

Time-domain astronomy with *Fermi* GBM in the Multi-Messenger Era

Colleen A. Wilson-Hodge (NASA/MSFC)
Fermi GBM PI
on behalf of the *Fermi* GBM team

231st AAS meeting, National Harbor, MD, Jan 9, 2018



Fermi Gamma-ray Space Telescope

<http://gammaray.nsstc.nasa.gov/>

GBM:

- FOV >8sr
- Whole sky every ~90min

Data products:

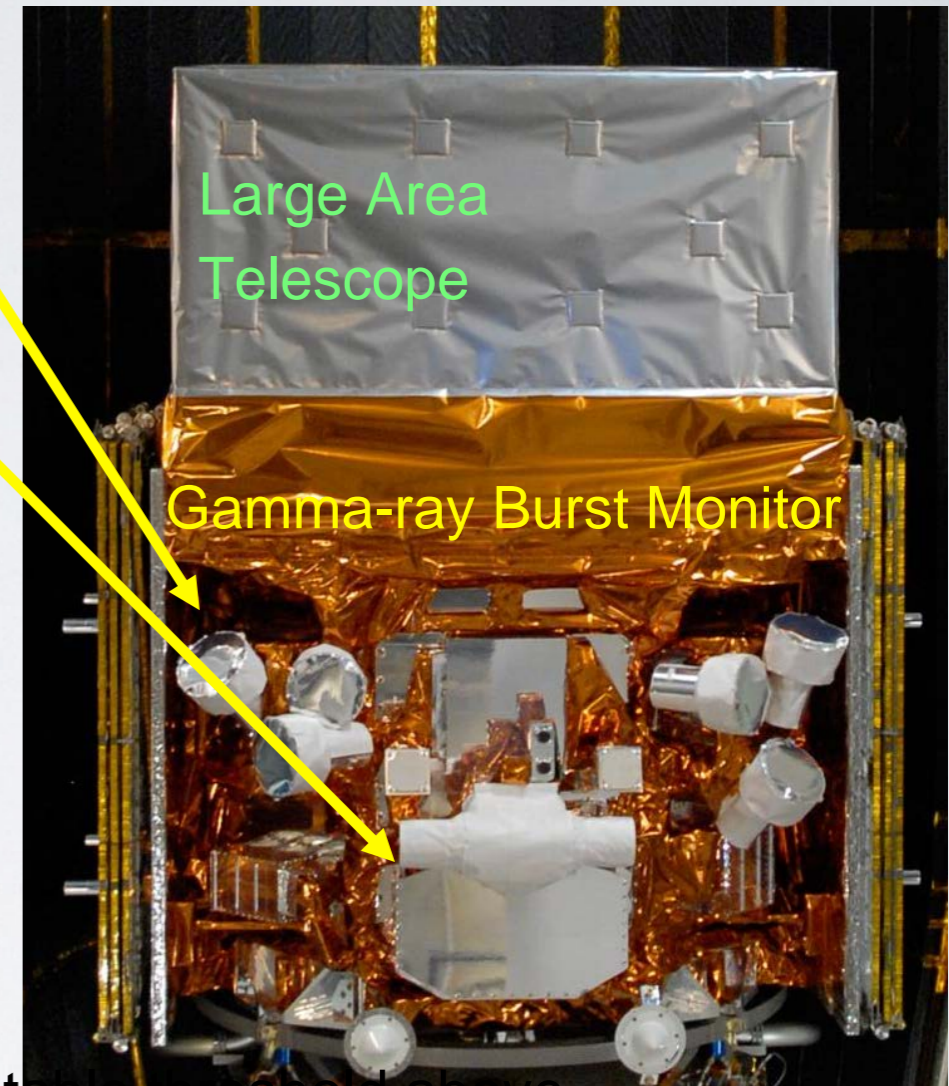
- CTIME (continuous high time resolution)
 - 256 / 64 ms, 8 energy channels
- CSPEC (continuous high spectral resolution)
 - 4096 / 1024 ms, 128 energy channels
- TTE / CTTE (time tagged events)
 - 2 μ s, 128 energy channels

