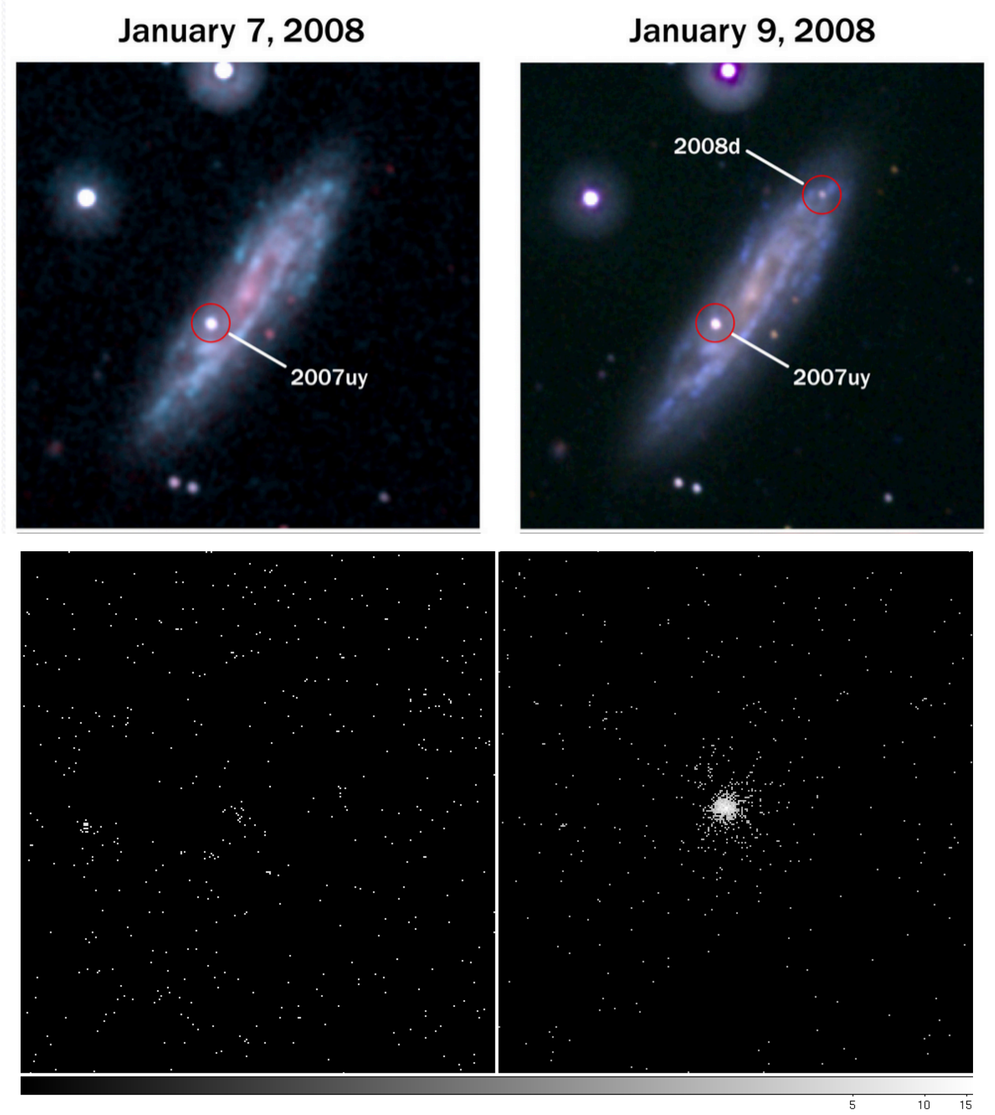
- How often do we expect to find transients? **We don’t know!**

Supernova 2009D

- January 7th, 2008, Swift-UVOT observed SN2007iy.
- January 9th, Swift-UVOT observed it again.
  - And also a new supernova…
  - … also seen in X-rays.



SN2008D.
Soderberg, Starling et al

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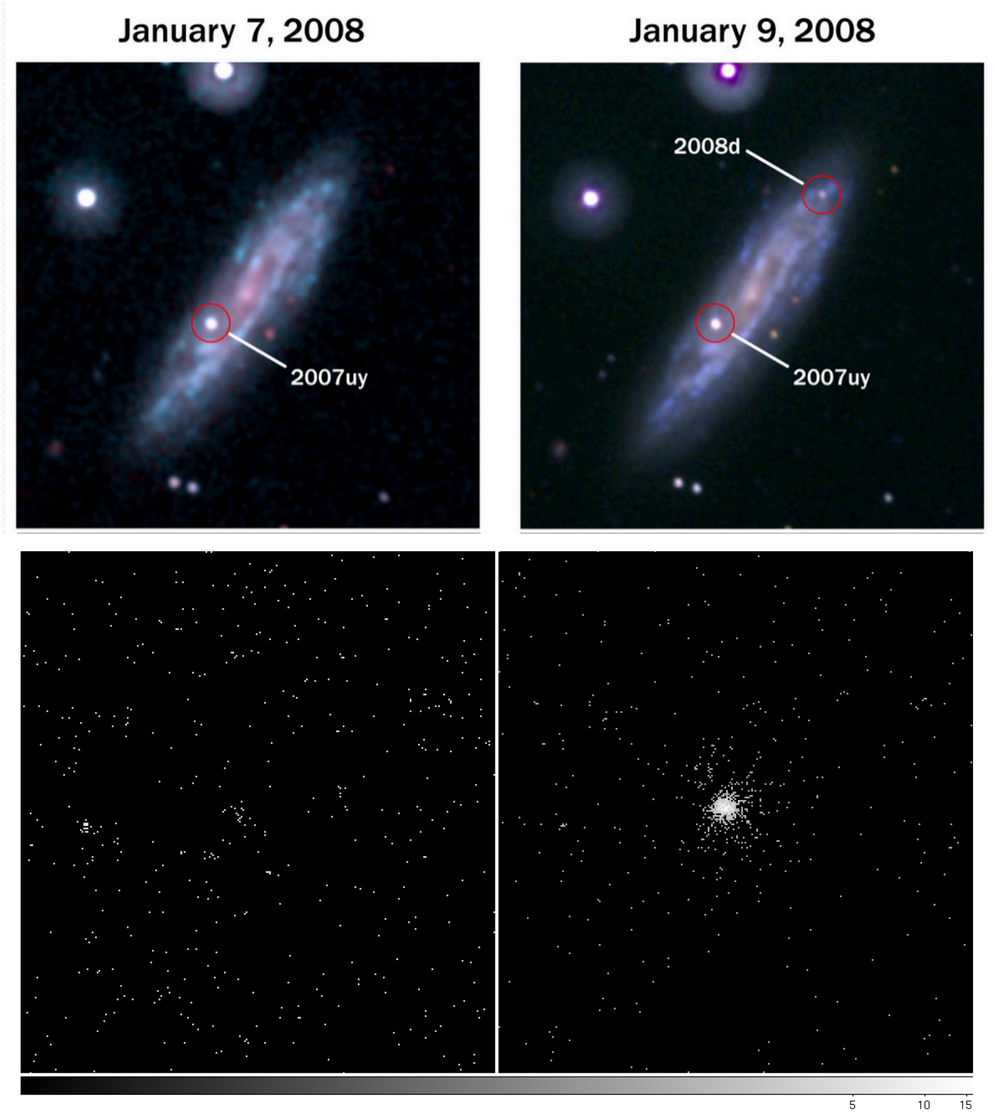

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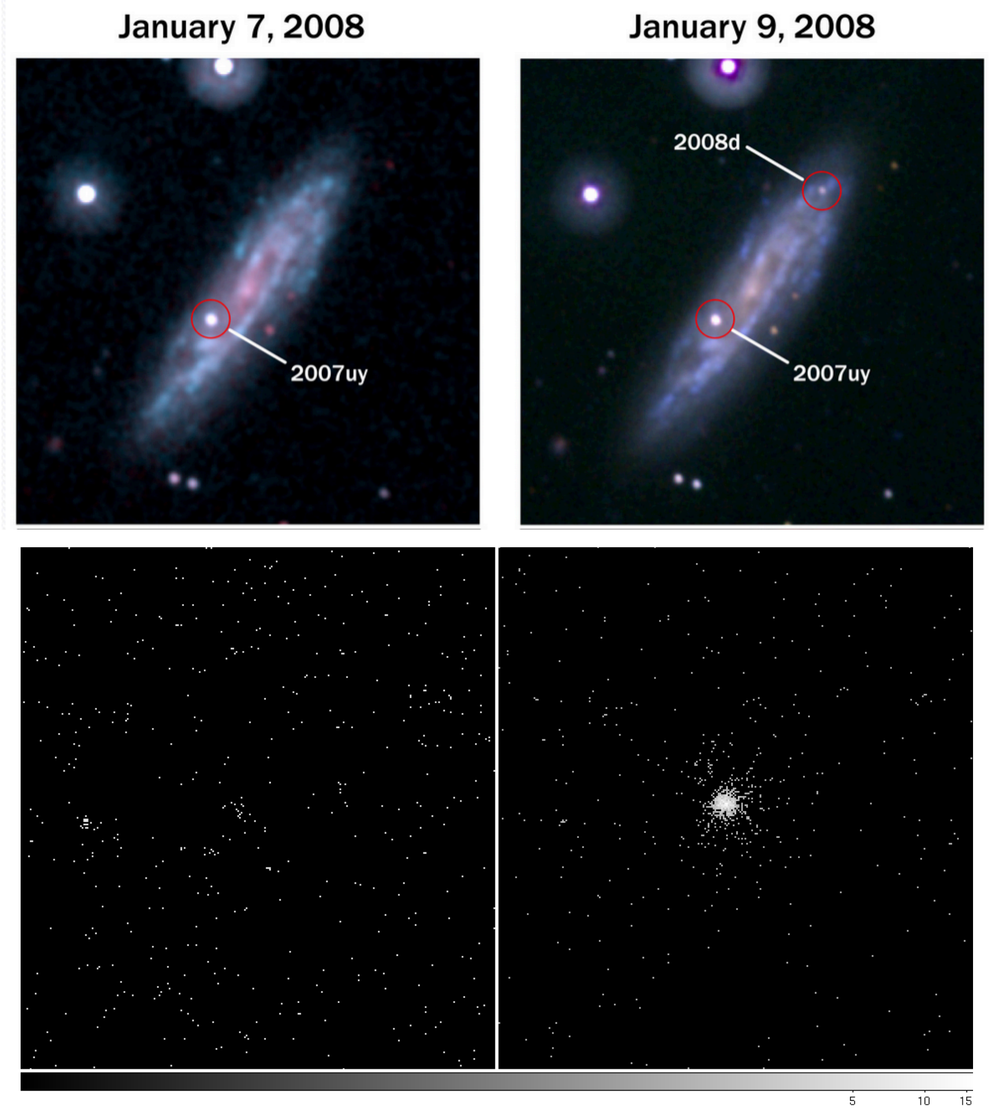
- What are the chances….?
  - We don't really know (quite low, probably).
    - But relying on the observer to spot it reduces them!



