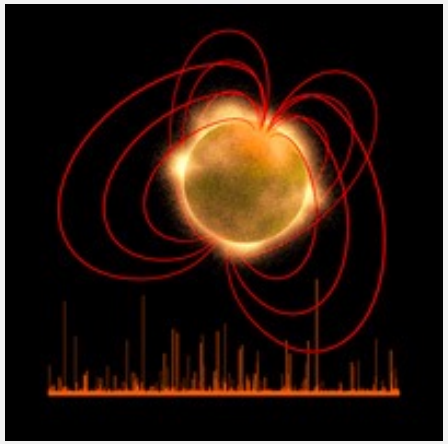
SCIENCE WITH FERMI-GBM

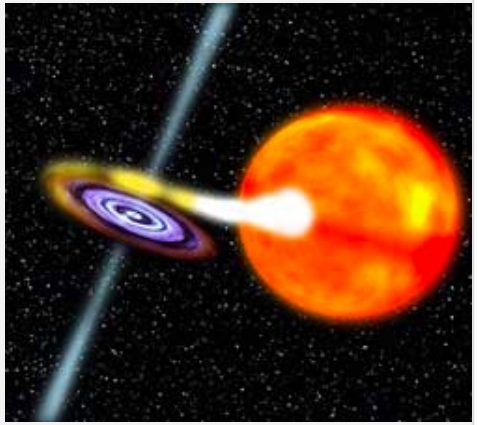
Cori Fletcher
Universities Space Research Association
at Marshall Space Flight Center
cfletcher@usra.edu

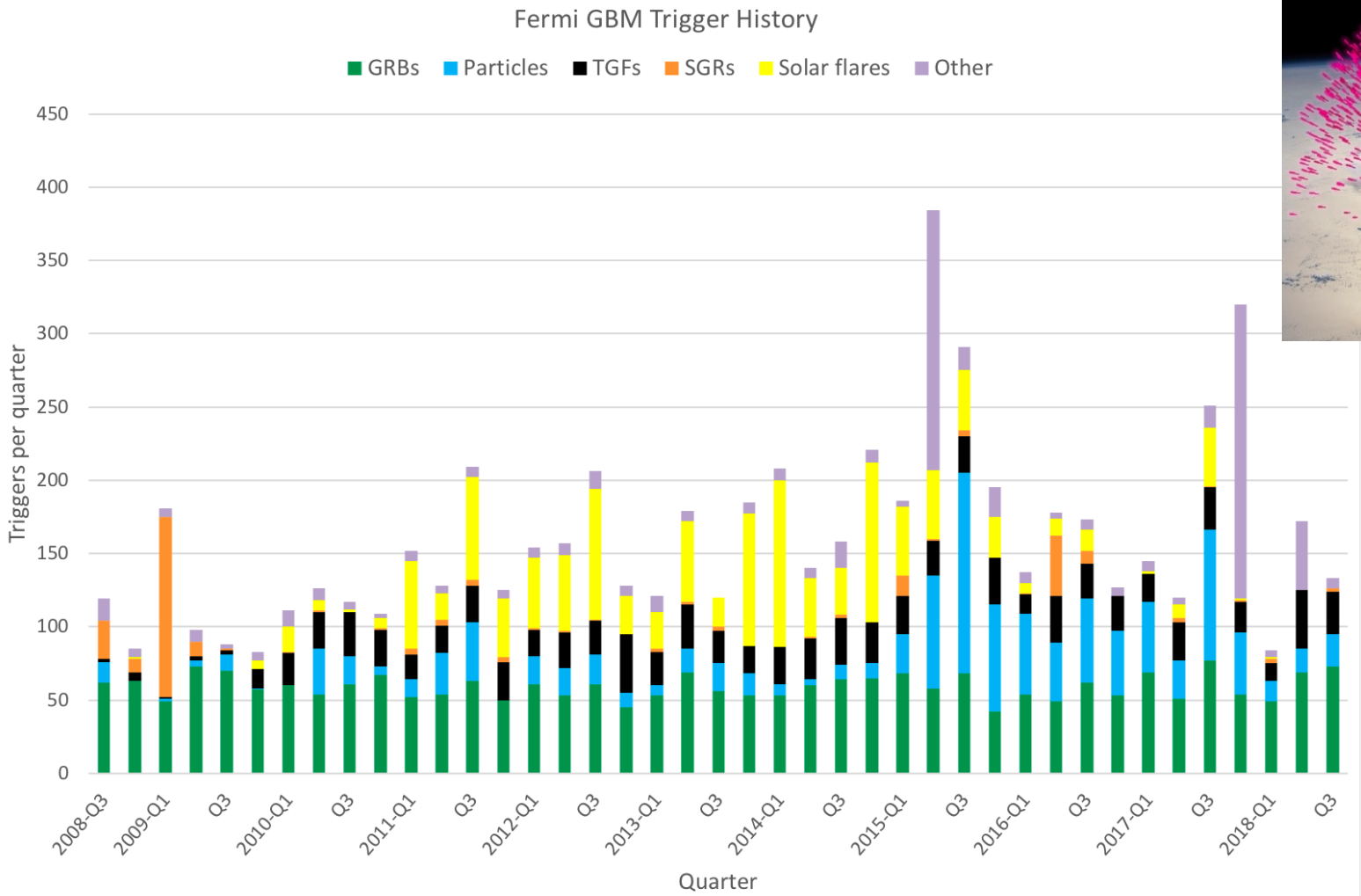
What does GBM observe?

Soft Gamma-ray Repeaters/Magnetars

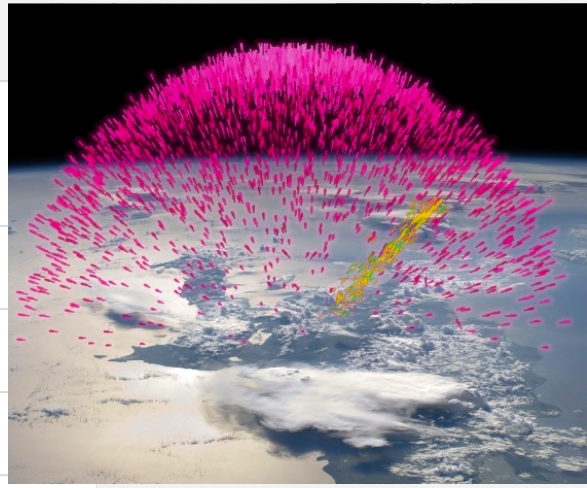


X-ray Binaries

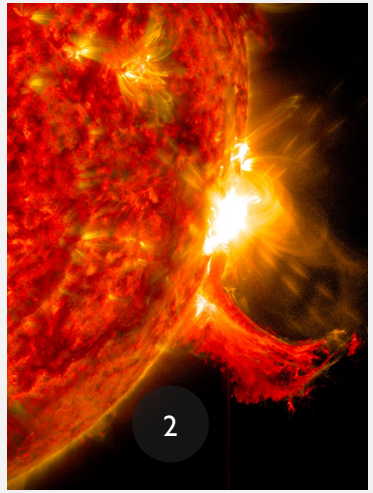




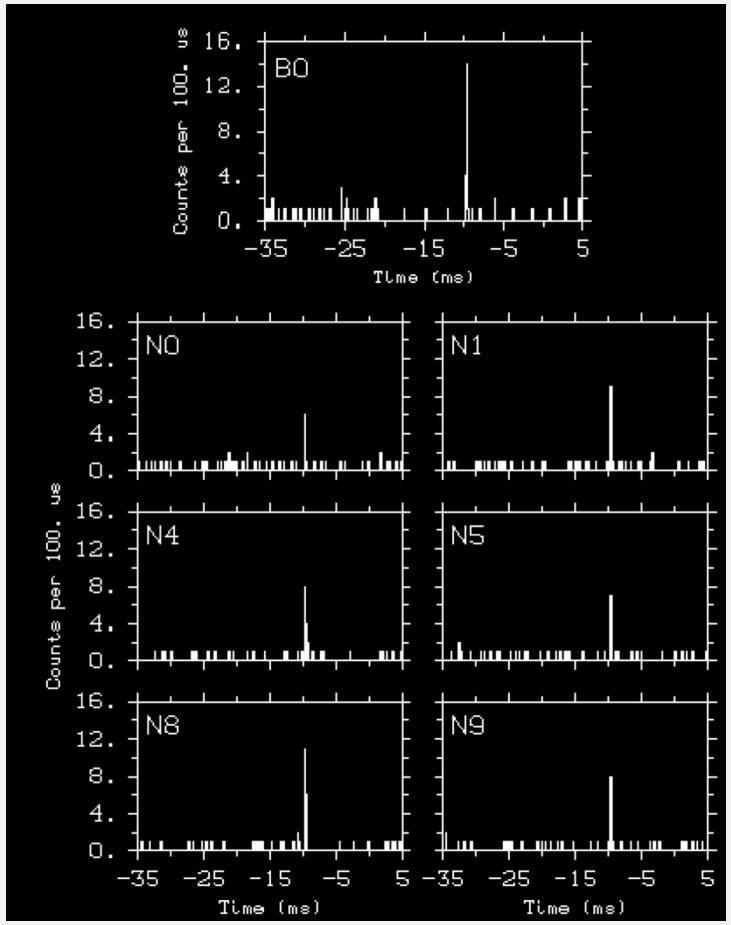
TGFs

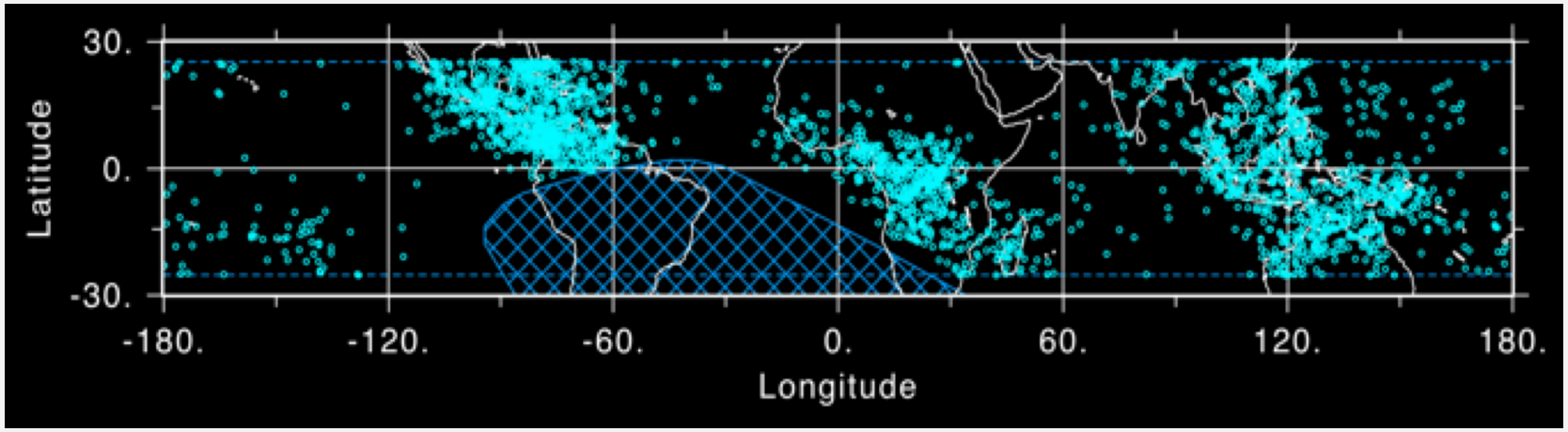


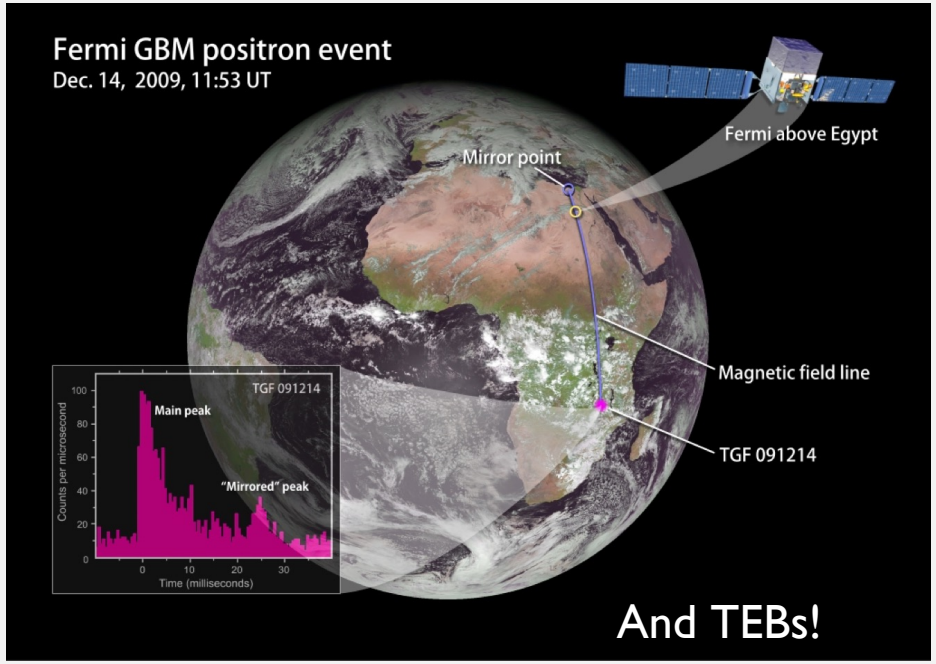
Solar Flares



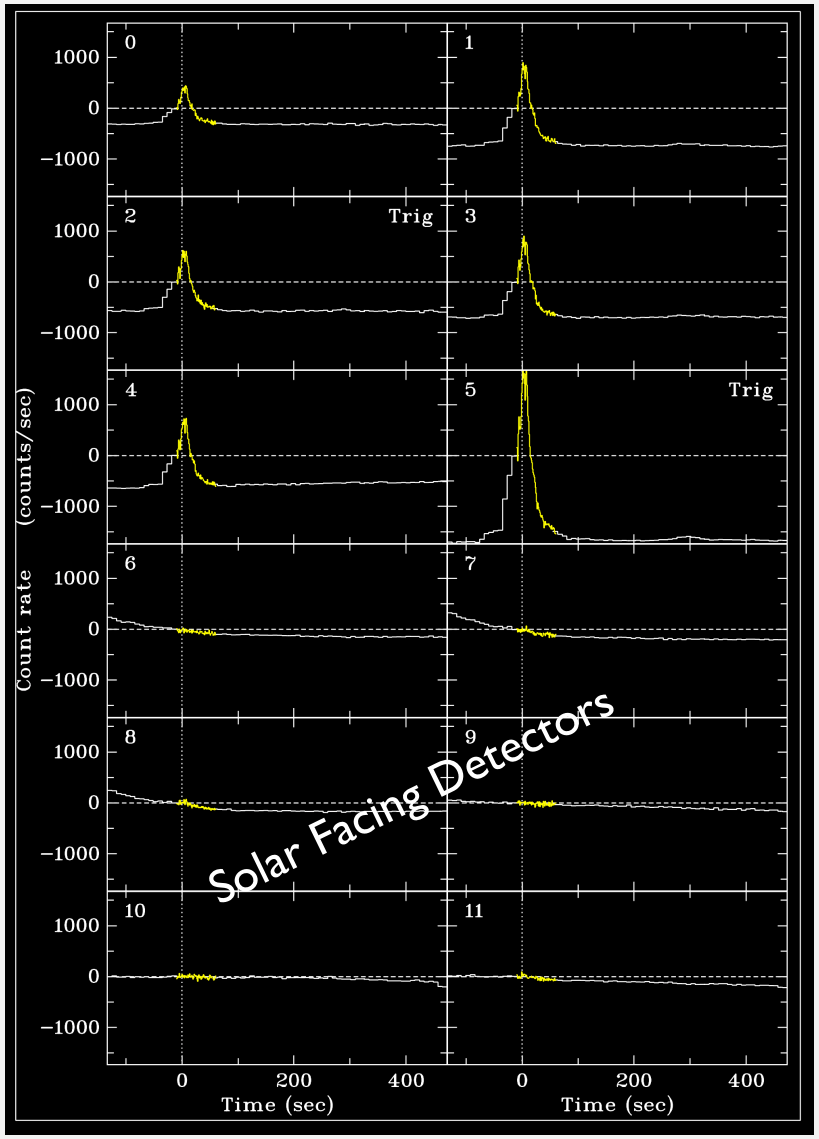
Terrestrial Gamma-ray Flashes (TGFs)

