NICER Magnetar Burst Catalog

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ASROC 2025

NICER Magnetar Burst Catalog

- Magnetar and its burst
- Data selection
- Burst searching
- Catalog

Artist’s illustration of a magnetar burst (Credit: NASA)

Magnetar

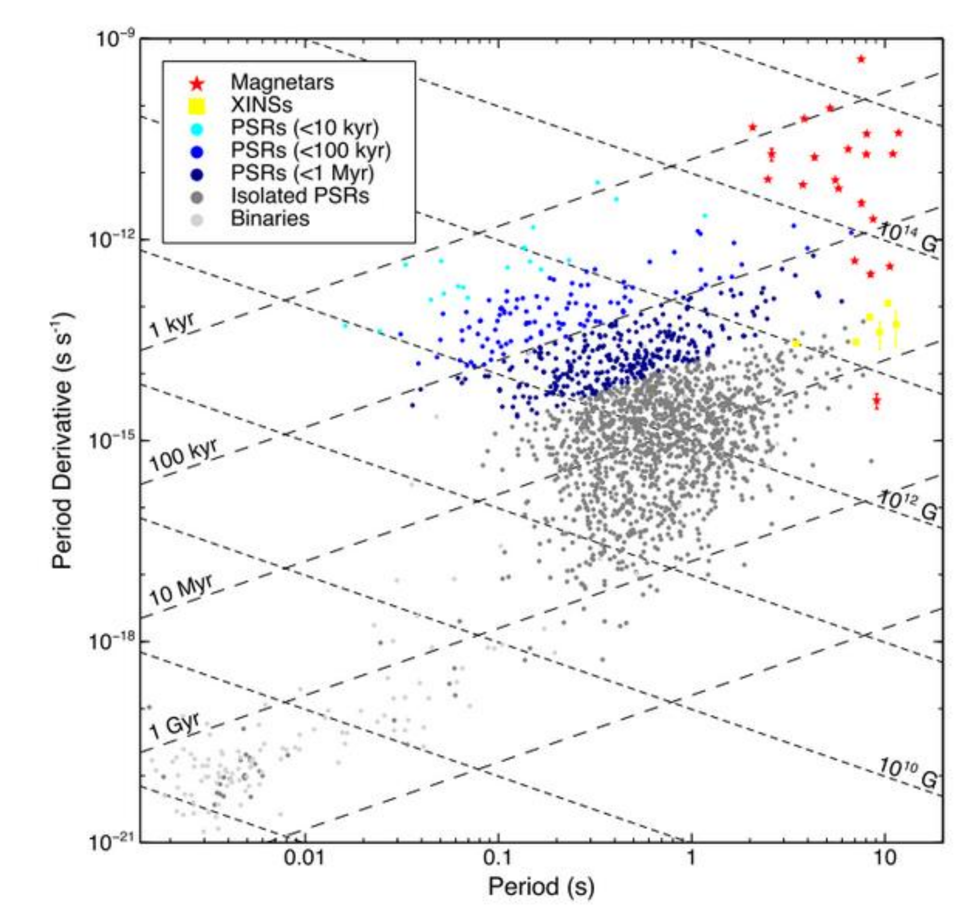
Neutron stars with extremely high magnetic field (Duncan & Thompson 1992)

Slow rotation period, high period derivative

→ high magnetic field

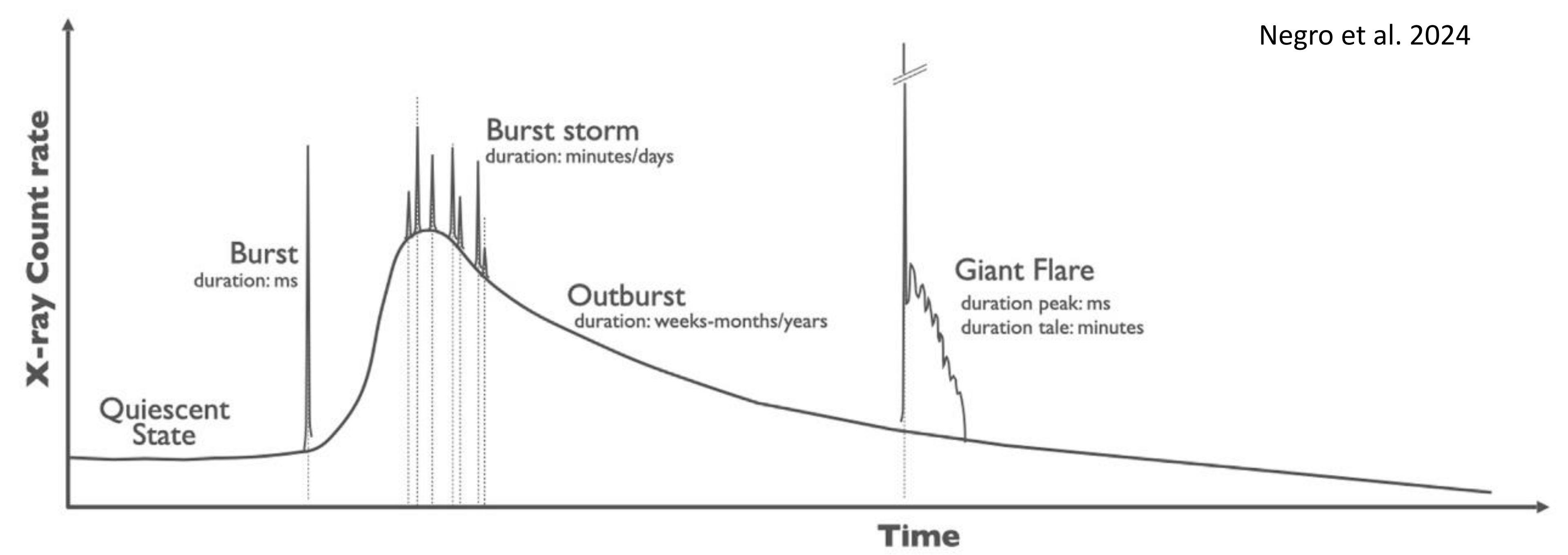
→ young characteristic age

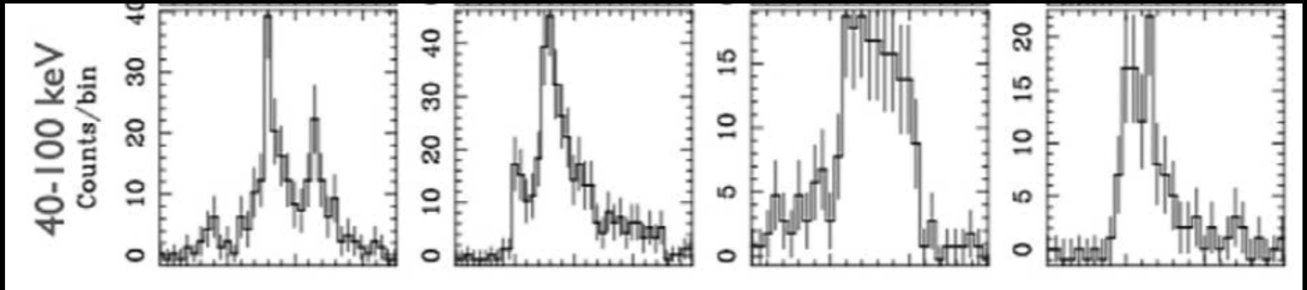
→ low spin-down power



Olausen & Kaspi (2014)