Triggering algorithms:

- In-orbit count rate increase in 2+ NaI detectors above adjustable threshold above background
 - 10 timescales — 16ms up to 4.096s
 - 4 energy ranges — [50-300], [25-50], >100, >300 keV
- Ground-based offline search for rate increase
- Earth occultation
- Pulsar phase folding

12 NaI detectors
(8keV—1MeV)

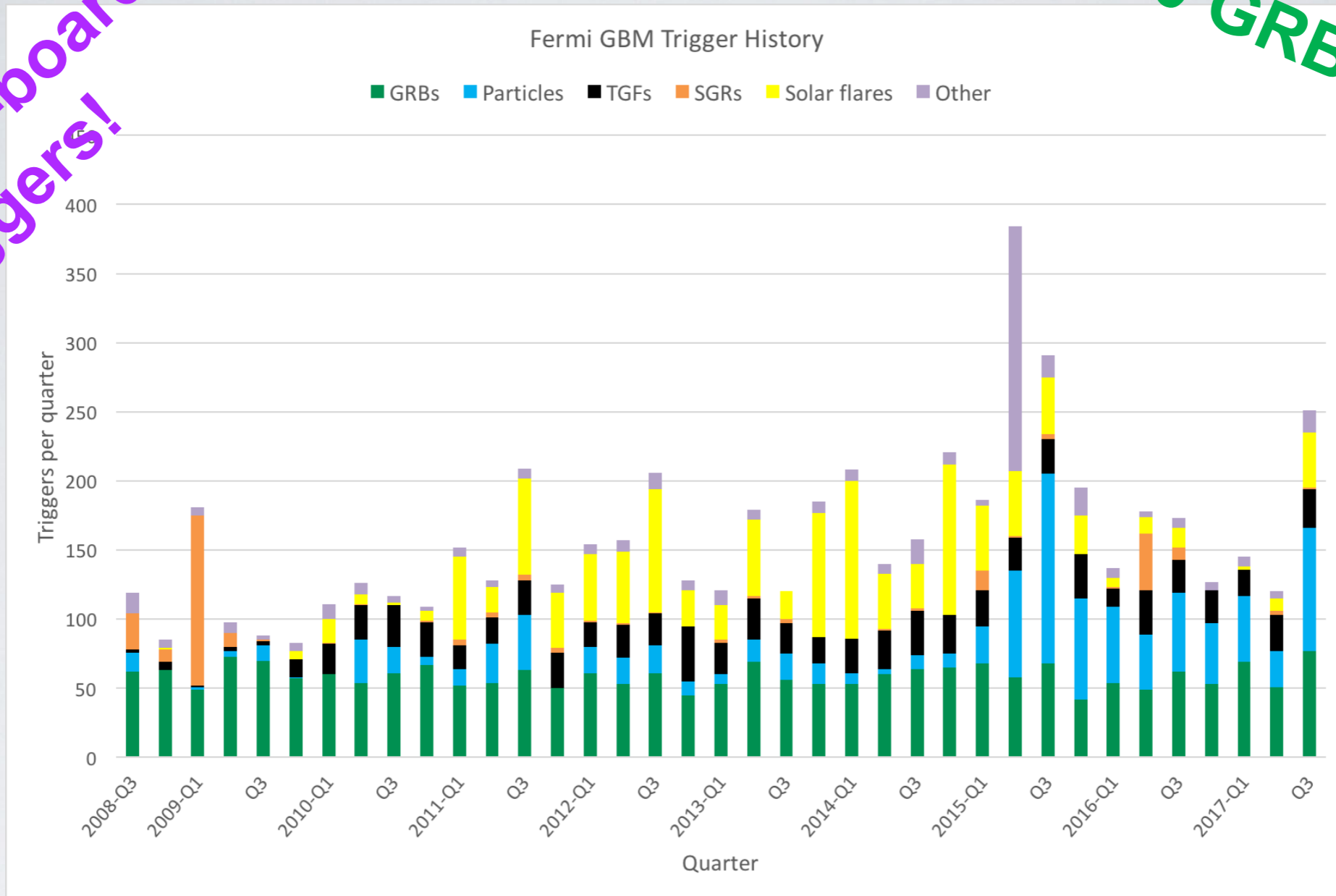
2 BGO detectors
(200keV—40MeV)



