The SXPS catalogues: serendipity and transients

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With special thanks to Andy Beardmore and Dick Willingale

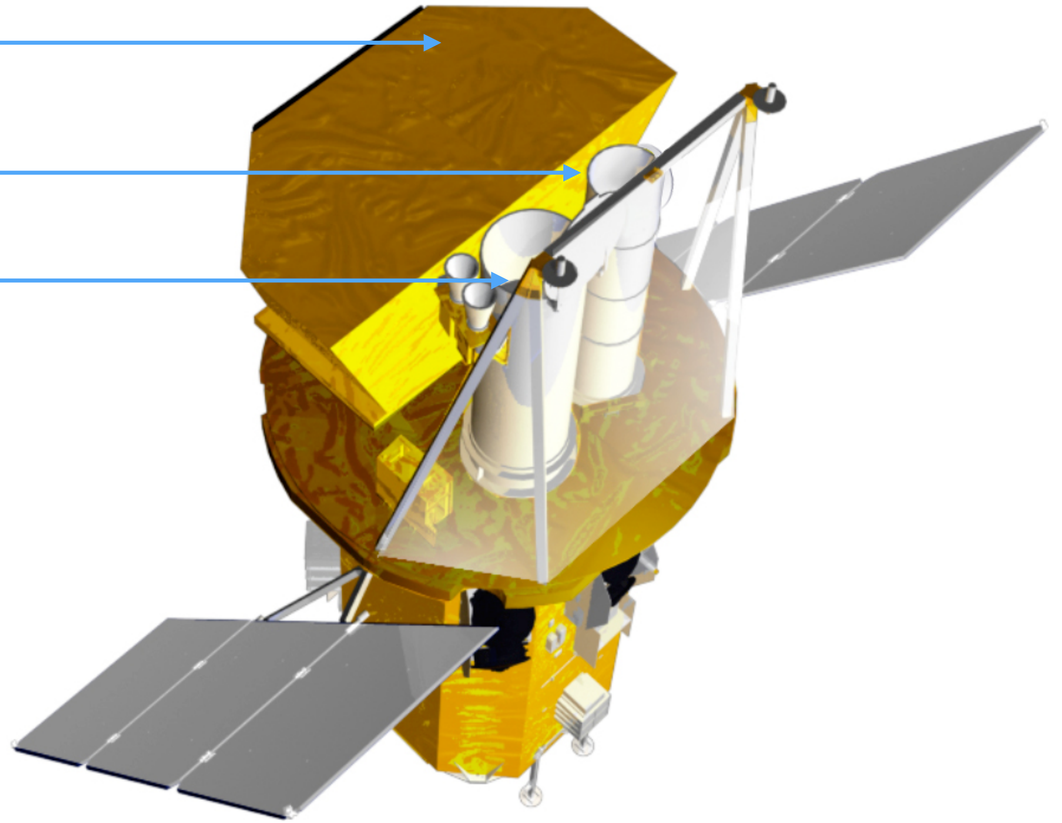
Brief introduction to Swift

BAT (hard X-ray, trigger instrument)

UVOT (~1900-7000 Å)

XRT (0.3-10 keV)

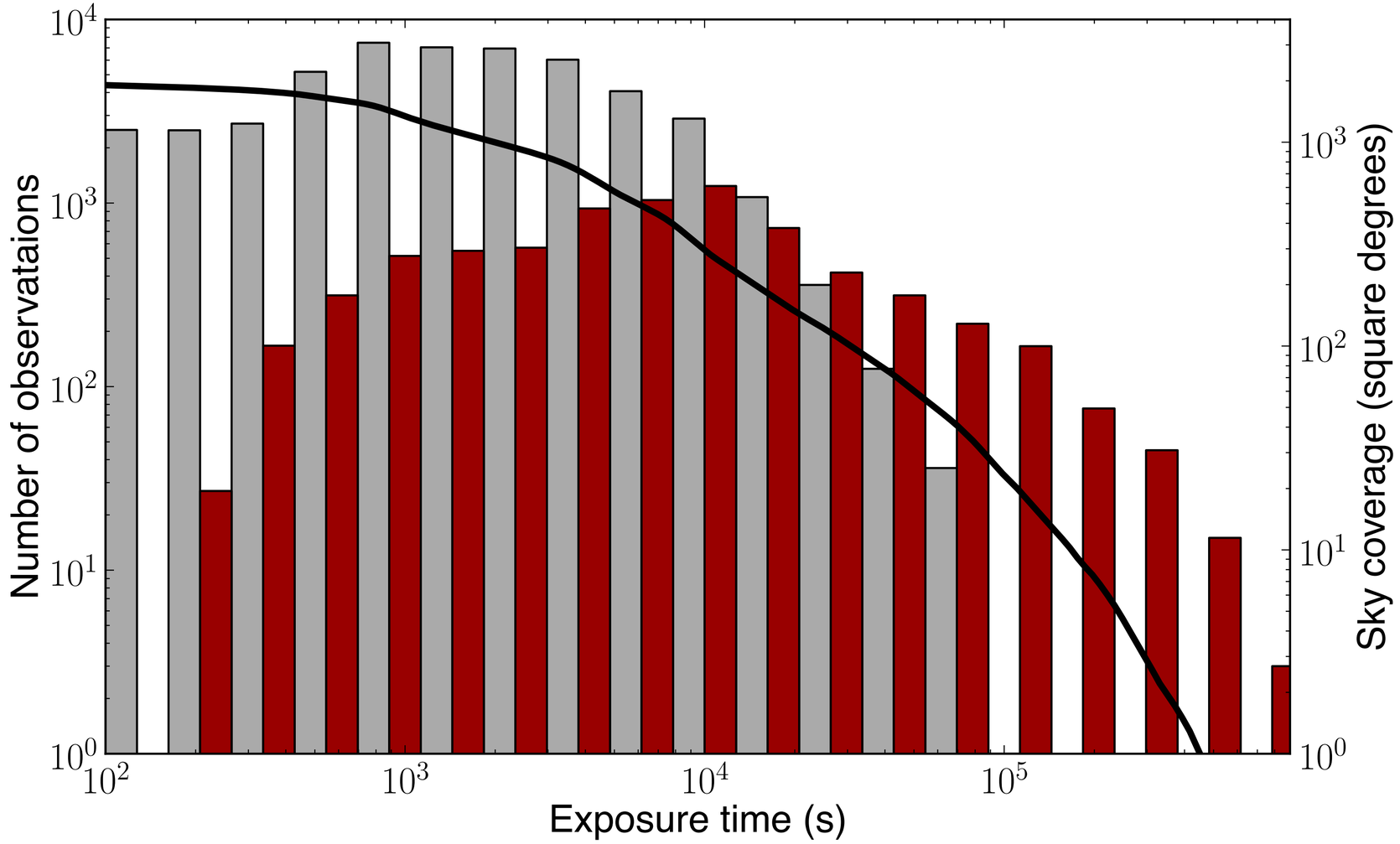
Reaches typical RASS limit in 350 s.



Swift typically does between ~80 and ~500 observations per day, so wide coverage.

Frequently used for ‘monitoring’ campaigns, so provides a good tool to test variability.

The 1SXPS catalogue



Grey: single observations

Red: Stacked images

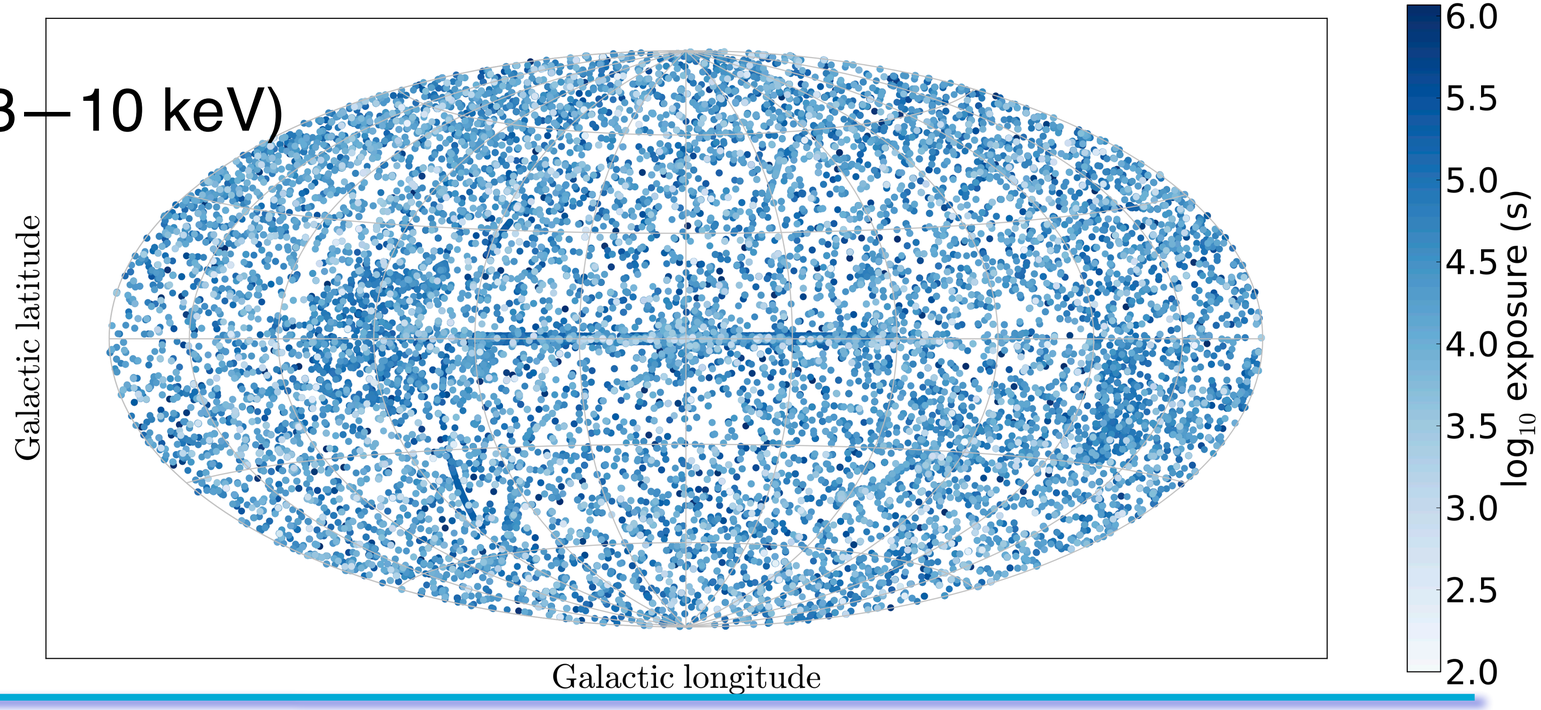
Evans et al., 2014

The 1SXPS catalogue

- All data up to 2012 October 12
- Covers 1905 square degrees (accounting for overlaps).
- 151,524 unique sources.
  - 69,967 in the “best” sample (all flags = 0).
- Sources have L-ratio value; calibrated to classify sources as, “good”, “reasonable” or “poor” based on FAR vs L.
- Median flux: 3×10^{-14} erg cm^{-2} s^{-1} (0.3—10 keV)
- Various source products
- Links to build custom products via our well-established online tools: (www.swift.ac.uk/user_objects)
- Upper limit tool.

http://www.swift.ac.uk/1SXPS

Evans et al., 2014, ApJS, 210, 8



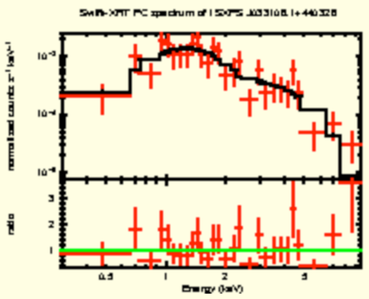
Source products

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	2.2 (+0.5, -0.4) ×10^{-13}	1.63 (±0.12) ×10^{-13}
	Unabsorbed	2.6 (±0.4) ×10^{-13}	1.95 (±0.14) ×10^{-13}
	Provenance	Fitted spectrum	Interpolated from HR
Fitted	Observed	2.2 (+0.5, -0.4) ×10^{-13}	No result. P=1.00
	Unabsorbed	2.6 (±0.4) ×10^{-13}	
			

Back to top.