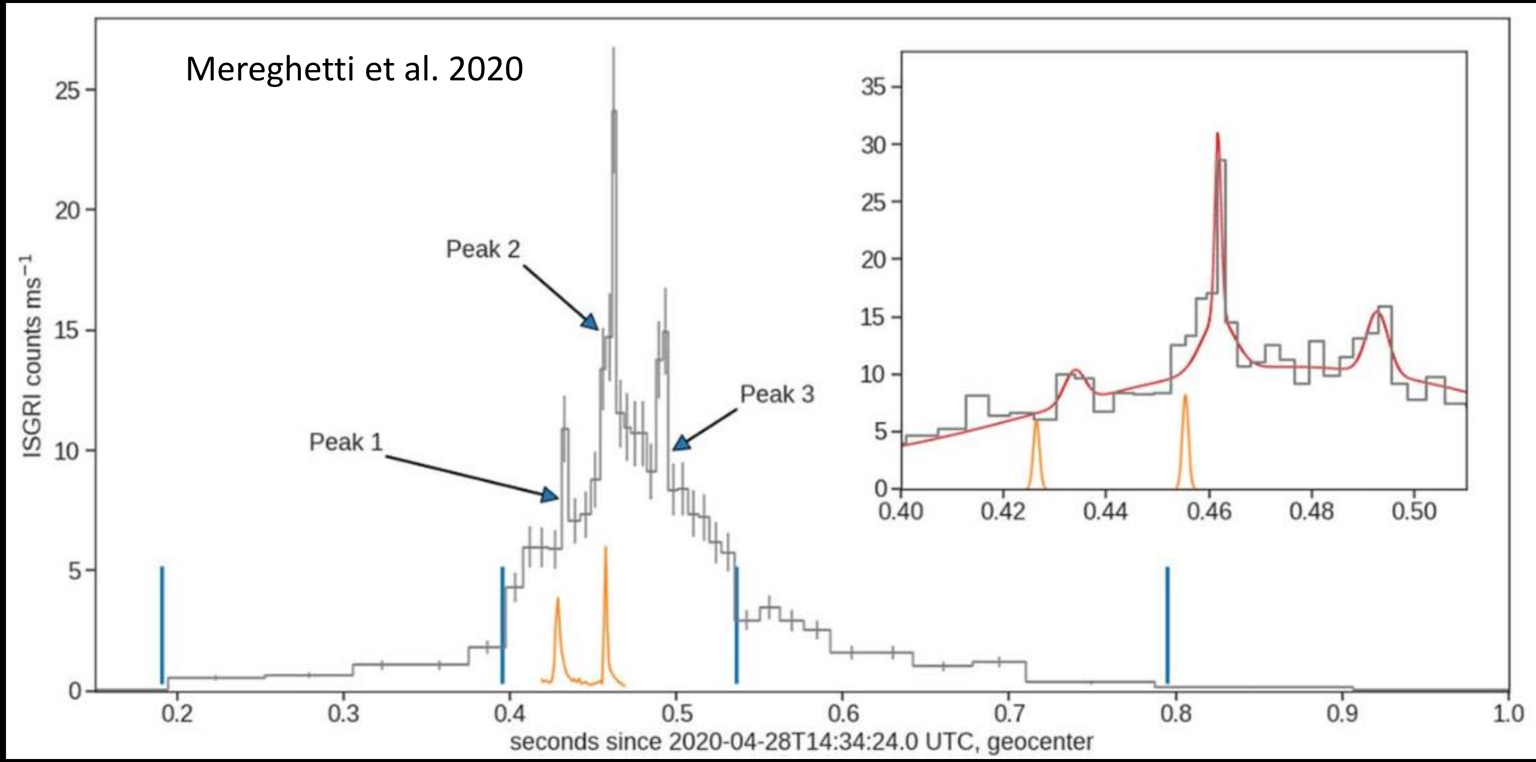
Magnetar burst





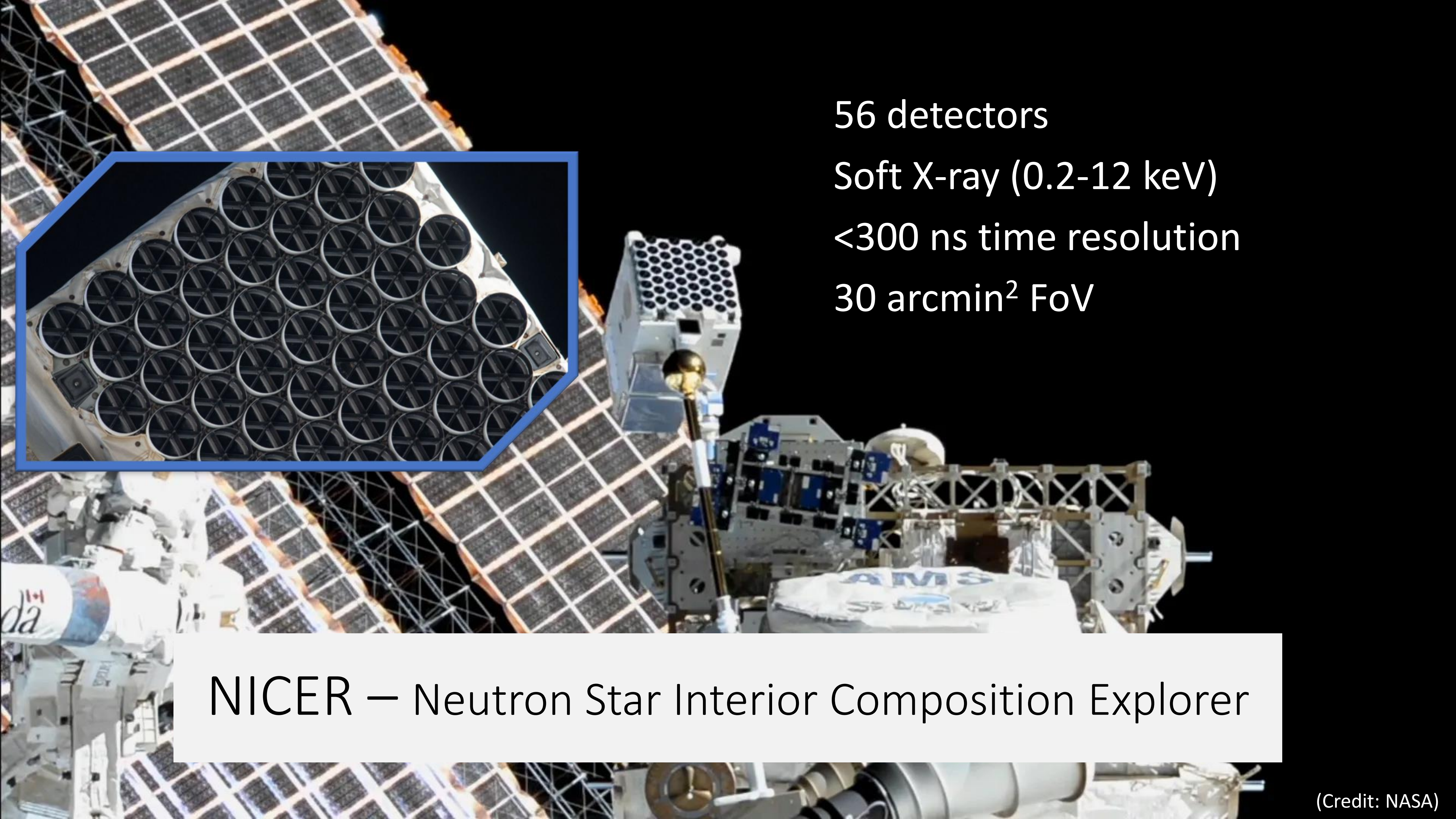
Short bursts from SGR 1806−20 observed with the IBIS instrument on board INTEGRAL (from Götz et al. 2004)

Magnetar burst – FRB association



FRB 200428 associate with a magentar X-ray short burst (Mereghetti et al. 2020)

Burst properties are different before and after an FRB (Hu et al. 2025)


56 detectors
Soft X-ray (0.2-12 keV)
<300 ns time resolution
30 arcmin^2 FoV
NICER – Neutron Star Interior Composition Explorer
(Credit: NASA)

Data

Magnetar	Exposure time (ks)
CXOU J010043.1-721134	644.6
4U 0142+61	305.7
SGR 0418+5729	18.7
SGR 0501+4516	484.9
1E 1048.1-5937	373.0
1E 1547.0-5408	78.7
Swift J1555.2-5402	118.1
PSR J1622-4950	46.0
CXOU J164710.2-455216	166.9
1RXS J170849.0-400910	84.1
CXOU J171405.7-381031	3.7
SGR J1745-2900	77.7
SGR 1806-20	37.2
XTE J1810-197	496.6
Swift J1818.0-1607	181.2
Swift J1822.3-1606	14.7
SGR 1830-0645	245.1
1E 1841-045	338.6
SGR 1900+14	0.4
SGR 1935+2154	1032.5
1E 2259+586	161.6

All the available magentar observations

2017 June – 2024 November (~7.5 yrs)

Total exposure of 4900 ks of data from 21 magnetars

Select 0.5 – 8 keV events for further analysis

Burst searching

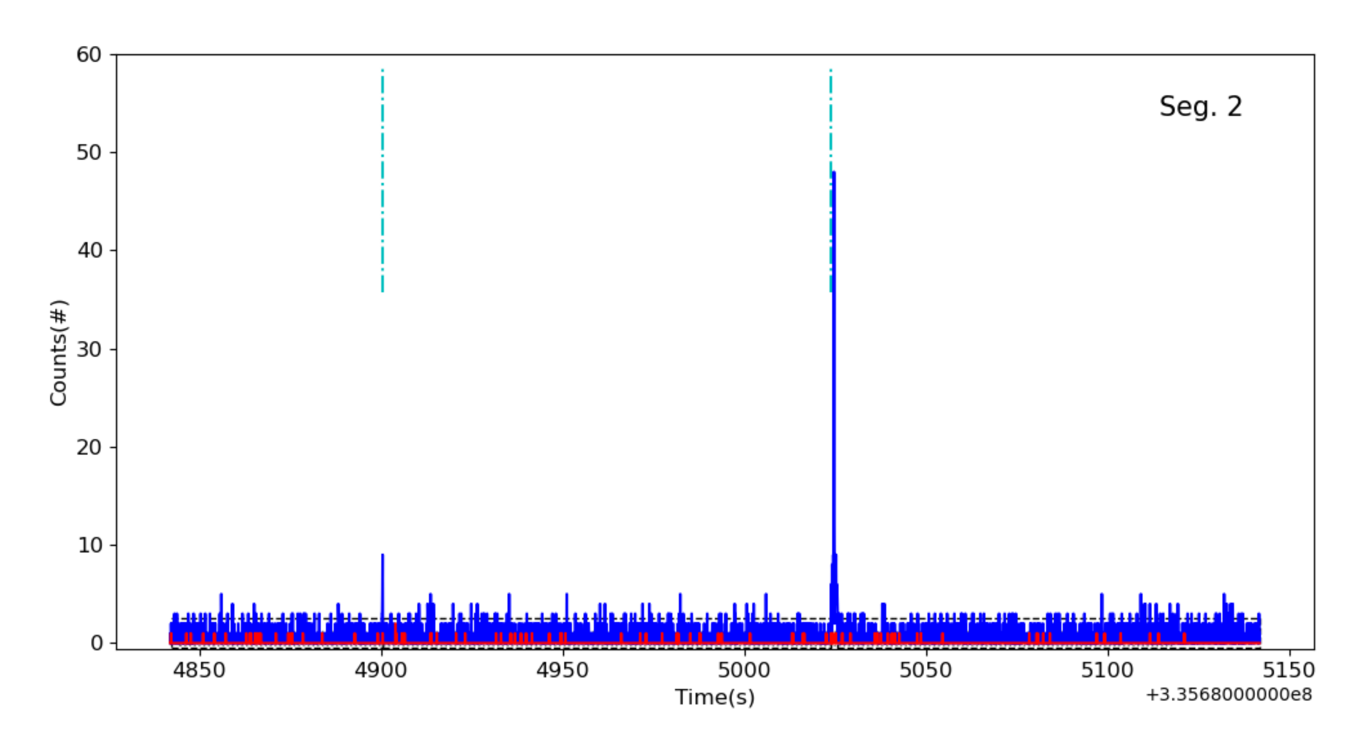
Apply Bayesian Block on the event list to detect rapid changes (Scargle 1998)