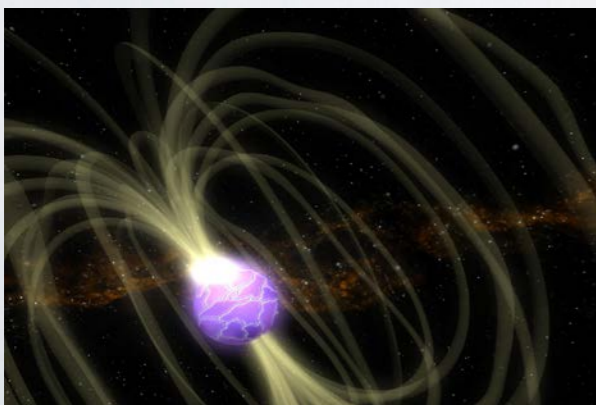
Fermi GBM Science

2180 GRB triggers!

>5900 on-board triggers!



Galactic — pulsars, magnetars



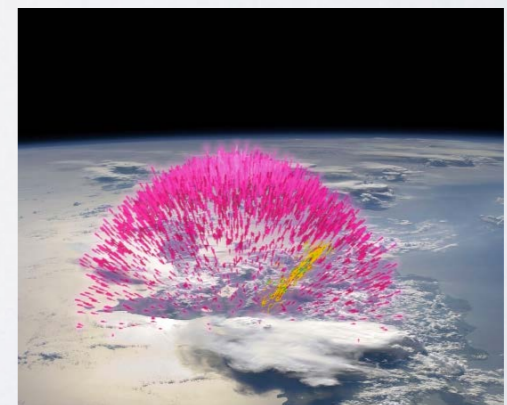
Colleen A. Wilson-HODGE

Gamma-Ray Bursts



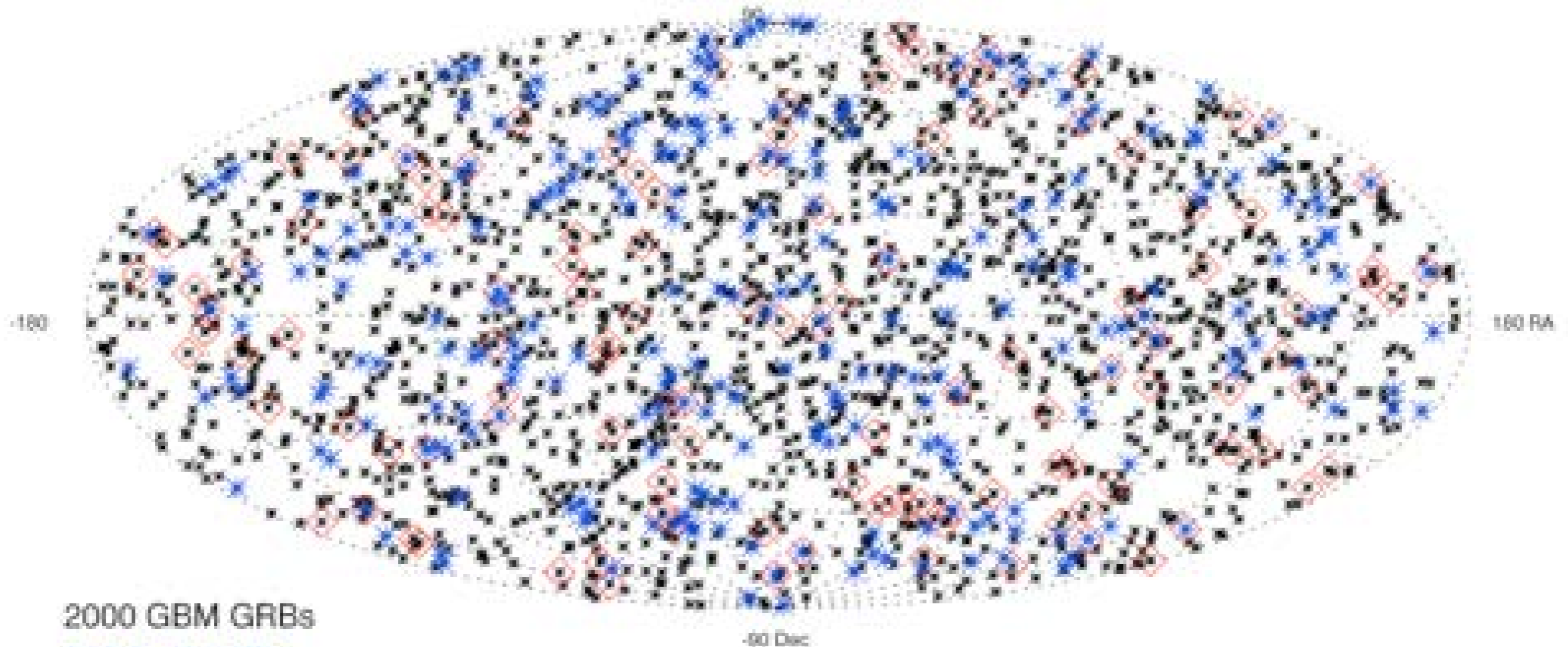
231st AAS Meeting 2018 National Harbor, MD