SN2008D.
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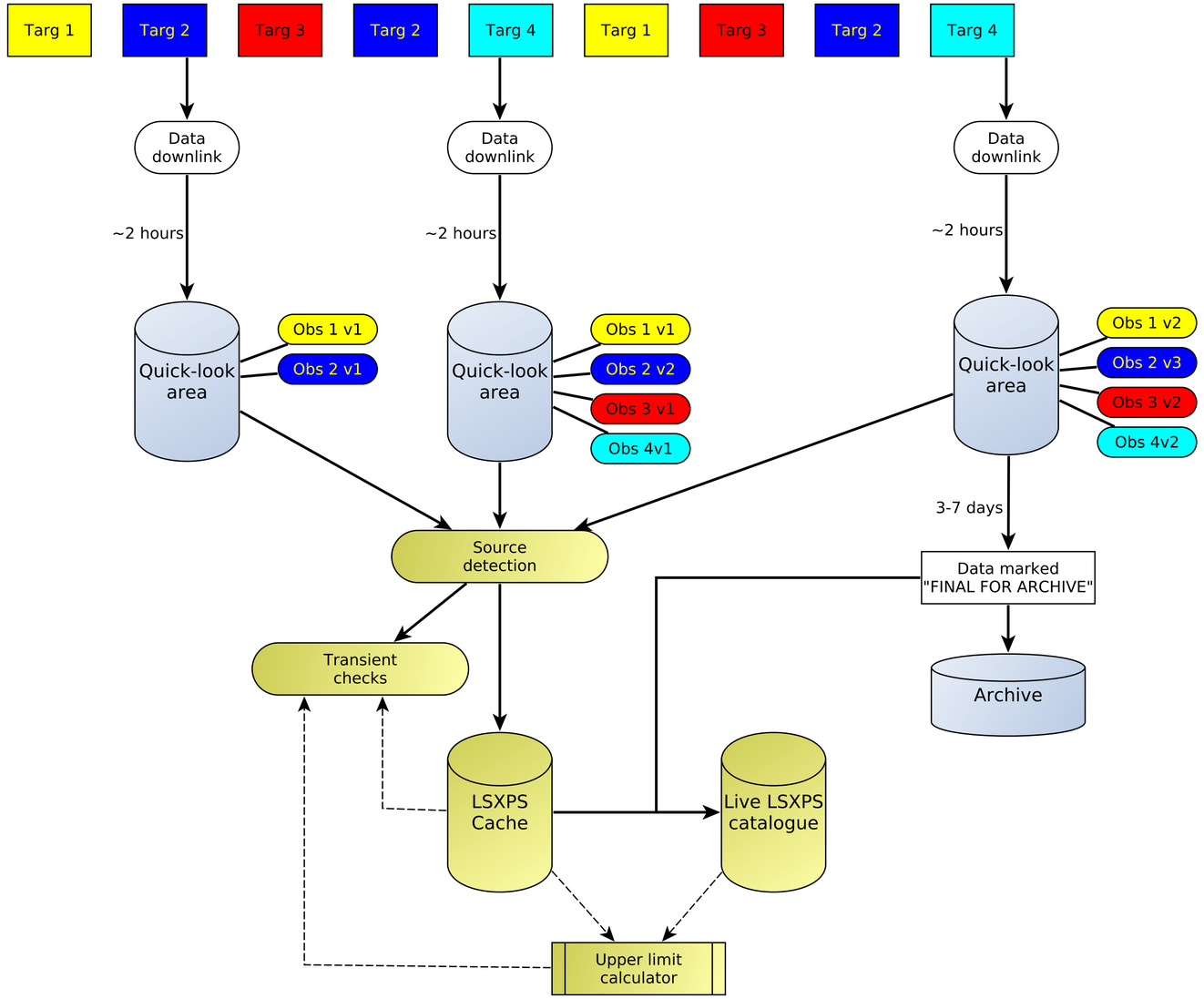
The “living” catalogue: concept

- *Swift* does multiple downlinks per day, but makes data available ASAP — “quicklook”.
- “quicklook” data can be incomplete, or even corrupt.
- LSXPS has a “cache” and “live” system.
  - Check for transients in the cache.
  - Only put “live” data in the catalogue.