Select block duration < 1s

Calculate Poisson probability

P-value < 10^{-4}

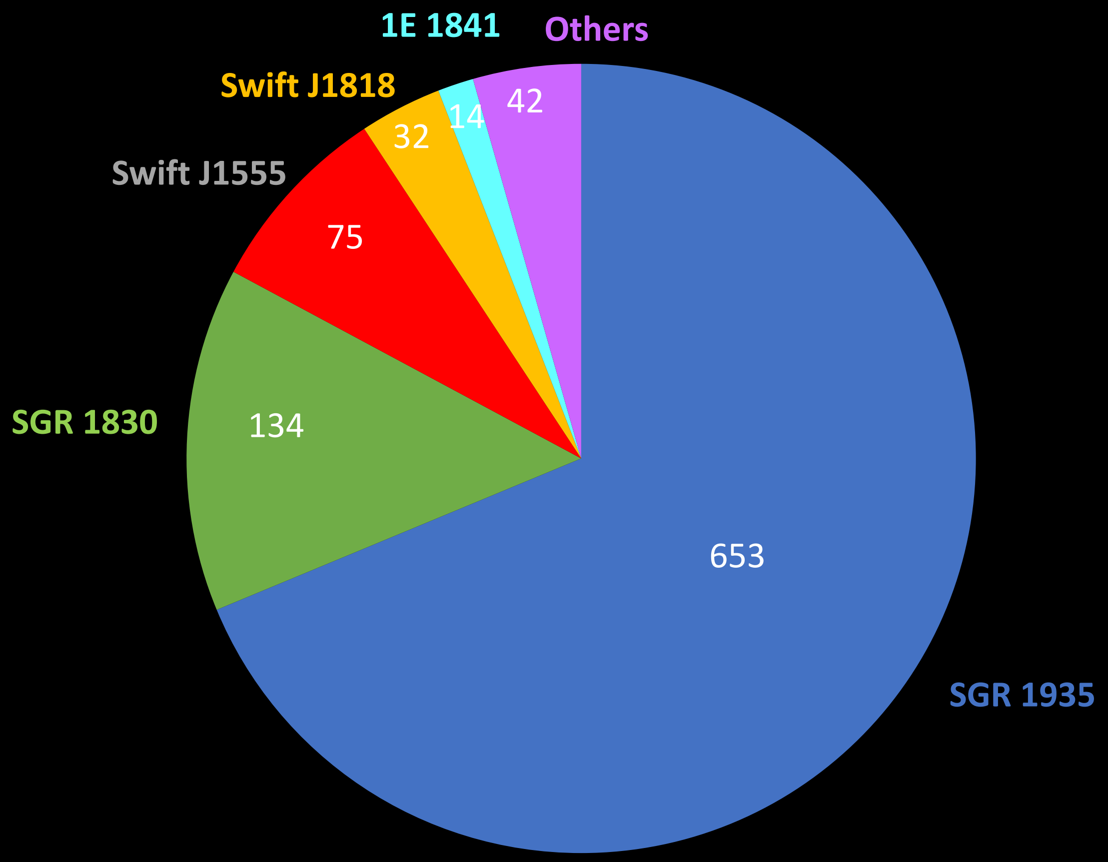
(# of trial considered)



Magnetar	Exposure time (ks)	Burst
CXOU J010043.1-721134	644.6	8
4U 0142+61	305.7	5
SGR 0418+5729	18.7	0
SGR 0501+4516	484.9	5
1E 1048.1-5937	373.0	5
1E 1547.0-5408	78.7	2
Swift J1555.2-5402	118.1	75
PSR J1622-4950	46.0	1
CXOU J164710.2-455216	166.9	1
1RXS J170849.0-400910	84.1	3
CXOU J171405.7-381031	3.7	0
SGR J1745-2900	77.7	2
SGR 1806-20	37.2	4
XTE J1810-197	496.6	3
Swift J1818.0-1607	181.2	33
Swift J1822.3-1606	14.7	2
SGR 1830-0645	245.1	134
1E 1841-045	338.6	14
SGR 1900+14	0.4	0
SGR 1935+2154	1032.5	653
1E 2259+586	161.6	1

Burst searching

We found 951 bursts from 18 magnetars



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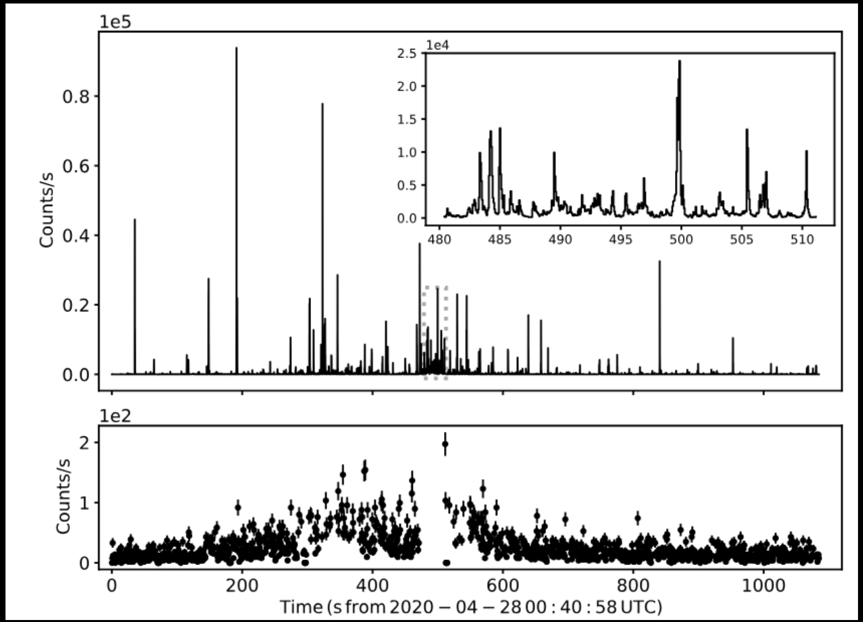
SGR 1935+2154



2020 Apr burst storm
(Younes et al. 2020)

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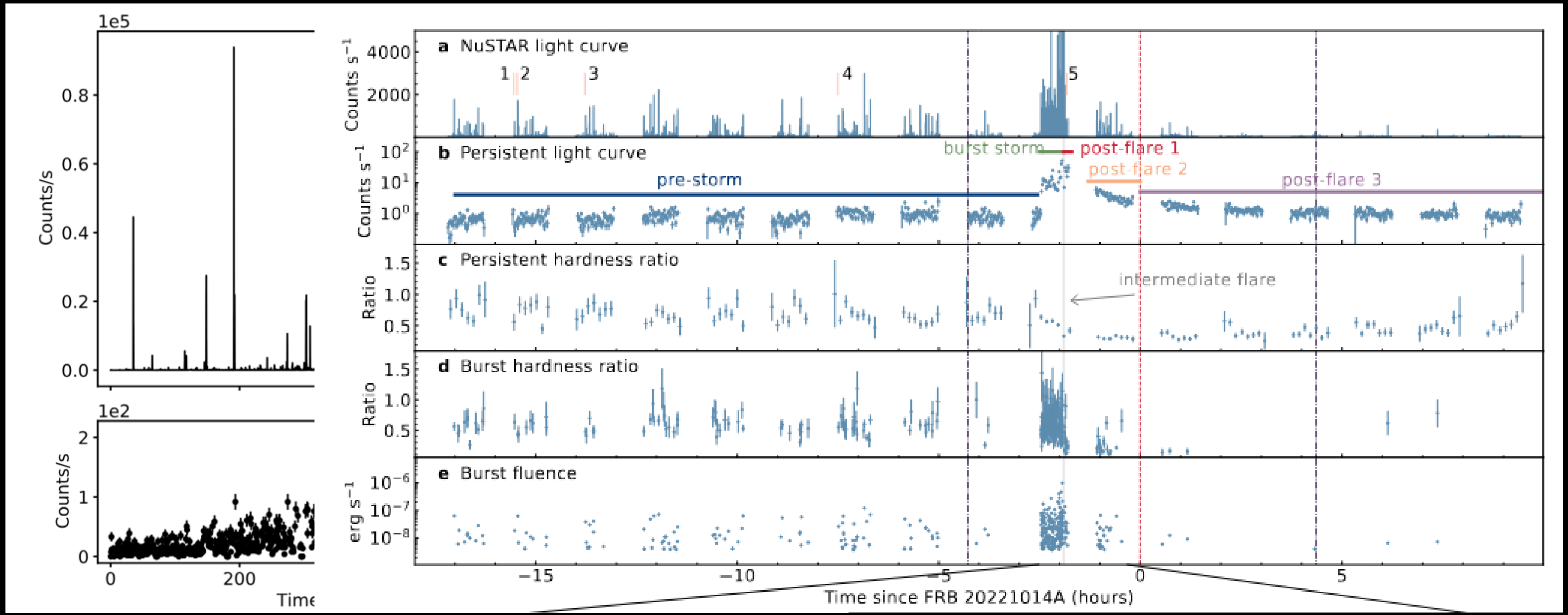
SGR 1935+2154