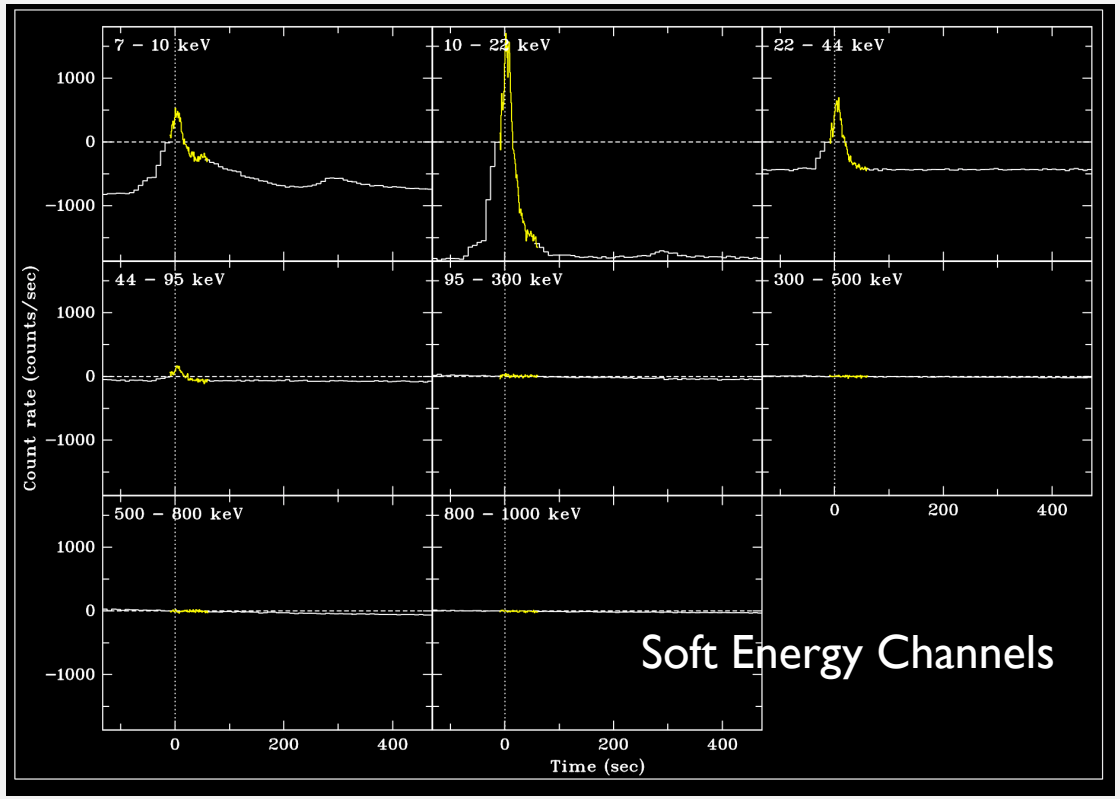




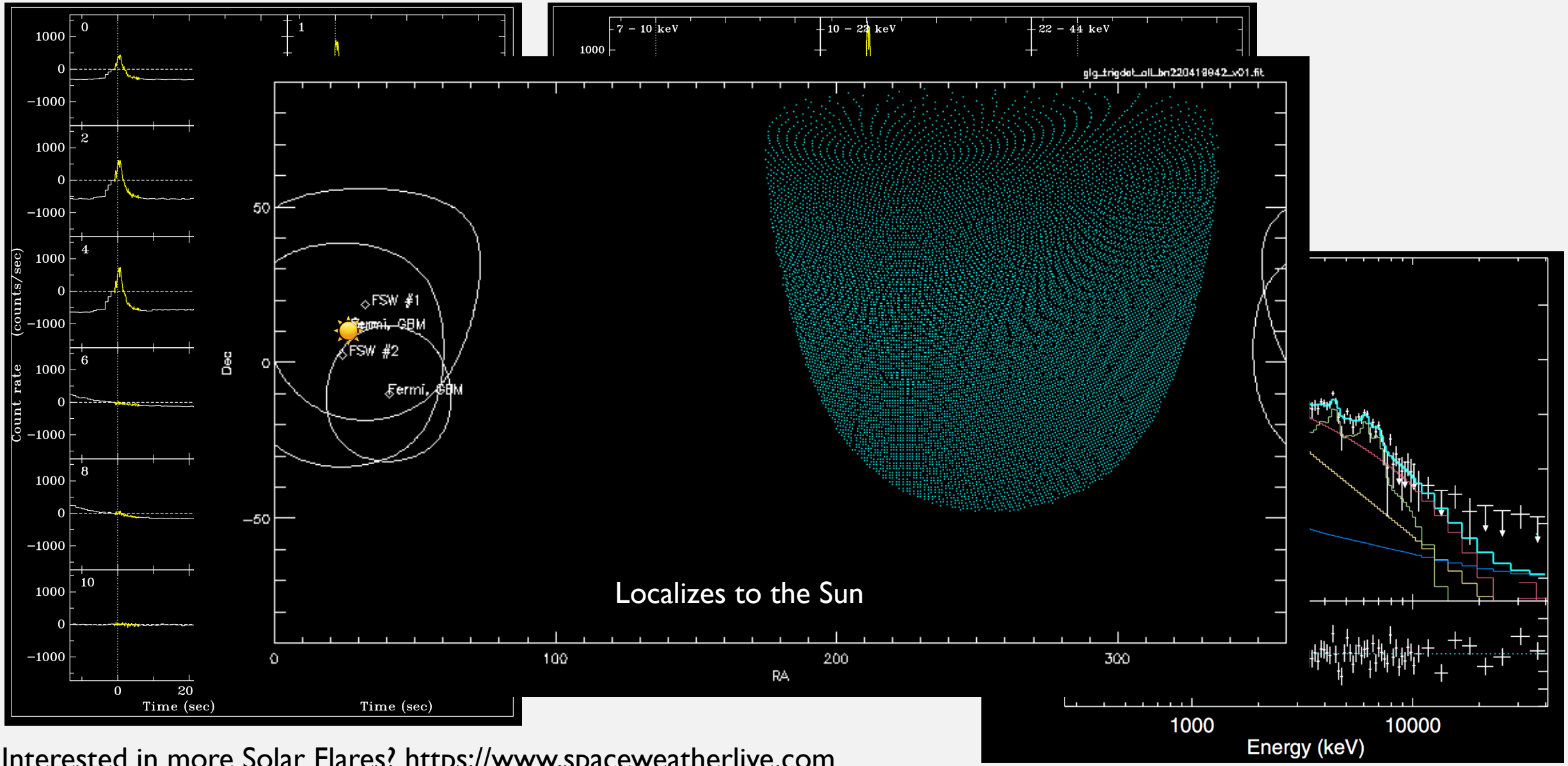


Solar Flares



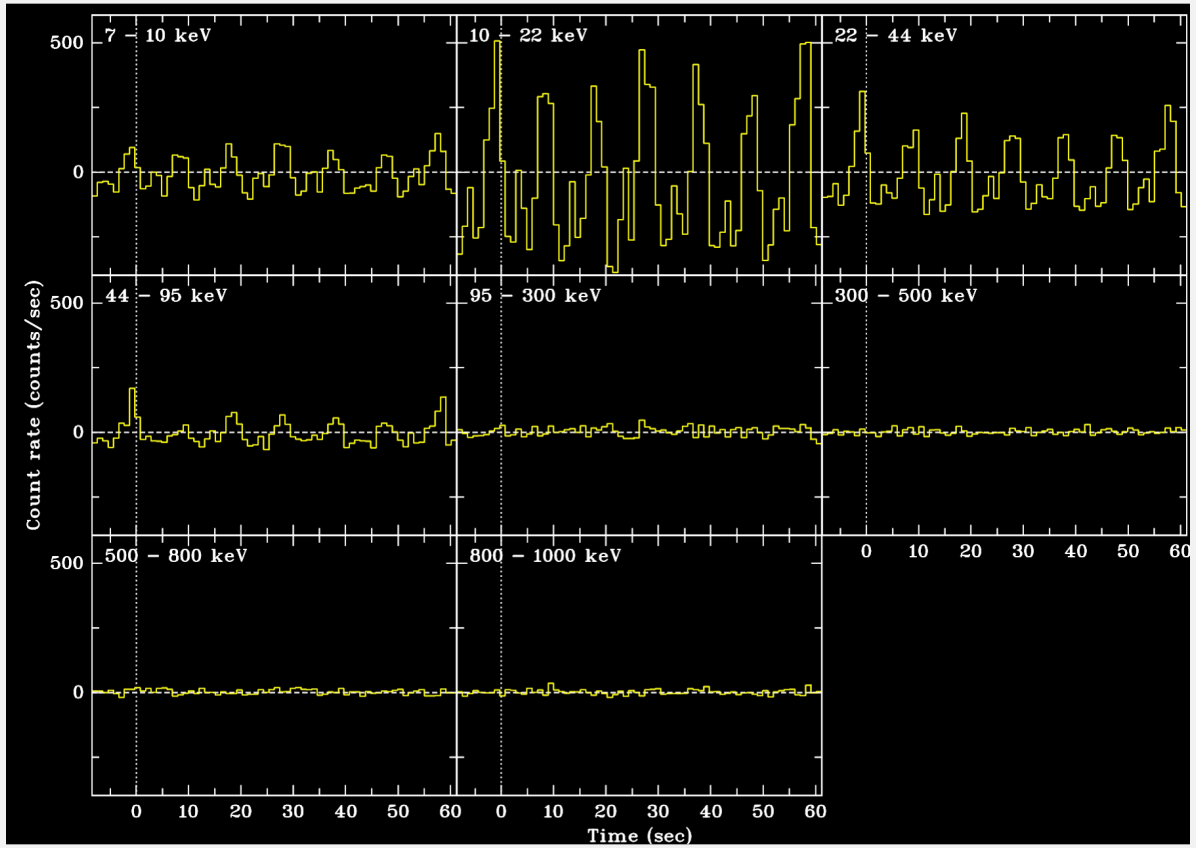


Solar Flares

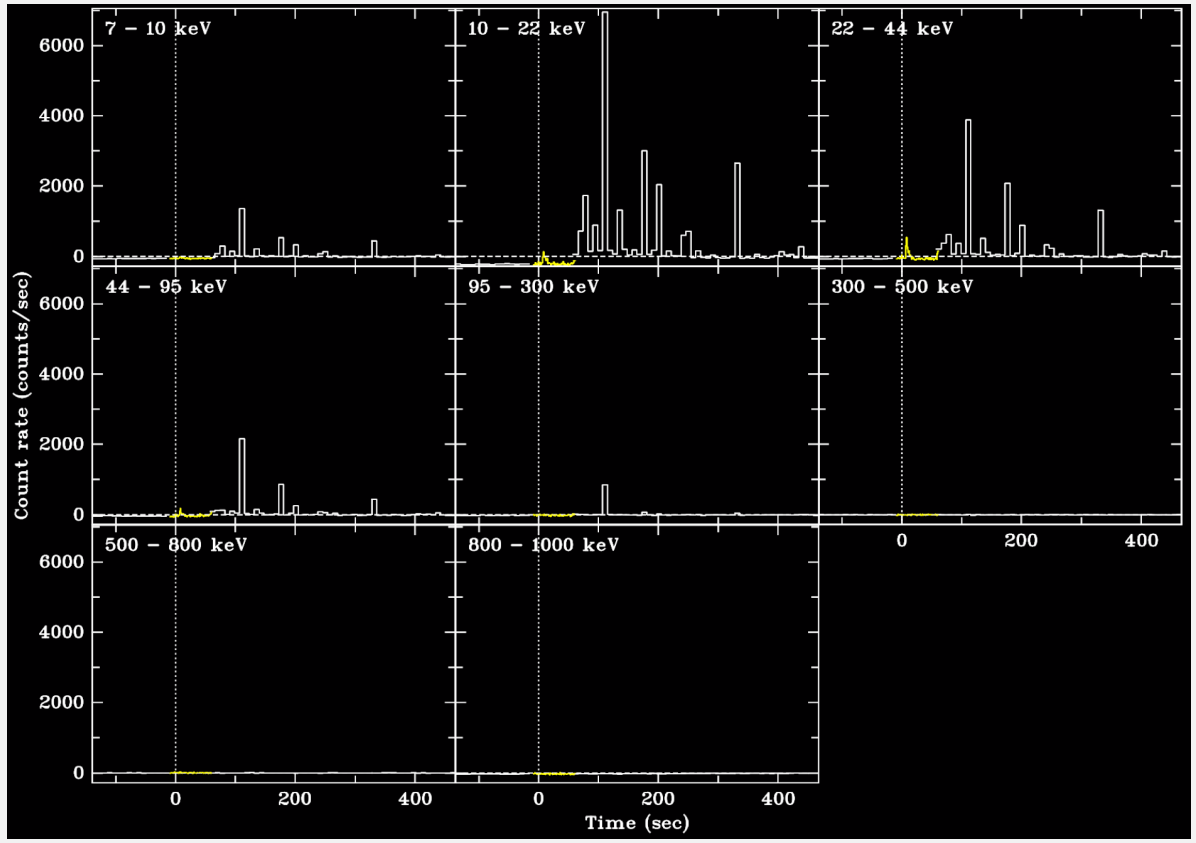


Interested in more Solar Flares? https://www.spaceweatherlive.com

Flaring/Pulsing Galactic Sources

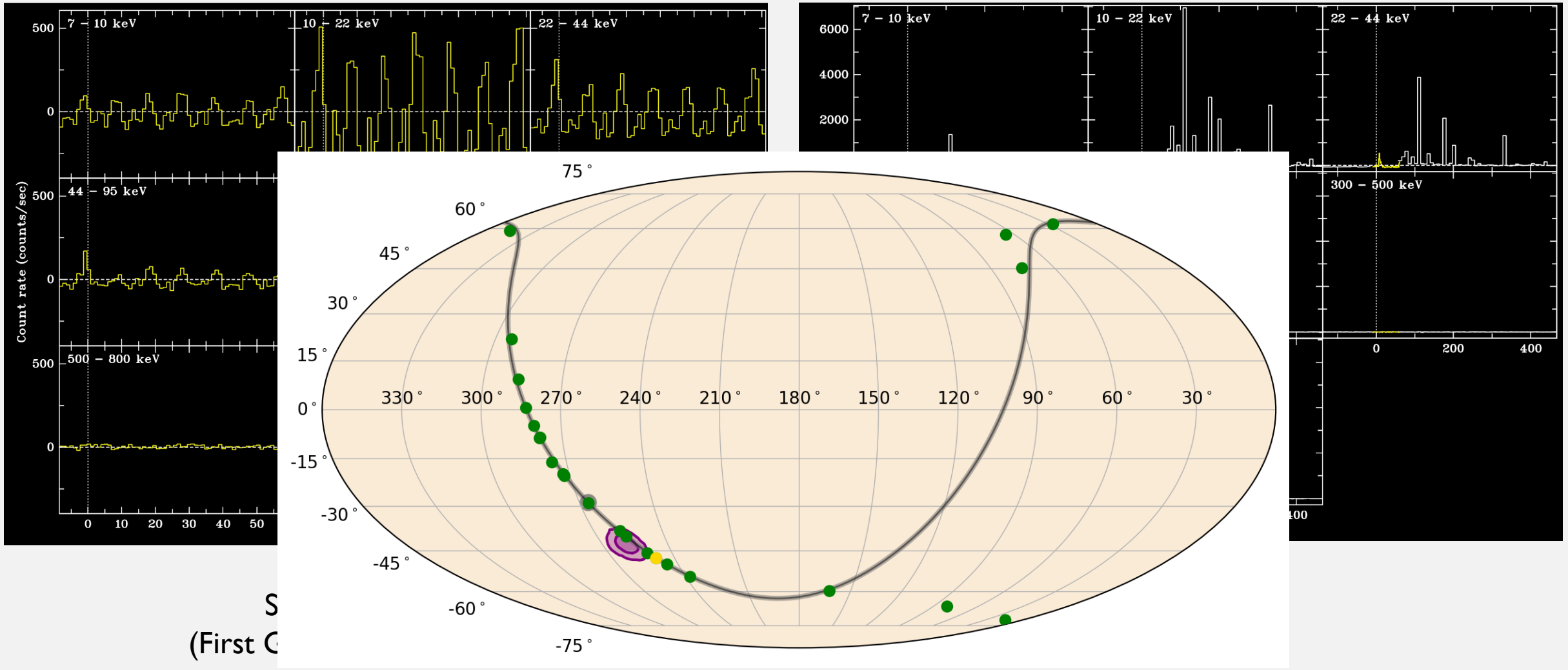


Swift J0243.6+6124
(First Galactic UL X-ray Pulsar)



SGR 1547-5408
(Magnetar)

Flaring/Pulsing Galactic Sources



S

(First G

Magnetars/SGRs

Transient behaviors:

Episodic bursts:

Most frequent

10^{-2} – 1s

$10^{36\text{-}41}$ erg

Intermediate flares:

Uncommon

1-50 s

$10^{41\text{-}43}$ erg

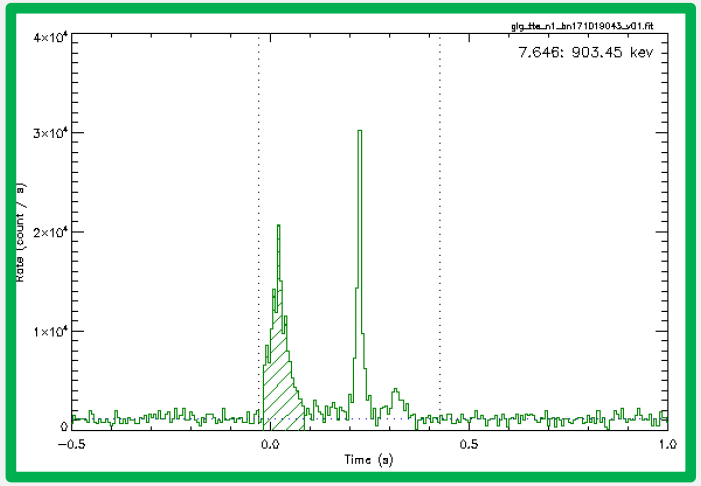
Giant Flares:

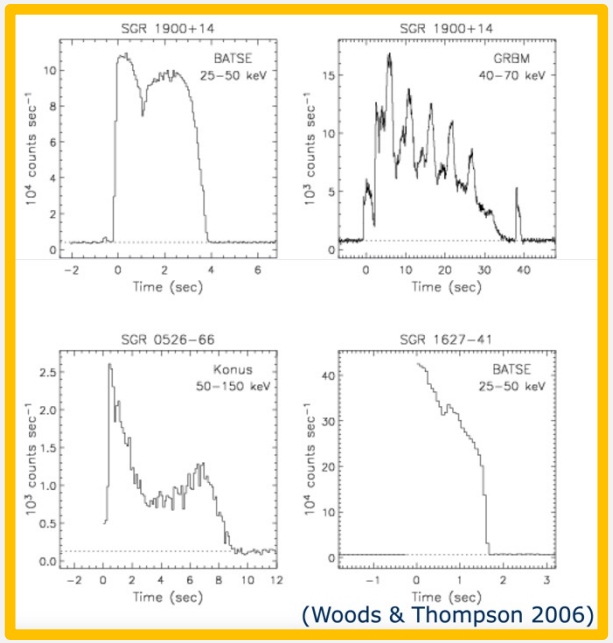
Rare

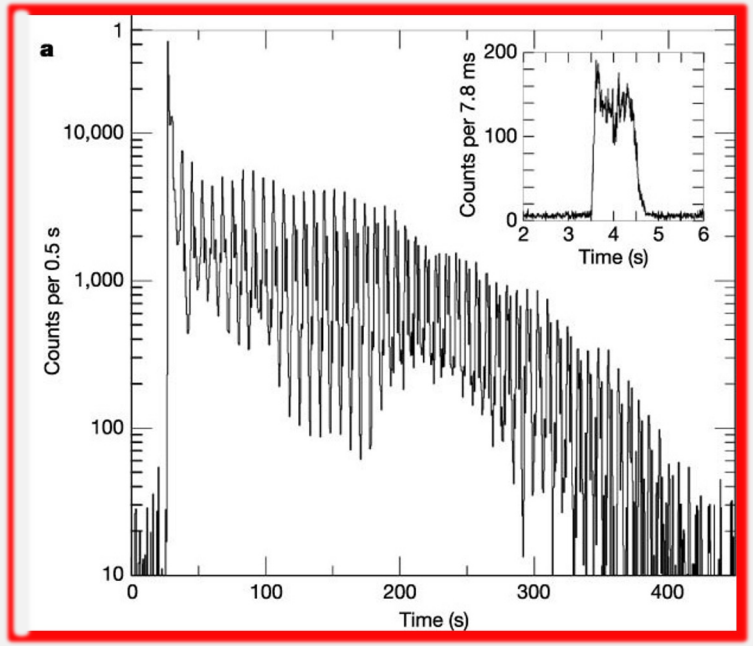
1000 s (bright spike and tail)