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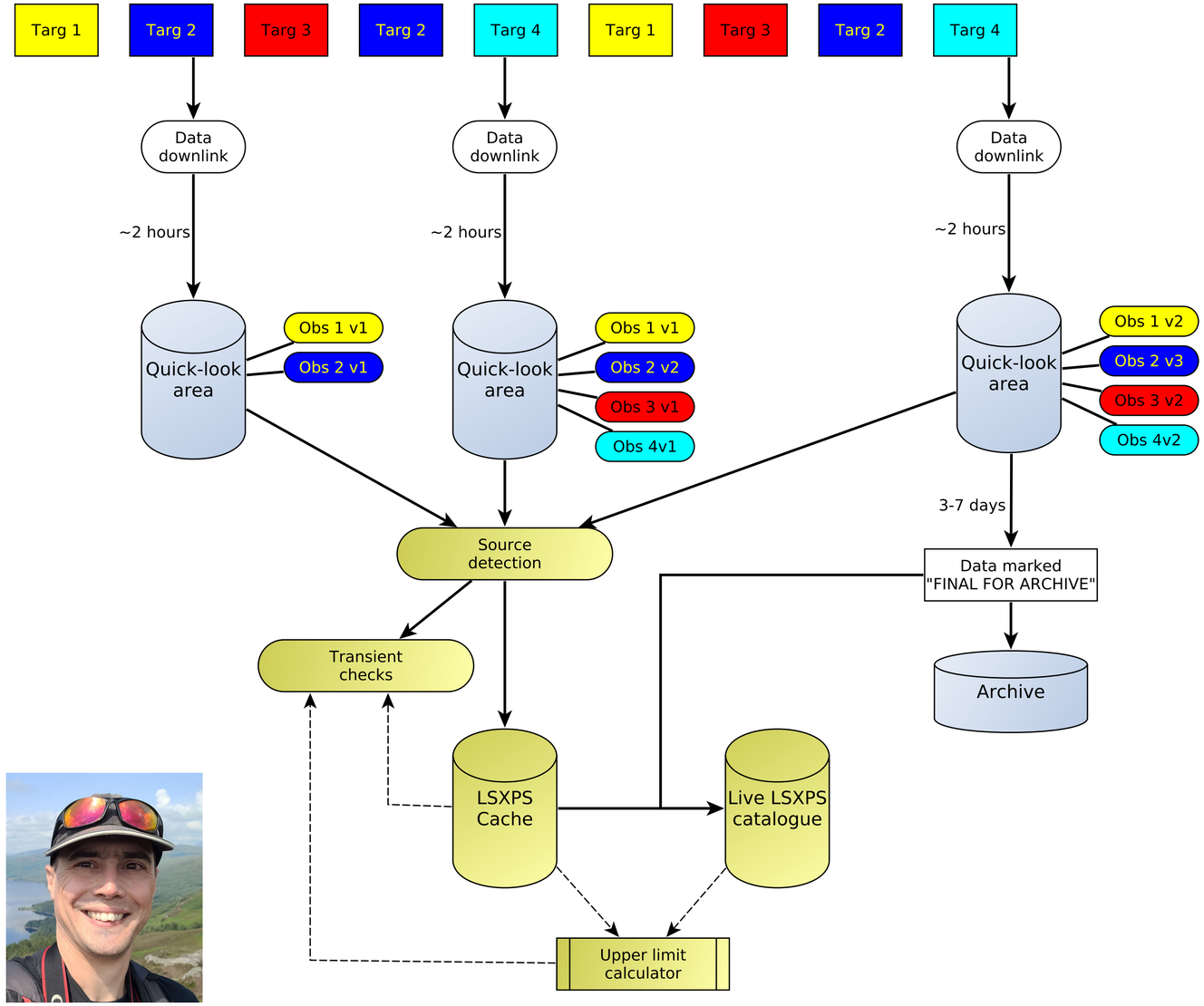
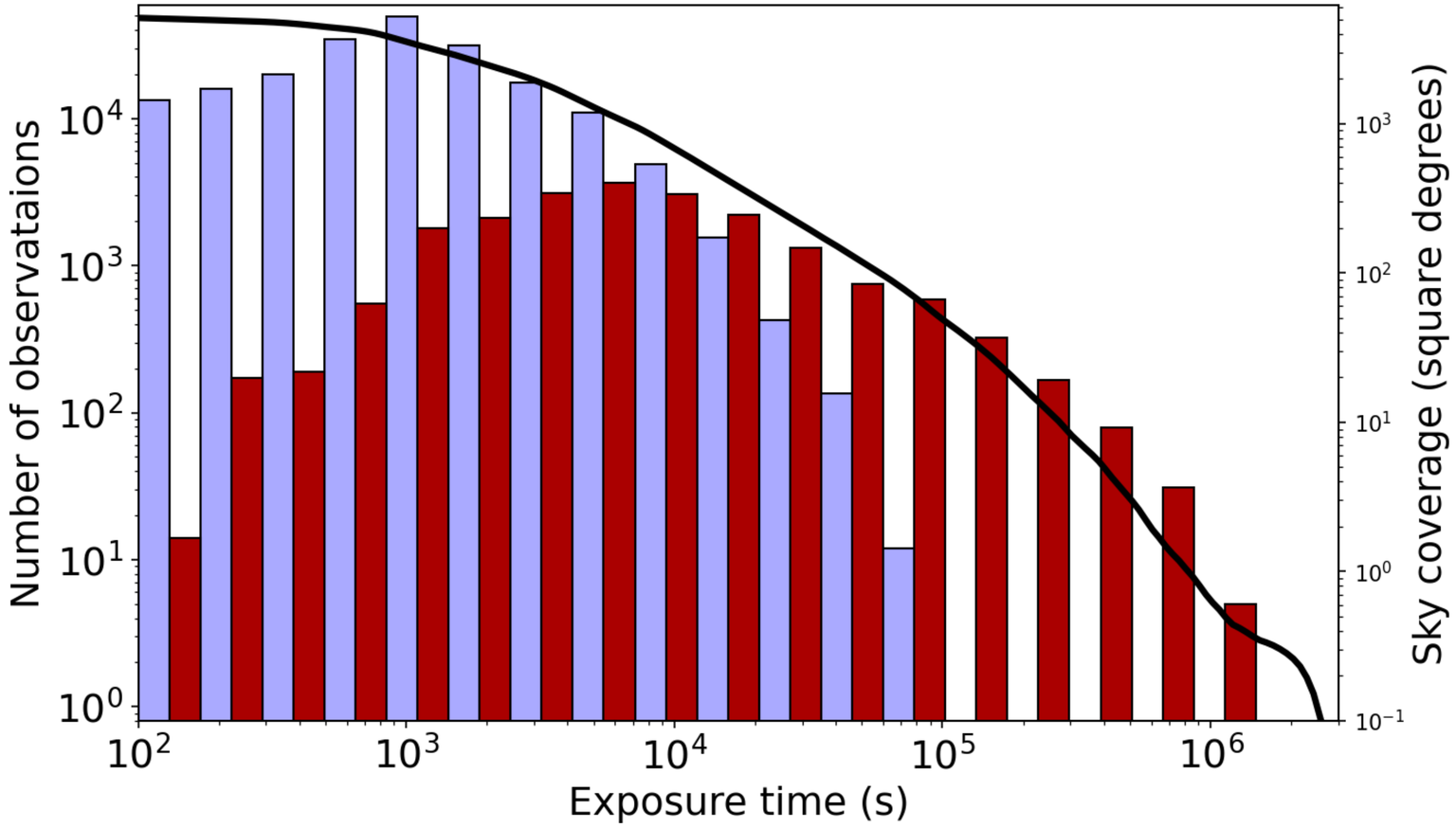


The team:

LSXPS: status



Stats as of Feb 26

~113 million photons

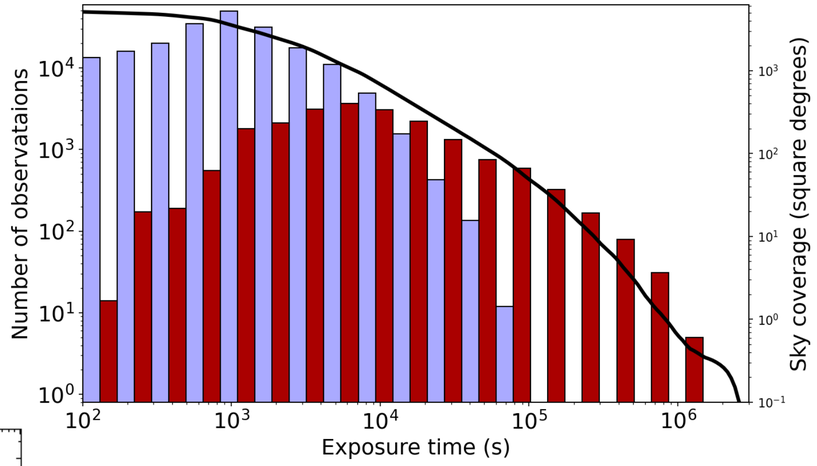
Data included	2005-01-01 — 2024-02-17 (376 Ms)
Sky coverage	5,489 square degrees
Detections	2,196,304
Unique sources	312,211
Variable sources	121,928
Uncatalogued sources	103,365

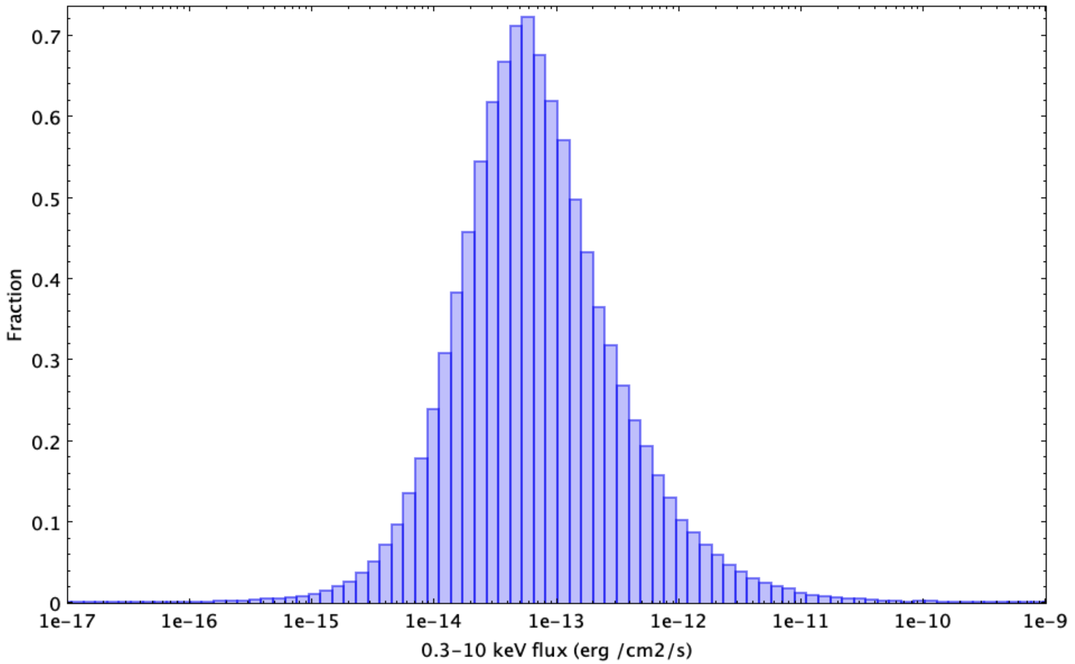
https://www.swift.ac.uk/LSXPS

https://www.swift.ac.uk/API

LSXPS: status

- Unique sky coverage increases by ~0.8 deg^2 /day.
- ~50 new unique sources /day.
- Typical “latency” is 7 days for the main catalogue.
- Median 0.3-10 keV flux: ~4 × 10^{-14} erg cm^{-2} s^{-1}.