2020 Apr burst storm
(Younes et al. 2020)

2022 Oct burst storm
(Hu et al. 2025)

Burst analysis

T90 duration (5% - 95% cts duration)

Fit a step function

→ step height = total burst cts

→ 5% and 95 % cts

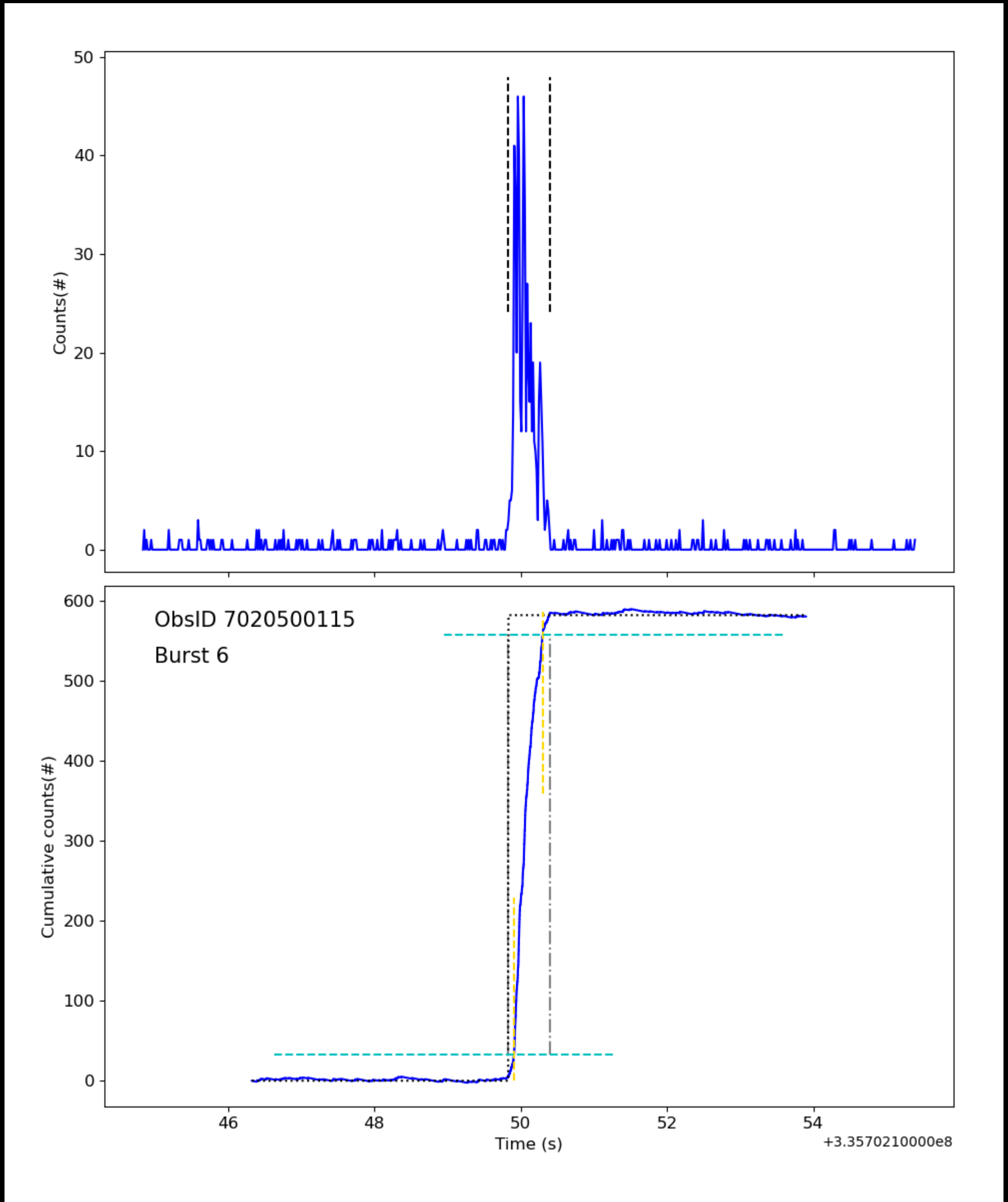
→ T5 and T95

Spectra fitting

Fit a black body radiation (BB)