Terrestrial Gamma-ray Flashes



Gamma-ray Bursts

2000 Fermi GBM GRBs



2000 GBM GRBs

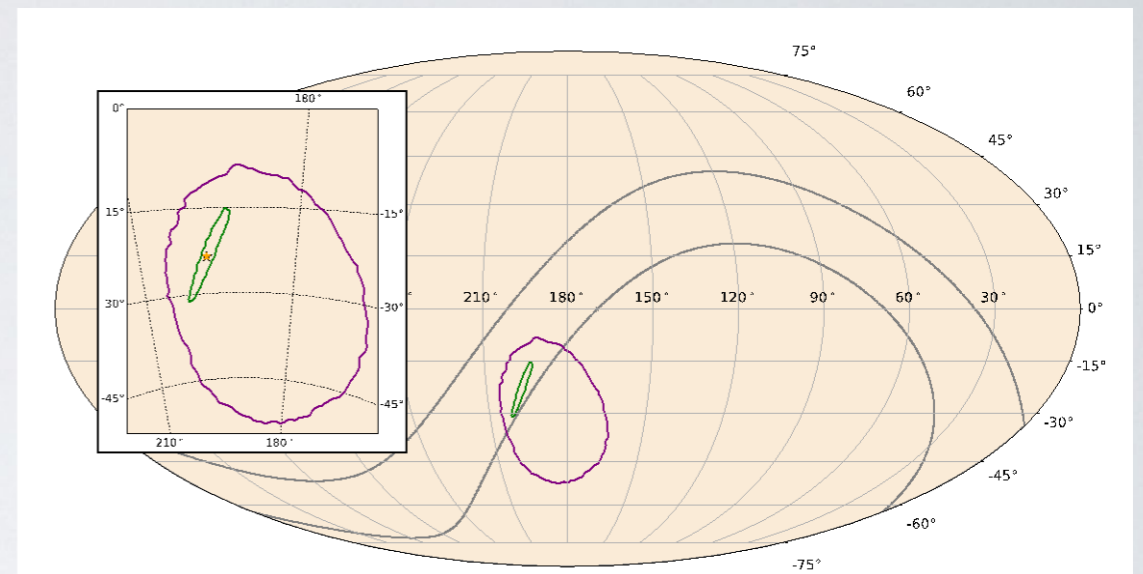
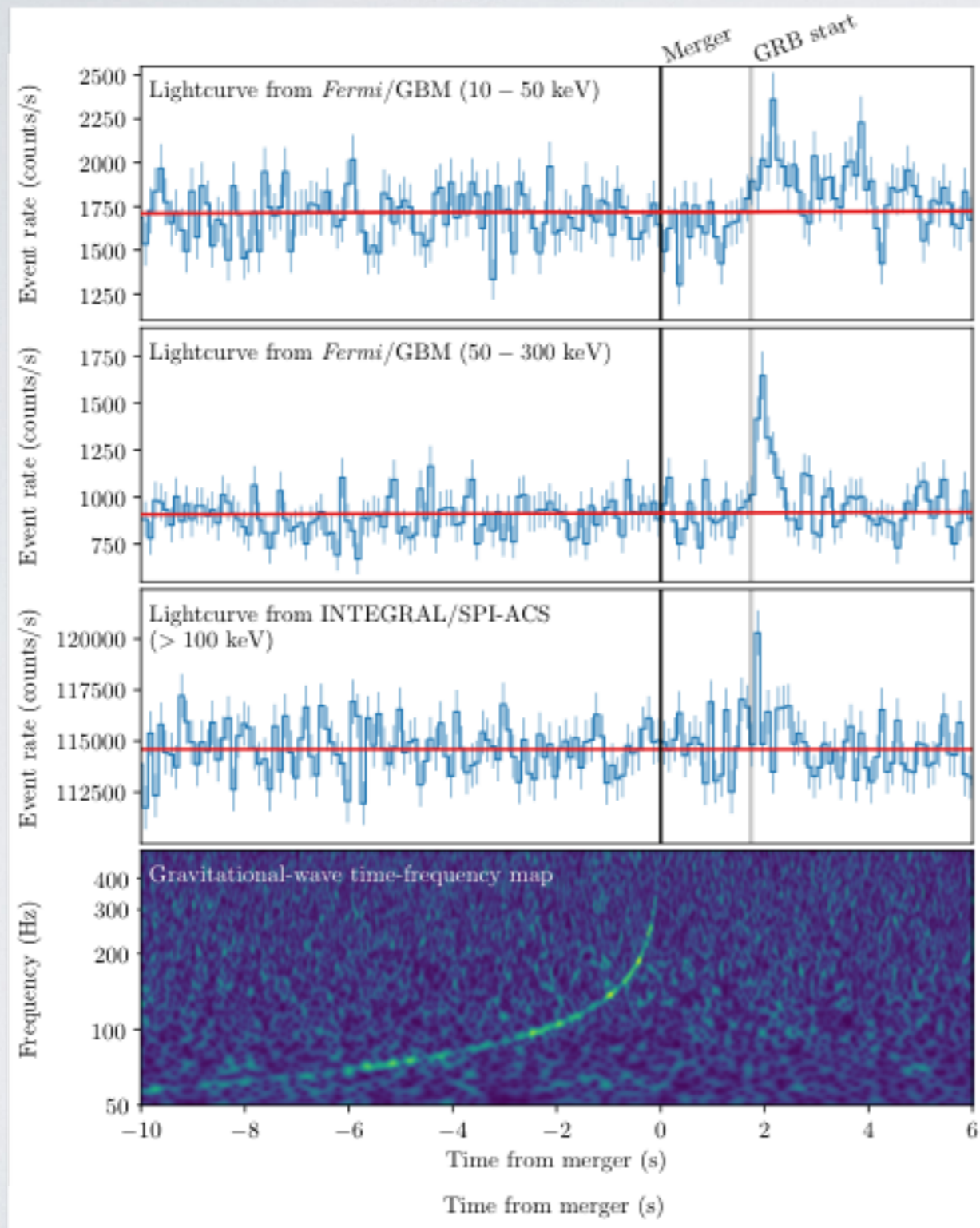
266 Swift GRBs