Provide fluxes from ‘fixed’ spectrum, HR interpolation, and fitted spectra.

Light curves include non-detections.

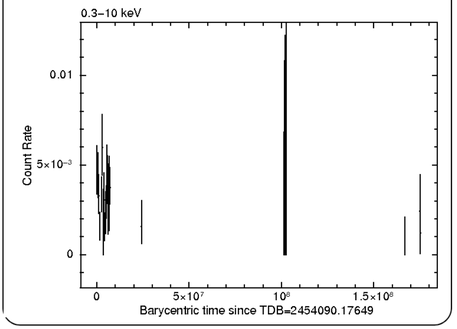
Temporal Information

Hide temporal section.

Band	Mean rate ct s^{-1}	Counts detected	BG counts	Corr fact	P$_{const,X}$
Total *(0.3—10 keV)*	3.19 (±0.23) ×10^{-3}	285	35.5	1.66	0.35 (obs) 8.44×10^{-3} (snapshot)
Soft *(0.3—1 keV)*	3.6 (+0.8, -0.7) ×10^{-4}	38	8.07	1.56	0.51 (obs) 0.11 (snapshot)
Medium *(1—2 keV)*	1.33 (±0.14) ×10^{-3}	112	6.3	1.63	0.76 (obs) 4.68×10^{-2} (snapshot)
Hard *(2—10 keV)*	1.51 (±0.16) ×10^{-3}	135	20.3	1.70	0.21 (obs) 2.17×10^{-2} (snapshot)

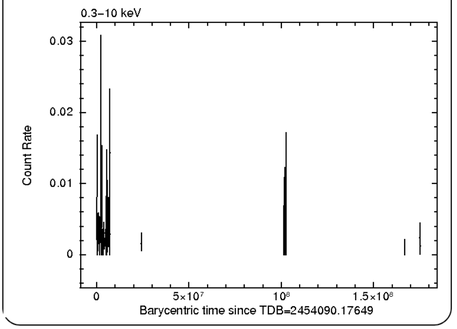
One bin per observation

Total | Soft | Medium | Hard | HR1 | HR2



One bin per snapshot

Total | Soft | Medium | Hard



Source products

Detections

Hide detections section.

Show table controls.

Stacked images

Stacked image ID (start date)	Detection Flag	SNR	Rate	Counts	BG Counts	Corr fact	$P_{const,X}$
Stacked im 241 (2006-12-20 16:14:43)	Flag=Good, Exposure=129 ks, HR1=0.53 (±0.07), HR2=0.04 (±0.08), Fieldflag=Good						
	Total (details)	Good	13	3.32 (±0.25) $\times10^{-3}$ ct s^{-1}	376	90	1.47	N/A

Observations

Obs ID (start date)	Detection Flag	SNR	Rate	Counts	BG Counts	Corr fact	$P_{const,X}$
00030842001 (2006-12-20 16:14:43)	Flag=Good, Exposure=3.9 ks, HR1=0.8873 (+0.1127, -0.0064), HR2=-0.18 (+0.25, -0.28), Fieldflag=Good						
	Total (details)	Good	2.6	4.6 (+1.5, -1.2) $\times10^{-3}$ ct s^{-1}	14	1.2	1.42	0.47
00030842002 (2006-12-26 02:28:58)	Flag=Good, Exposure=4.5 ks, HR1=-0.0 (+0.3, -0.4), HR2=0.23 (+0.36, -0.26), Fieldflag=Good						
	Total (details)	Good	2.4	4.3 (+1.4, -1.1) $\times10^{-3}$ ct s^{-1}	15	1.5	1.45	9.67×10^{-3}
00030842003 (2007-01-02 12:45:45)	Flag=Good, Exposure=4.7 ks, HR1=0.40 (+0.41, -0.25), HR2=-0.06 (+0.29, -0.37), Fieldflag=Good						
	Total (details)	Good	2.2	3.27 (+1.18, -0.97) $\times10^{-3}$ ct s^{-1}	12	1.4	1.45	0.99

Non-detections

Hide non-detections section.

Show table controls.

Stacked images

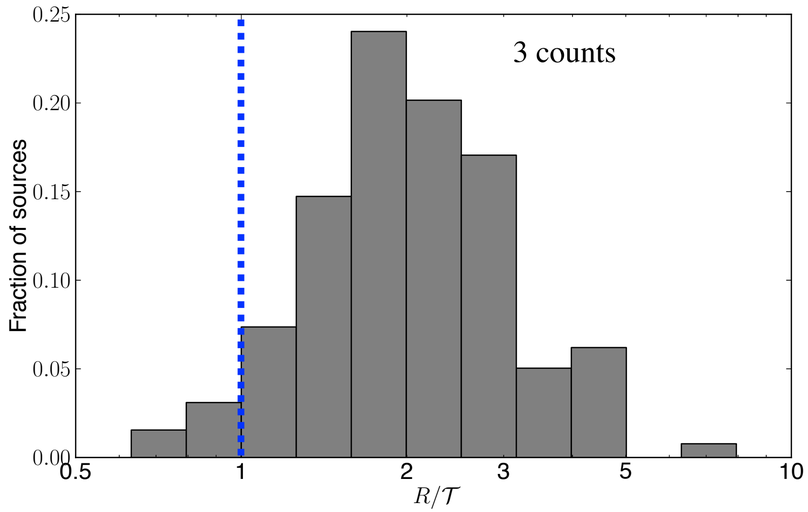
No observations found.

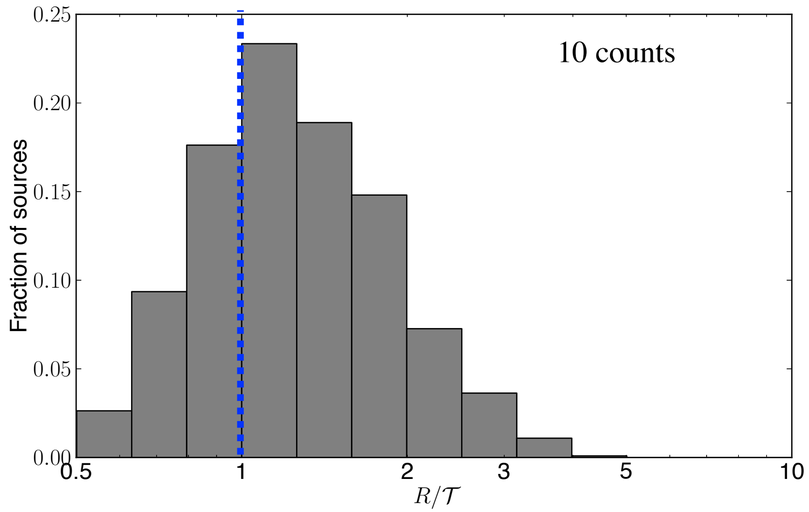
Observations

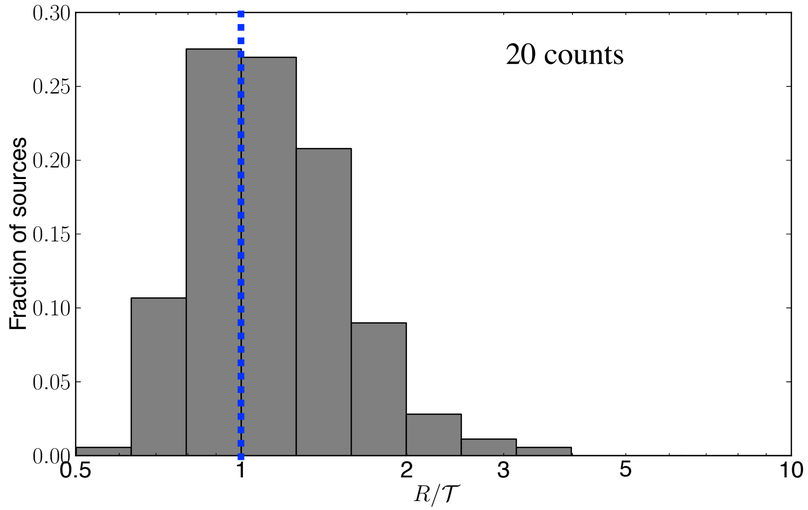
Showing only the first 10 (/37) rows. Show all.

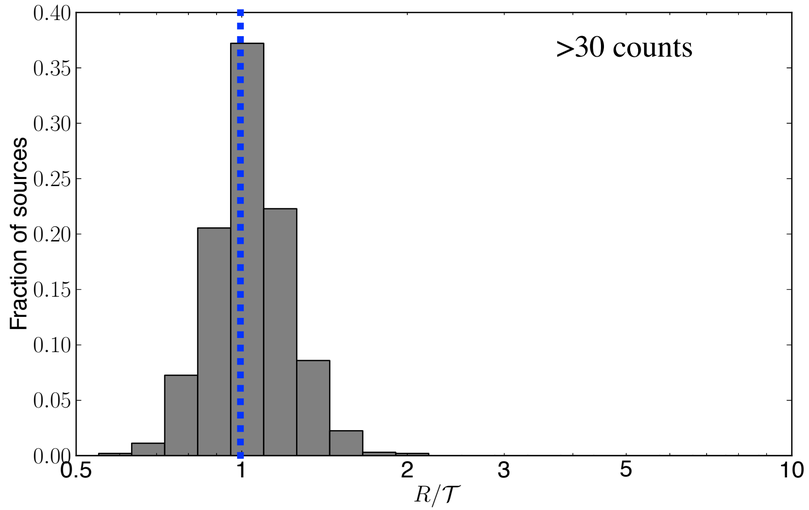
Obs ID	Band	3-σ upper limit	Counts	BG Counts	Corr fact	Exposure
00030842007	Total	1.33×10^{-2} ct s^{-1}	1	0.29	1.63	955 s
00030842008	Total	8.60×10^{-3} ct s^{-1}	7	0.83	1.95	3.9 ks
00030842009	Total	4.69×10^{-3} ct s^{-1}	6	1.3	1.61	5.2 ks
00030842011	Total	7.24×10^{-3} ct s^{-1}	5	0.69	1.49	2.9 ks
00030842016	Total	7.40×10^{-3} ct s^{-1}	5	0.91	1.63	3.1 ks
00030842018	Total	1.30×10^{-2} ct s^{-1}	3	0.37	4.73	4.1 ks
00030842020	Total	7.42×10^{-3} ct s^{-1}	3	0.66	2.03	3.0 ks
00030842021	Total	9.18×10^{-3} ct s^{-1}	3	0.42	1.52	1.9 ks
00030842022	Total	6.39×10^{-3} ct s^{-1}	1	0.41	1.54	1.8 ks
00030842023	Total	9.89×10^{-3} ct s^{-1}	2	0.41	1.53	1.5 ks

Eddington bias!