fix nH

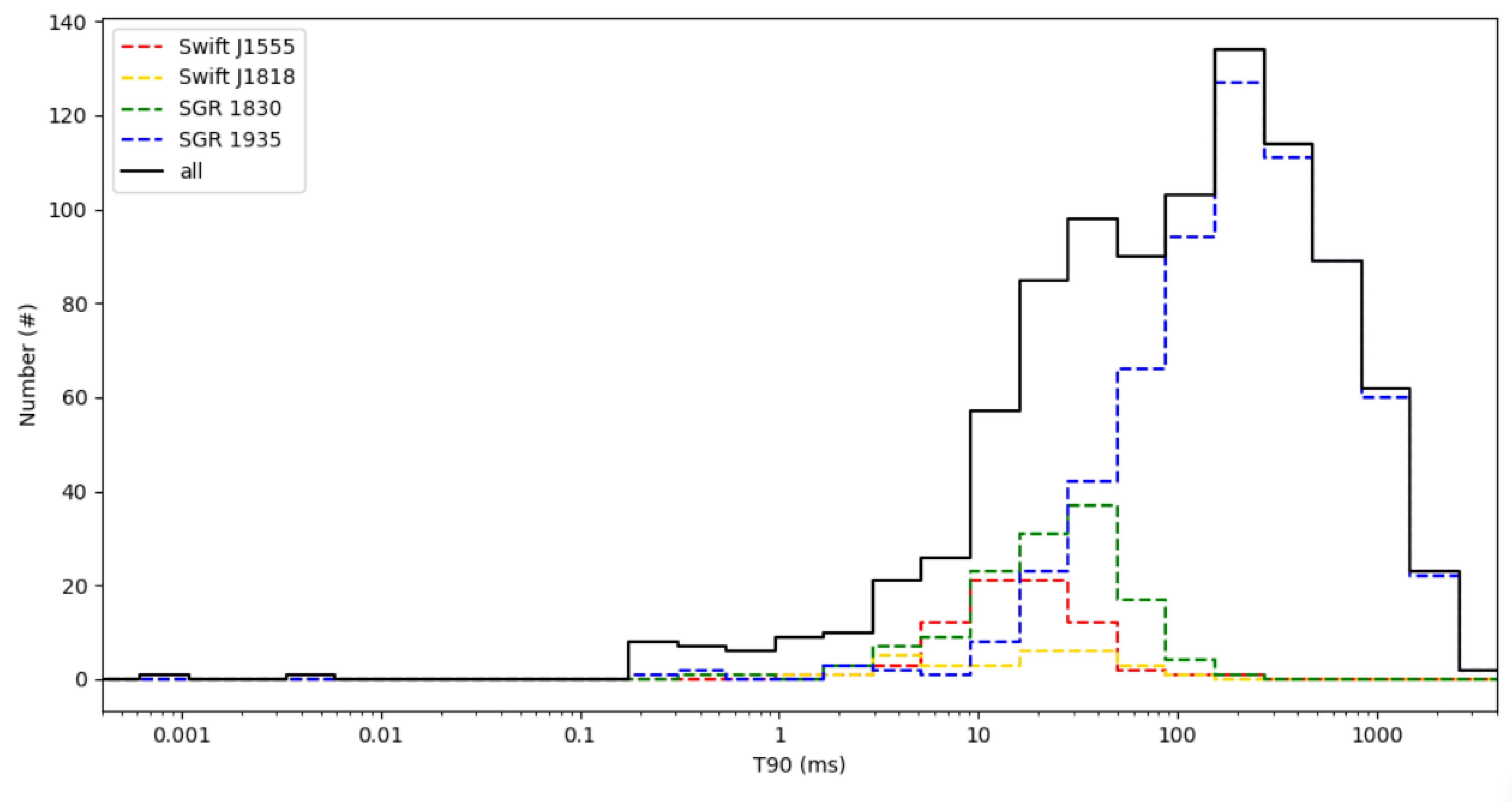
fix BB temp. for low-cts burst



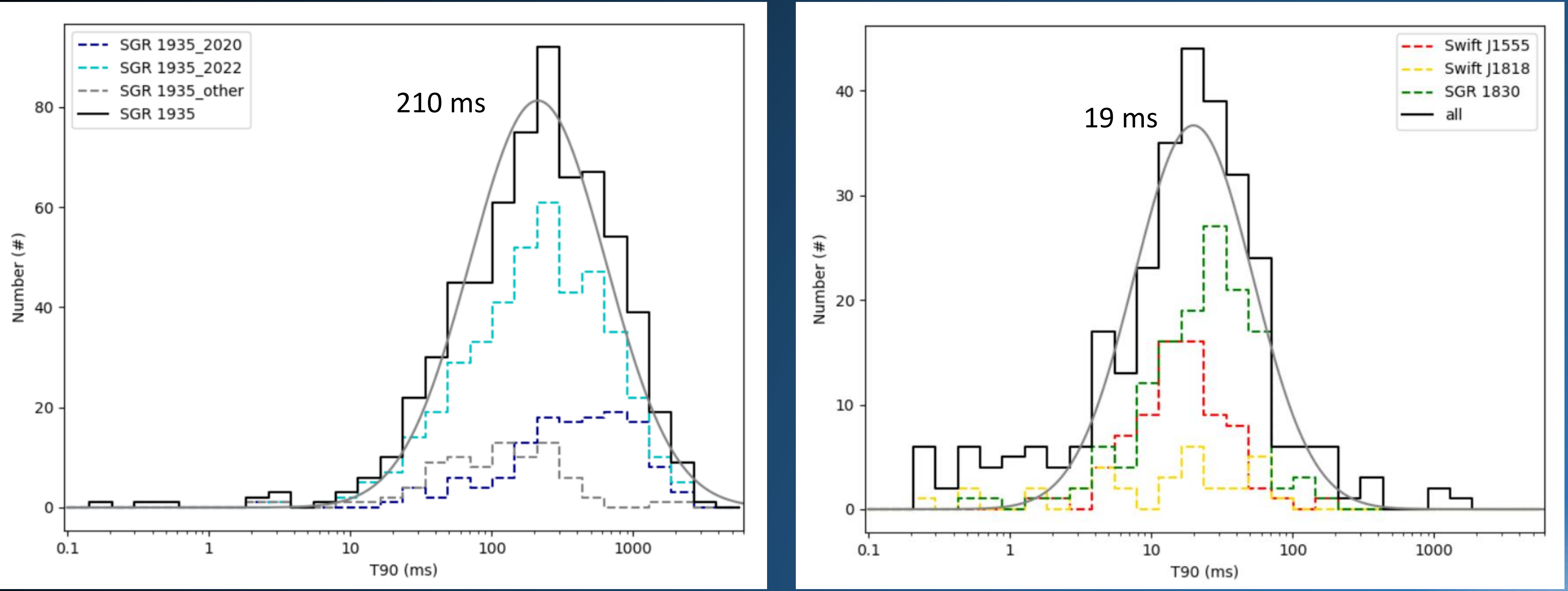
T90 distribution

SGR 1935 is different from others

2 μs-scale bursts



T90 distribution



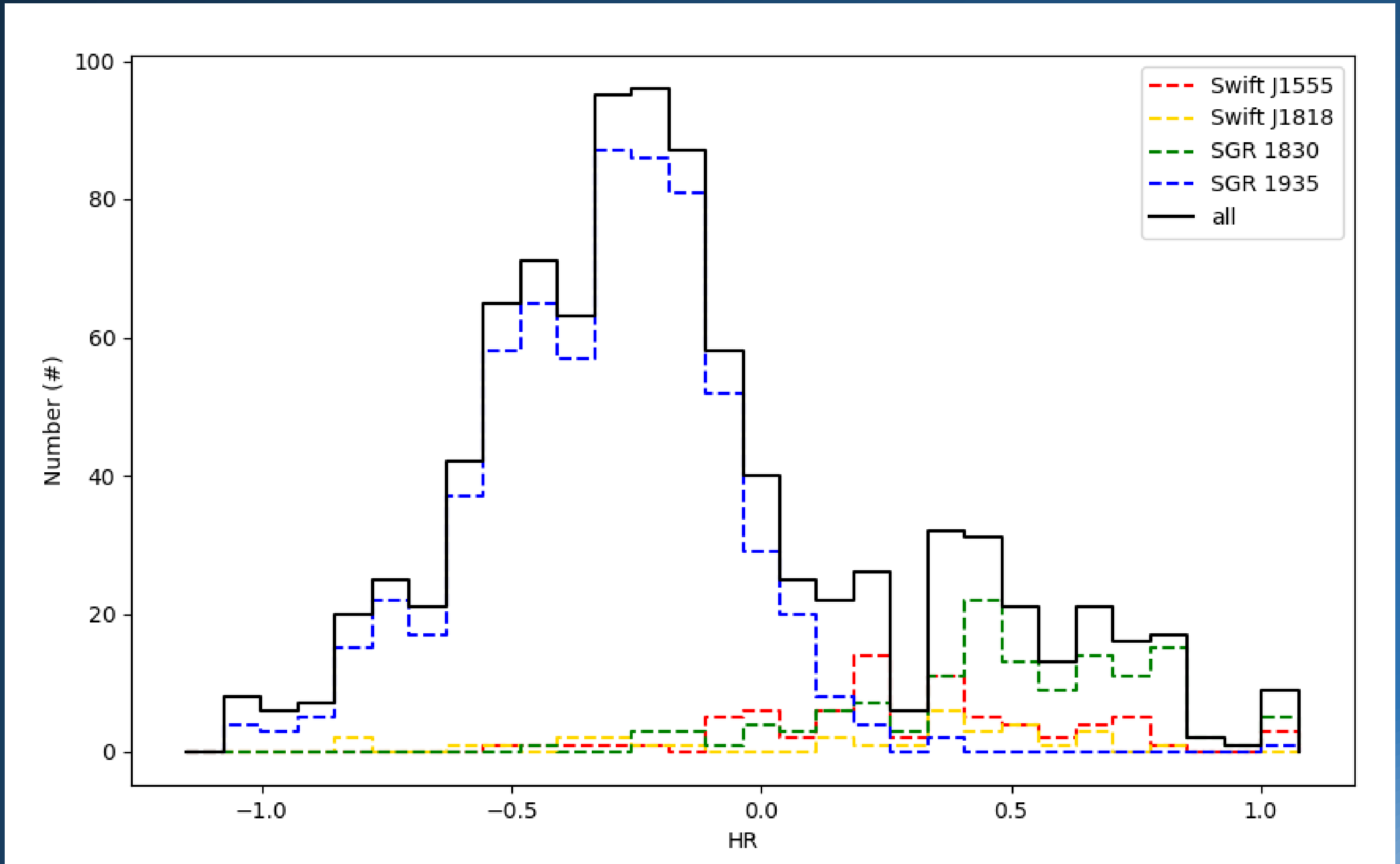
Fermi/GBM magnetar burst catalog (8-200 keV) T90 peak at ~ 150 ms (Collazzi et al. 2015)

Hardness ratio (HR) distribution

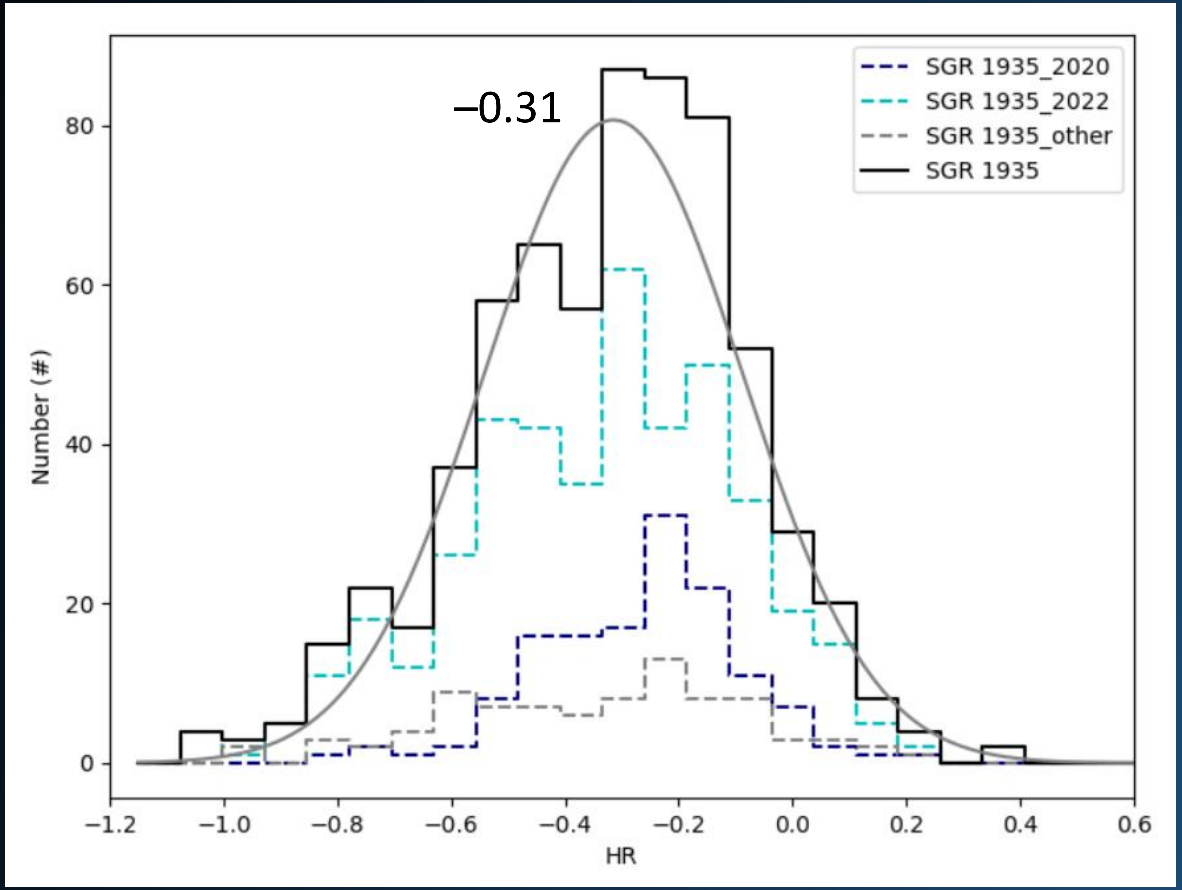
$$\mathrm{HR} = \frac{hard - soft}{hard + soft}$$