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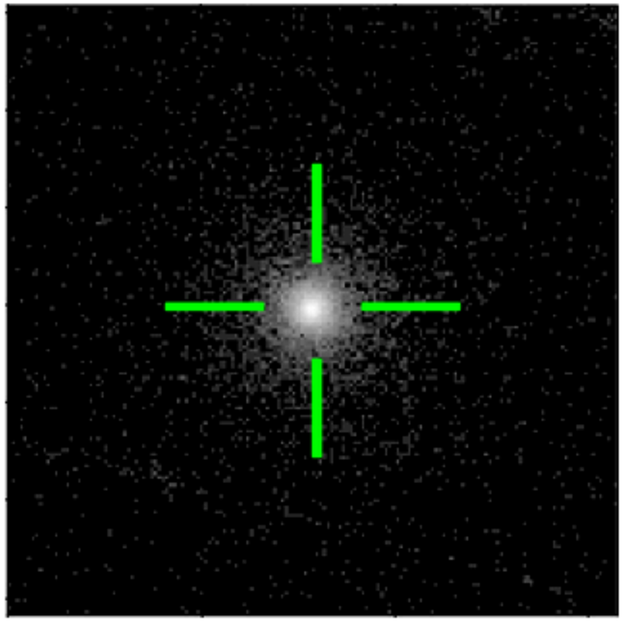
LSXPS: source products

LSXPS J221755.4-082100

[Spectral/flux information | Temporal information | External catalogue matches | Detections | Non-detections]

Detection flag:	Good	
Total exposure:	44 ks	
RA (J2000):	$22^h\ 17^m\ 55.41^s$	=334.4809°
Dec (J2000):	-08° 21′ 00.4″	=-8.3501°
Err_{90}:	3.5′′	(Star trackers)
l:	+53° 00′ 05.4″	=53.0015°
b:	-49° 09′ 26.0″	=-49.1572°
Mean count rate	0.474 (±0.004) ct s^{-1}	
Galactic N_H	5.5×10^{20} cm^{-2}	
HRs	HR1=0.536 (±0.022) HR2=0.664 (±0.011)	
Observed between:	2006-04-28 02:14 and 2019-10-18 21:06	
Present in:	20 datasets (total) 20 datasets (with blind detections) 20 datasets (count-rate detections)	
External catalogue matches:	12 Search Vizier | Simbad.	
LSXPS ID	106107	
Nearest neighbour	LSXPS J221751.7-082232 — 106″ away	
Nearest 'OK' neighbour	LSXPS J221751.7-082232 — 106″ away	

Total | Soft | Medium | Hard | Exposure



This image is 160 pixels (=6.3′ to a side).
LSXPS J221755.4-082100 is indicated by the cross-hairs.
What do the colours mean?The next nearest source is 106″ away.

LSXPS: source products

LSXPS J221755.4-082

[Spectral/flux information | Temporal information | External catalogue matc

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Spectral / Flux information

Hide spectral section.

Show table controls.

All fluxes are in erg cm^{-2} s^{-1} over the 0.3—10 keV band.

		Power-law	APEC
Best	**Observed flux**	5.93 (±0.05) $\times10^{-11}$	4.06 (±0.04) $\times10^{-11}$
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	Provenance	Fitted spectrum	Fitted spectrum
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		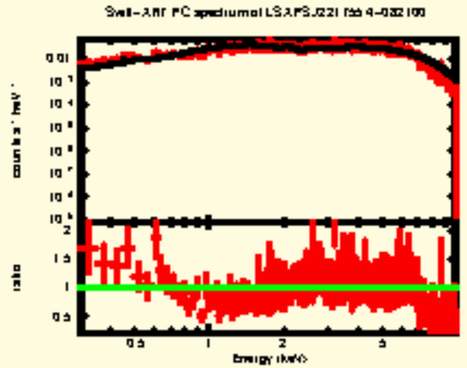	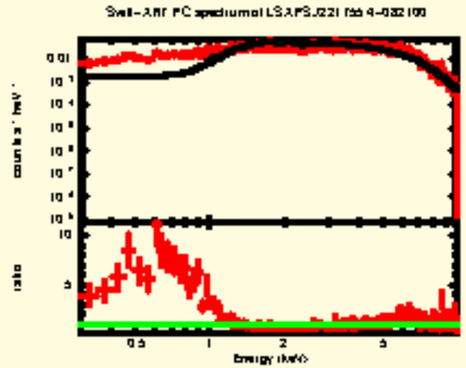

Back to top.

LSXPS: source products

LSXPS J2

[Spectral/flux information | Temporal informa

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One bin per observation

Total | Soft | Medium | Hard | HR1 | HR2

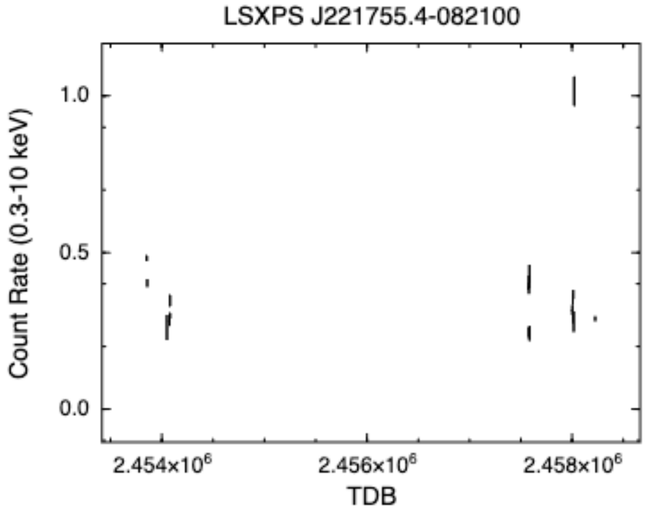
X-axis: TDB Non-detections: Auto select

Show bin markers? ☐ Include flagged bins? ☐

Show plot axis controls or click to zoom [more].

Time range: Logarithmic? ☐ Rate range: Logarithmic? ☐

Data file | Enlarge.



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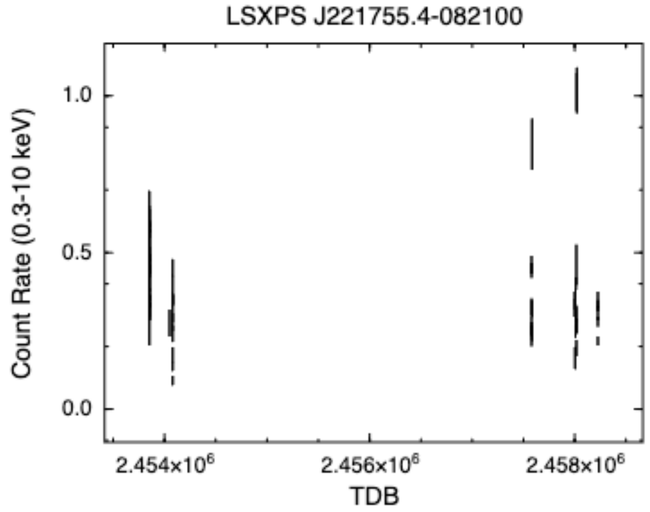

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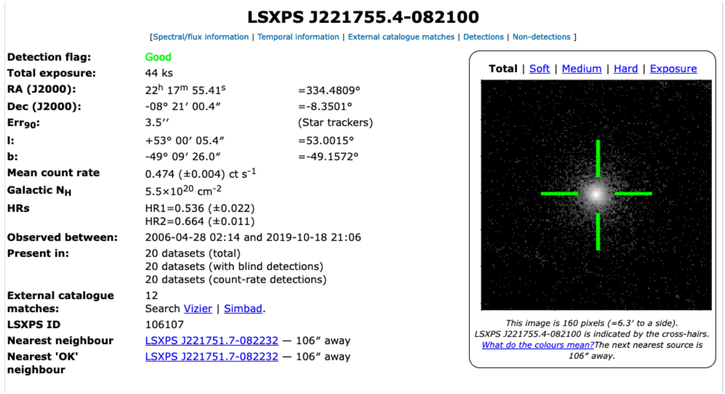

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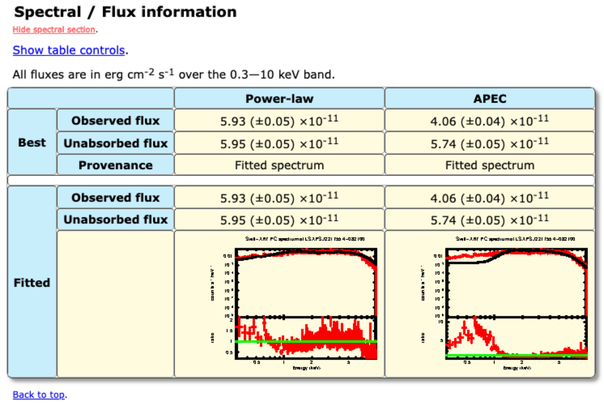

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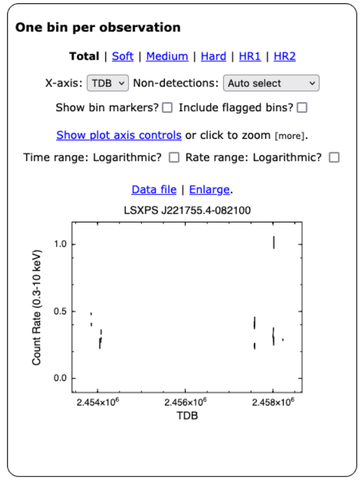

One bin per observation

Total | Soft | Medium | Hard | HR1 | HR2

X-axis: TDB Non-detections: Auto select

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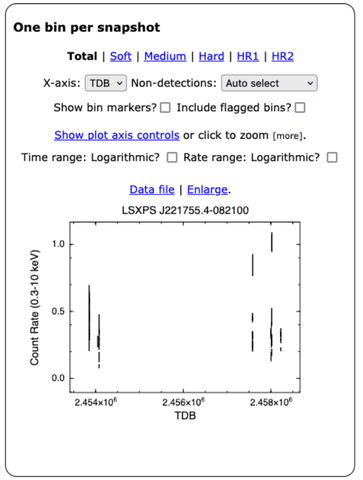
Show plot axis controls or click to zoom [more].

Time range: Logarithmic? Rate range: Logarithmic?

Data file | Enlarge.

LSXPS J221755.4-082100



One bin per snapshot

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Data file | Enlarge.