$10^{44\text{-}47}$ erg

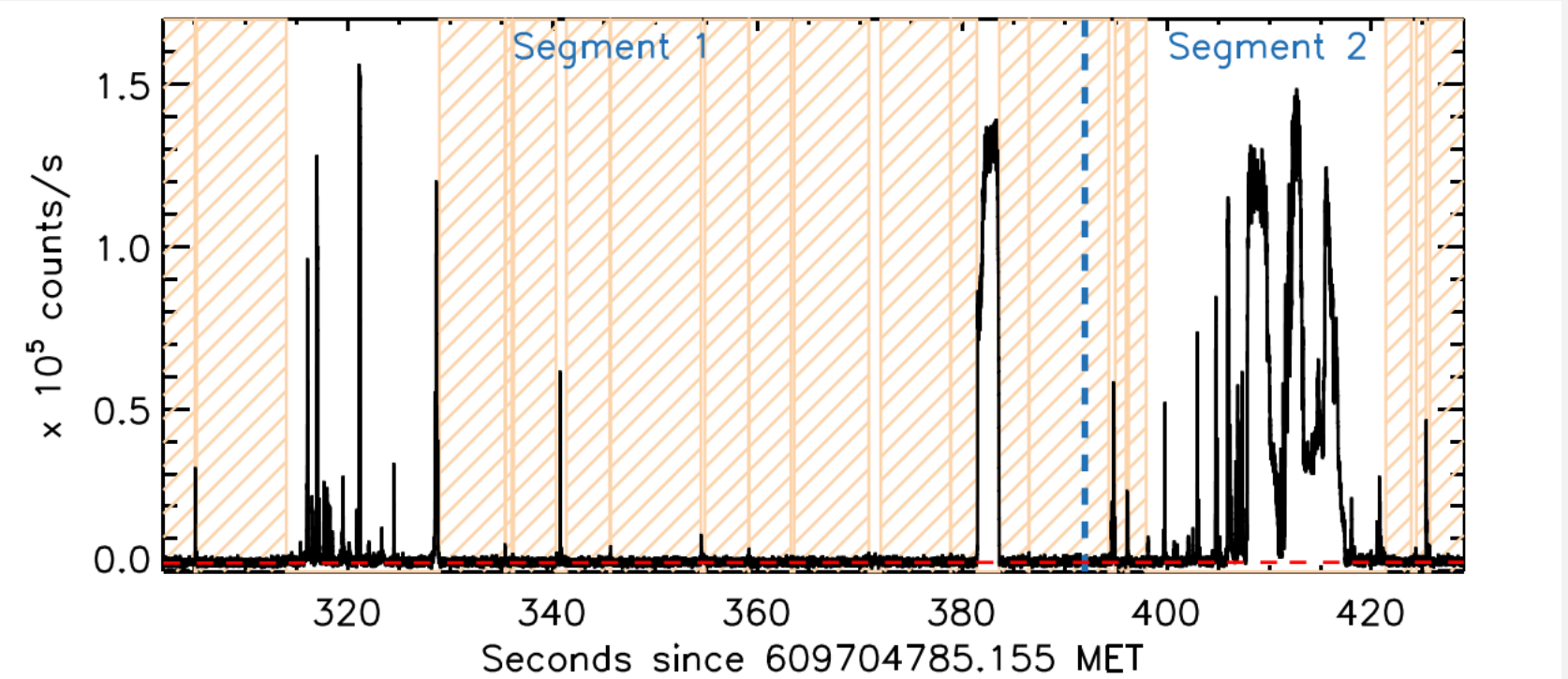
Three giant flares from galactic magnetars saturated instruments. Less of an issue with increased distance.







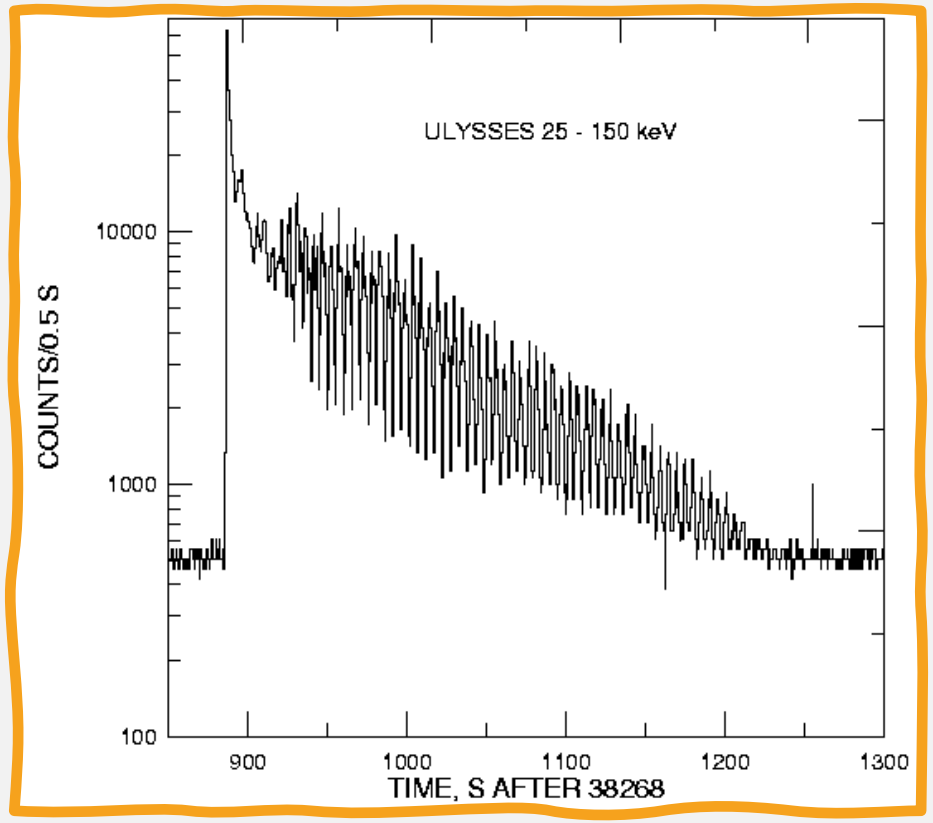
Magnetar Burst Forests

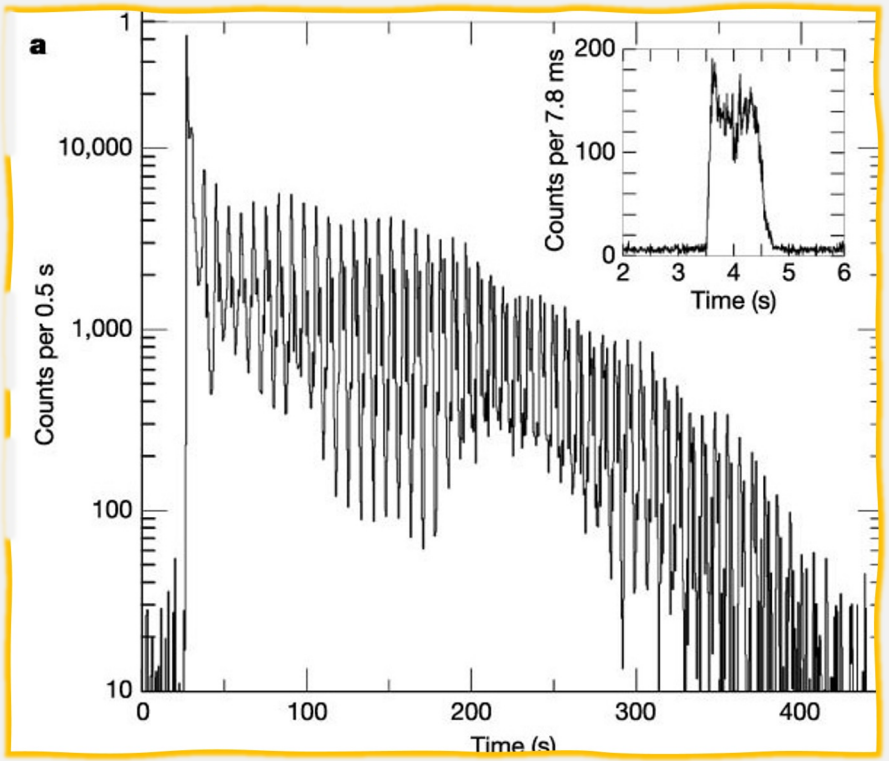


- April 2014, SGR J1935+2154 began bursting.
- Resulting in hundreds of bursts over the past years (last one was Monday!)
- On April 27, 2020 there was an intense period of bursting that lasted 130 s dubbed a Burst Forest.

Kaneko et al. 2021

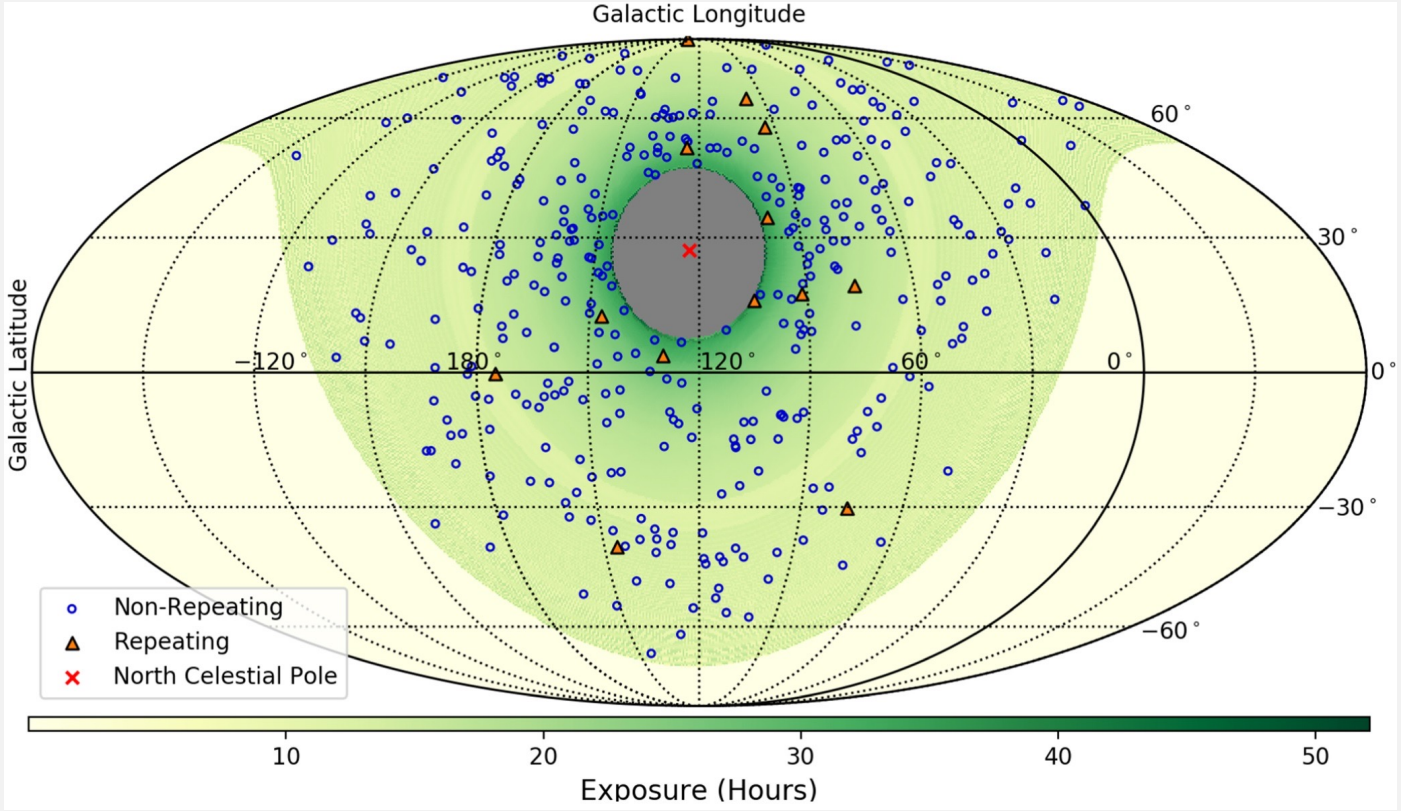
Magnetar Giant Flares





Fast Radio Bursts

- Discovered in 2007 while looking through pulsar data
- Bright millisecond flashes in the radio wavelengths, some repeat
- Typically of extragalactic origin
- Has been a mysterious radio source ever since…
  - Little green men?



The First CHIME/FRB Fast Radio Burst Catalog

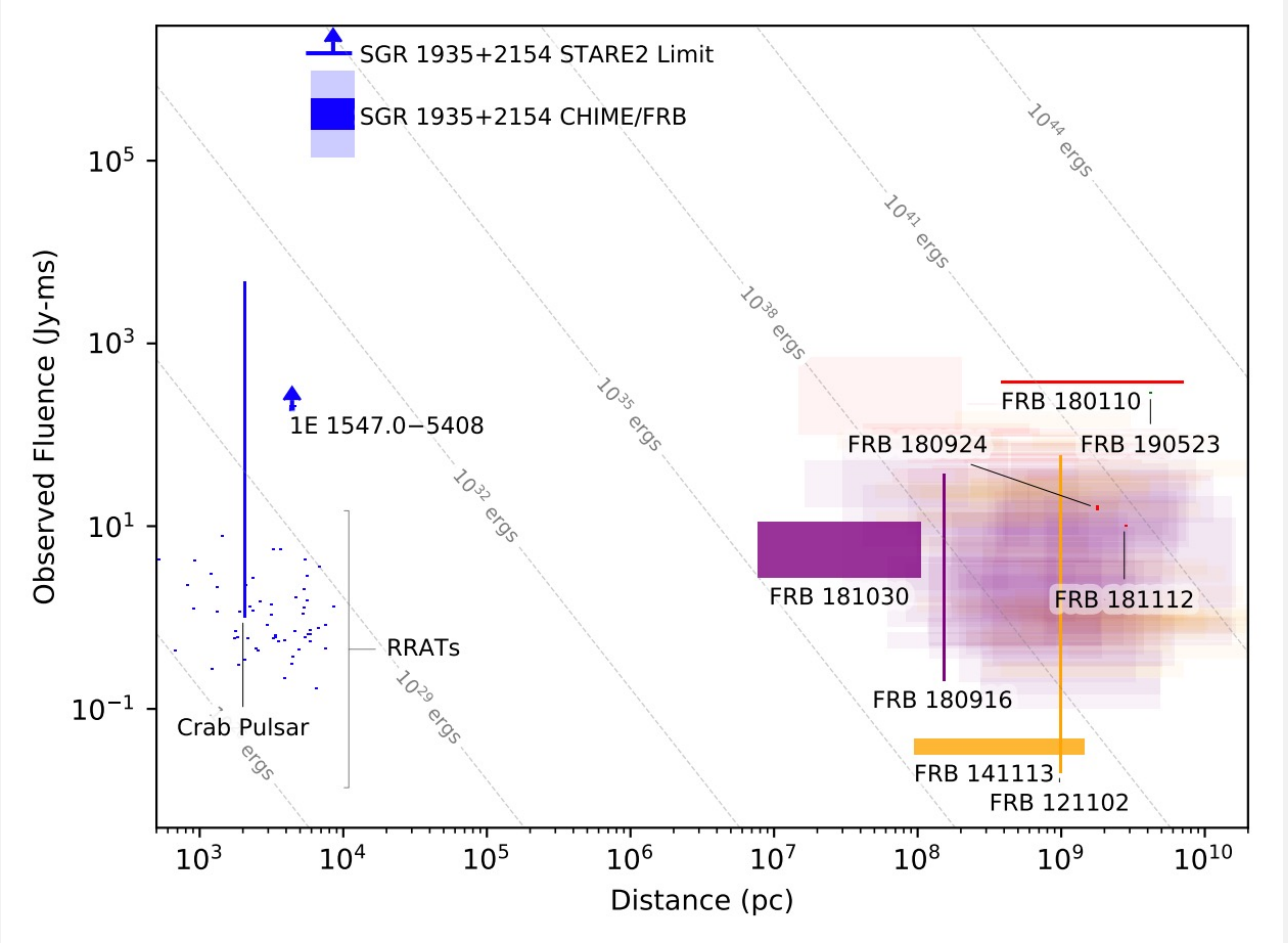
Cool, but how does this relate to gamma rays?

Magnetars!

- Thought to be progenitors for a long time but FRBs are predominantly extragalactic