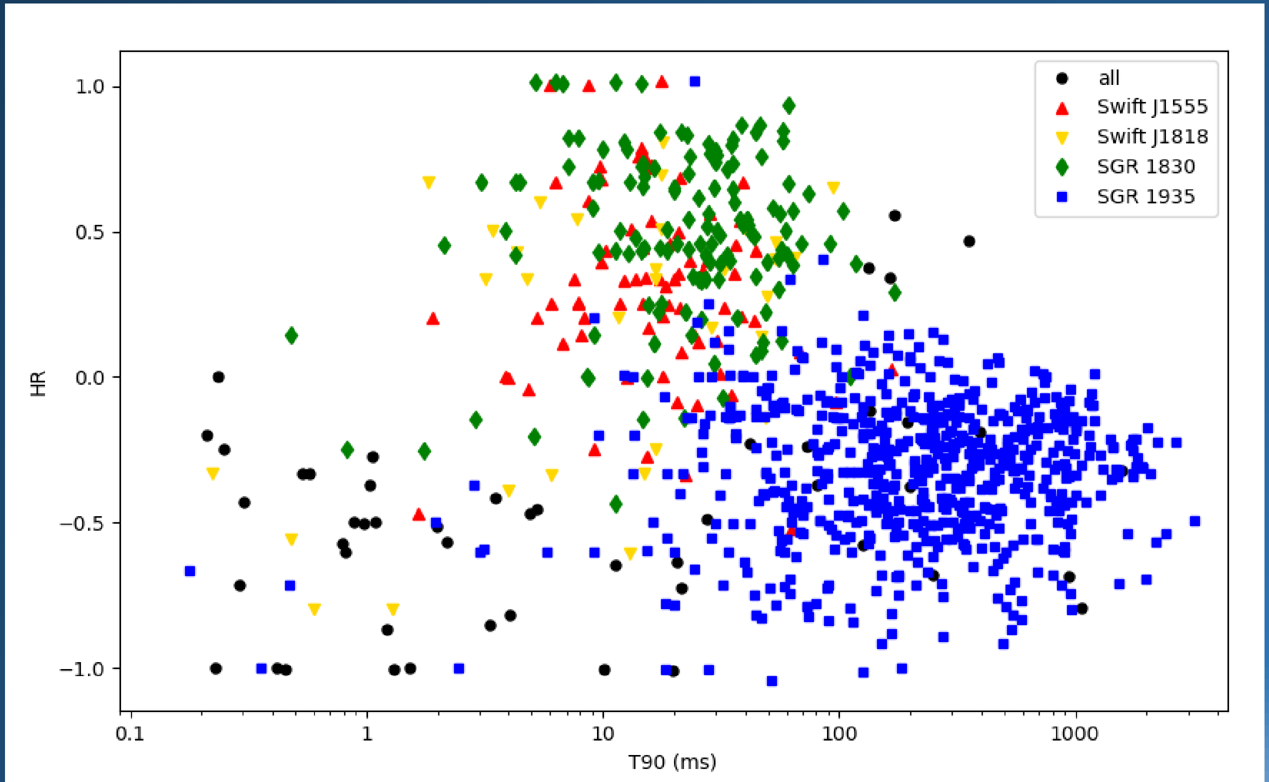
Soft photon: 0.5-4 keV

Hard photon: 4-8 keV



HR distribution (vs T90)