LSXPS J221755.4-082100

Also includes:

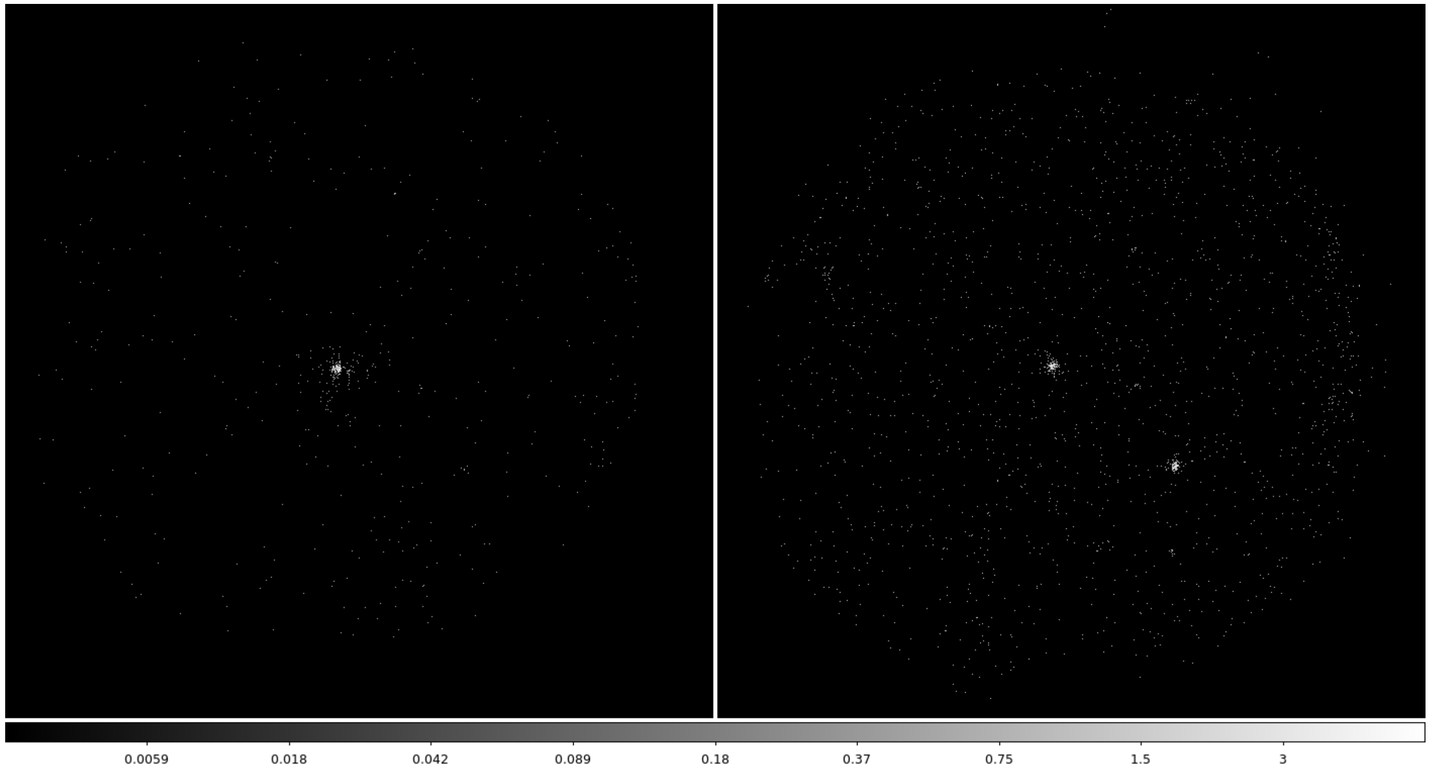
- Cross matches with other catalogues (inc. XMM, Rosat, SIMBAD, 2MASS, WISE).
- Details of individual (non)detections.
- Links to build custom products of the source.

All functionality also available through the Python API:

`swifttools.ukssdc.query`

Real-time transient searches

- For everything we detect:
  - Is it catalogued? (X-ray Master, LSXPS)
  - Is it new? (XMM & Rosat UL check via HILIGT; LSXPS internal check)