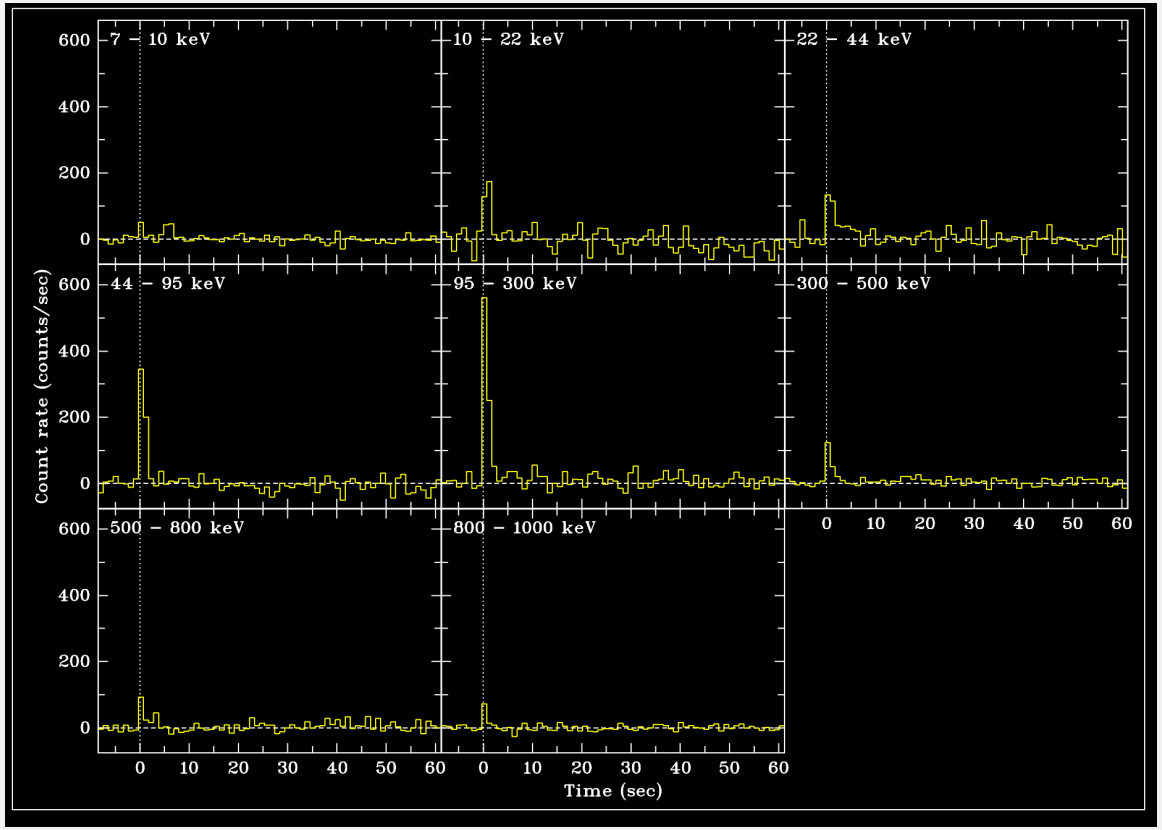
SGR J1935+2154

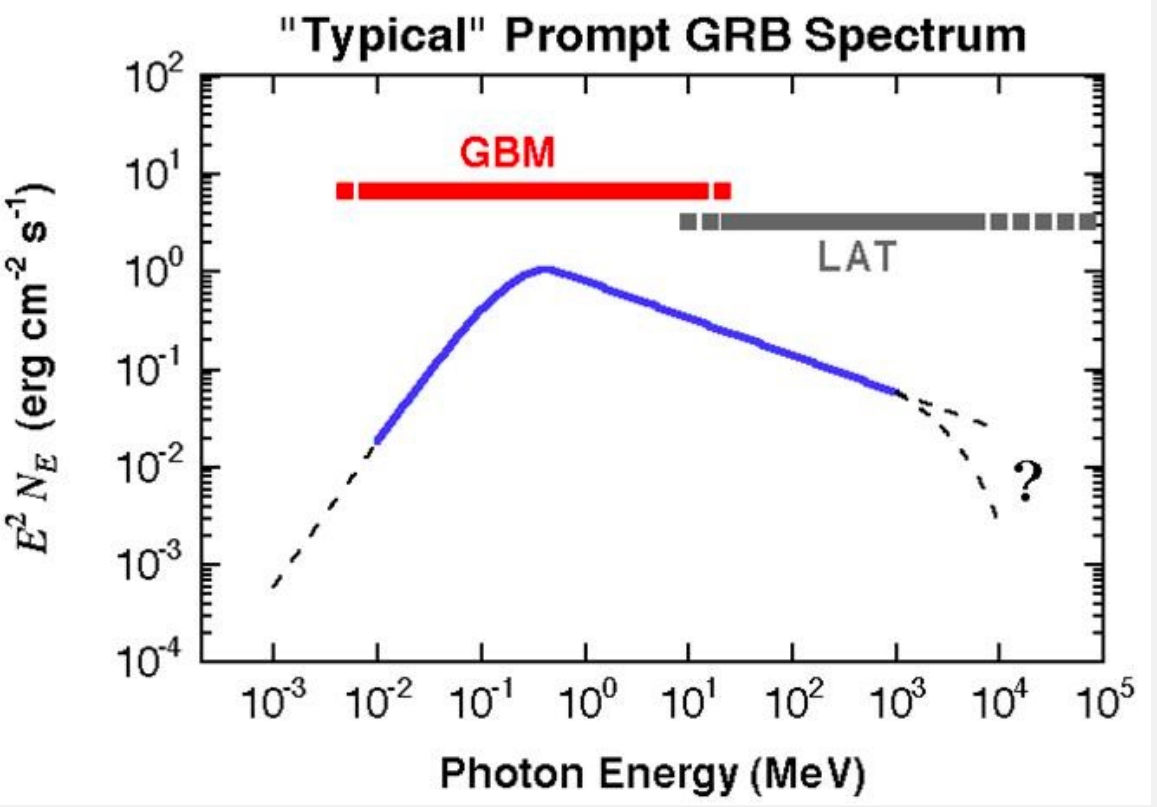
- On August 28, 2020, CHIME detected an extremely bright FRB, during a period of intense burst activity from SGR J1935
- After CHIME localized the FRB it was found to be coming from the direction of SGR J1935



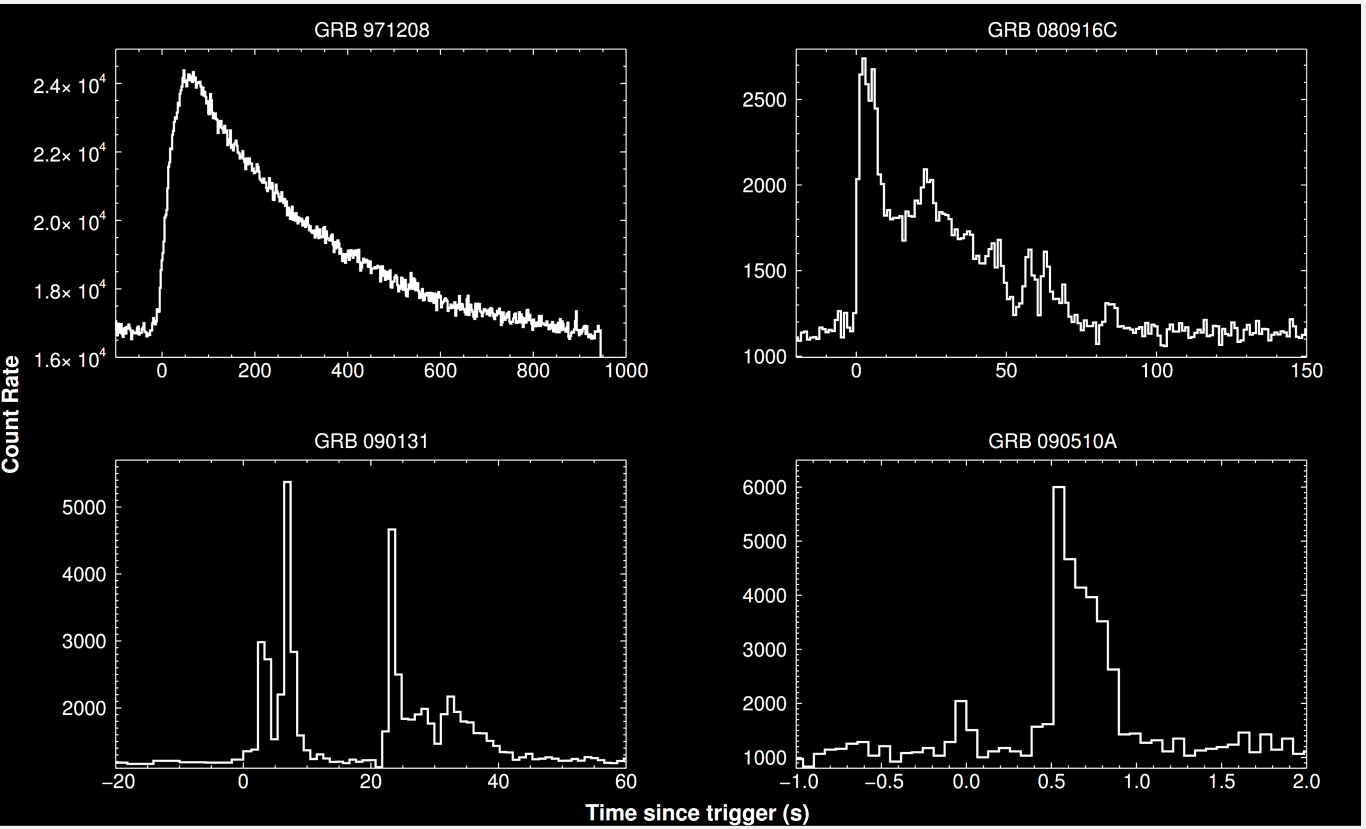
CHIME et al. 2020

Gamma-ray Bursts



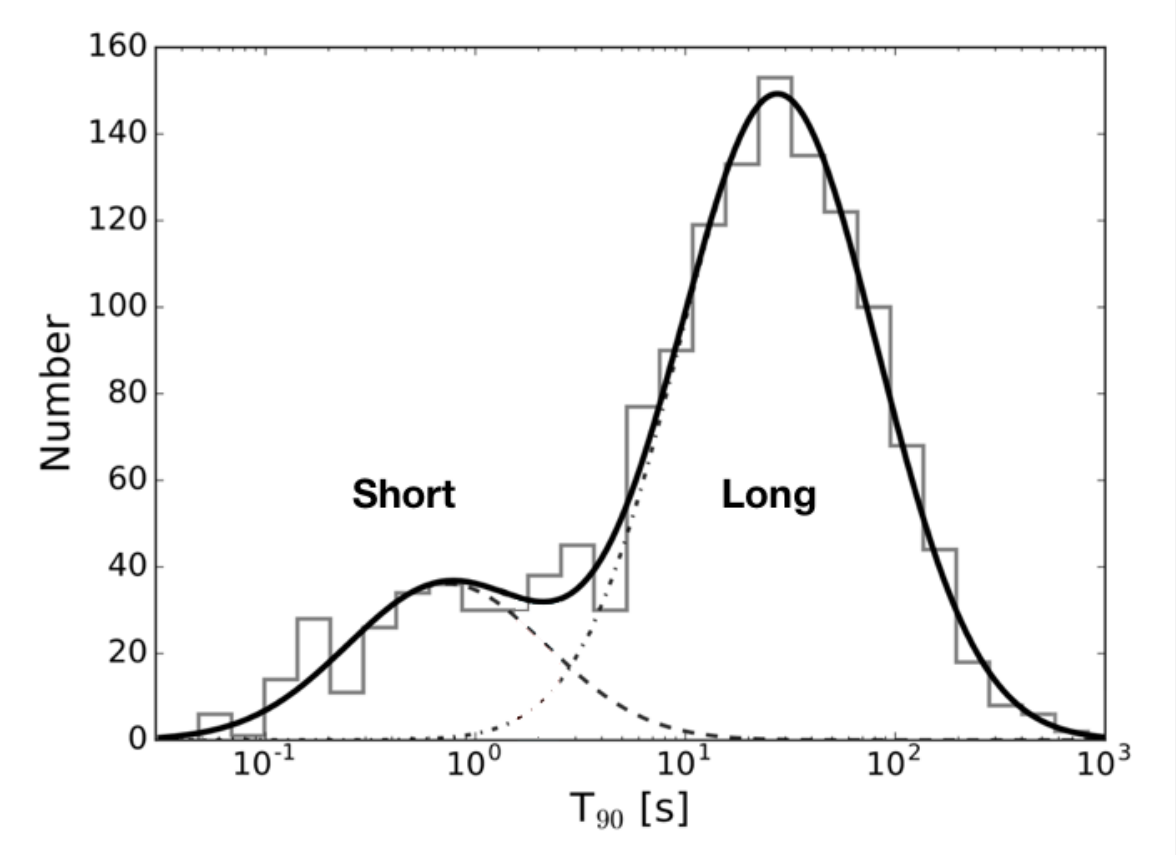


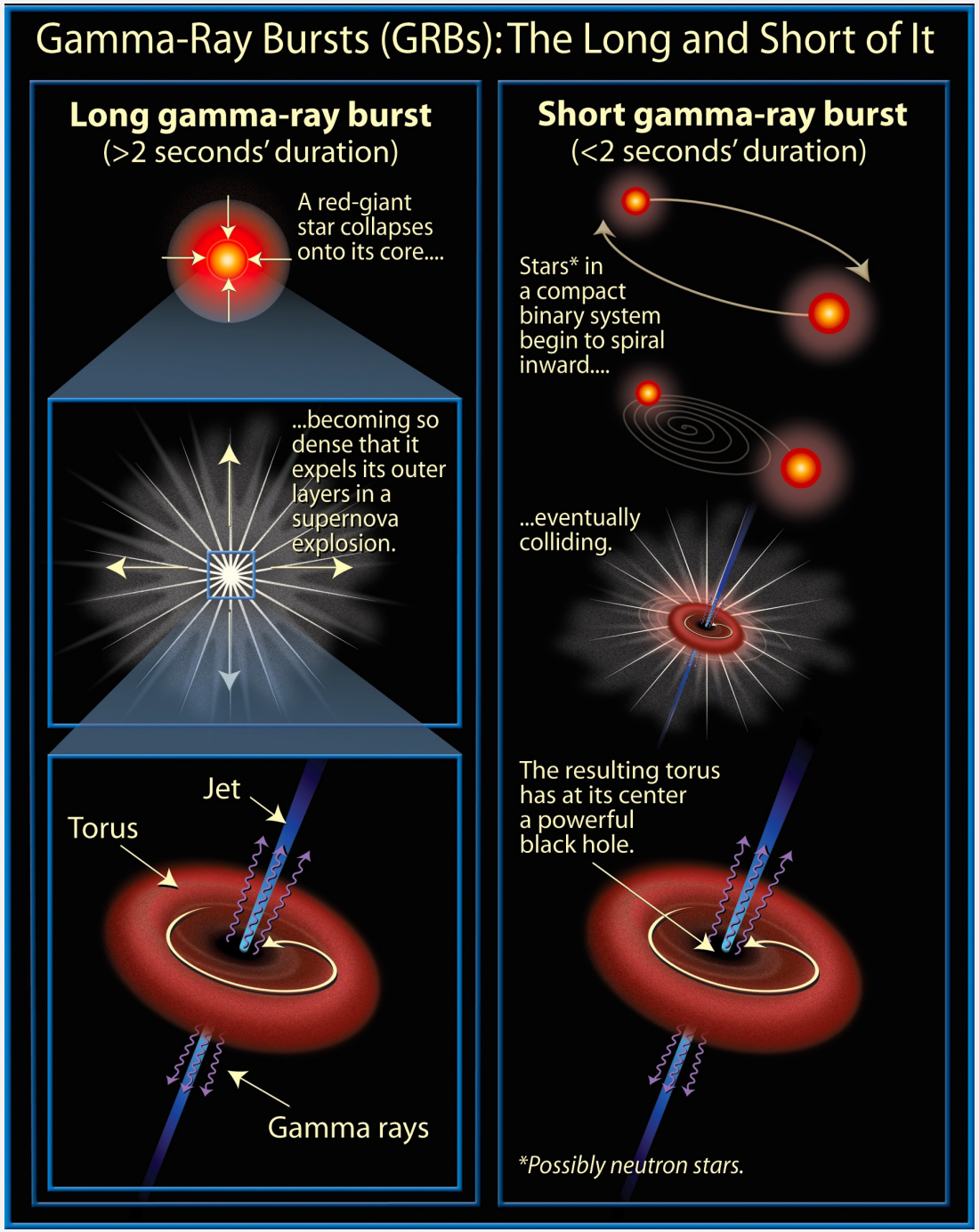
Gamma-ray Bursts



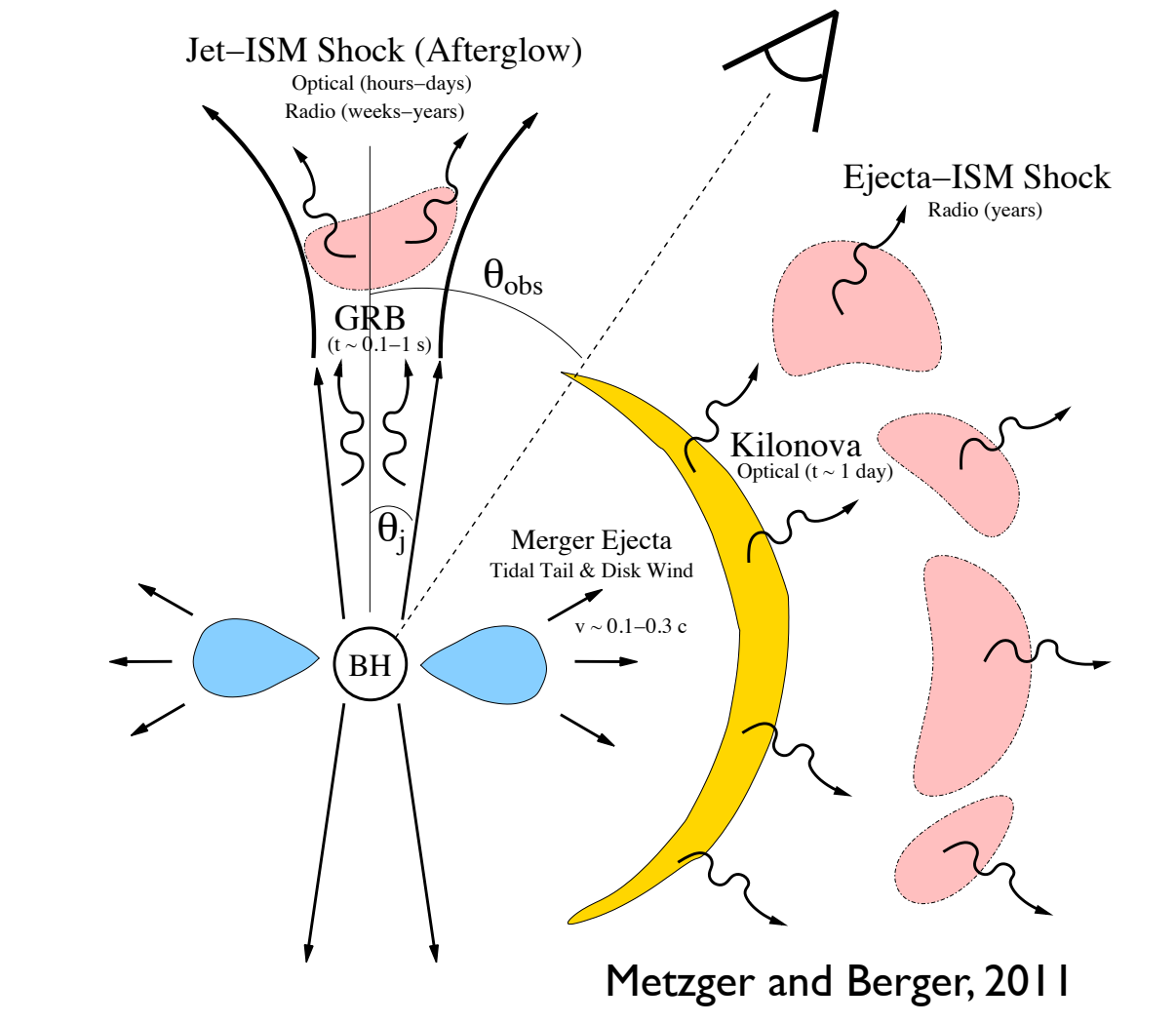
- Properties:
  - Detected Redshift range z < 0.01 — 9
  - Energetics: E_{iso} ~10^{46}–10^{54} erg
  - Durations: 10s of ms —several minutes
  - Wide variety of SED peak energies
  - Wide variety of lightcurves
  - Spectral evolution throughout burst

What are Gamma-ray Bursts?