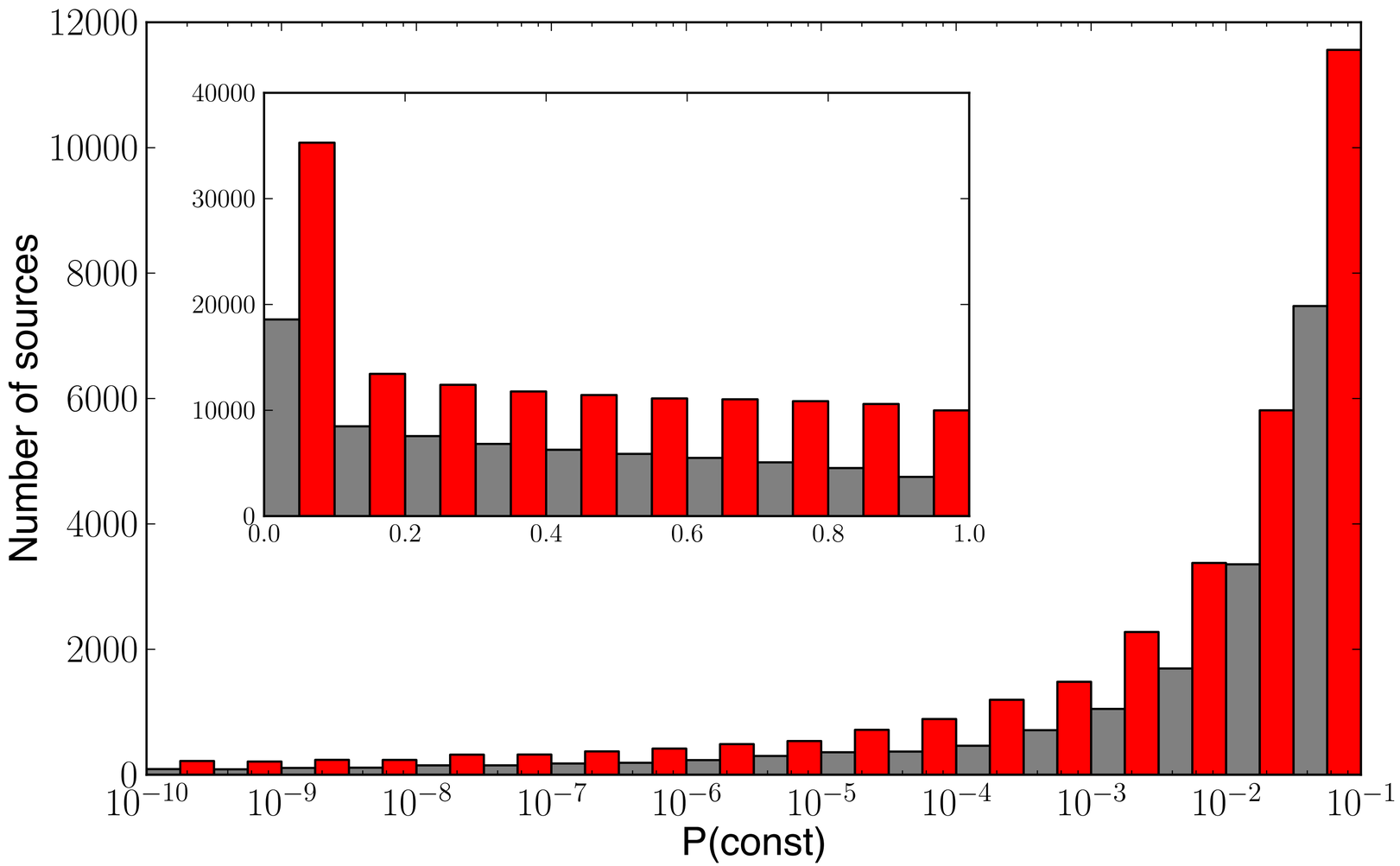




Sources close to the detetion threshold have count-rates (=fluxes) systematically higher than reality, due to the Eddington Bias.