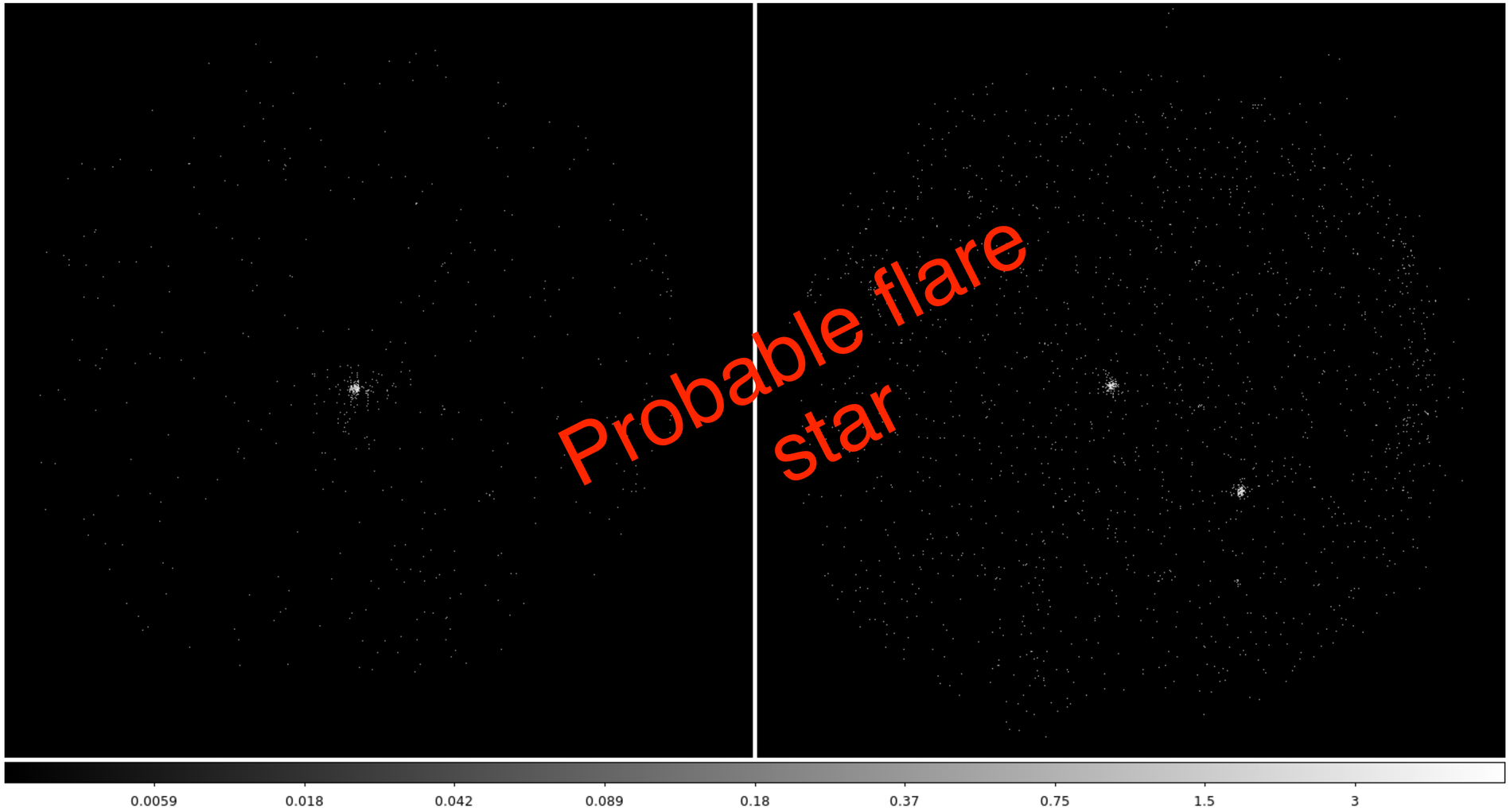


Example transients

2022-03-25 17:18:29 — 2022-03-25 18:39:59 UT

2022-03-25 18:55:11 — 2022-03-26 12:30:07 UT

Example transients



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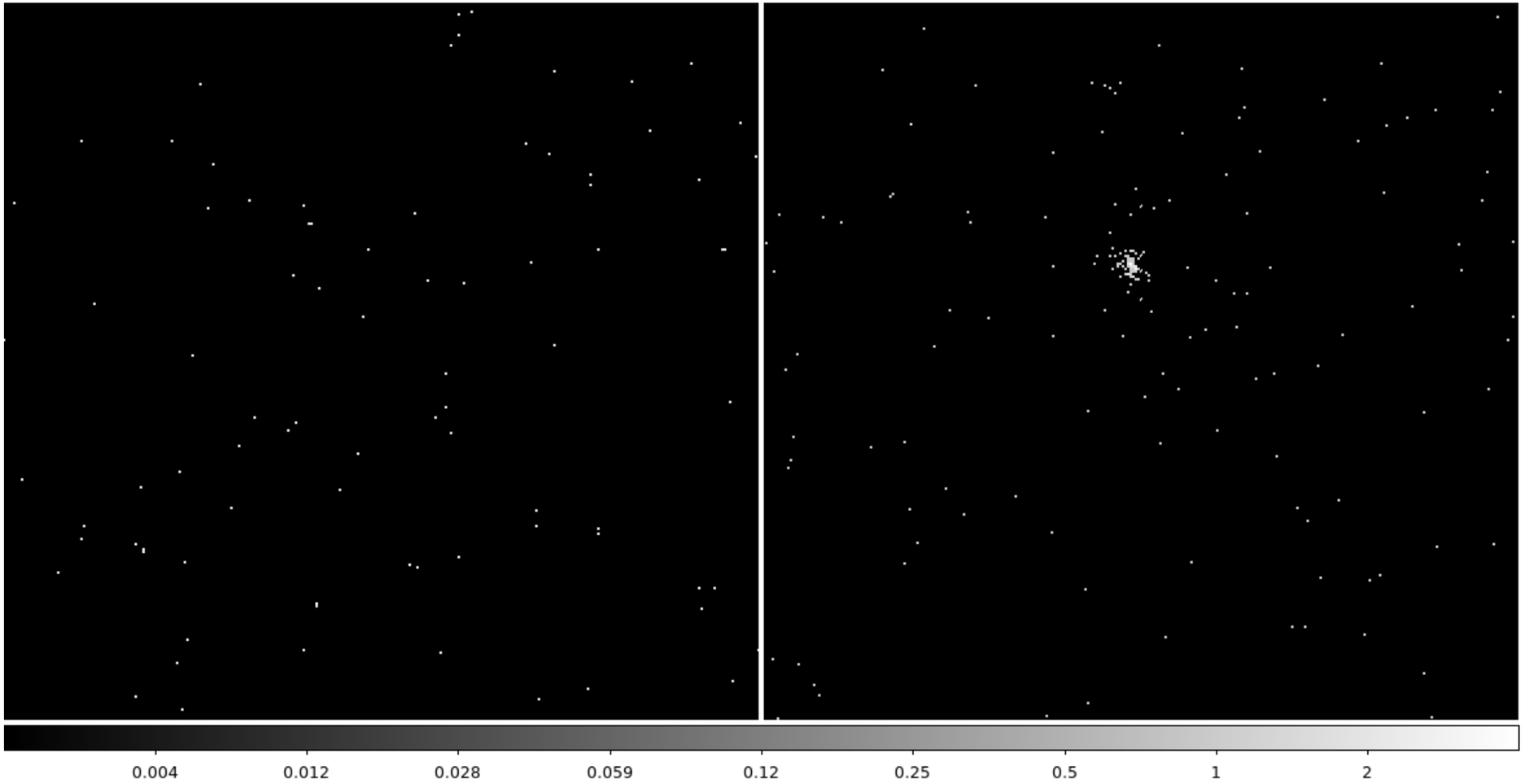
Transient challenges



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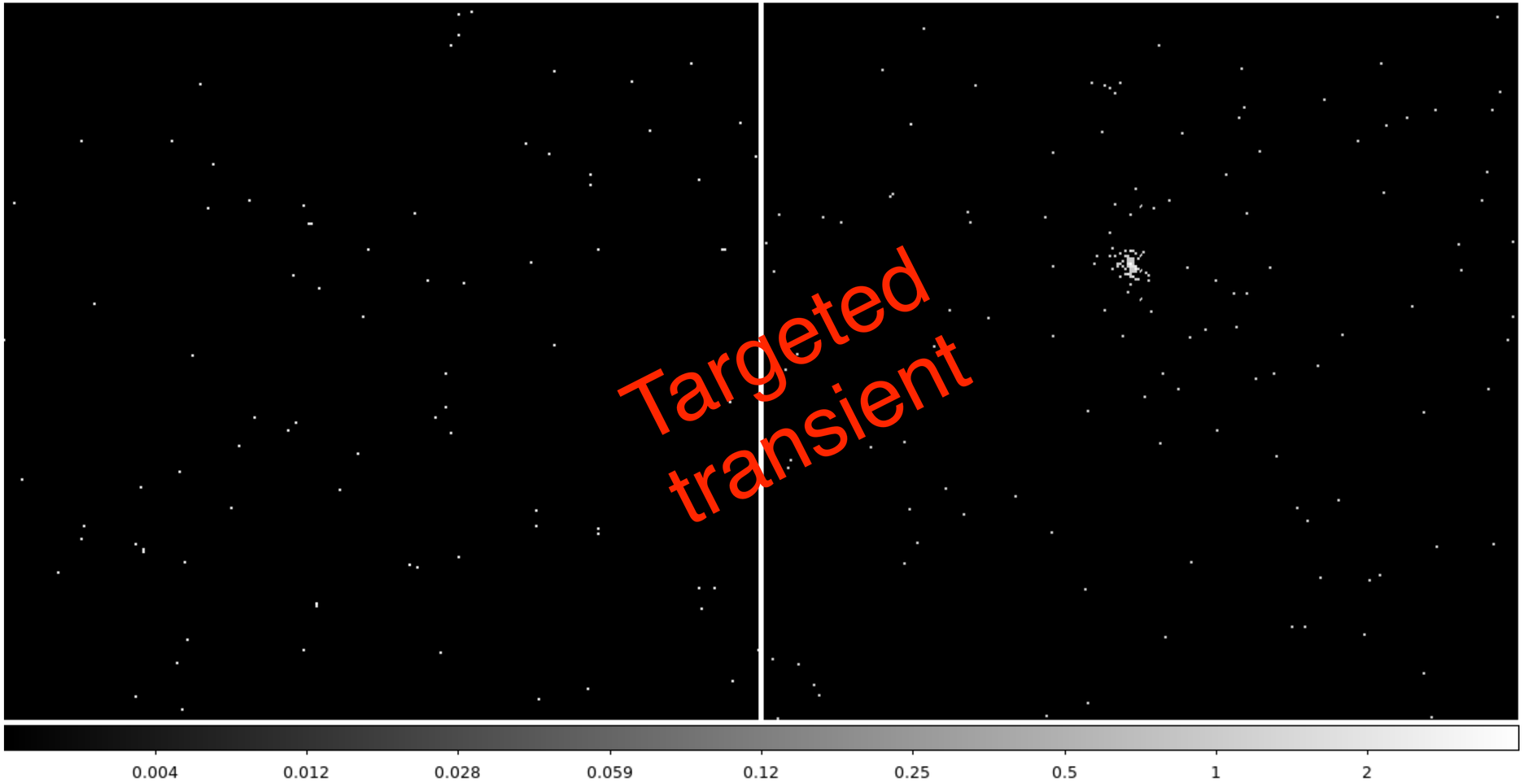
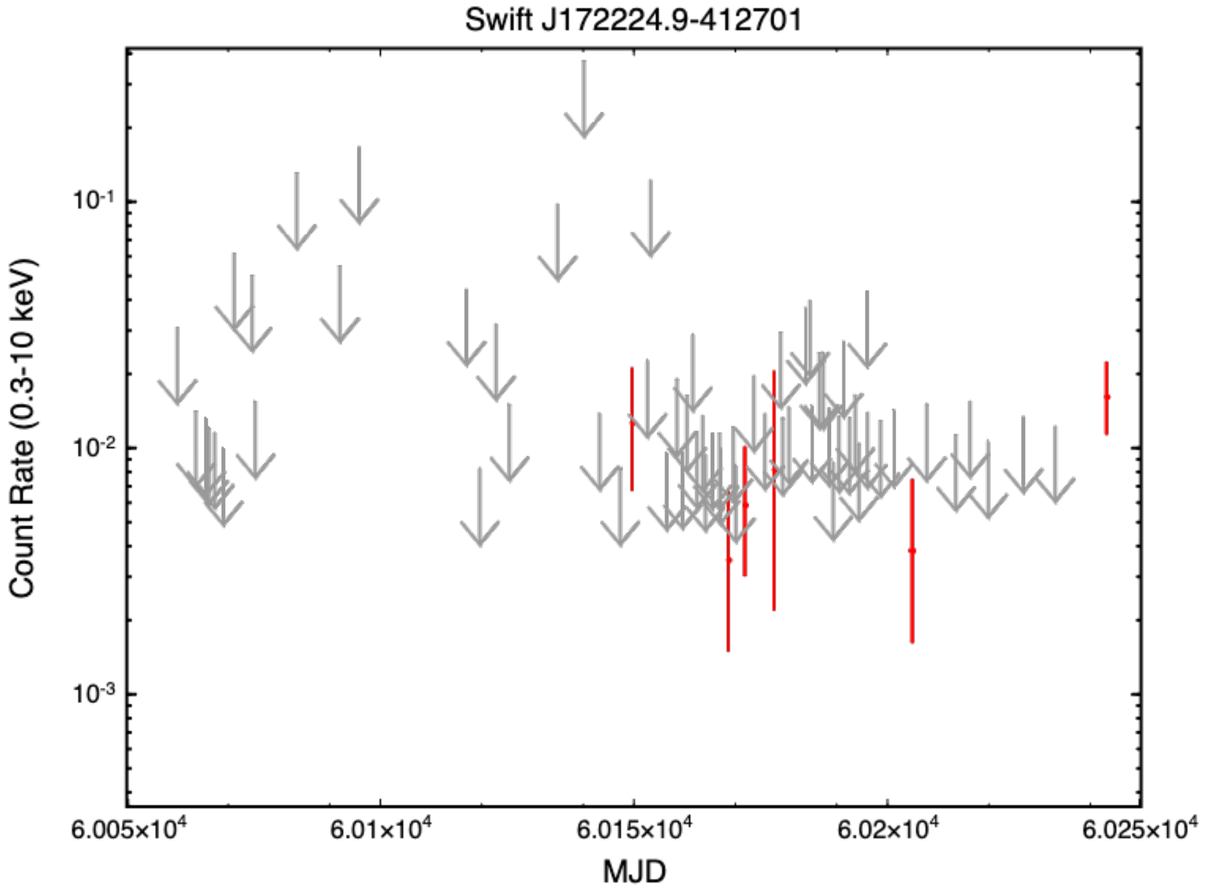


Transient challenges

Blind searches don't find everything: targeted photometry is more sensitive.