Short GRBs and GWs



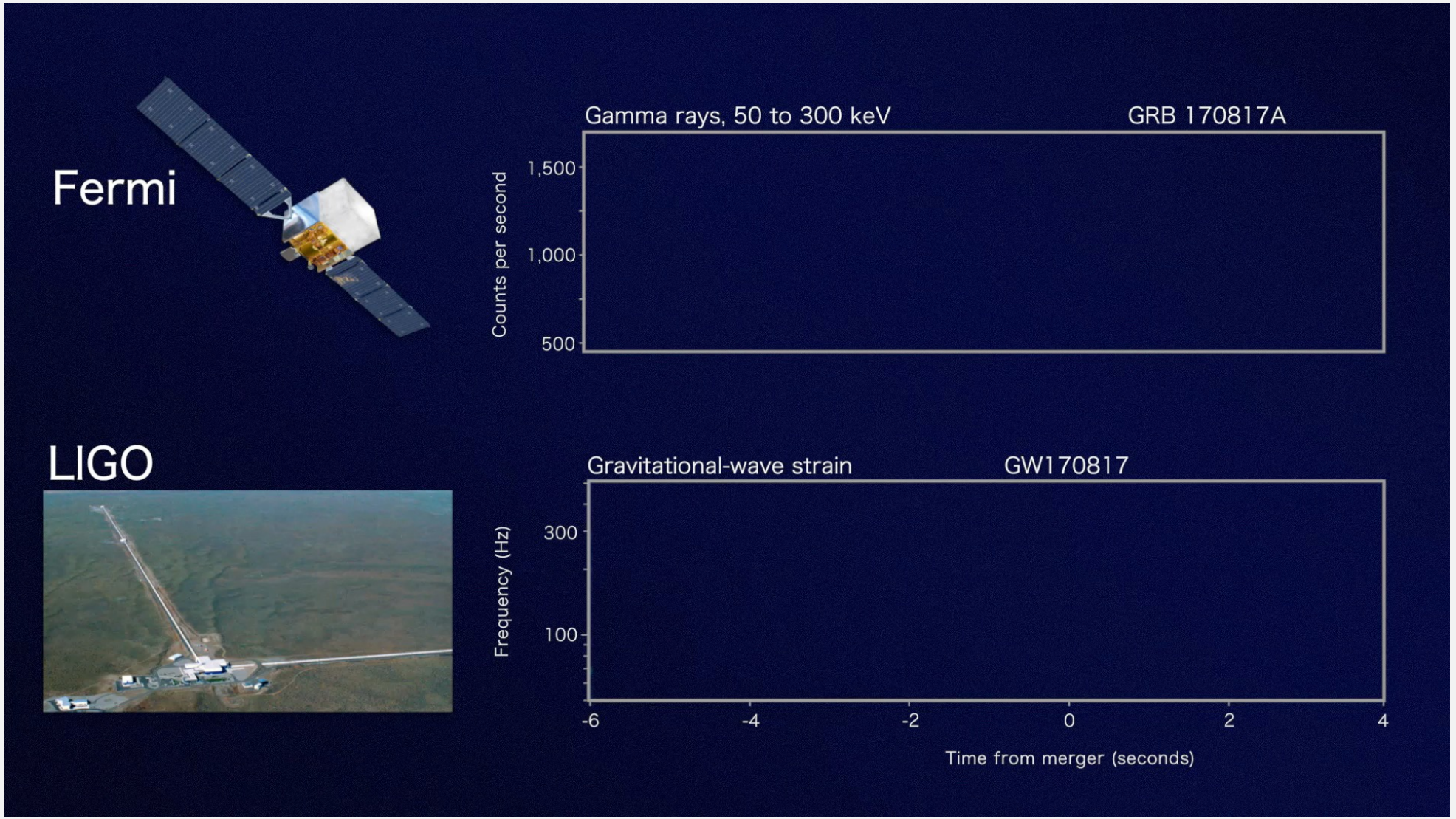
GW

- In-spiral confirms CBC progenitor model
- Information about binary system parameters
- precise merger time
- standard candle -> luminosity distance

EM

- Detection confidence
- EM energetics
- X-ray or optical afterglow gives precise location
- Host galaxy/redshift
- Local environment information

GW 170817-GRB 170817A

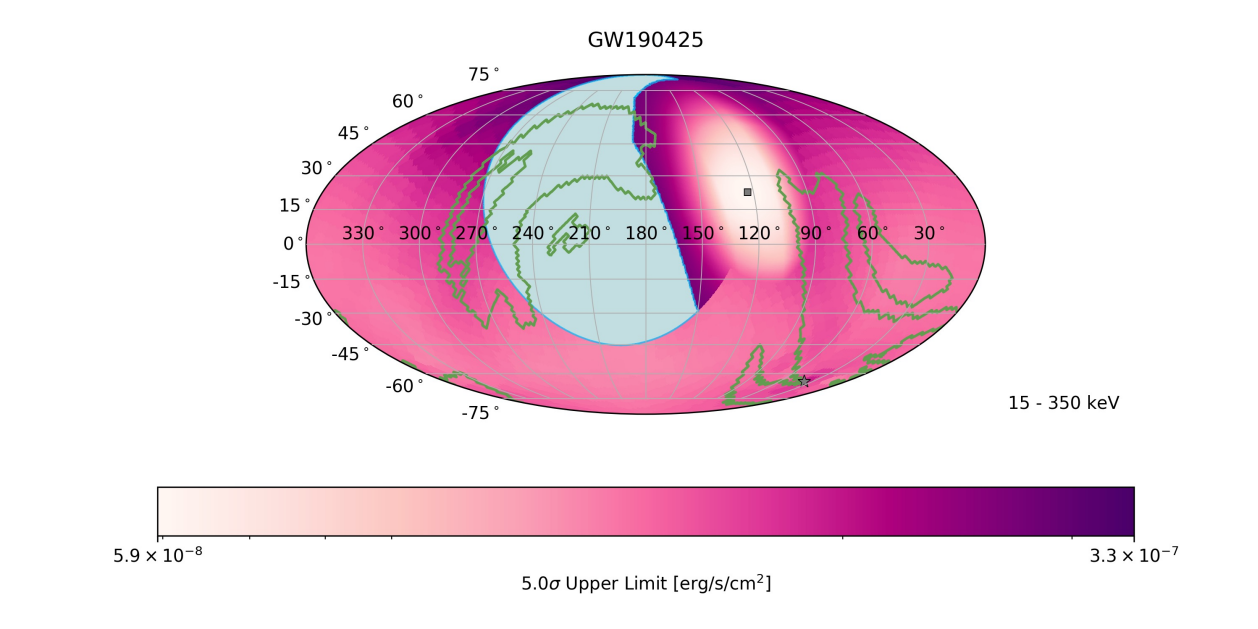


Fermi Science with GW170817

- Relativistic Jet physics — emission radius/timescale, deceleration radius/timescale
- Stellar populations — rate of NS-NS mergers/short GRBs
- Condensed matter physics — Neutron Star Equation of State
- Fundamental physics — measurement of the speed of gravity
- General Relativity — testing the Equivalence Principle between gravity and EM, and Lorentz Invariance Violation

All from ONE observation!

What about GW190425?



- During O3 we followed up public and subthreshold GW events with GBM and found no counterparts
- Perform offline searches using GWTC events with Swift BAT for O3 (Fletcher et al. in prep., Hamburg et al. 2020)
- Perform offline searches using subthreshold GW events from the LVK.

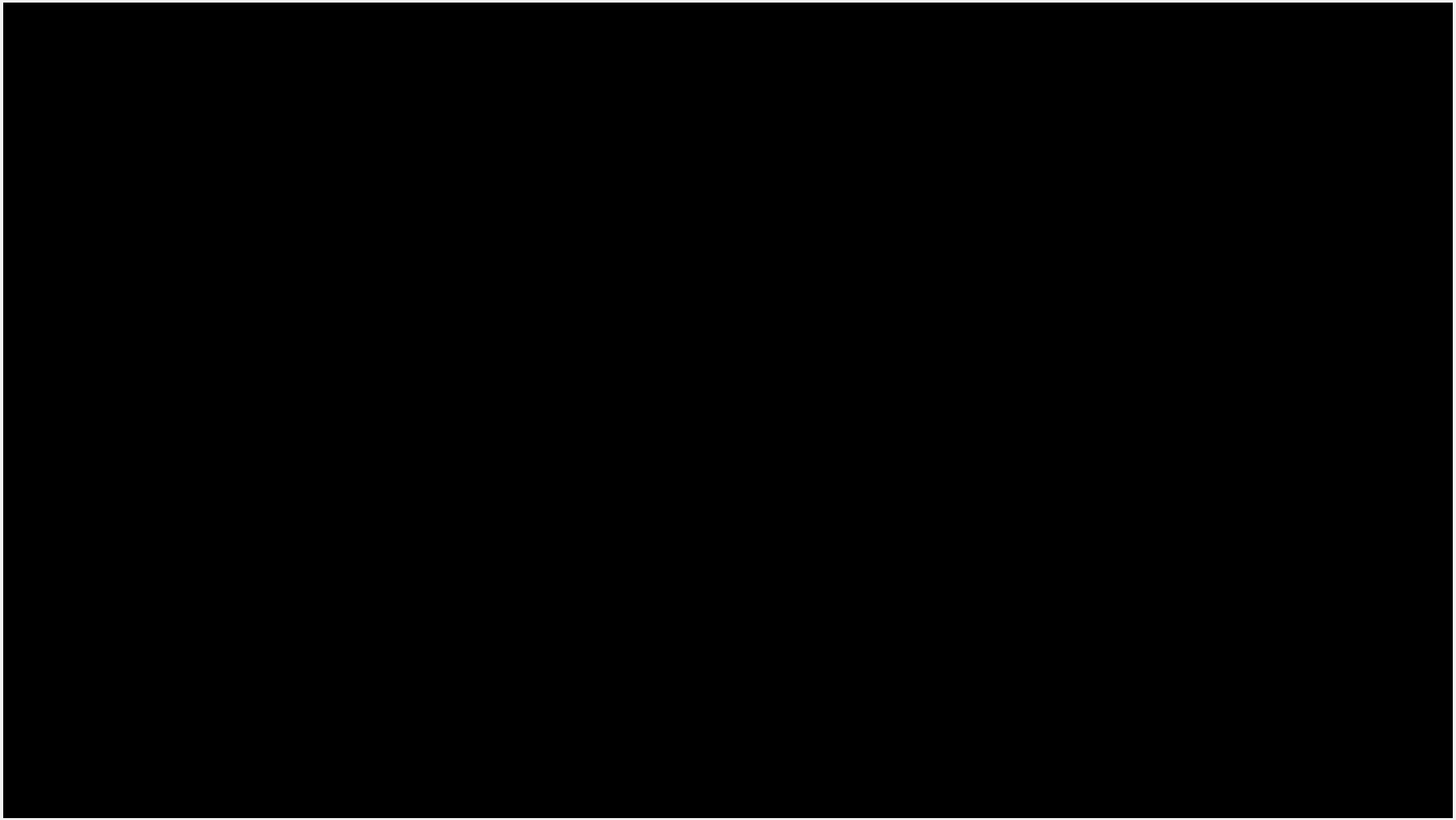
- GBM/BAT only see ~60% of the GW localization region
- GW190425 is 4 times further away

What's going on with O4?

- The LVK began their 4th observing run on May 24th (last week). O4 is planned to be 18 months long with 1-2 month long commissioning periods in the middle.
- A month long engineering run before O4 began to finish up calibration and test out their public alert pipeline.
- During the ER we had 6 events (4 likely BBH, one NSBH and 1 unknown)
- Since O4 began, we have had 10 events. (Find the events https://gracedb.ligo.org/superevents/public/#O4)
- Summary of the Detector performance for the day is https://gwosc.org/detector_status/day/today/
- GBM is following running our subthreshold searches automatically over all public events during O4.

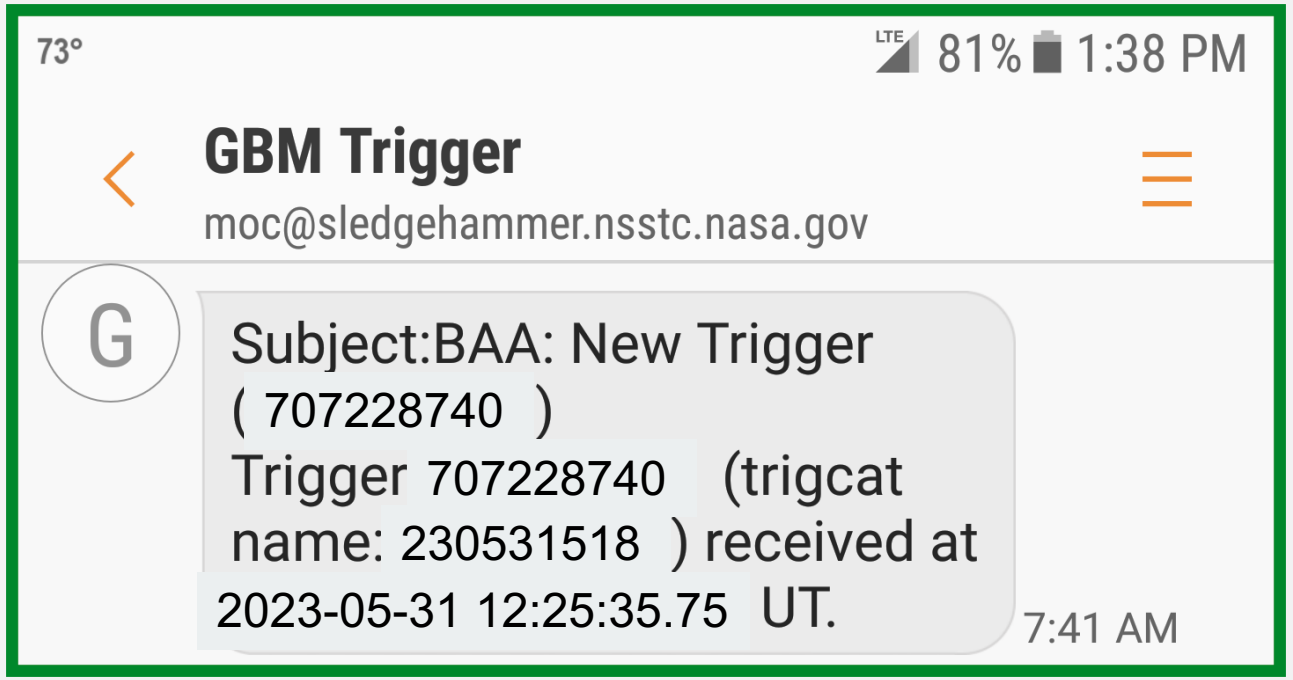
- Fingers crossed!

Will we get another Joint Detection?



A Day in the Life of a BA

Ding Ding! We received a trigger!



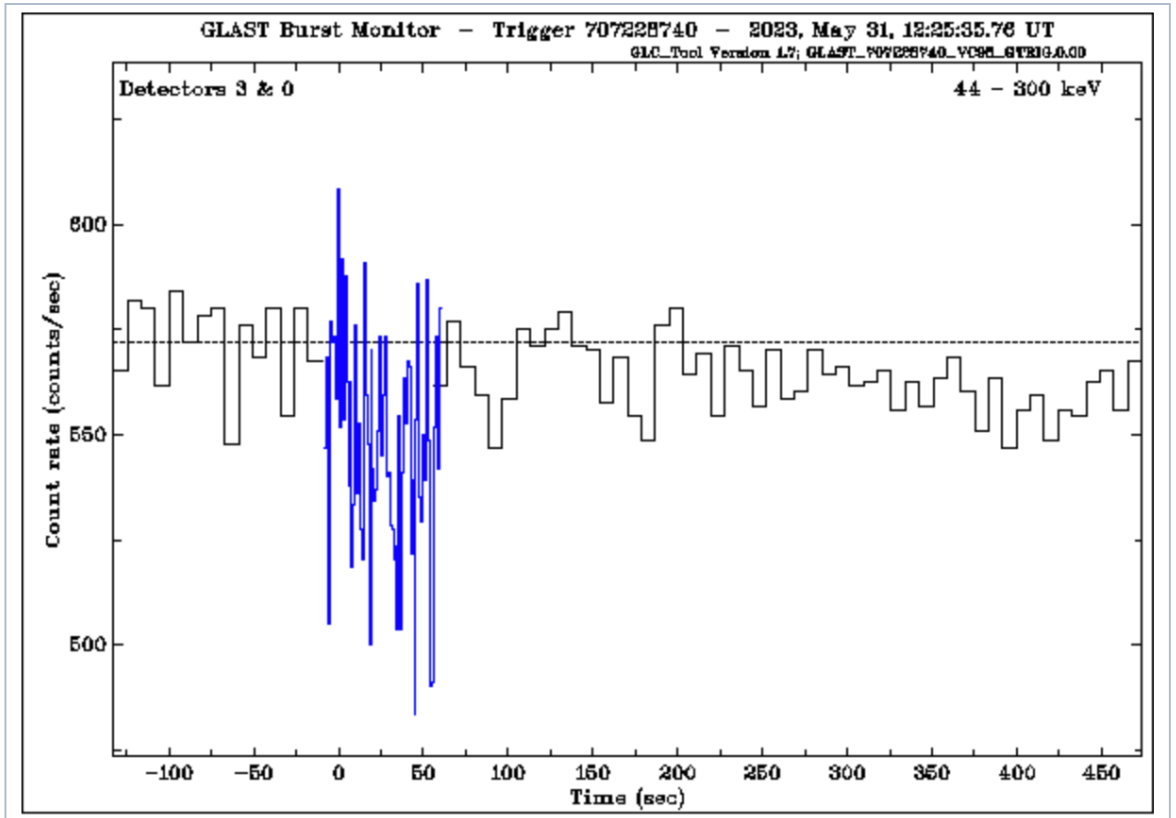
A Day in the Life of a BA

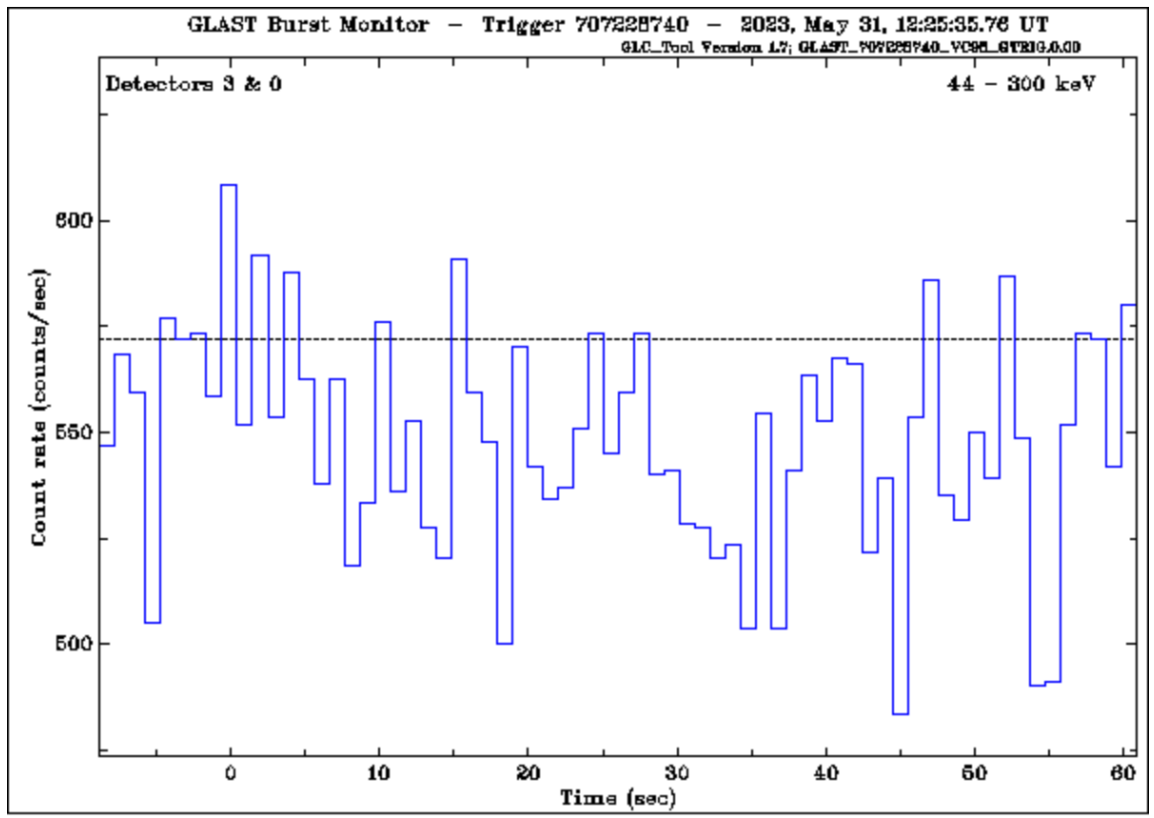
Flight Software Classification

	Triggered detectors	0 & 3
	Triggering algorithm	25
	Energy range	23-47 keV
6	**Integration time**	64 ms
)	**Trigger significance**	5.9 sigma
3	**Trigger classification**	
	Mc Ilwain L	1.10