Evans et al., 2014

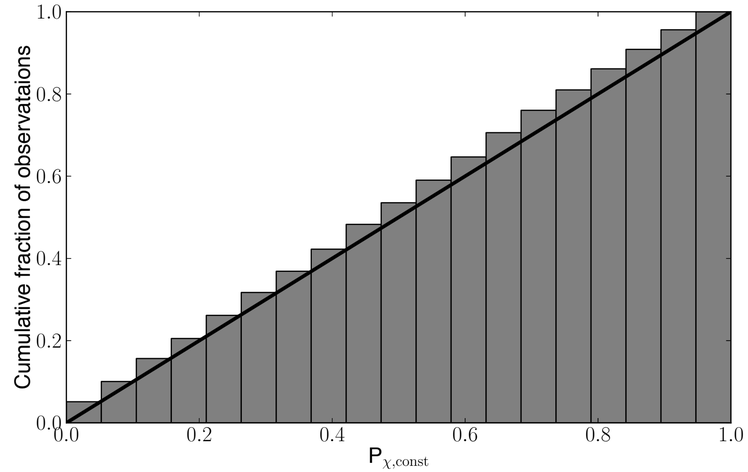
Variability



Evans et al., 2014

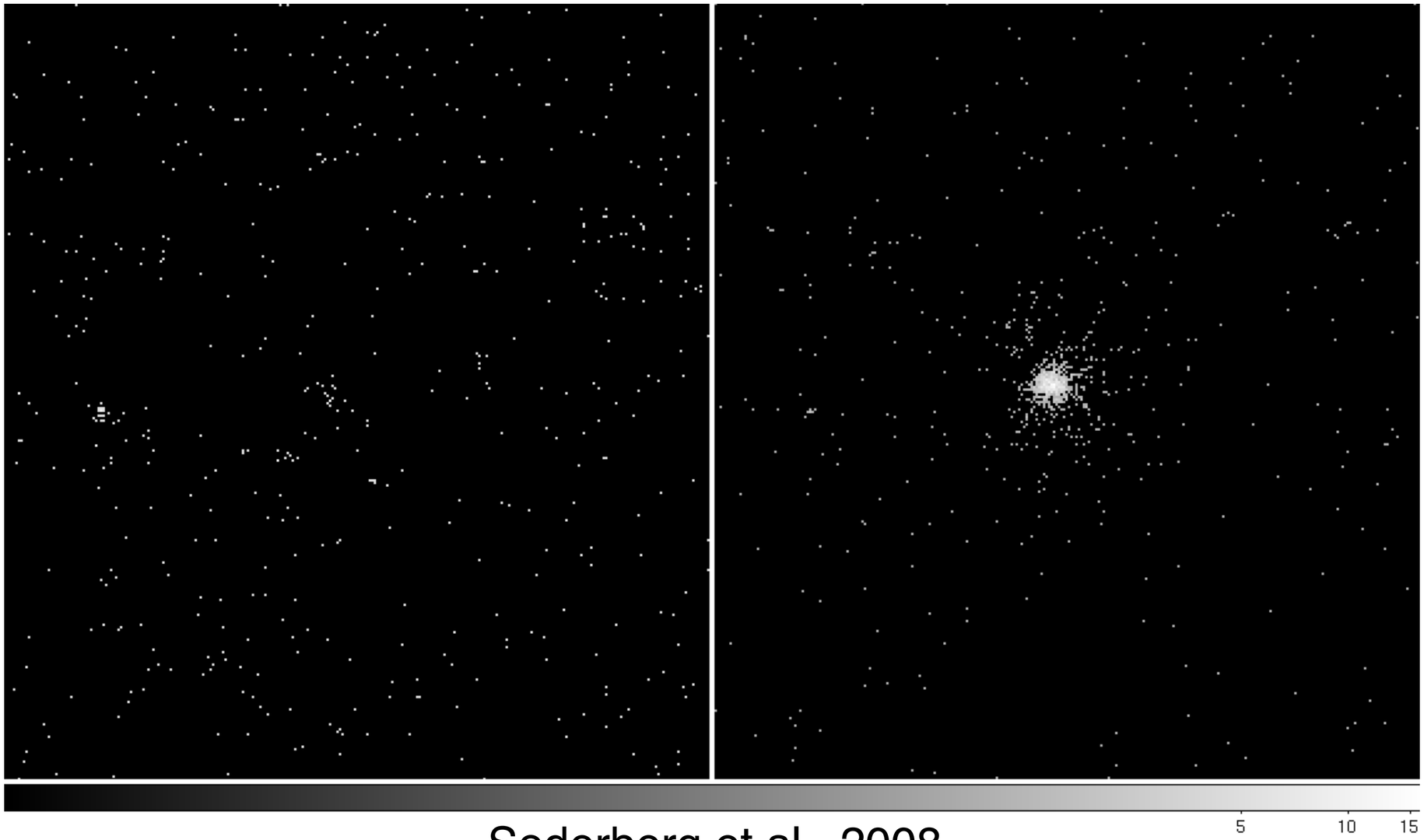
Grey: within observations

Red: between observations



Cumulative plot for simulated constant sources

Transients — SN 2008D

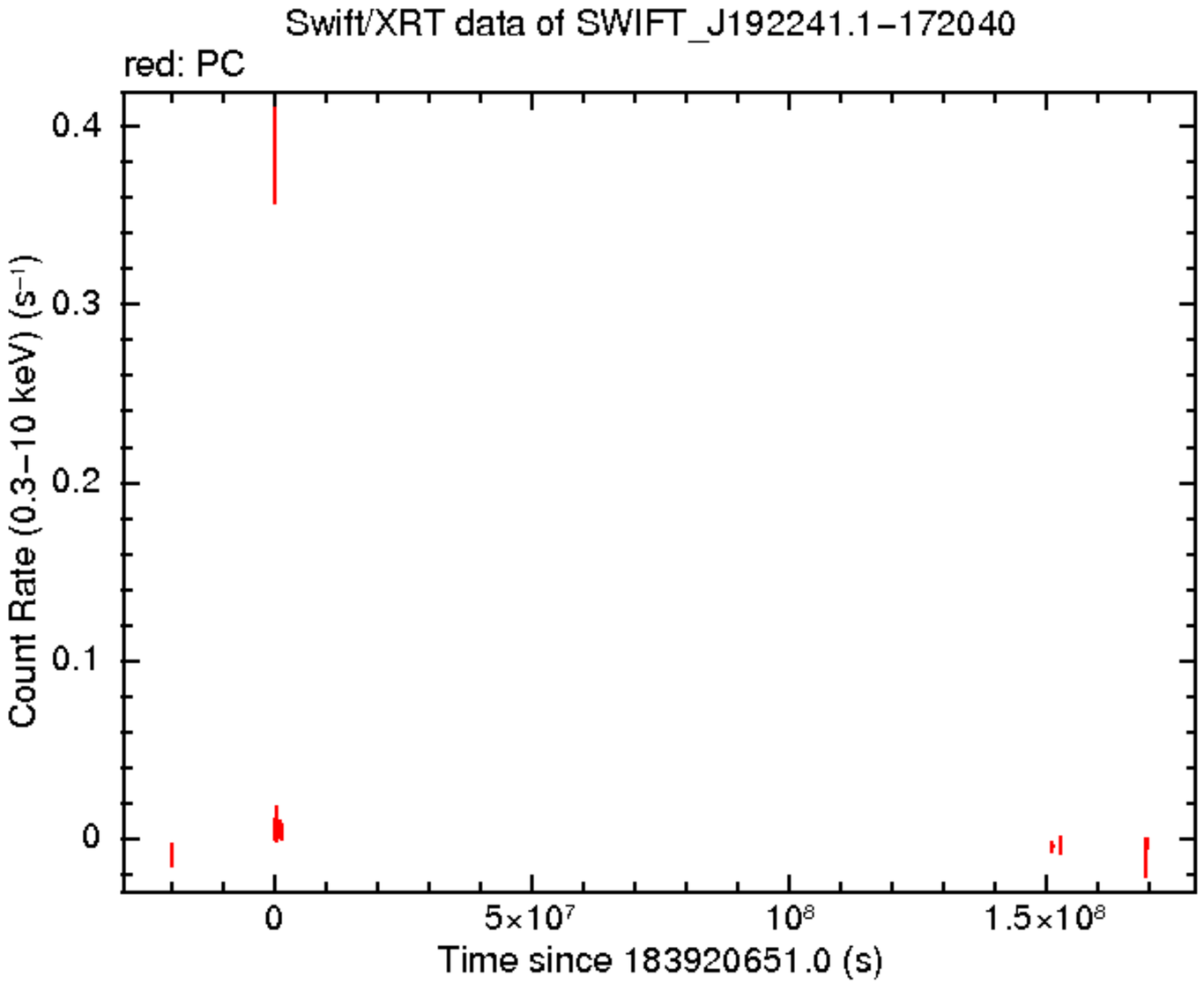


Soderberg et al., 2008

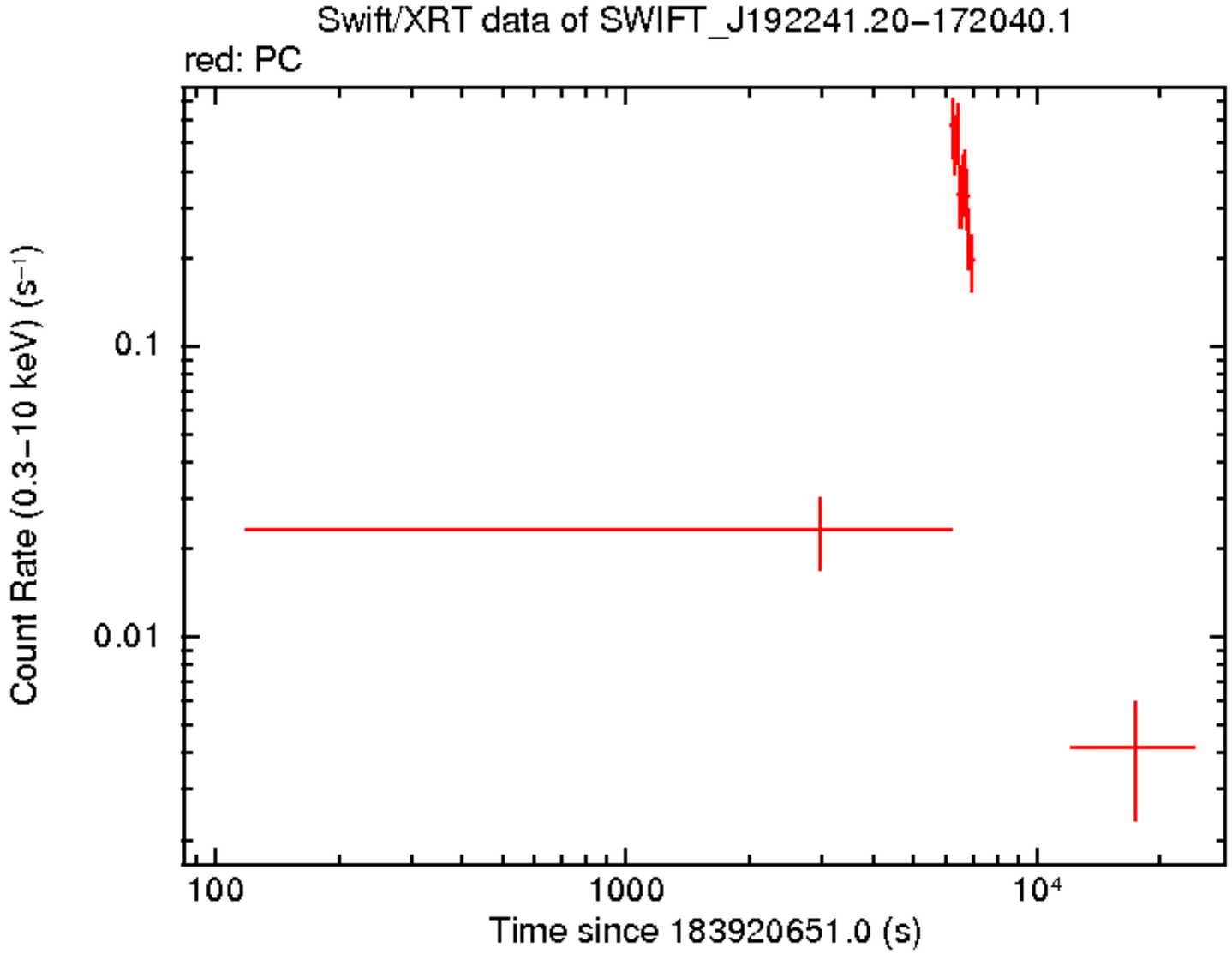
Transients — how to find them

- Look for sources above preexisting limits (RASS / XMM SL)
  - Limits sensitivity to that of existing catalogues.
  - Ditto bandpass.
  - Estimated rate: 1 per 1.64 Ms per 0.12 sq degrees (Evans+ 2016a).
- Looking for sources which ‘turn on’ between observations

Transients — example



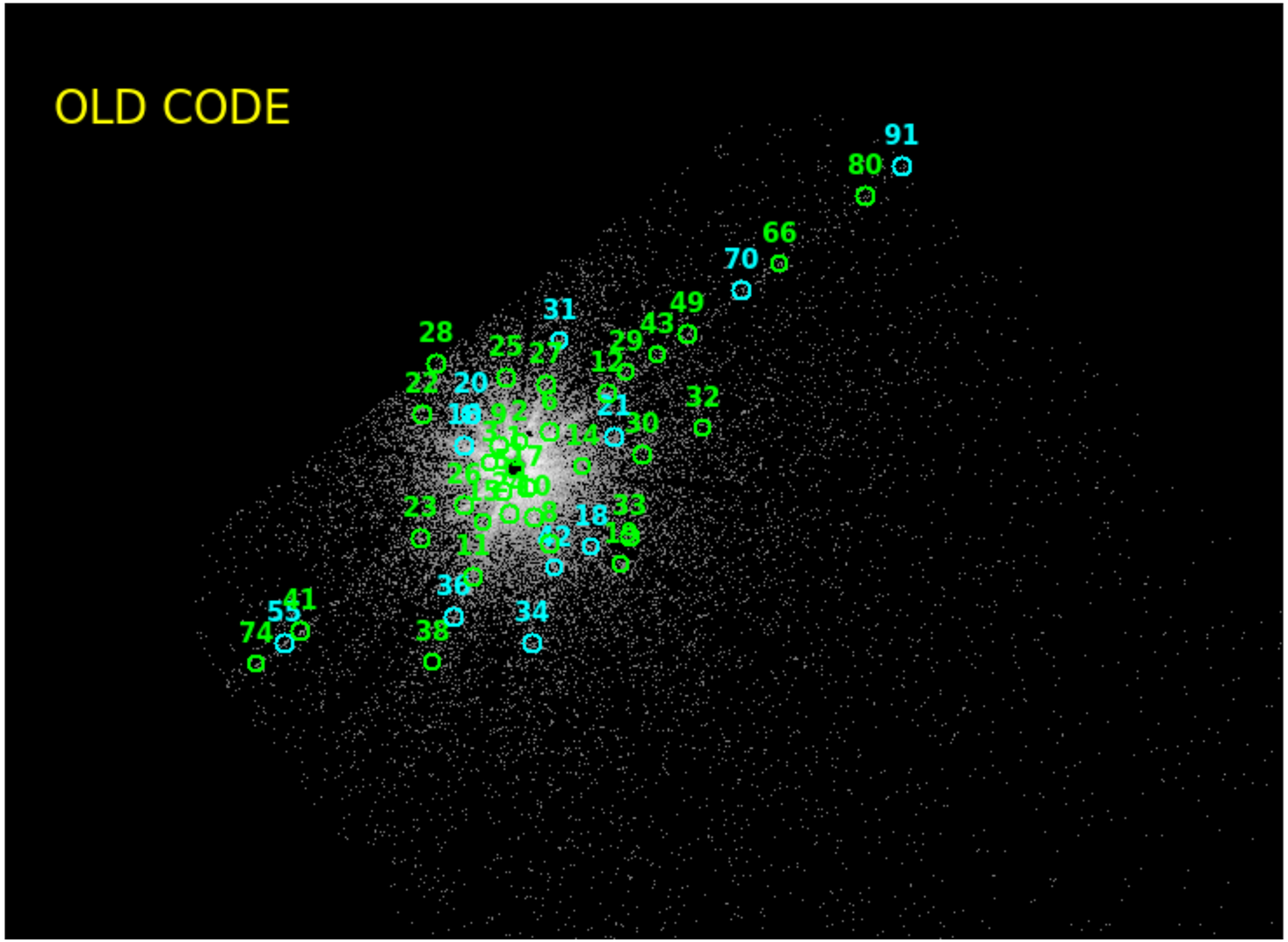
Transients — example



LSXPS and the live transient system

- 2SXPS is intended for release later this year, as part of…
- LSXPS (‘live SXPS’), continually updated with automated transient and outburst notifications.
- New definition of ‘stacked images’
  - Maximum of 40’ radius, minimum number of ‘blocks’ such that every observation *and every overlap between observations* is included.
- But, spurious detections really mess us up:

Problems 1: Bright source aliases



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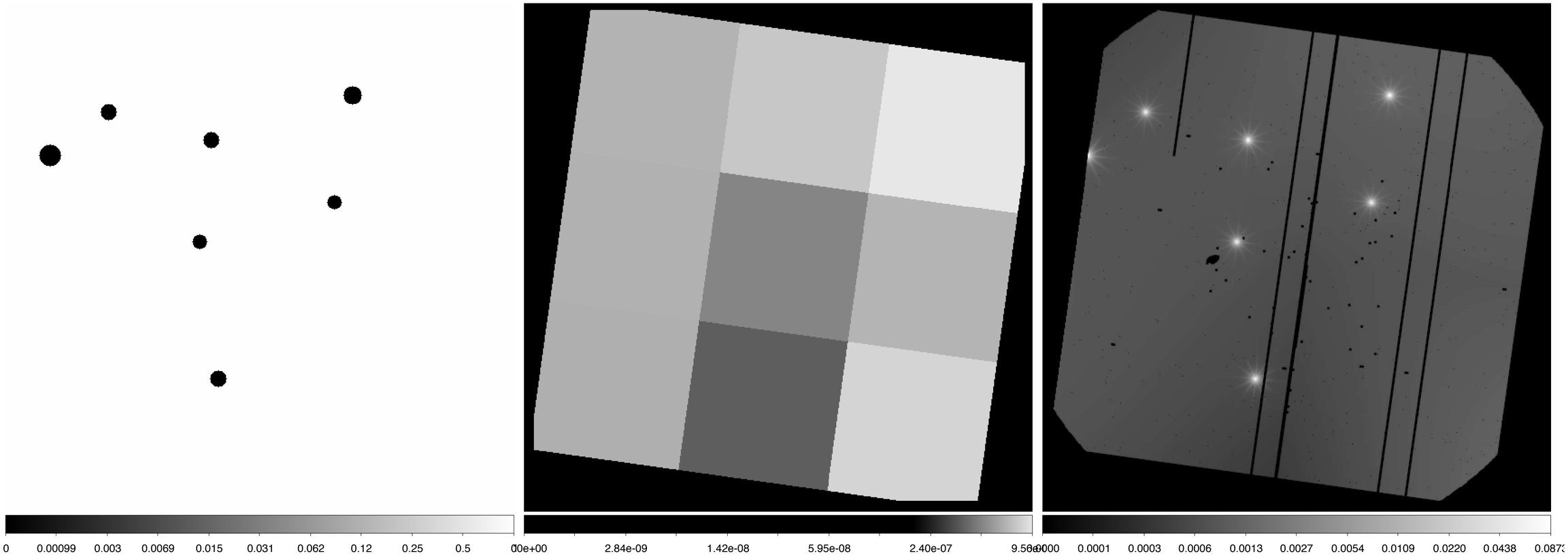
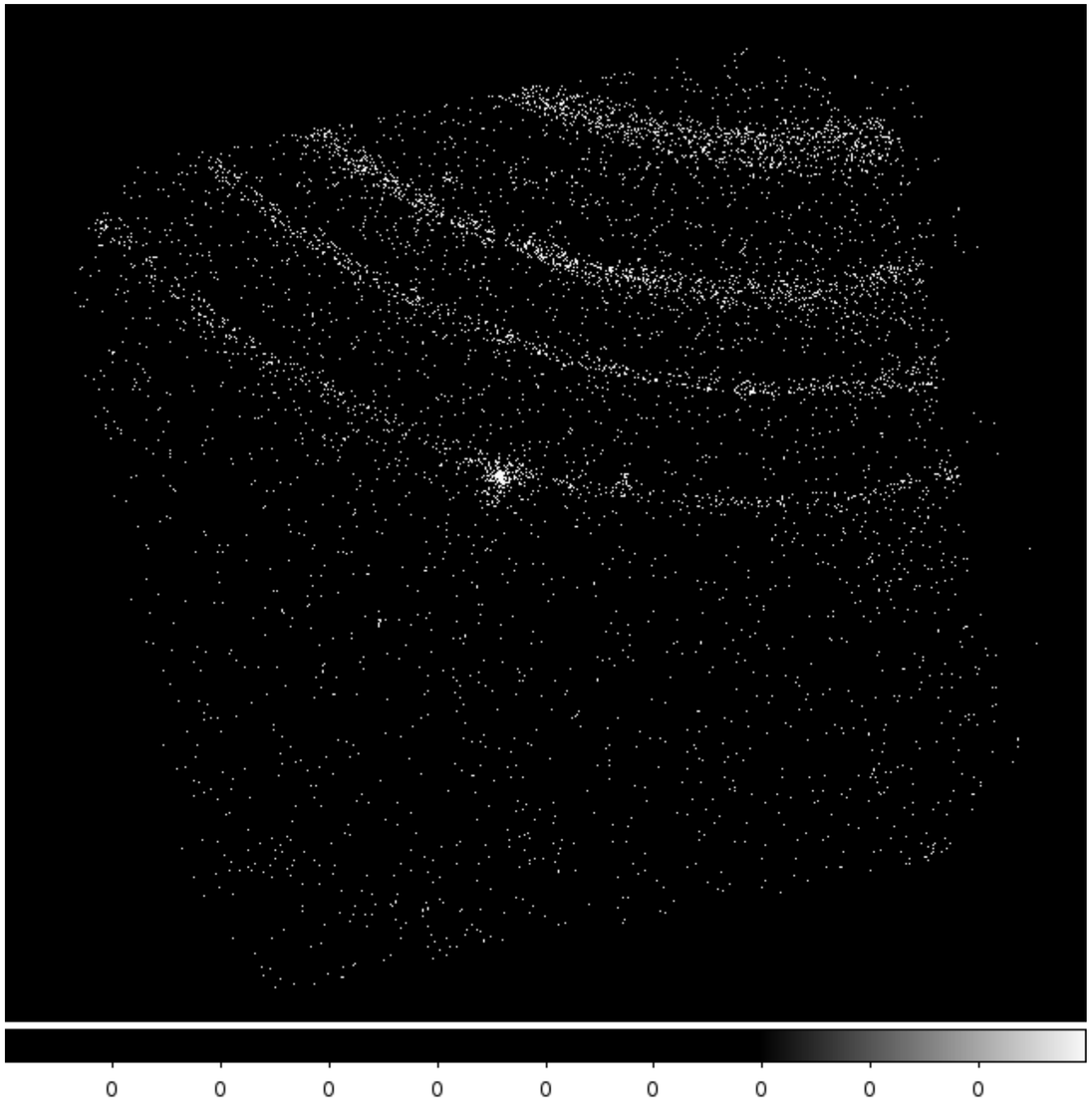
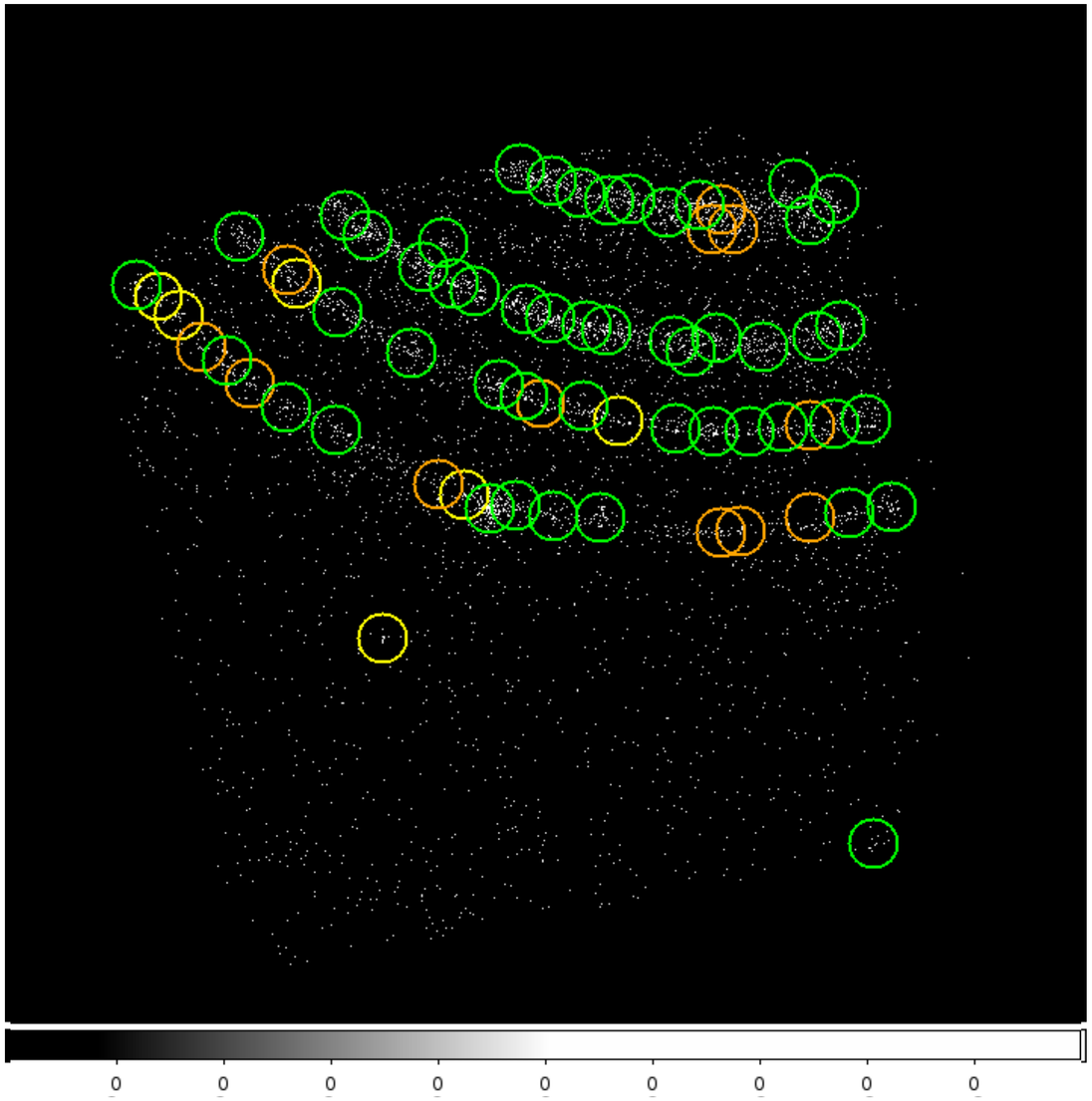