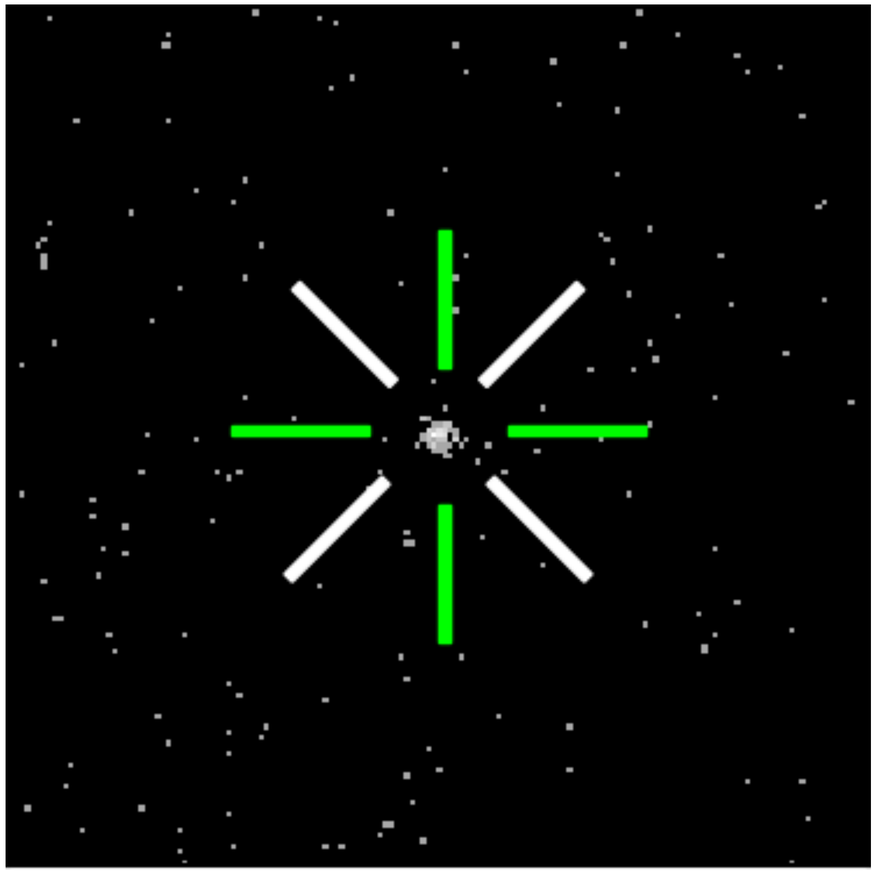
Some 'transients' are 'outbursts'.



Transient issues

Spurious detections often come up as transient.

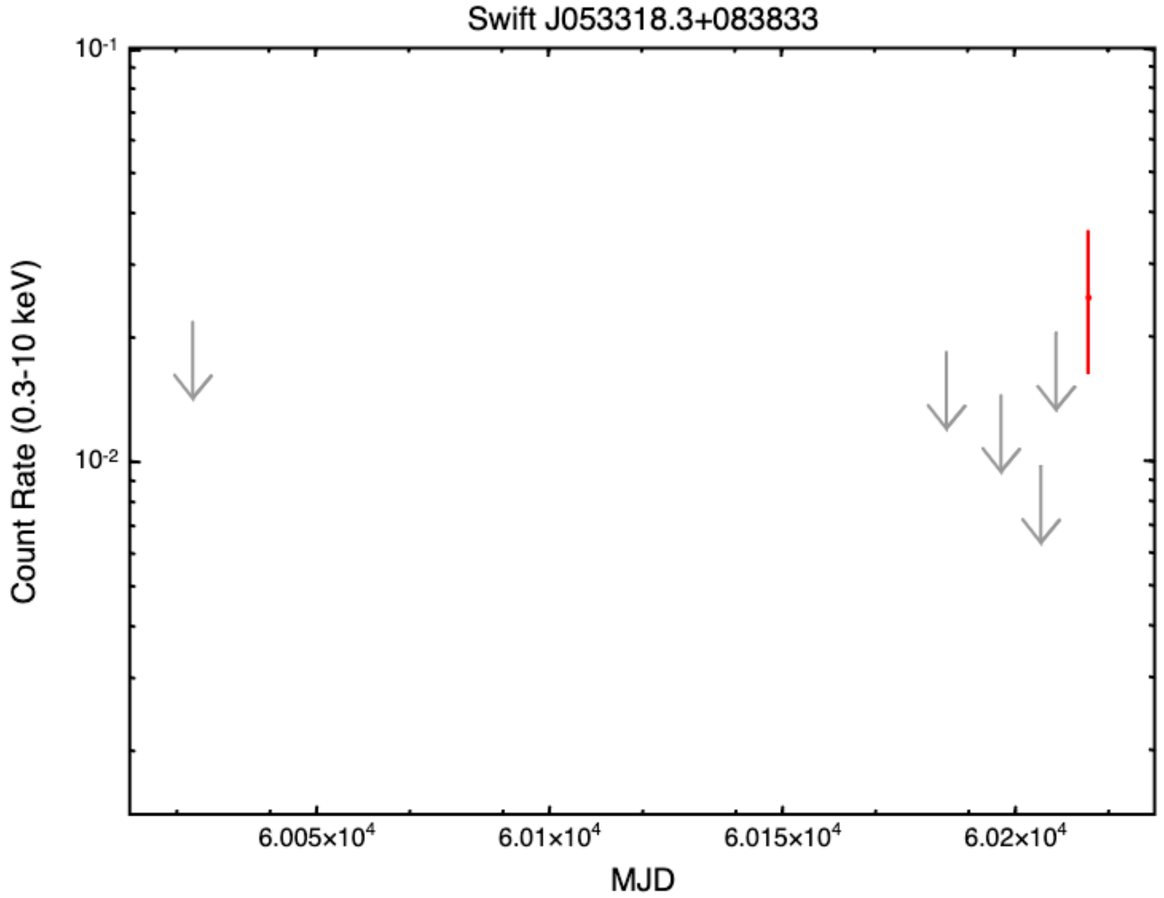
- Optical loading (as right).
- Noisy quick-look data.
- Other artifacts.



Transient issues

Most transients are “low significance”.

- Eddington bias suggests many are not transient.
  - Ongoing work (Srijan) to improve this classification.



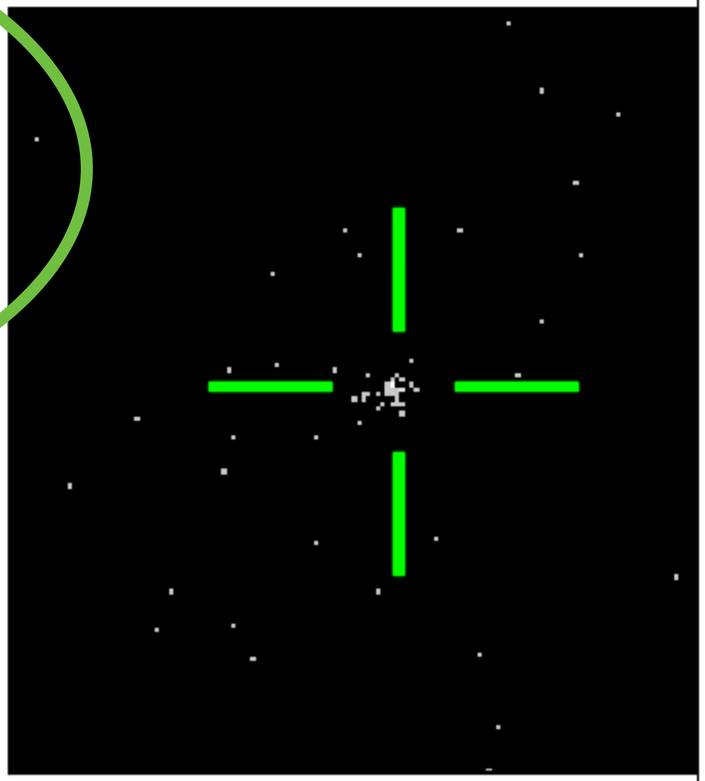
And when it works well…

Status:	Confirmed transient
Announced?	Yes — via release of discovery dataset.
LSXPS Name:	LSXPS J023016.9+283603
Detection flag:	Good
RA (J2000):	37.5712 = 02h 30m 17.09s
Dec(J2000):	28.6012 = +28° 36′ 04.4″
Position CI:	1.4″ (radius, 90% conf
Gal long:	147.8594°
Gal lat:	-29.4421°
Discovery Analysis:	2022-06-22 14:54:14
Discovery Obs:	2022-06-22 08:19:34 = MJD 59752 obs 00014936012 v3 [uf][cl] =Dataset: 222765 (source 1).
Last detected:	obs 14936012 v4
Still detected?	Yes
Has det spec?	Yes — Confirms transient status
Has full spec?	Yes — Confirms transient status
Database ID:	690
Keep updated?	Yes

Peak rate (0.3 — 10 keV):	2.7 (+0.6, -0.5) $\times 10^{-2}$ ct s^{-1}
Peak rate (0.3 — 2 keV):	2.8 (+0.7, -0.5) $\times 10^{-2}$ ct s^{-1}
Best upper limit	1.51×10^{-3} XRT ct/sec (0.3 — 10 keV) From LSXPS (10000000668) Show all limits.
Outburst strength	5.13 σ
Net counts	32.7
Using spectrum for CF?	Yes
Observation target:	'SN 2021afkk' at (37.4998, +28.6342) [255.0″ from this object]
Transients this obs	1
Search 5-σ radius	SIMBAD [Vizier].
Stellar colours	In Zombeck.
All observations	Search.
Public note	*Possible TDE, see ATEL #15454*

Build custom products for this transient.