	Classification	**Probability**
	Unreliable location (n/a)	100% (0%)
	Solar Flare (GRB)	63% (18%)

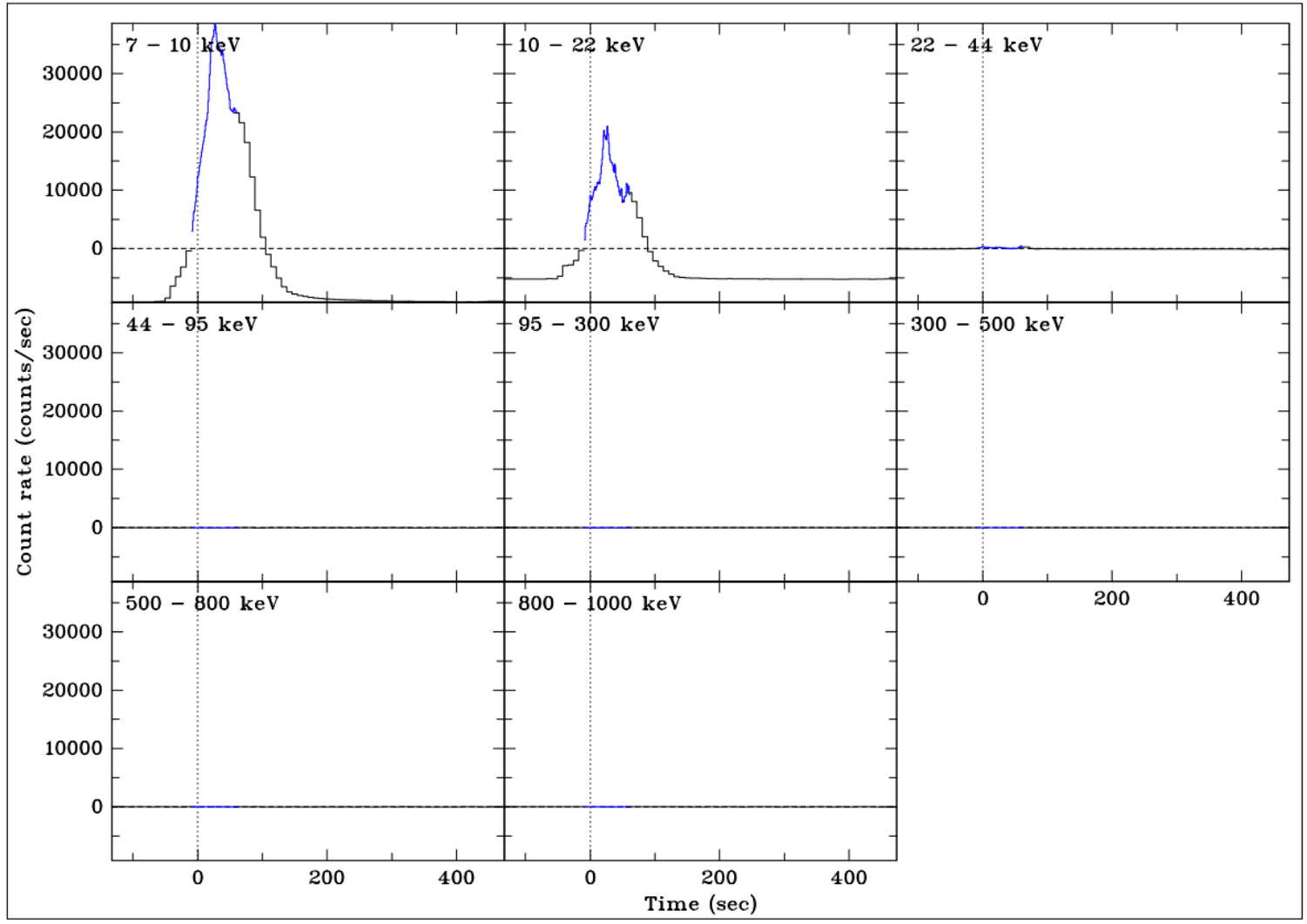
A Day in the Life of a BA





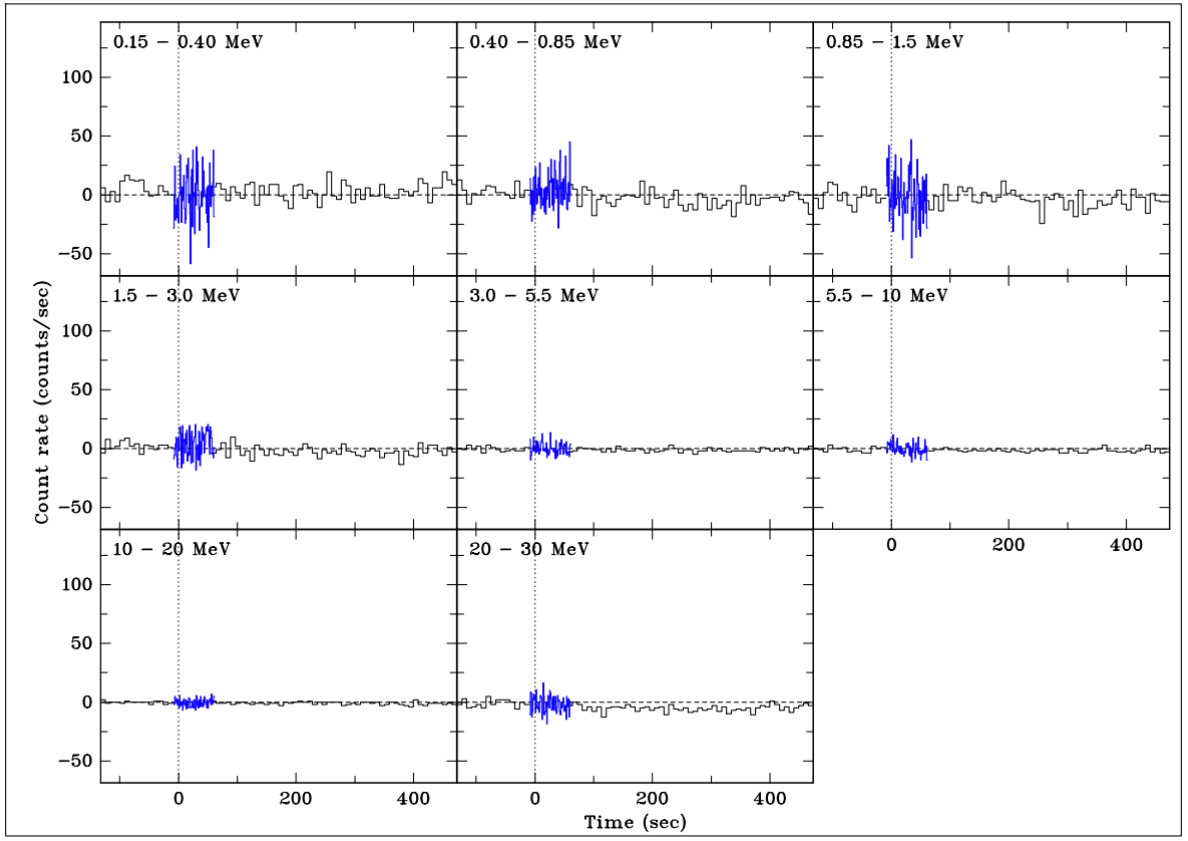
A Day in the Life of a BA

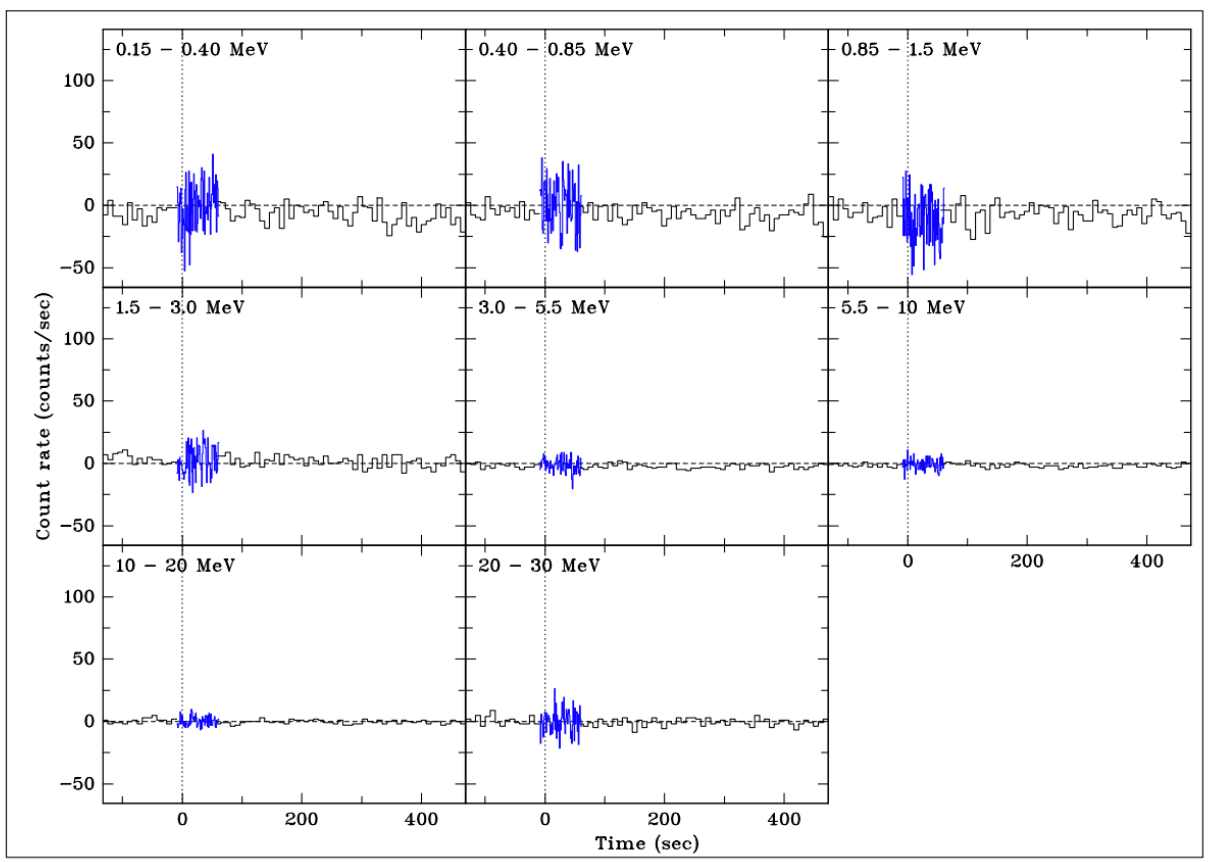
Let's look at the energy range!



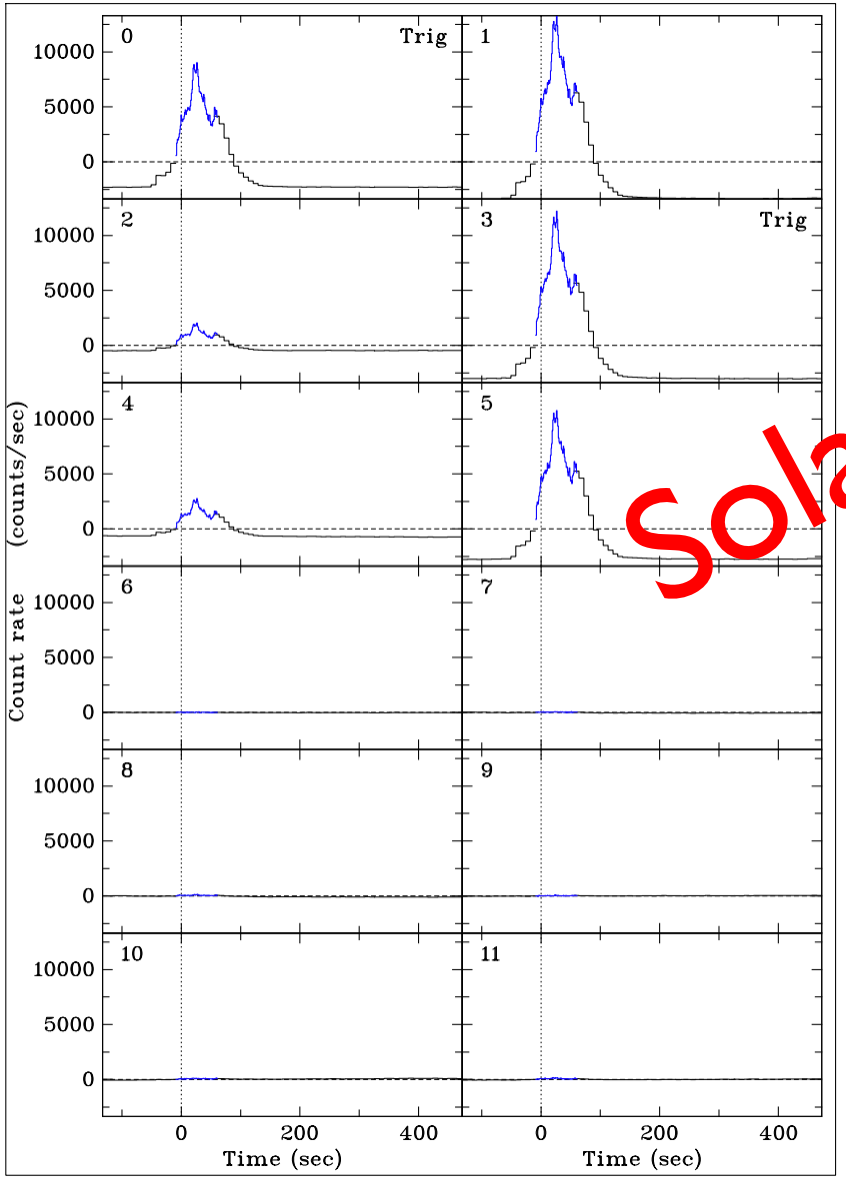
A Day in the Life of a BA

What about the BGOs?





A Day in the Life of a BA



Solar Flare

Alright let's look the individual detectors.

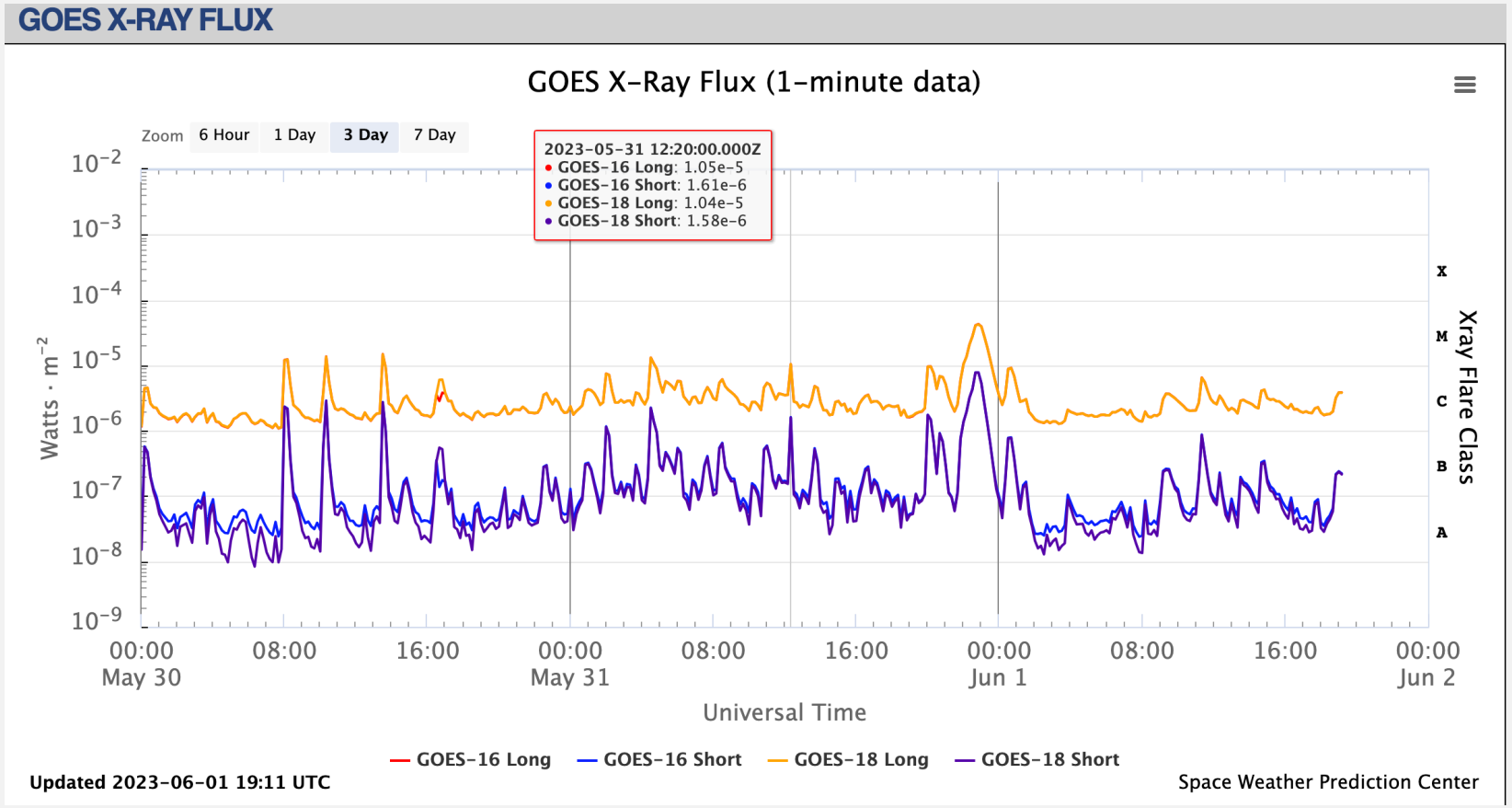
Since we know its peaks in the softer energy channels we will just look at the lightcurves summed over energy channels 1/2

Any thoughts one what this event is?