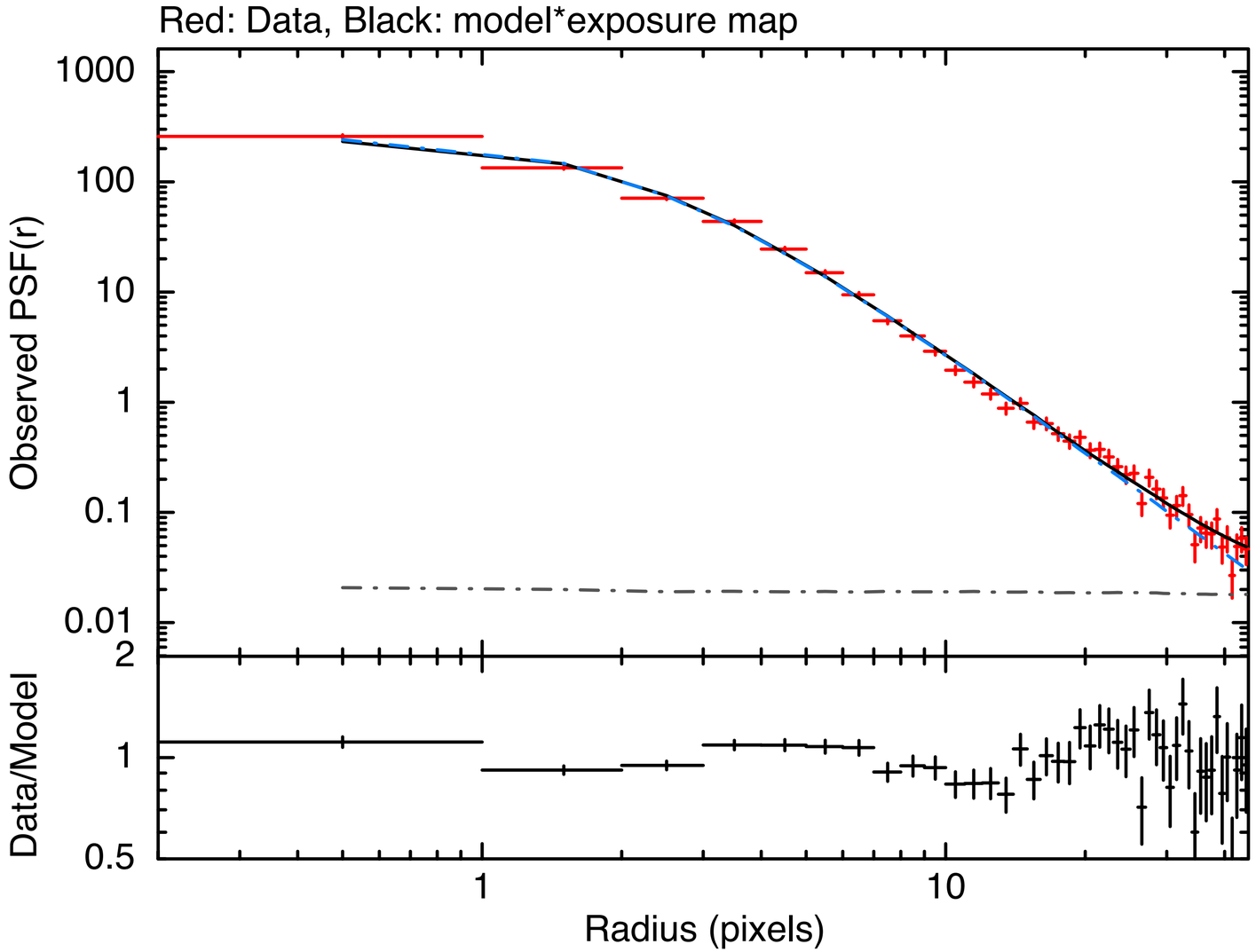
Problems 2: Stray Light



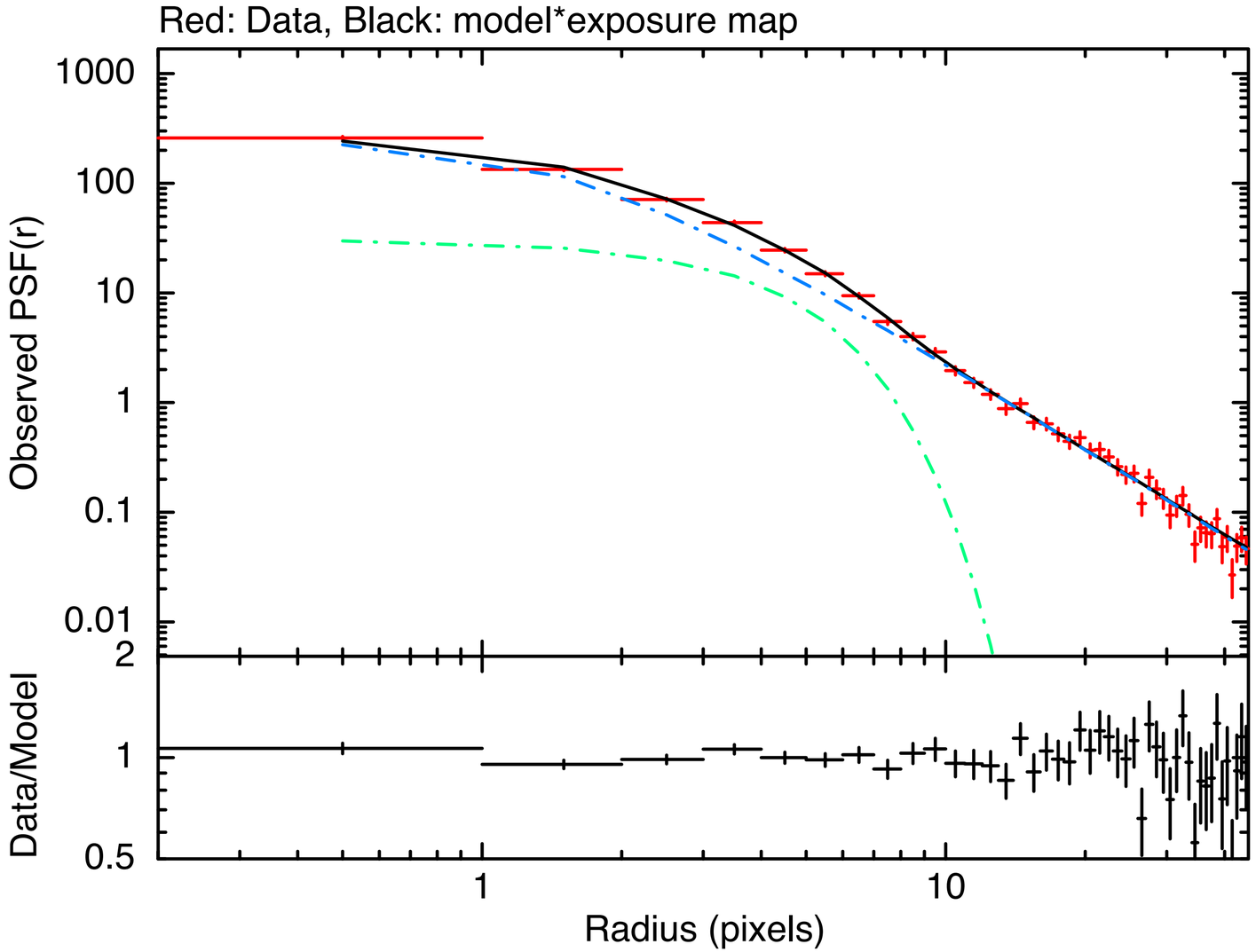
Problems 2: Stray Light



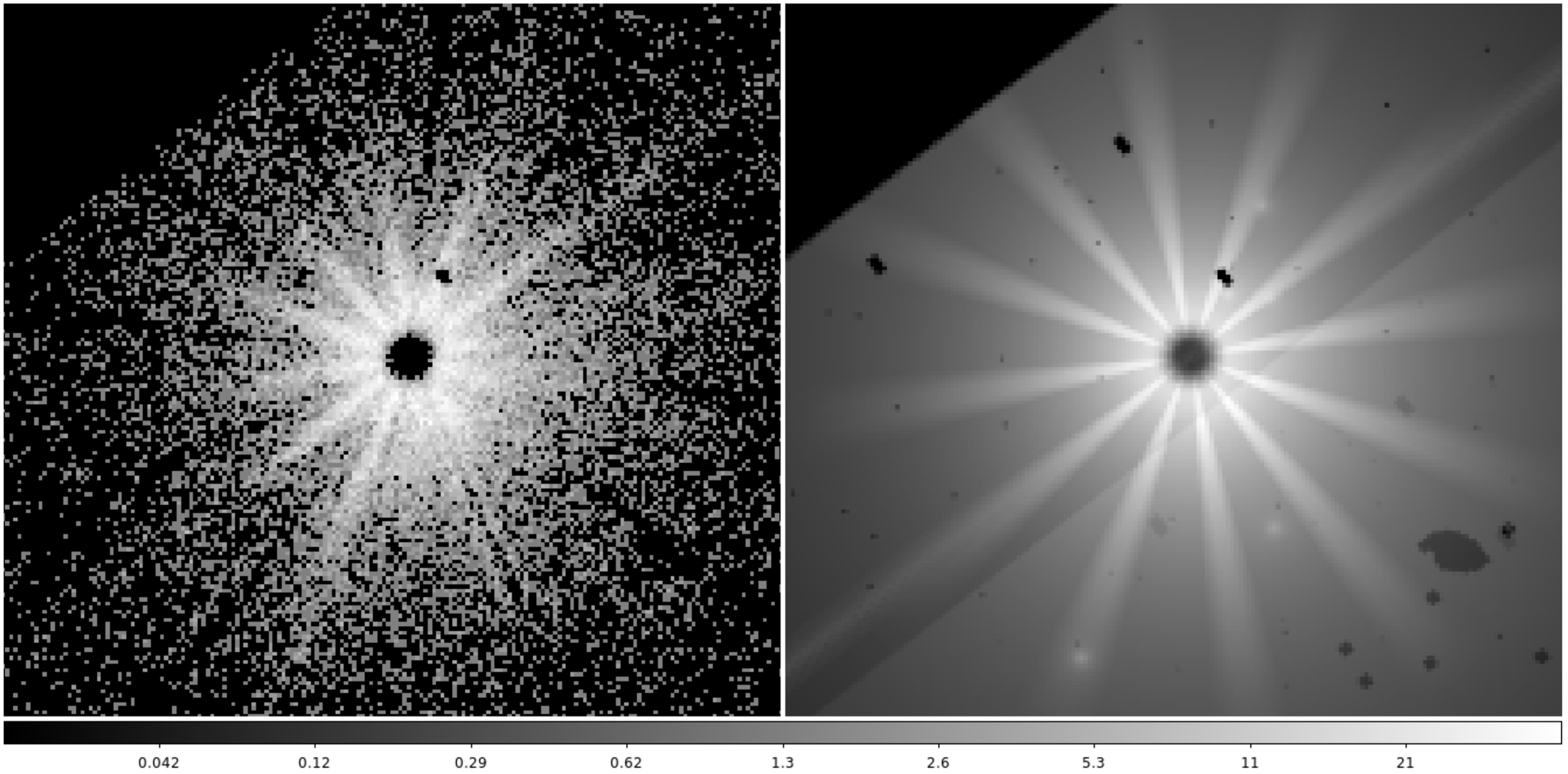
Solving the aliasing



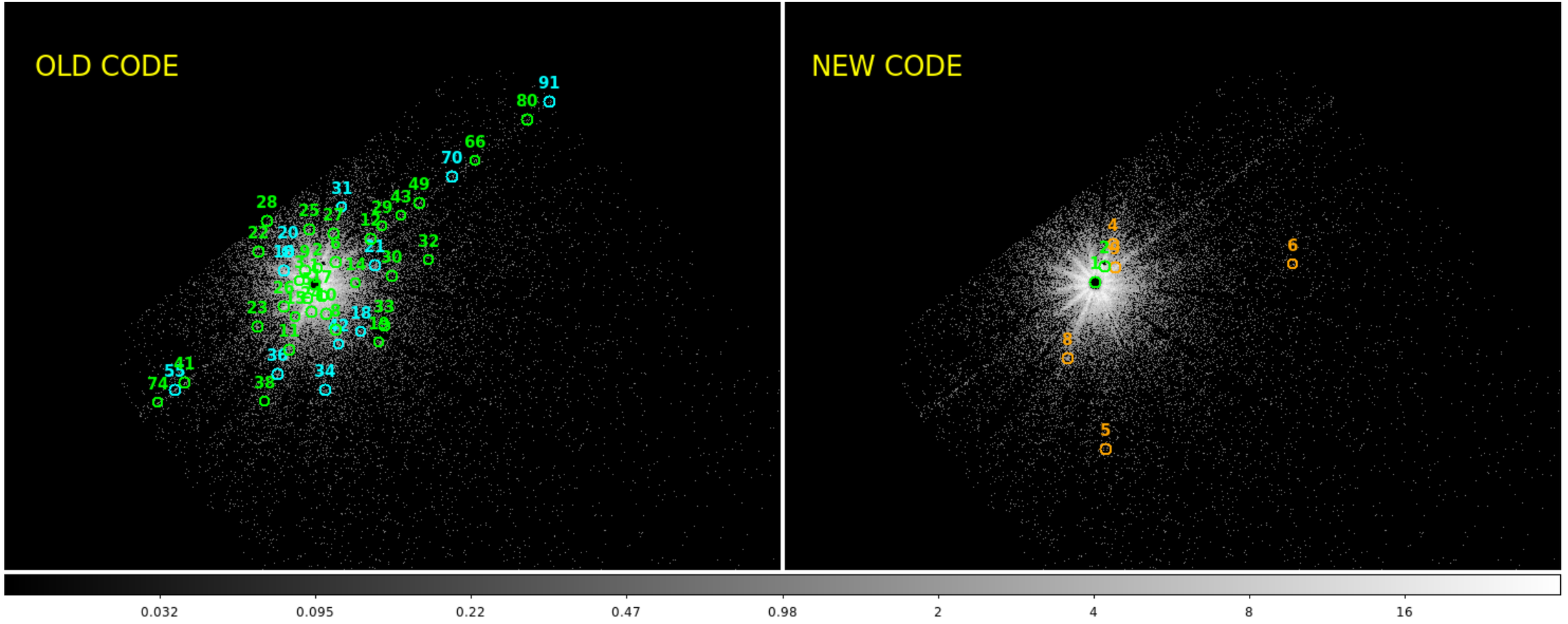
Solving the aliasing



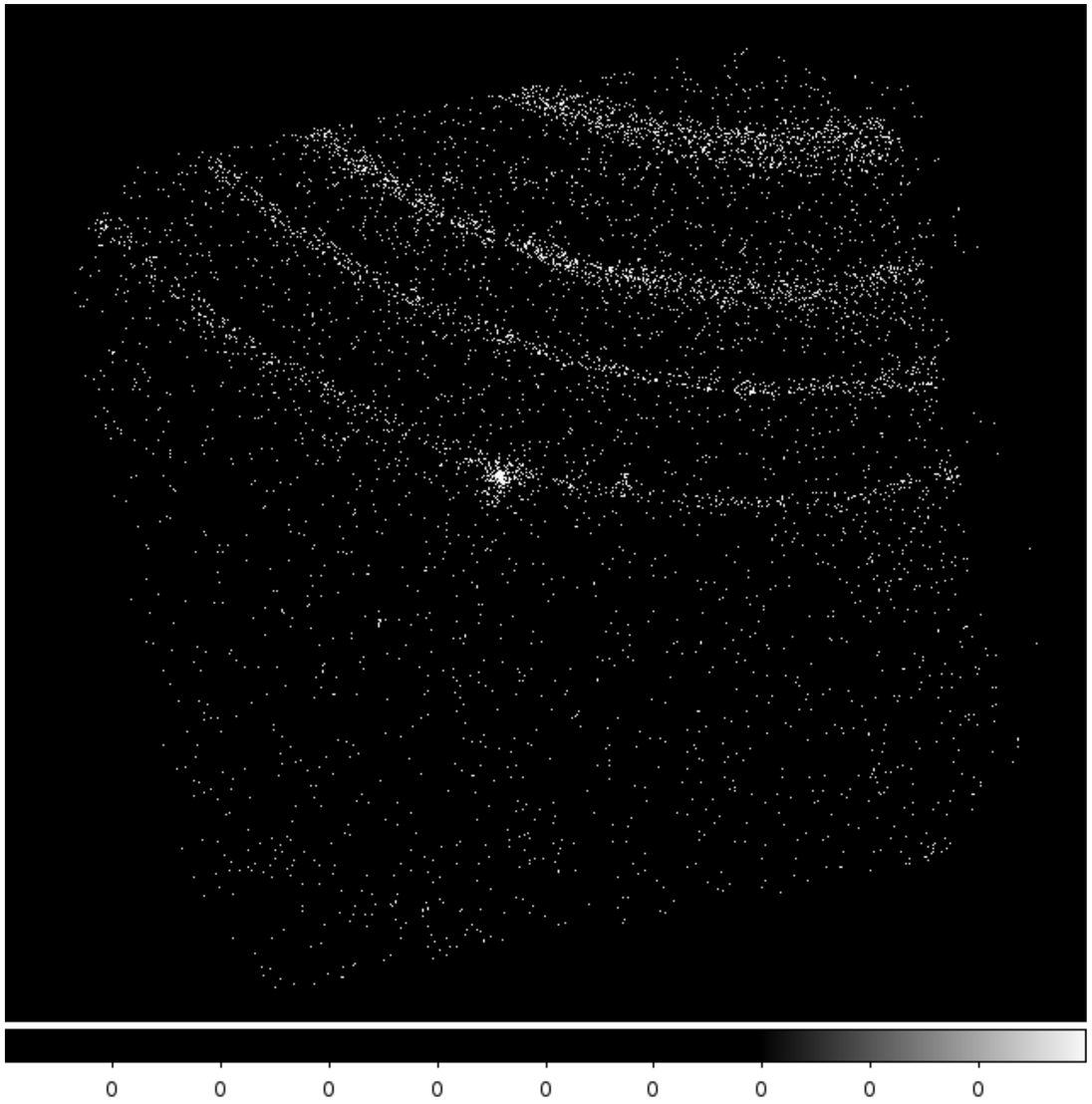
Pile-up and PSF model



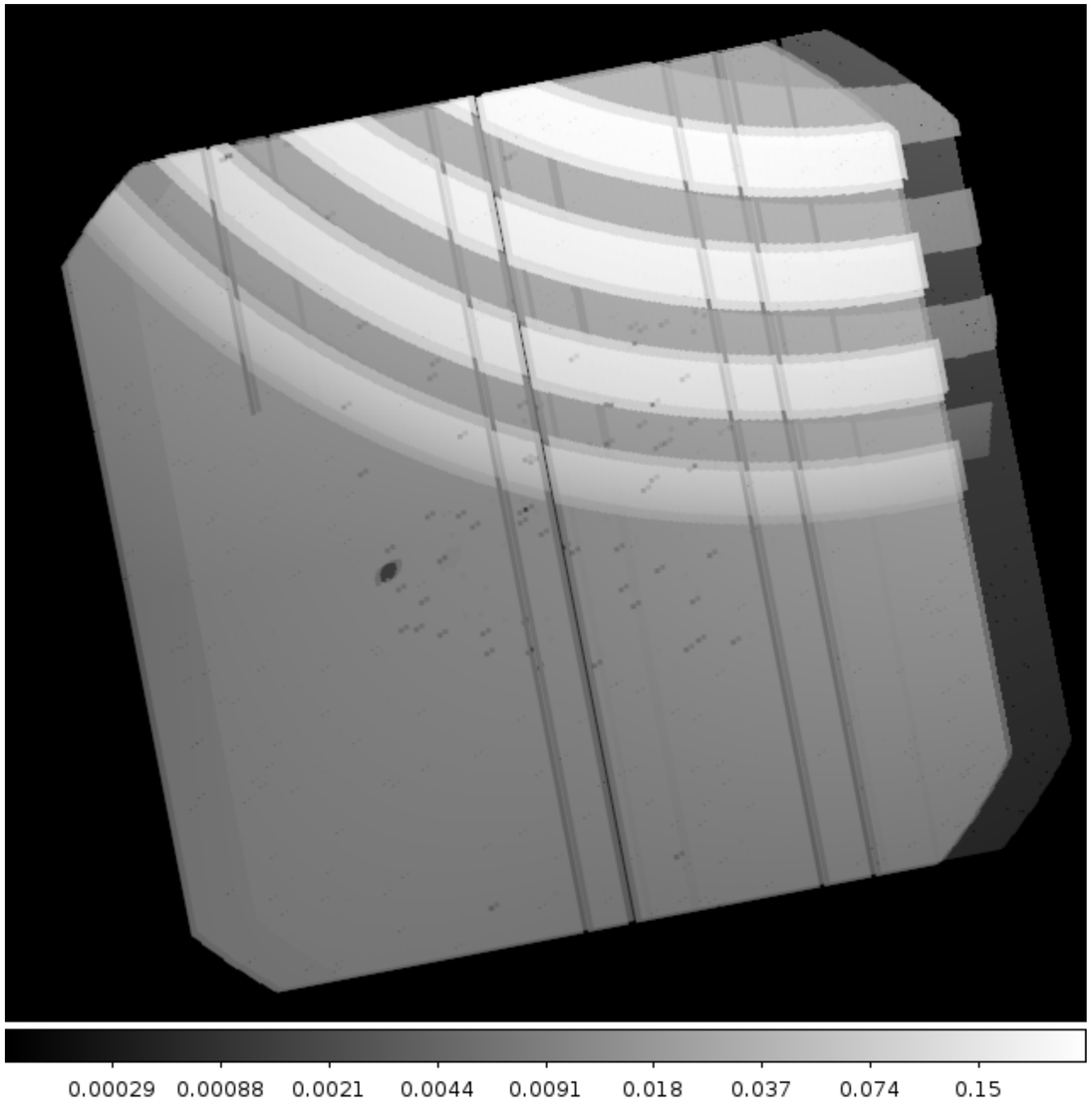
Solving the aliasing



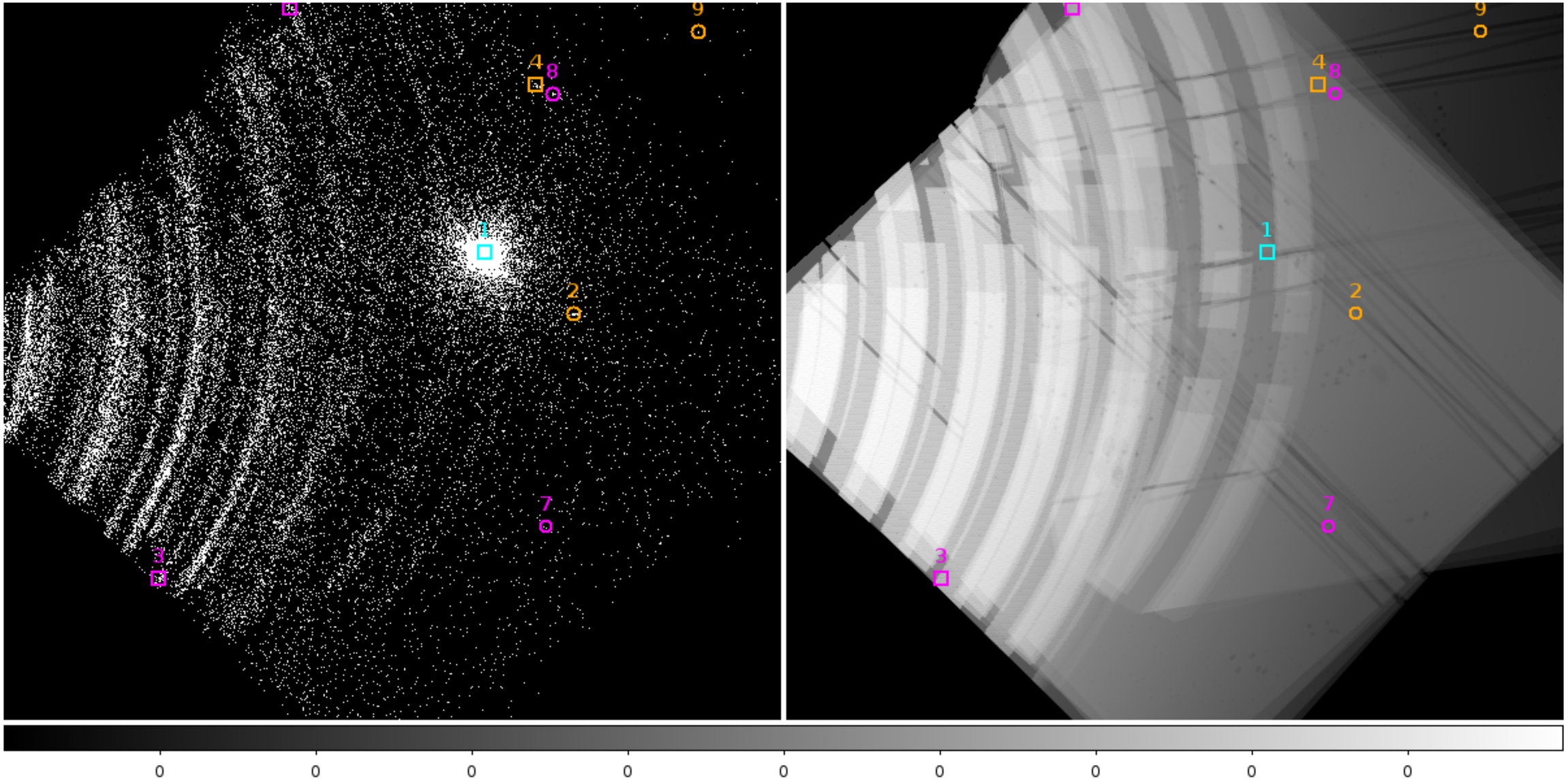