Fluence distribution

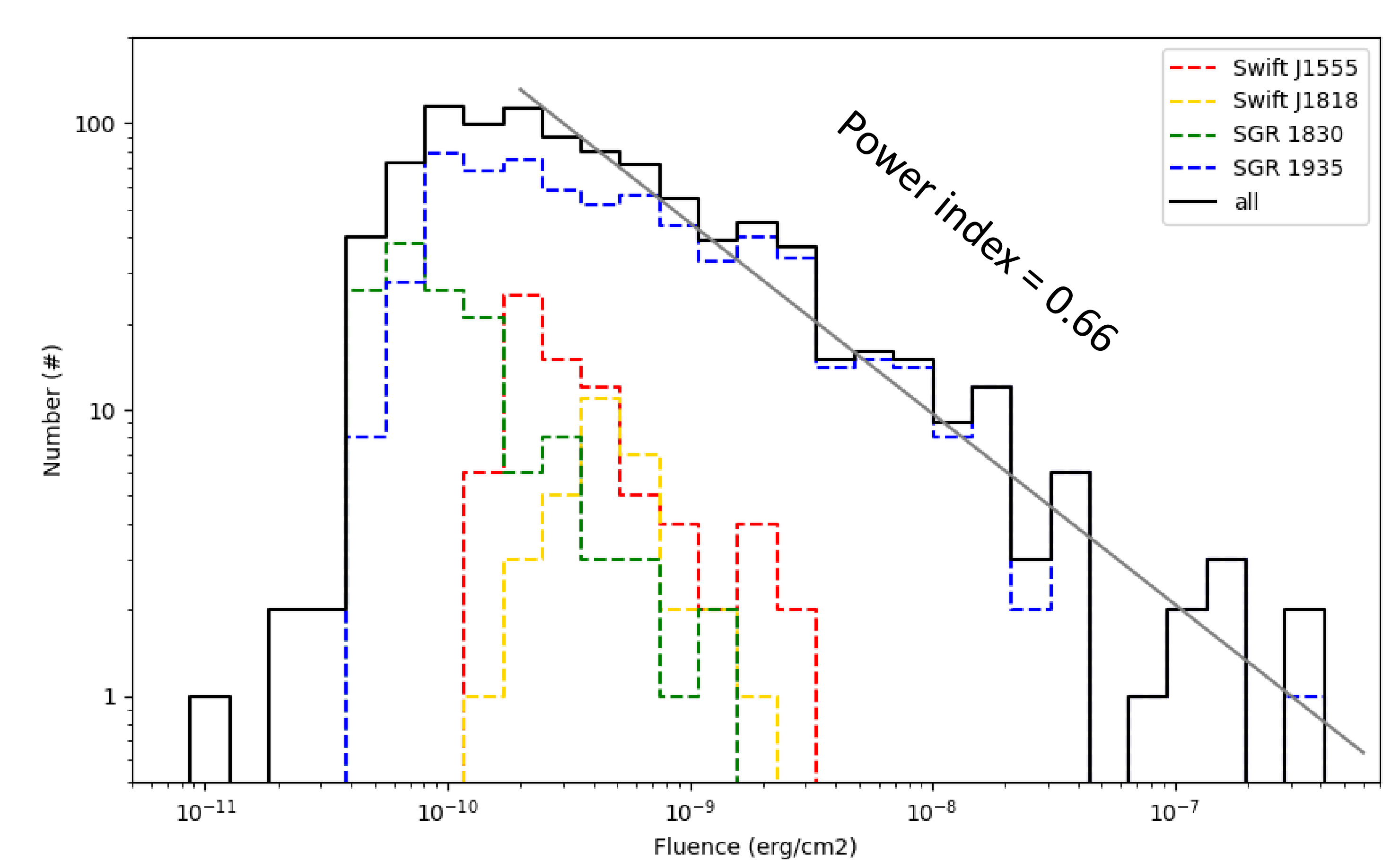
Fit fluence > 10^{-10}

with power law

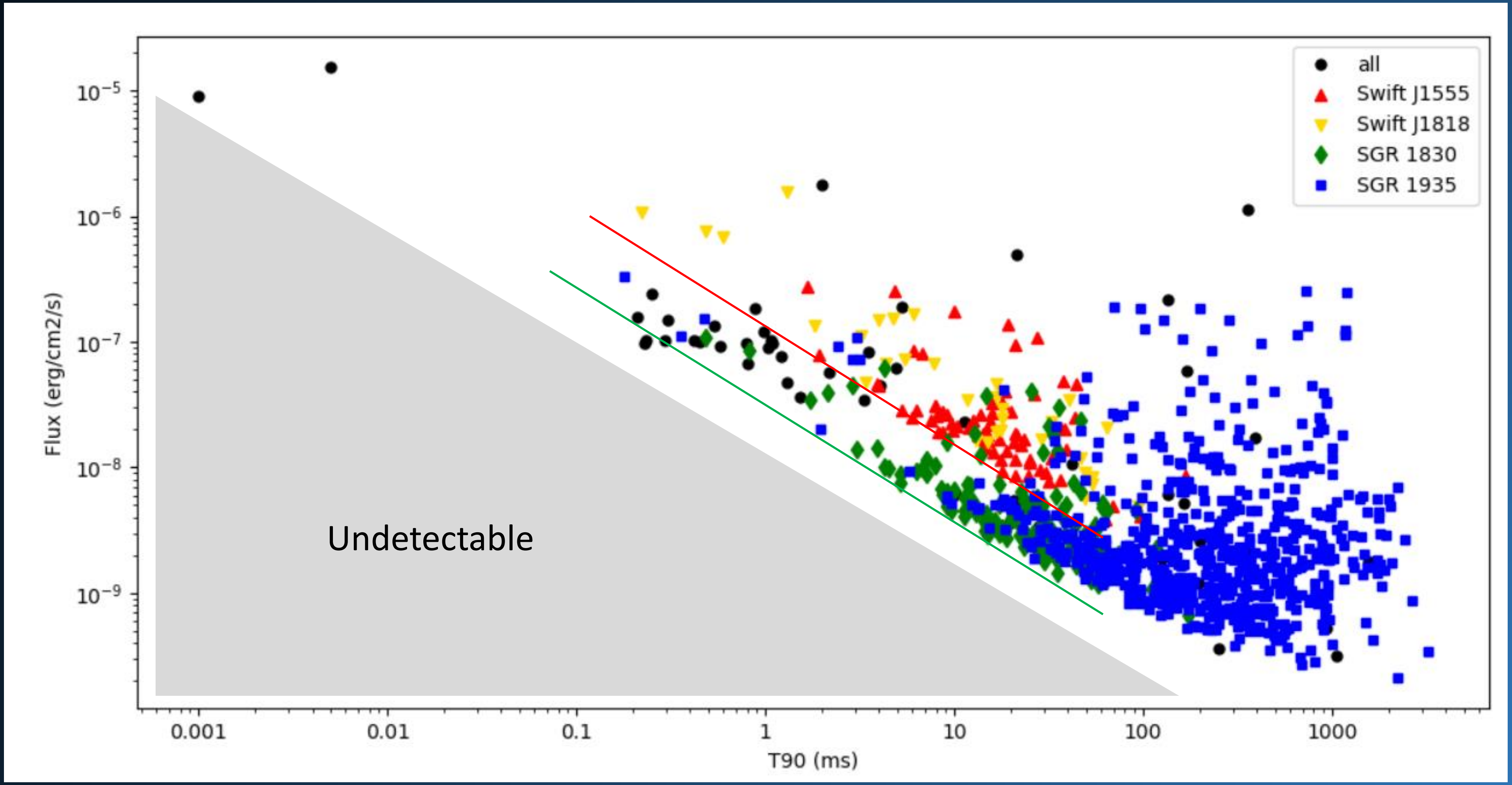
Detection limit ~ 4×10^{-11}

100% detection efficiency

~ 2×10^{-10}

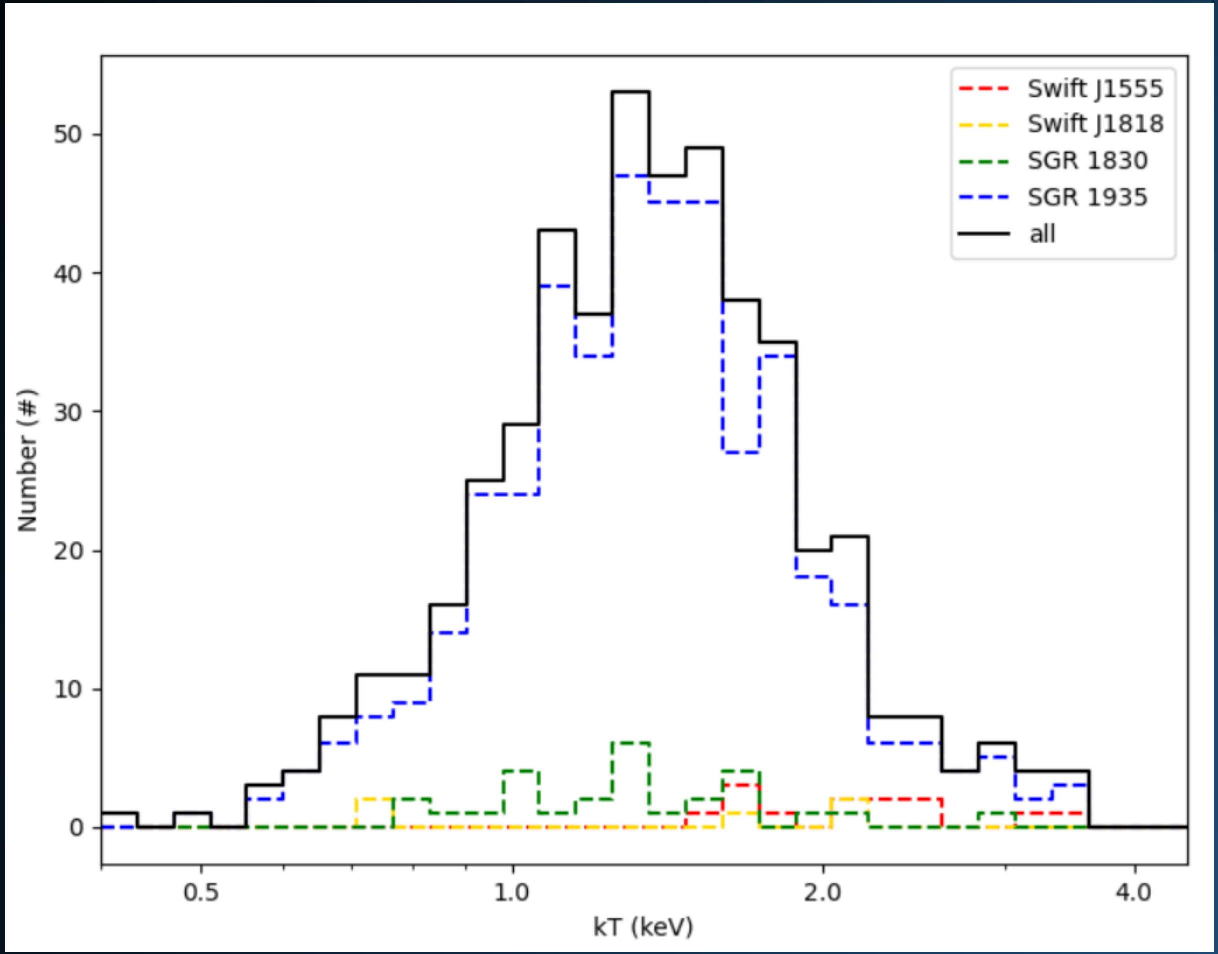


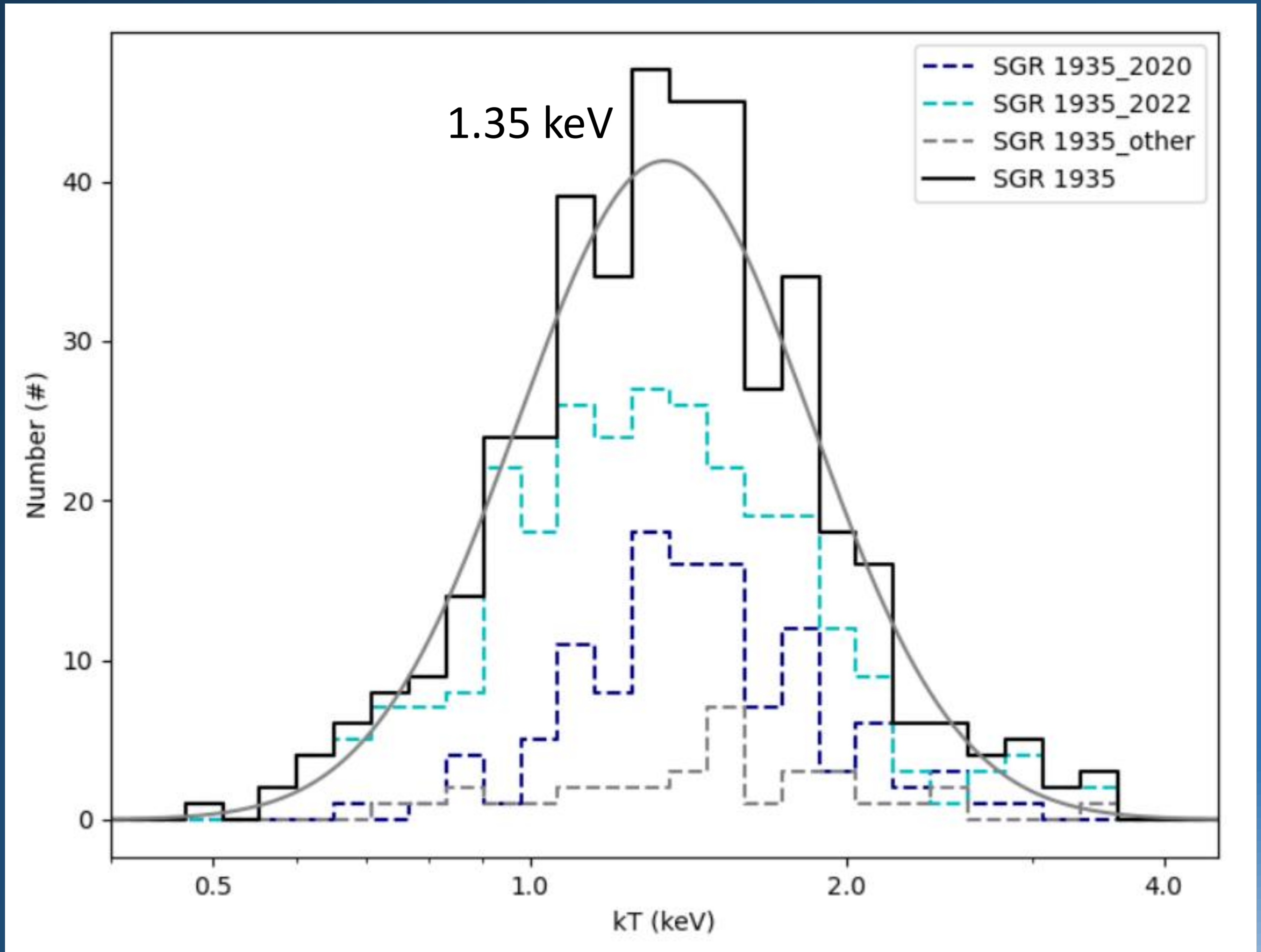
Flux vs T90



all
Swift J1555
Swift J1818
SGR 1830
SGR 1935
Undetectable
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
Flux (erg/cm2/s)
0.001
0.01
0.1