A Day in the Life of a BA

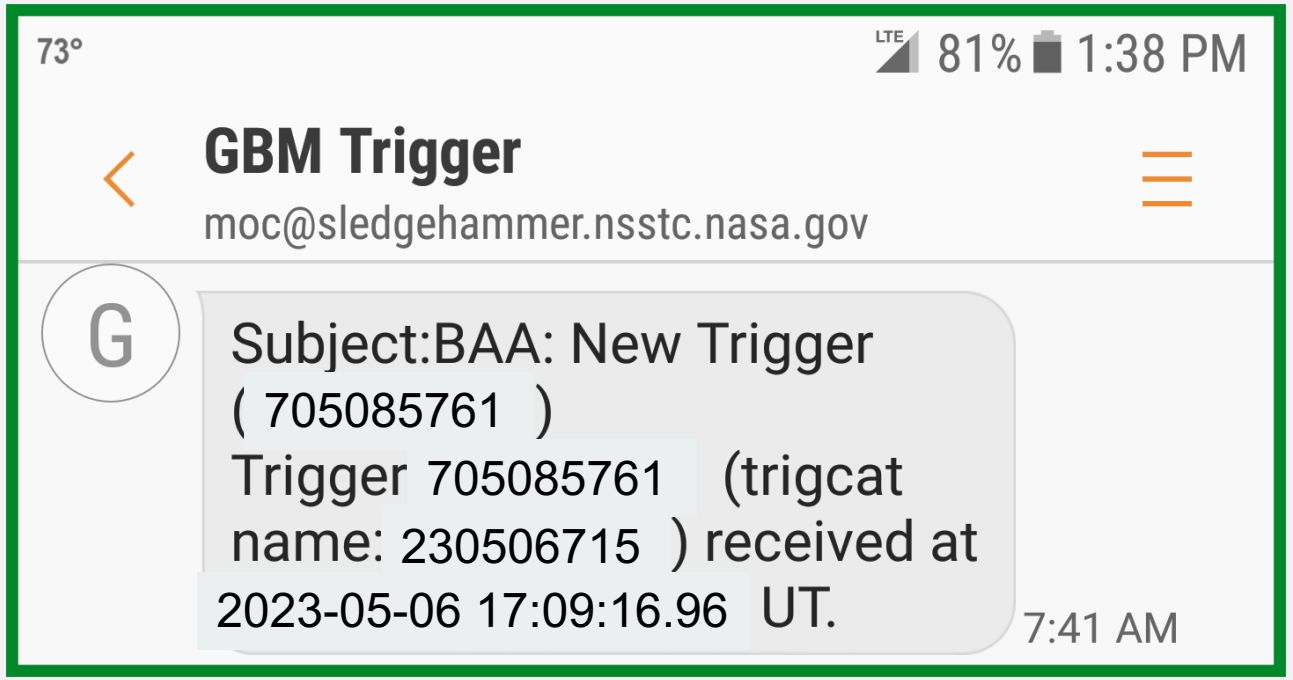
We can double check this with the Goes X-ray Plots.

Trigger Time (UT)	2023/151 2023-05-31 12:25:35.759



A Day in the Life of a BA

Ding Ding! We received another trigger!

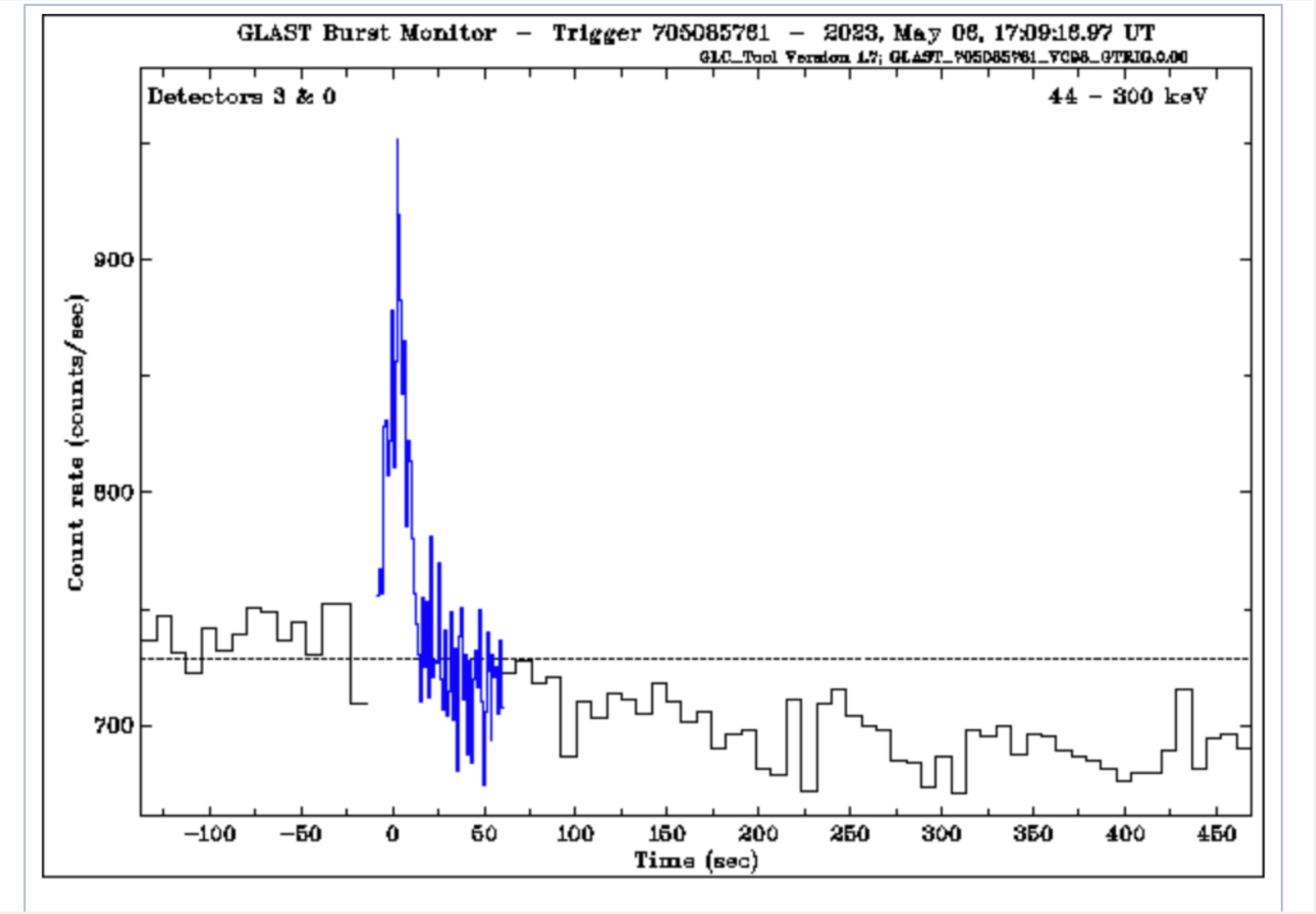


A Day in the Life of a BA

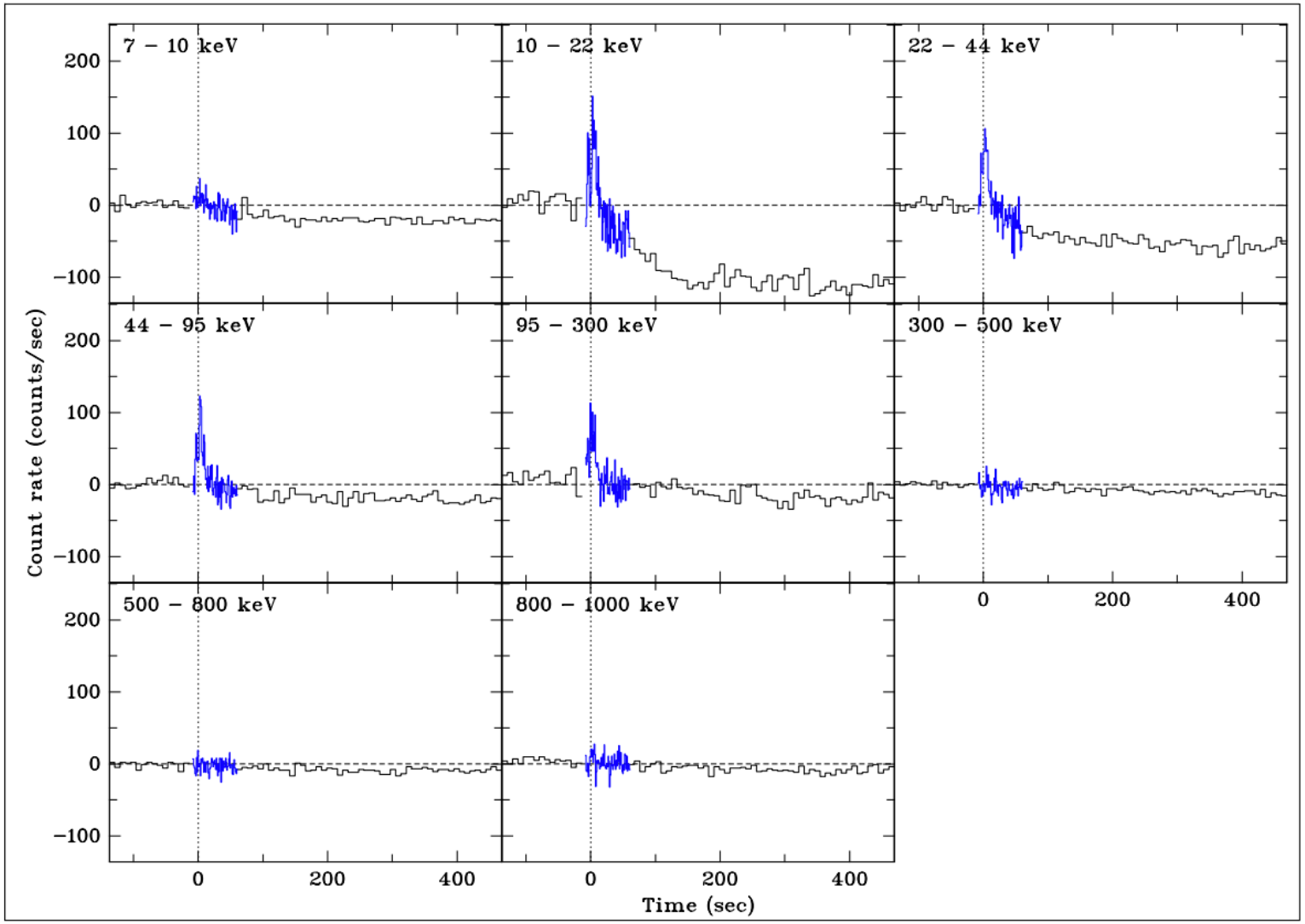
Triggered detectors	0, 3 & 4
Triggering algorithm	17
Energy range	47-291 keV
Integration time	4096 ms
Trigger significance	4.9 sigma
Trigger classification	
Mc Ilwain L	1.05

	RA	Dec	Err	Long L	Lat B	Sigma	Integration Time	Theta	Phi	Classification	Probability
FSW (1)	110.700	+58.783	22.85	158.09	26.93	4.90	4.096	30.00	300.00	GRB (GRO_J0422_32)	96% (2%)
FSW (2)	135.867	+45.750	10.43	174.51	41.68	9.10	4.096	15.00	260.00	GRB (Generic SGR)	98% (1%)
GND (1)	133.700	+42.080	3.14	179.36	40.11	10.20	4.096	11.00	259.00		

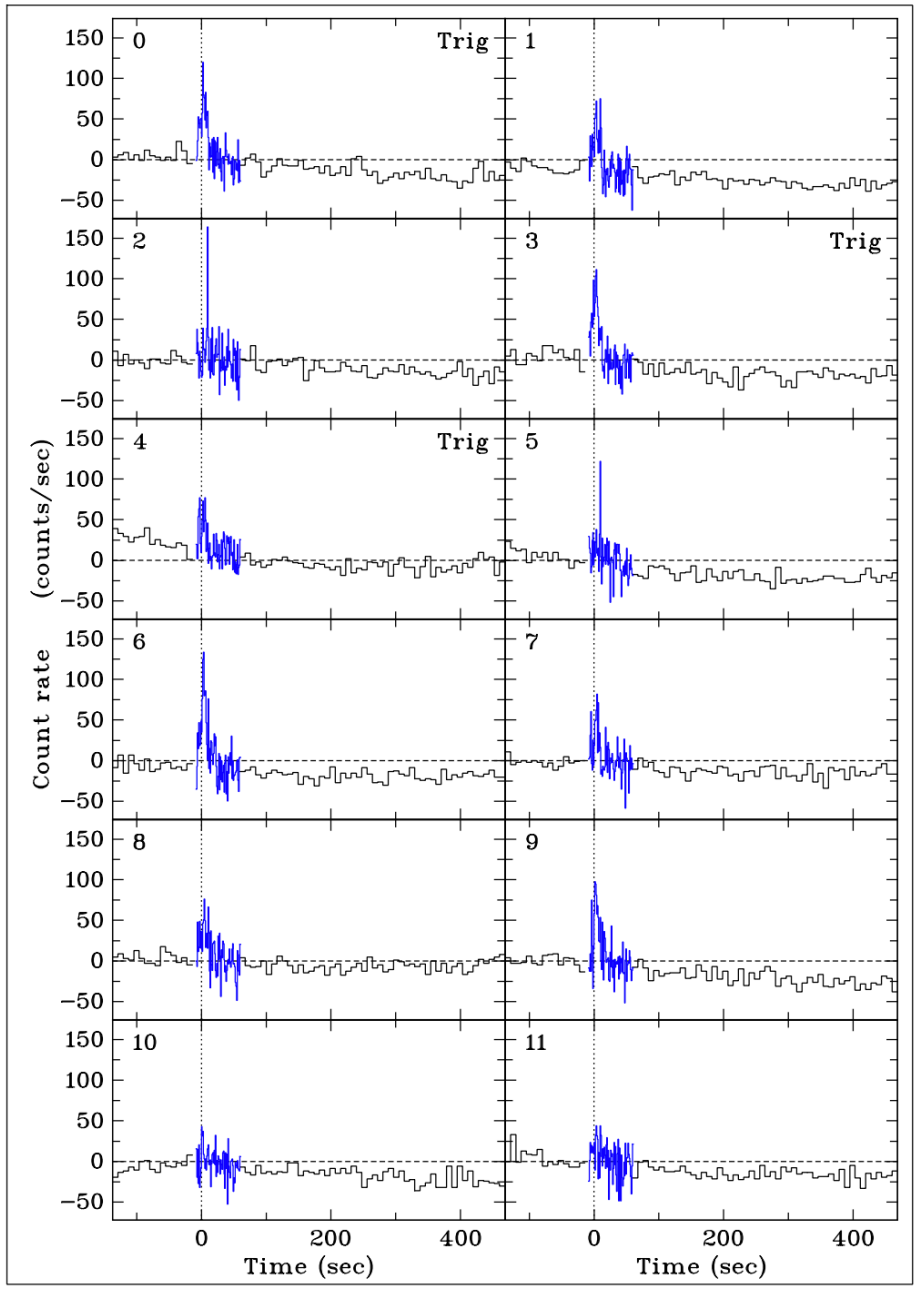
A Day in the Life of a BA



A Day in the Life of a BA



A Day in the Life of a BA



Channel 3/4?

So What do you think it is?

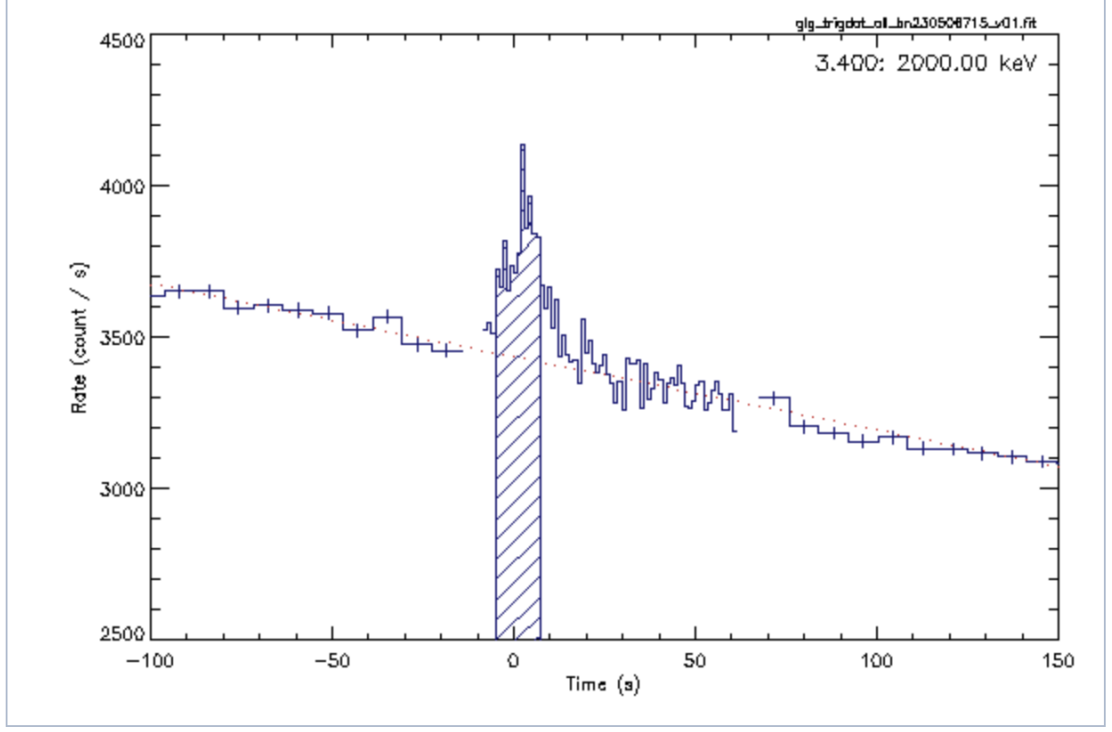
Looks to be a GRB!

A Day in the Life of a BA

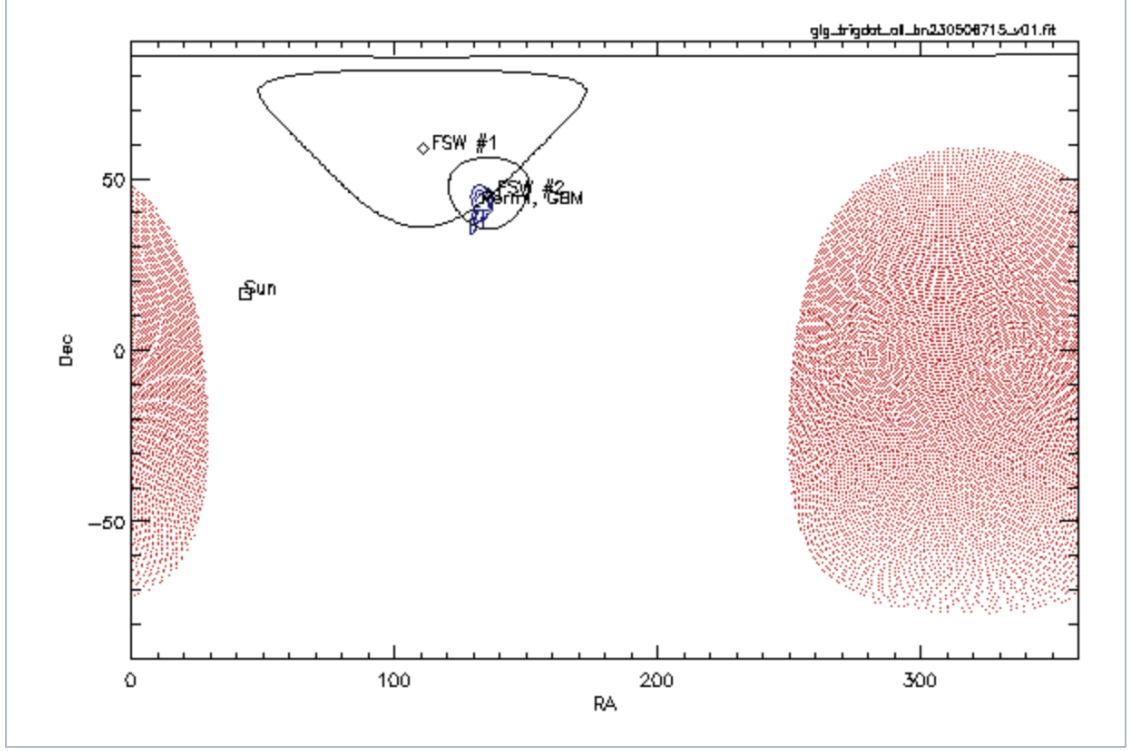
Let's do a quick Localization!