Solving Stray Light



Solving Stray Light

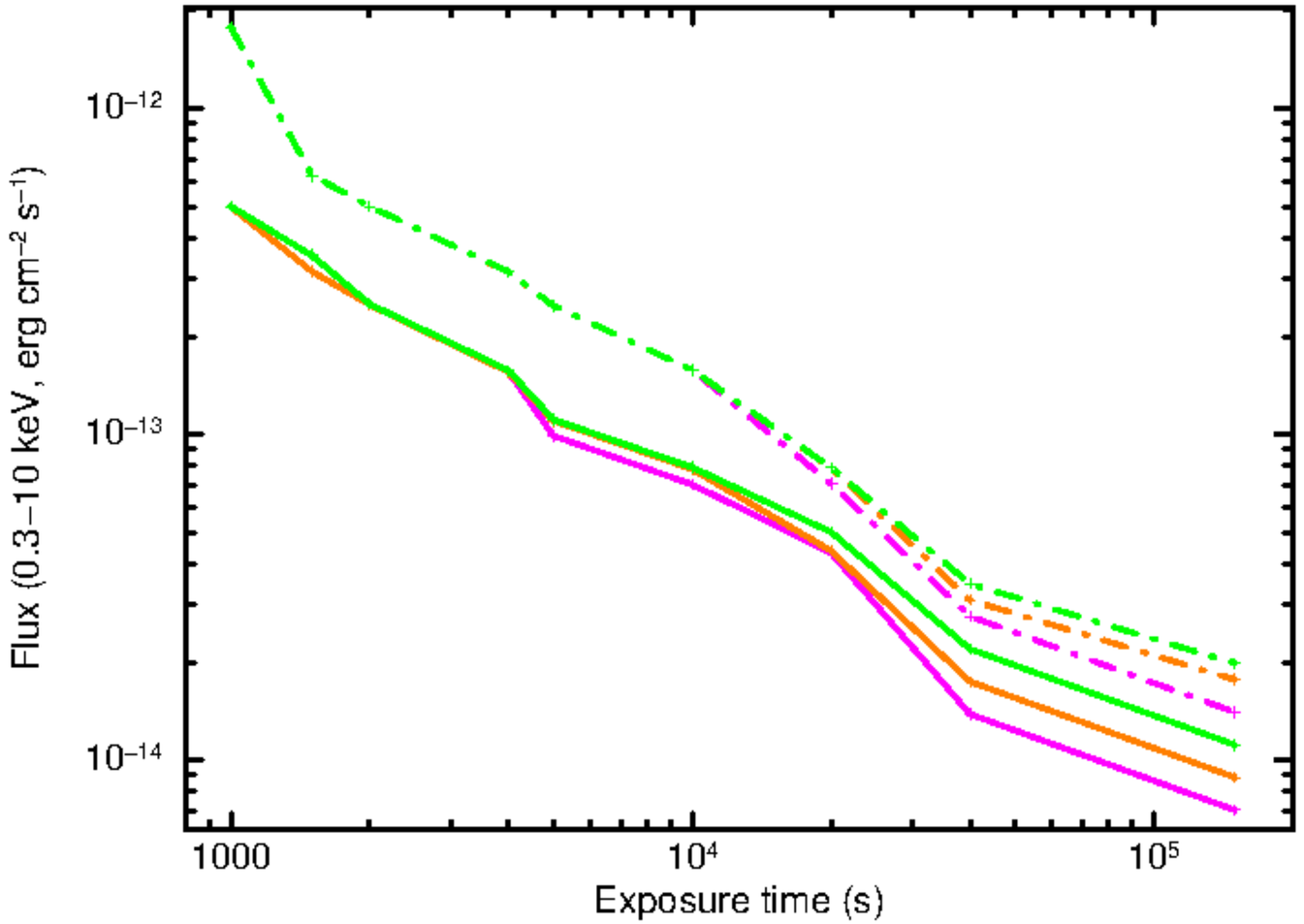


Solving Stray Light



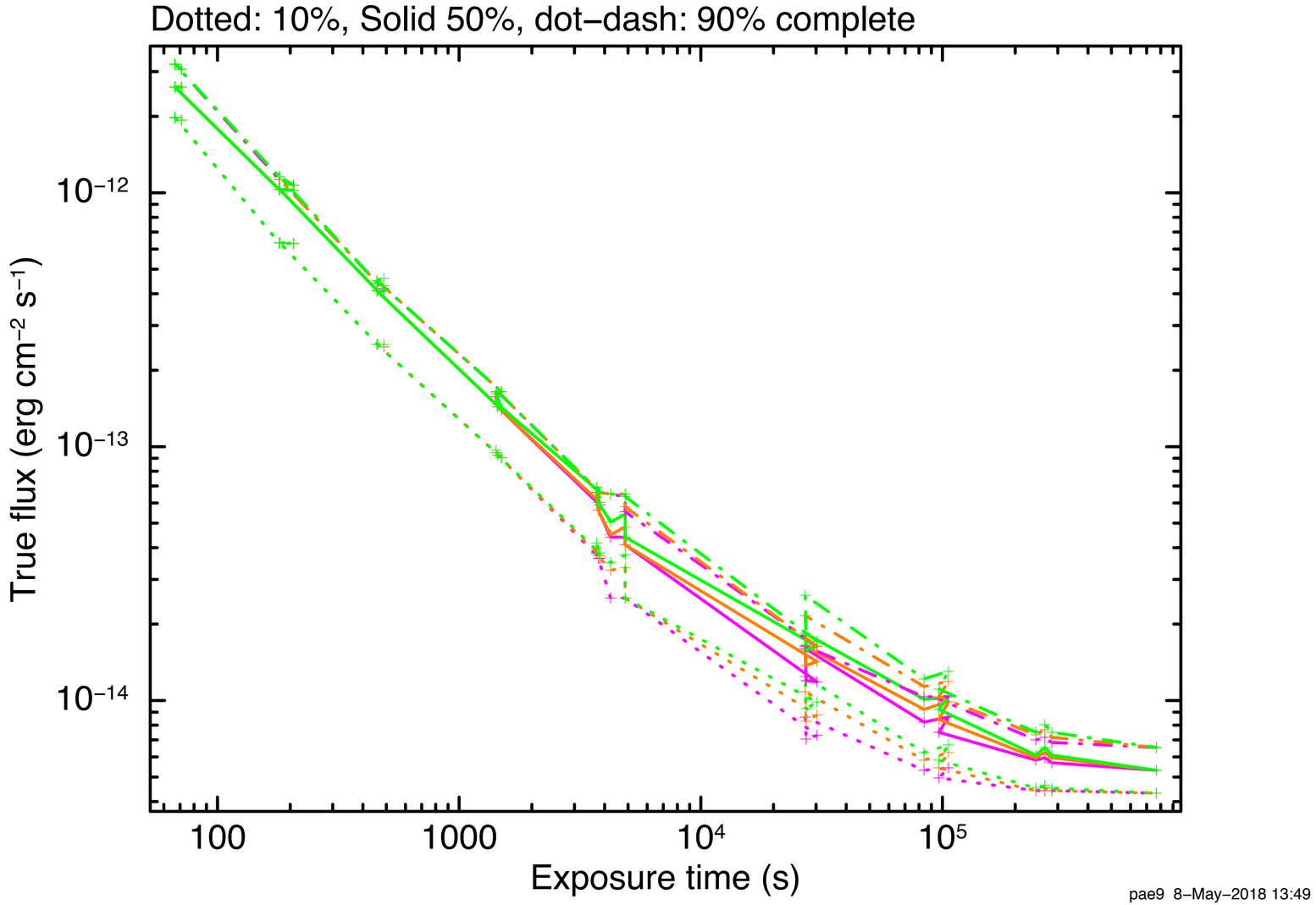
Comparison with 1SXPS

Completeness: 1SXPS. Solid: 50%, broken 90%



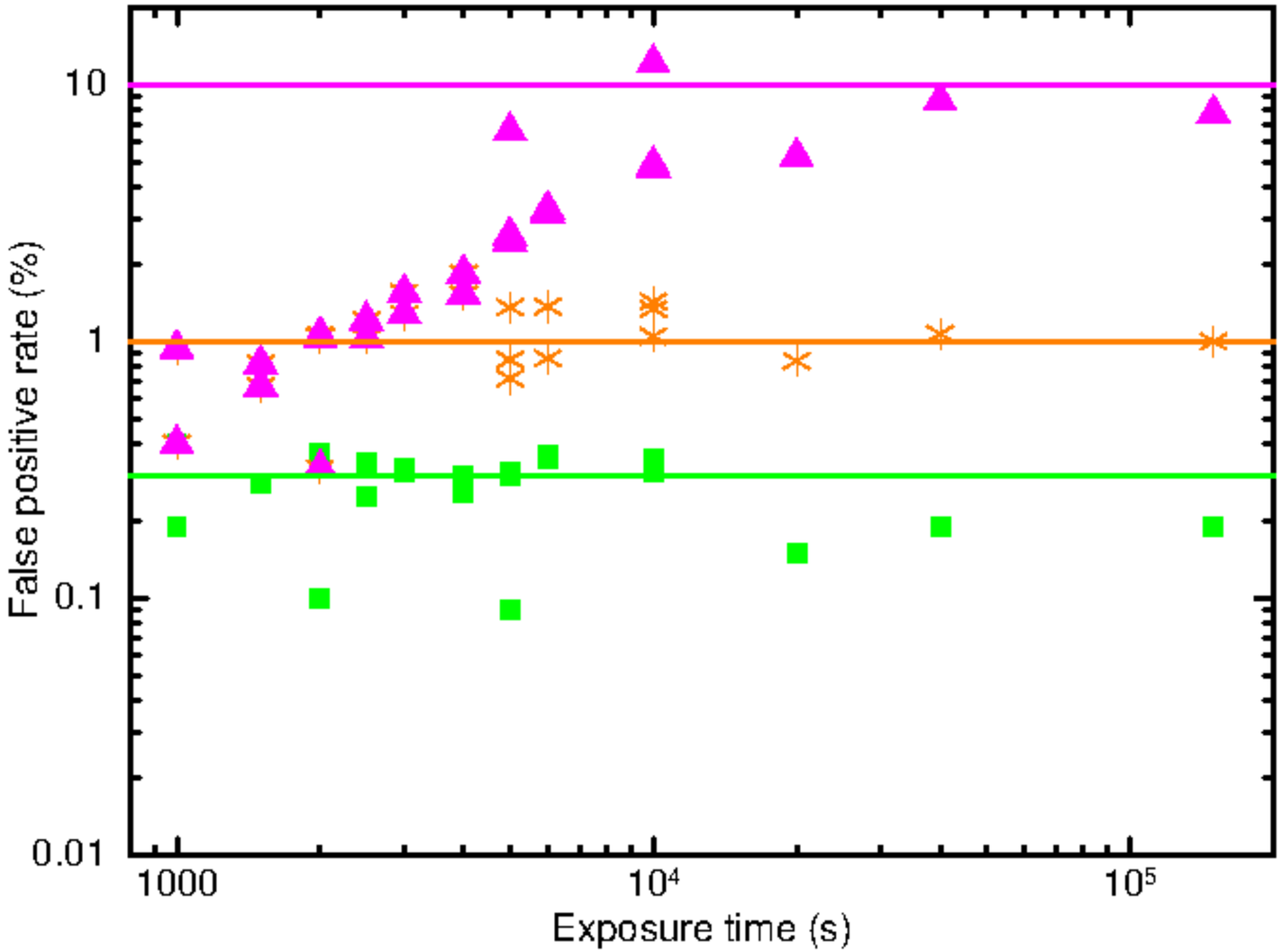
Comparison with 1SXPS

Completeness: new.



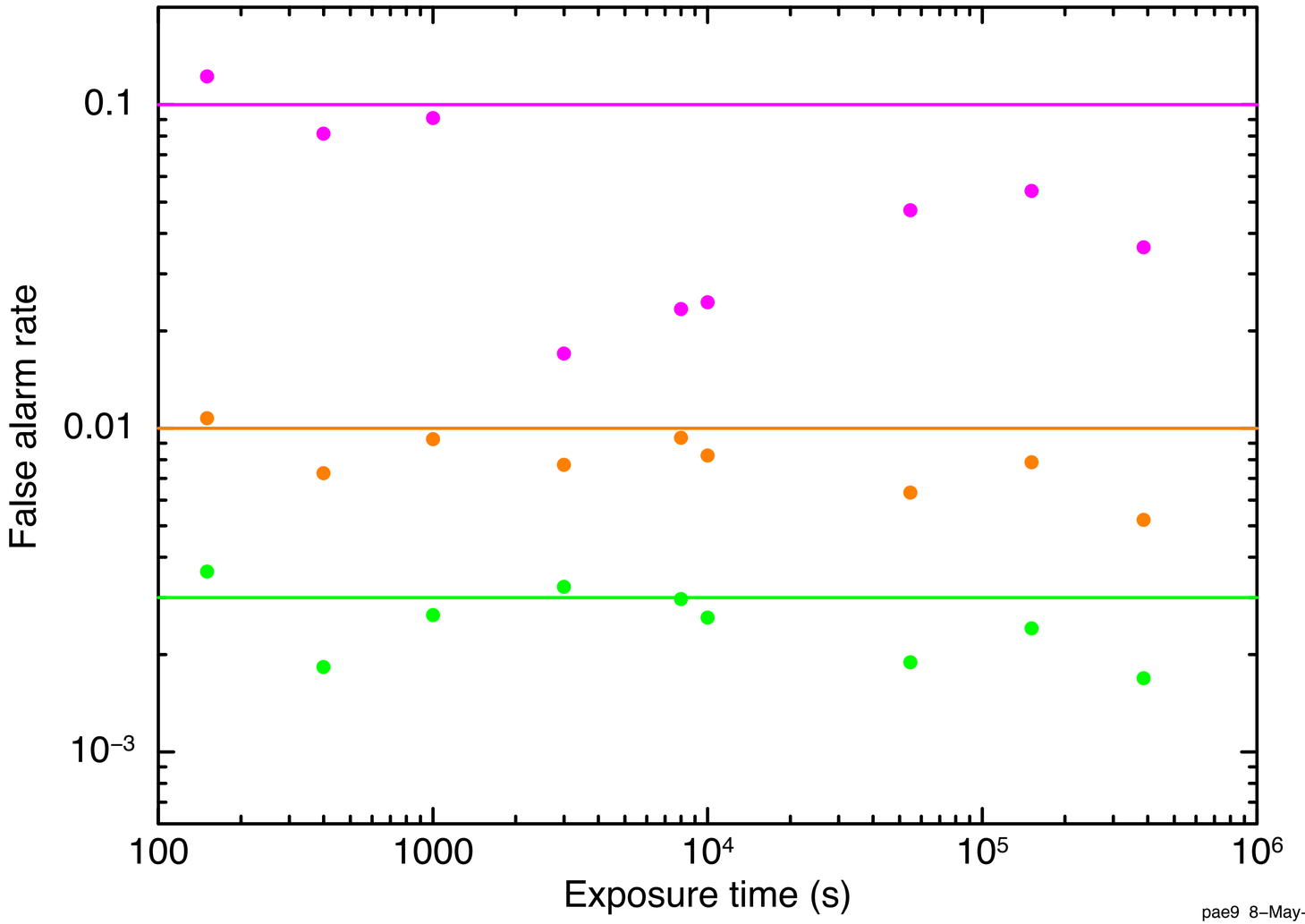
Comparison with 1SXPS

FAR: 1SXPS.



Comparison with 1SXPS

FAR: New.



Conclusions / prospects

- 2SXPS will (hopefully) be completed this year.
  - It will be more sensitive and less prone to certain artefacts.
- LSXPS will go live around the same time, with periodic ‘frozen’ data releases.
- This will include a real-time transient and outburst detector.
- Swift-*XRT* is a fantastic resource for serendipitous X-ray variability studies, and 1SXPS contains many “hidden treasures” in the form of variable and transient sources.