1
10
100
1000
T90 (ms)

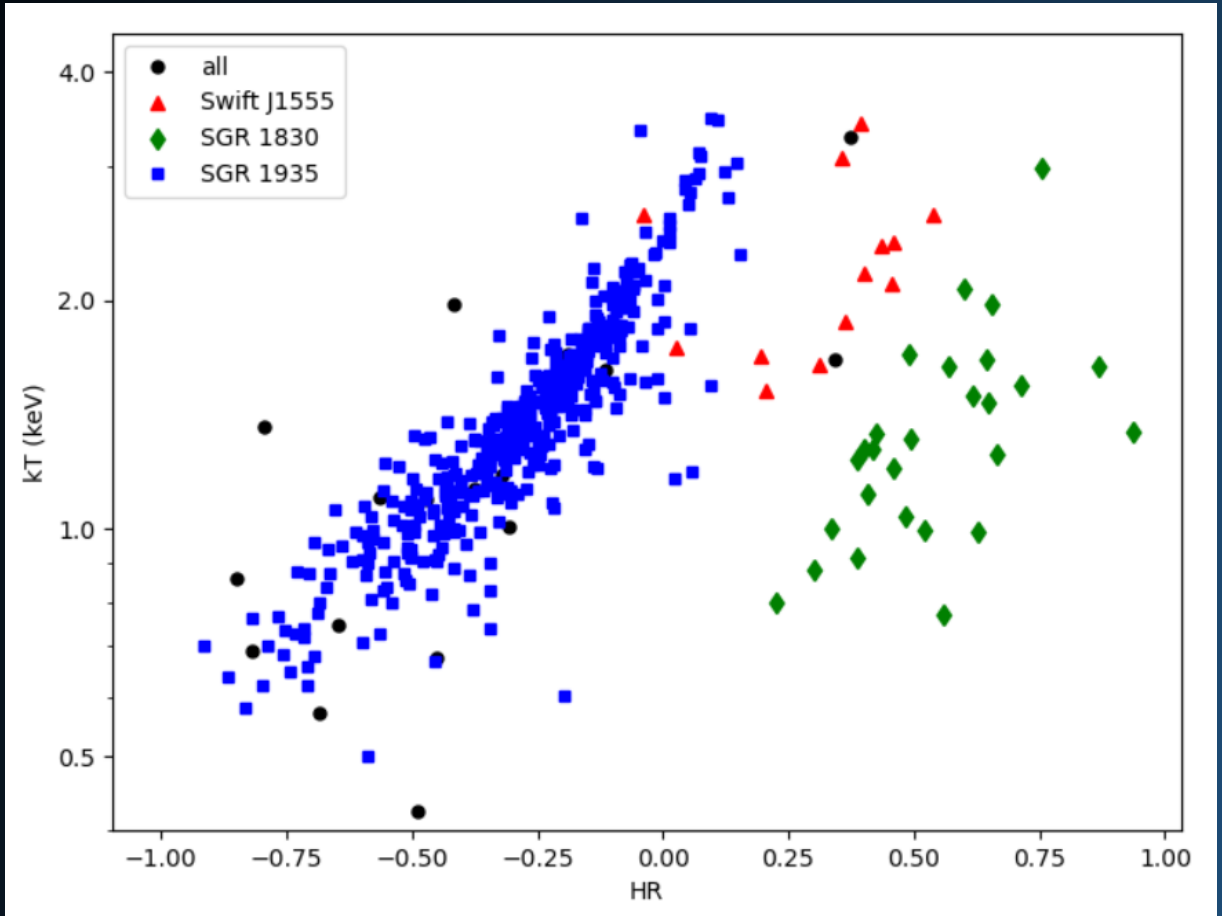
BB temperature distribution

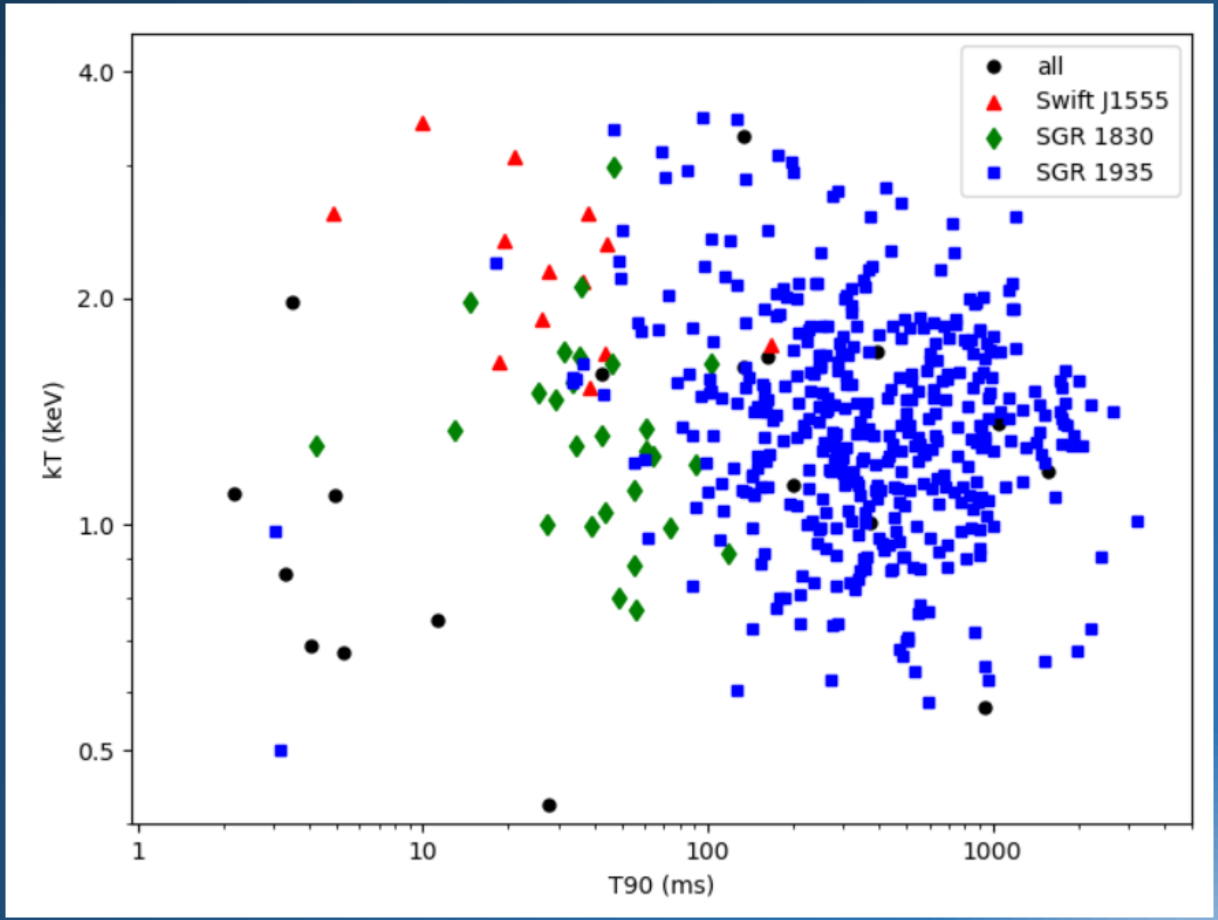




*low-counts bursts excluded

BB temperature vs HR and T90





*low-counts bursts excluded

Summary

We build a magnetar burst catalog using NICER data

Bursts of SGR 1935+2154 differ significantly from others

Future work

Study SGR 1935+2154 in detailed

Include magnetar-like pulsar PSR J1119-6127 and PSR J1846-0258