	Time bin	Dt (sec)	RA (deg)	Dec (deg)	Err (deg)	LAT angle (deg)	Chi^2 with norm	Model Rates
0		-5.12 : 7.17	133.43	42.66	1.06	12.00	27.02	2

Location Lightcurve



Best Contour Map



A Day in the Life of a BA

Ding Ding! Swift BAT saw the same GRB!

RA (deg)	Dec (deg)	Err (deg)
133.43	42.66	1.06

GCN Circular 33731

Subject GRB 230506C: Swift detection of a burst
Date 2023-05-06T17:21:56Z (a month ago)
From David Palmer at LANL <palmer@lanl.gov>

A. Tohuvavohu (U Toronto), J. A. Kennea (PSU),
K. L. Page (U Leicester), D. M. Palmer (LANL), M. H. Siegel (PSU) and
M. A. Williams (PSU) report on behalf of the Neil Gehrels Swift
Observatory Team:

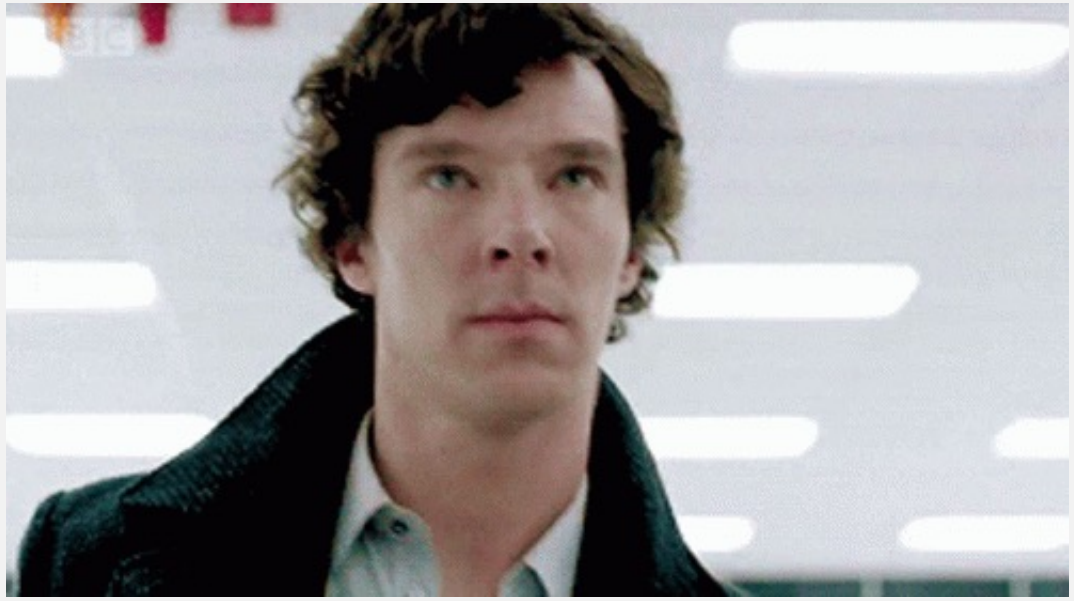
At 17:09:19 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 230506C (trigger=1167288). Swift did not immediately slew
due to an observing constraint. The BAT on-board calculated location is
RA, Dec 134.373, +45.126 which is
RA(J2000) = 08h 57m 30s
Dec(J2000) = +45d 07' 32"
with an uncertainty of 3 arcmin (radius, 90% containment, including
systematic uncertainty). The BAT light curve showed a complex
structure with a duration of about 30 sec. The peak count rate
was ~1200 counts/sec (15-350 keV), at ~0 sec after the trigger.

Due to an observing constraint, Swift will not slew until T0+55.3
minutes. There will be no XRT or UVOT data until this time.

Burst Advocate for this burst is A. Tohuvavohu (aaron.tohu AT gmail.com).
Please contact the BA by email if you require additional information
regarding Swift followup of this burst. In extremely urgent cases, after
trying the Burst Advocate, you can contact the Swift PI by phone (see
Swift TOO web site for information: http://www.swift.psu.edu/)

A Day in the Life of a BA

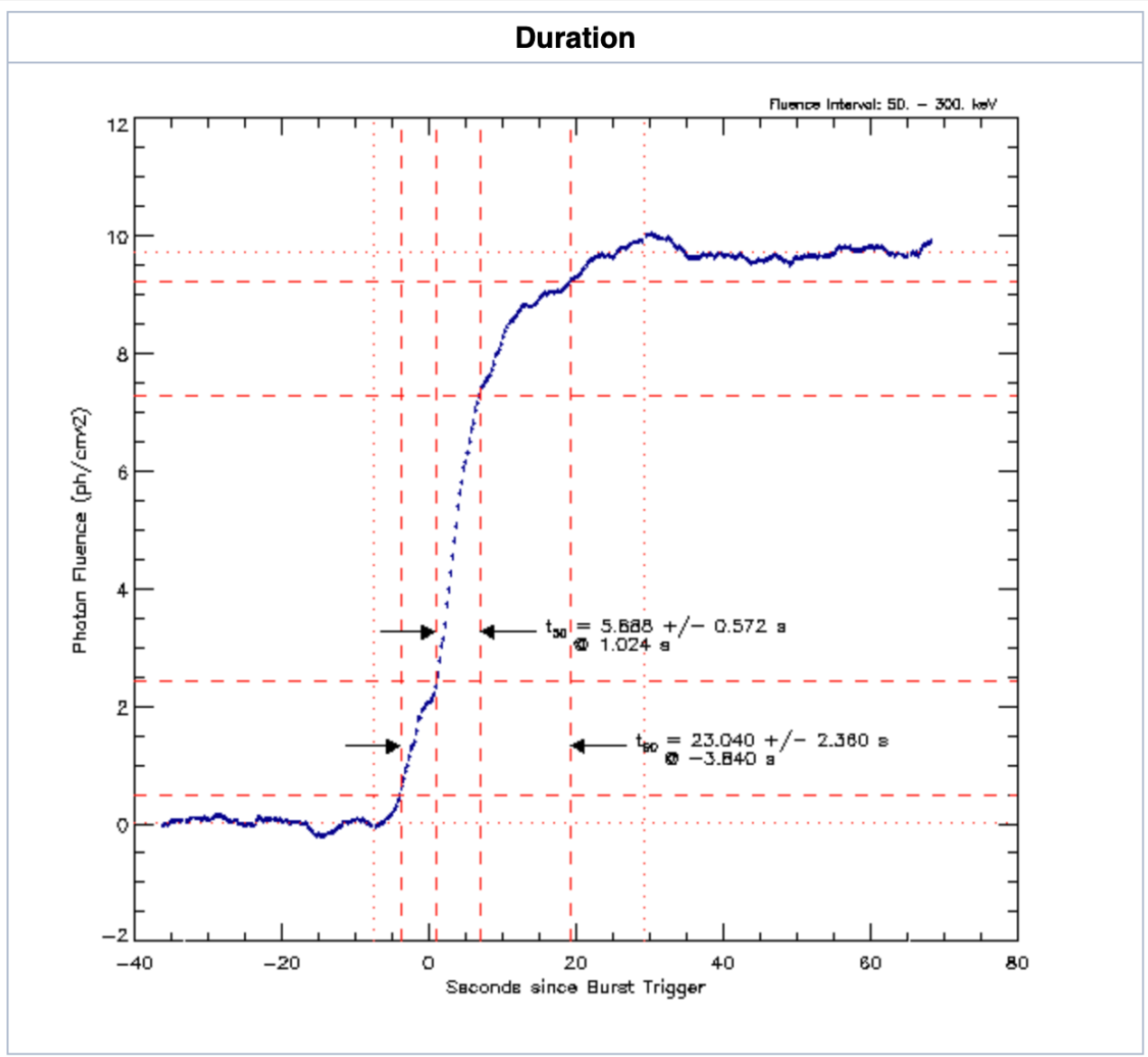
We need to wait for the science data to come down first.



A Day in the Life of a BA

Let's look at the T90 (duration)

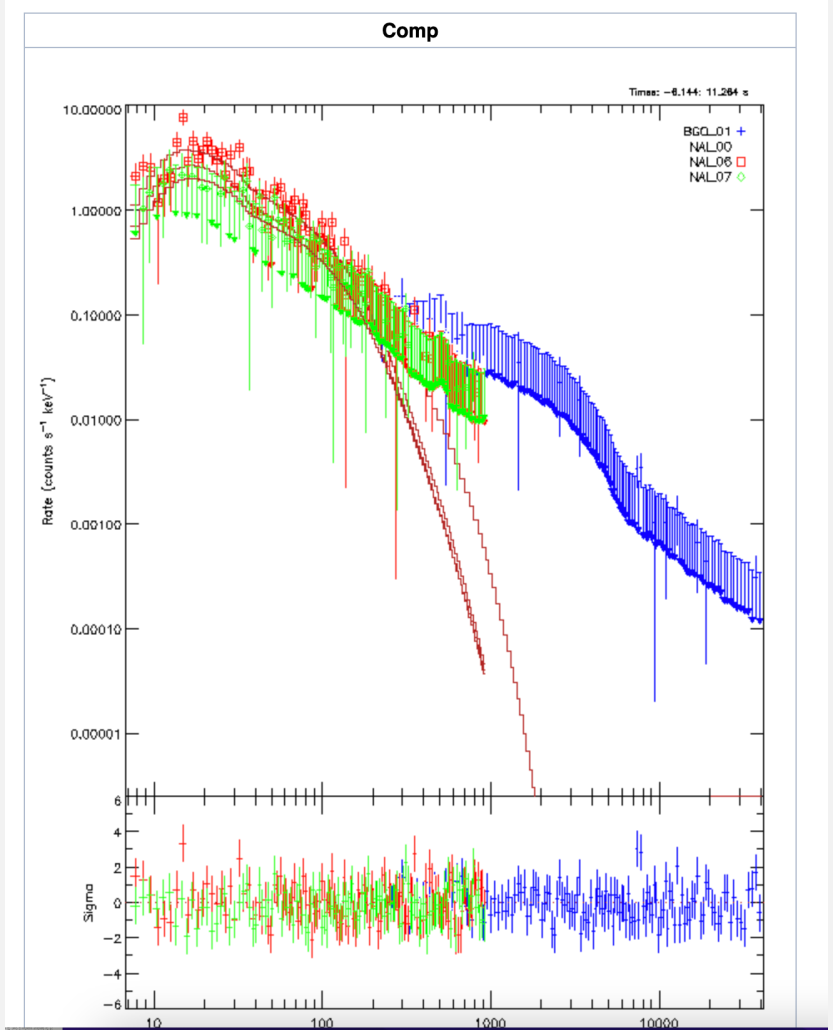
Det.	Det/Src Angles	Det/Earth Angles
0	30.9695	150.131
1	55.1624	131.991
2	101.109	97.7158
3	38.7481	110.093
4	81.1233	65.1262
5	91.9351	75.9814
6	13.1555	146.777
7	37.3579	126.908
8	79.2364	82.8531
9	53.5589	158.947
A	99.4810	114.212
B	88.0928	103.779



A Day in the Life of a BA

Let's look at the Spectral Analysis

<:>#	Detectors	Data	Dt (s)	Model	Epeak	Alpha/Index	Beta	C-Stat/DOF	Ph. Flux	En. Flux
1	n0+n6+n7+b1	TTE	-6.144: 11.264	PL	-	-1.64 +/- 0.03	-	581.91/486	1.84 +/- 0.07	(2.370 +/- 0.120)E-07
2	n0+n6+n7+b1	TTE	-6.144: 11.264	Comp	163.10 +/- 29.90	-1.19 +/- 0.11	-	547.82/485	1.77 +/- 0.07	(1.781 +/- 0.160)E-07
3	n0+n6+n7+b1	TTE	-6.144: 11.264	Band	164.70 +/- 30.90	-1.20 +/- 0.11	-20.39 +/- 5.98E+09	547.83/484	1.77 +/- 0.07	(1.787 +/- 0.160)E-07



A Day in the Life of a BA

Now we write up our science circular!

GCN Circular 33755

Subject GRB 230506C: Fermi GBM detection
Date 2023-05-10T17:37:35Z (22 days ago)
From Suraj Poolakkil at UAH <sp0076@uah.edu>

S. Poolakkil (UAH) and C. Meegan (UAH)
report on behalf of the Fermi GBM Team:

"At 17:09:16.97 UT on 6 May 2023, the Fermi Gamma-Ray Burst Monitor (GBM)
triggered and located GRB 230506C (trigger 705085761 / 230506715)
which was also detected by the Swift/BAT (Tohuvavohu et al. 2023, GCN 33731).

The angle from the Fermi LAT boresight at the GBM trigger time is 15 degrees.

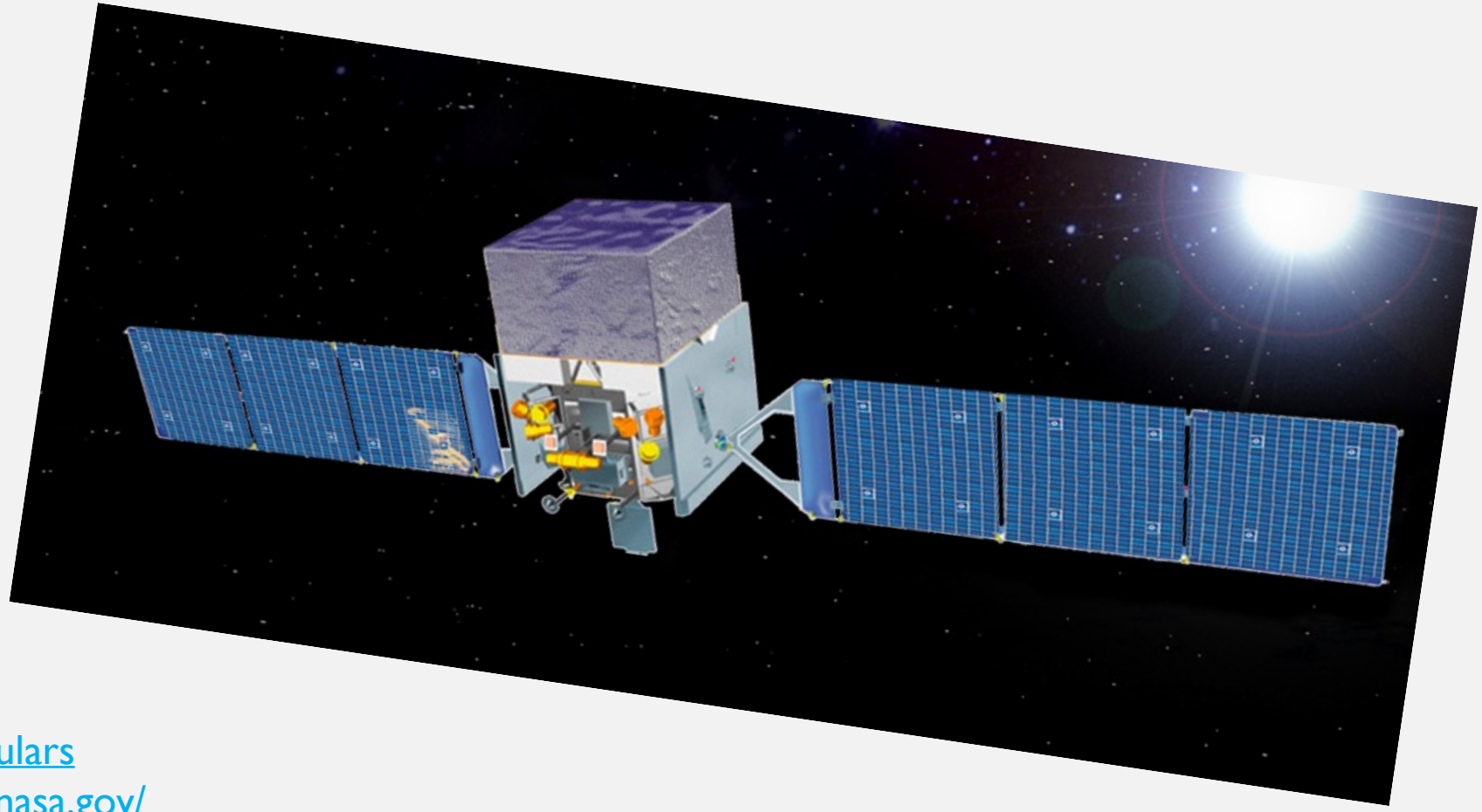
The GBM light curve consists of a single peak followed
by some extended emission with a duration (T90) of about 23 s (50-300 keV).
The time-averaged spectrum from T0-6.1 s to T0+11.3 s
is best fit by a power law function with an exponential
high-energy cutoff. The power law index is -1.19 +/- 0.11 and
the cutoff energy, parameterized as Epeak, is 163 +/- 30 keV.

The event fluence (10-1000 keV) in this time interval is
(3.1 +/- 0.3)E-06 erg/cm^2. The 1-sec peak photon flux measured
starting from T0+3.0 s in the 10-1000 keV band
is 3.3 +/- 0.2 ph/s/cm^2.

The spectral analysis results presented above are preliminary;
final results will be published in the GBM GRB Catalog:
https://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermigbrst.html

For Fermi GBM data and info, please visit the official Fermi GBM Support Page:
https://fermi.gsfc.nasa.gov/ssc/data/access/gbm/"

Useful Links



GCN Archive: https://gcn.nasa.gov/circulars
GBM Website: https://gammaray.nsstc.nasa.gov/
Magnetar Catalog: http://www.physics.mcgill.ca/~pulsar/magnetar/main.html
CHIME Catalog: https://iopscience.iop.org/article/10.3847/1538-4365/ac33ab
CHIME website: https://chime-experiment.ca
LIGO Website: https://www.ligo.org/
Virgo Website: https://www.virgo-gw.eu/
LVK Instruments: https://www.ligo.caltech.edu/page/ligo-sister-facilities