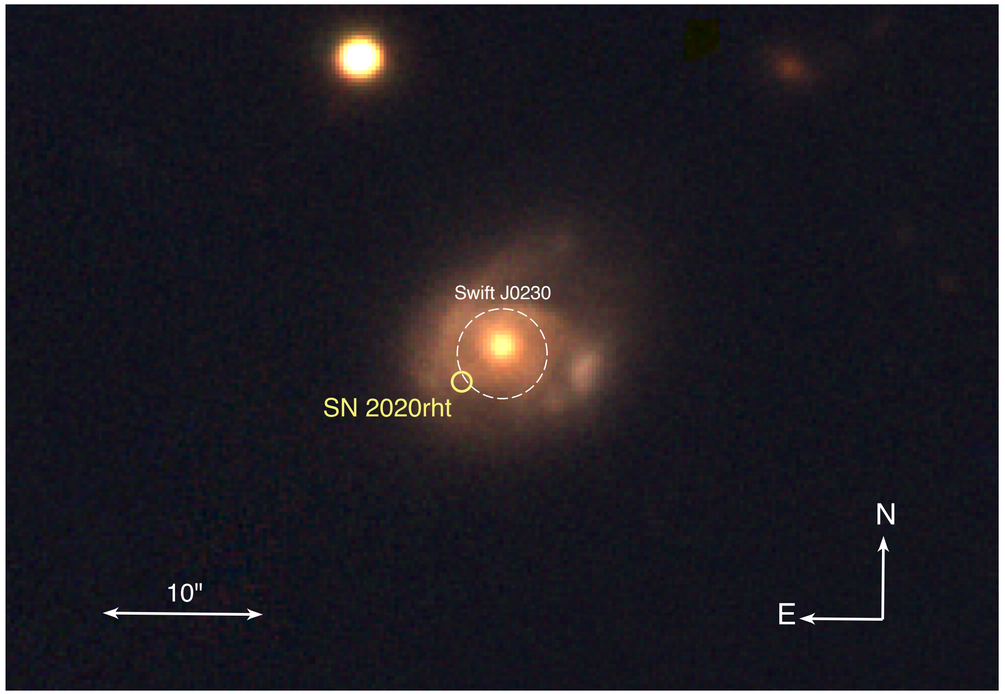
Total | Soft | Medium | Hard | Exposure



This image is 160 pixels (=6.3′ to a side).
Swift J023017.0+283603 is indicated by the cross-hairs.

Very soft spectrum (all counts <2 keV), well-fit by a blackbody

Swift J0230

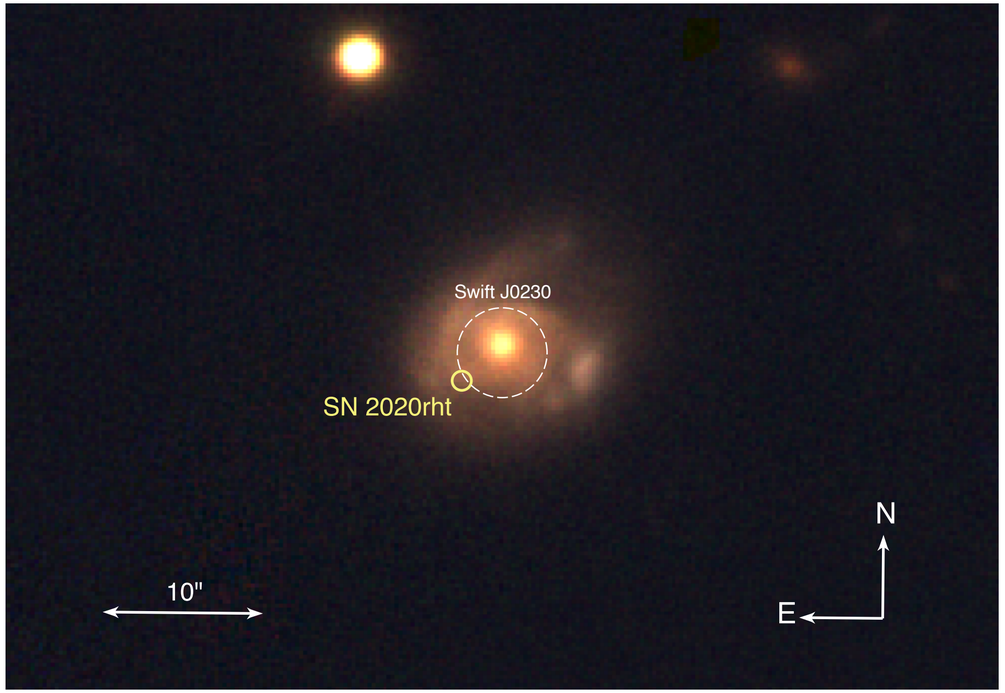


PanSTARRS image, from Daniele Malesani

D_L = 160.7 Mpc

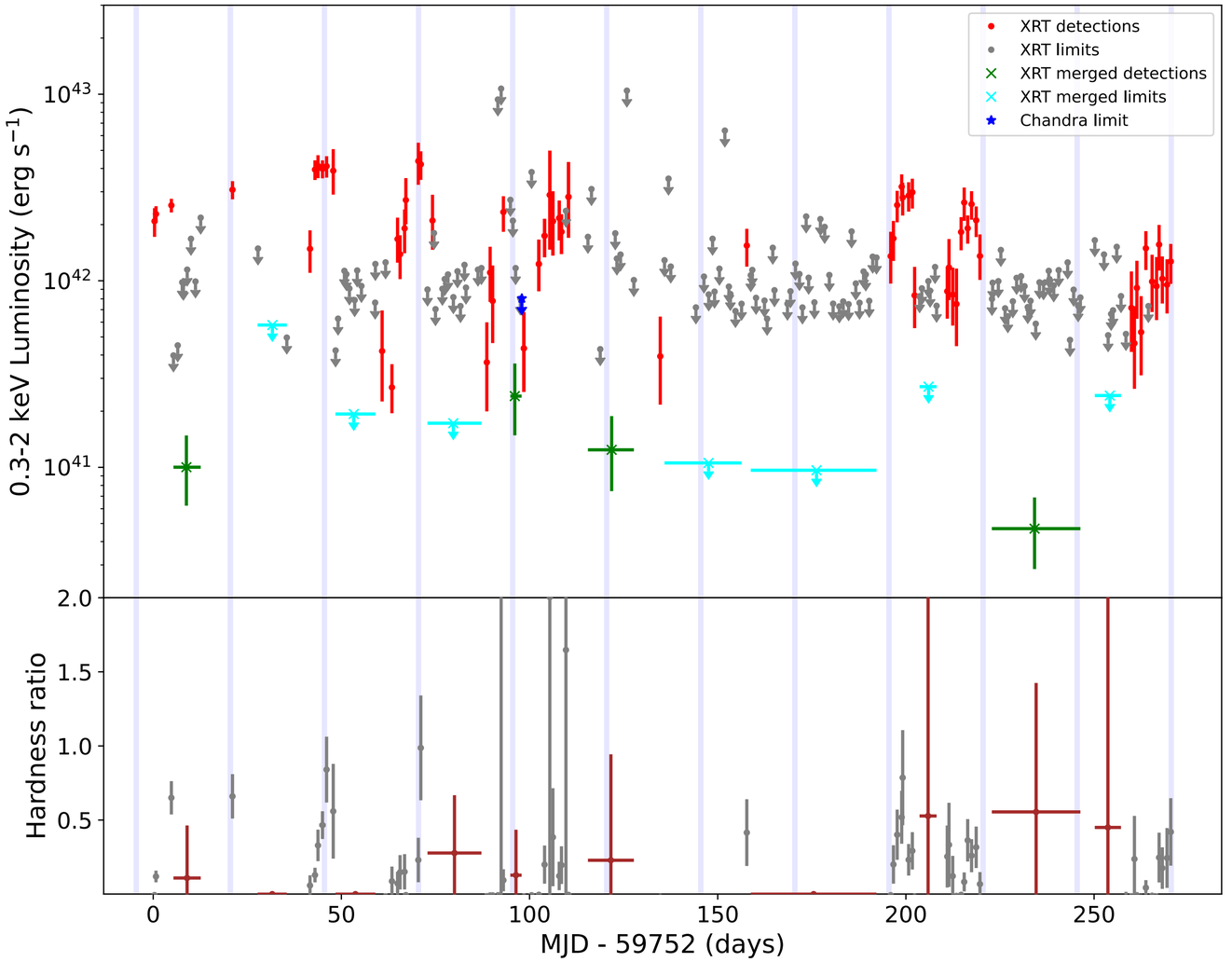
Evans+ 2023

Swift J0230



PanSTARRS image, from Daniele Malesani

D_L = 160.7 Mpc



Evans+ 2023

Final notes

LSXPS: The “Living” Swift-XRT Point Source Catalogue.

- A low-latency, constantly-updated X-ray catalogue.
- Near real-time transient detection.
  - Currently, human verification before transients are published.
- Grows at ~0.8 deg^2/day; 50 new sources/day.
- Typical sensitivity / observation = 2e-13 cgs.

https://www.swift.ac.uk/LSXPS

https://www.swift.ac.uk/API

`swifttools.ukssdc.query`

Data included	2005-01-01 — 2024-02-17 (376 Ms)
Sky coverage	5,489 square degrees
Detections	2,196,304
Unique sources	312,211
Variable sources	121,928
Uncatalogued sources	103,365