121 LAT GRBs

- Over 2000 GRBs have been detected since launching in 2008.
 - 200 long GRBs / year -> massive star collapse.
 - 40 short GRBs / year -> compact merger event.
 - 13% seen by Swift.
 - 52% within *Fermi* LAT FOV, 6% detected.

GRB 170817A: GBM's most famous trigger

Talk by A. Goldstein tomorrow 10:20am HEAD Special Session



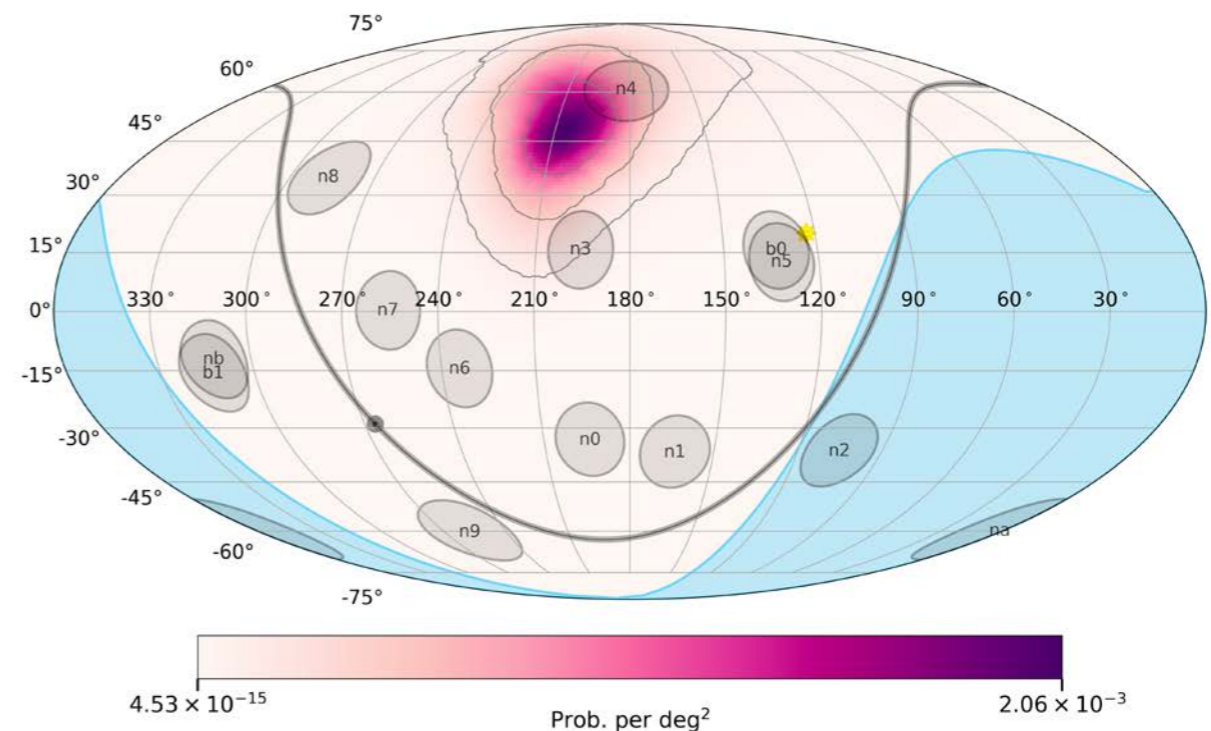
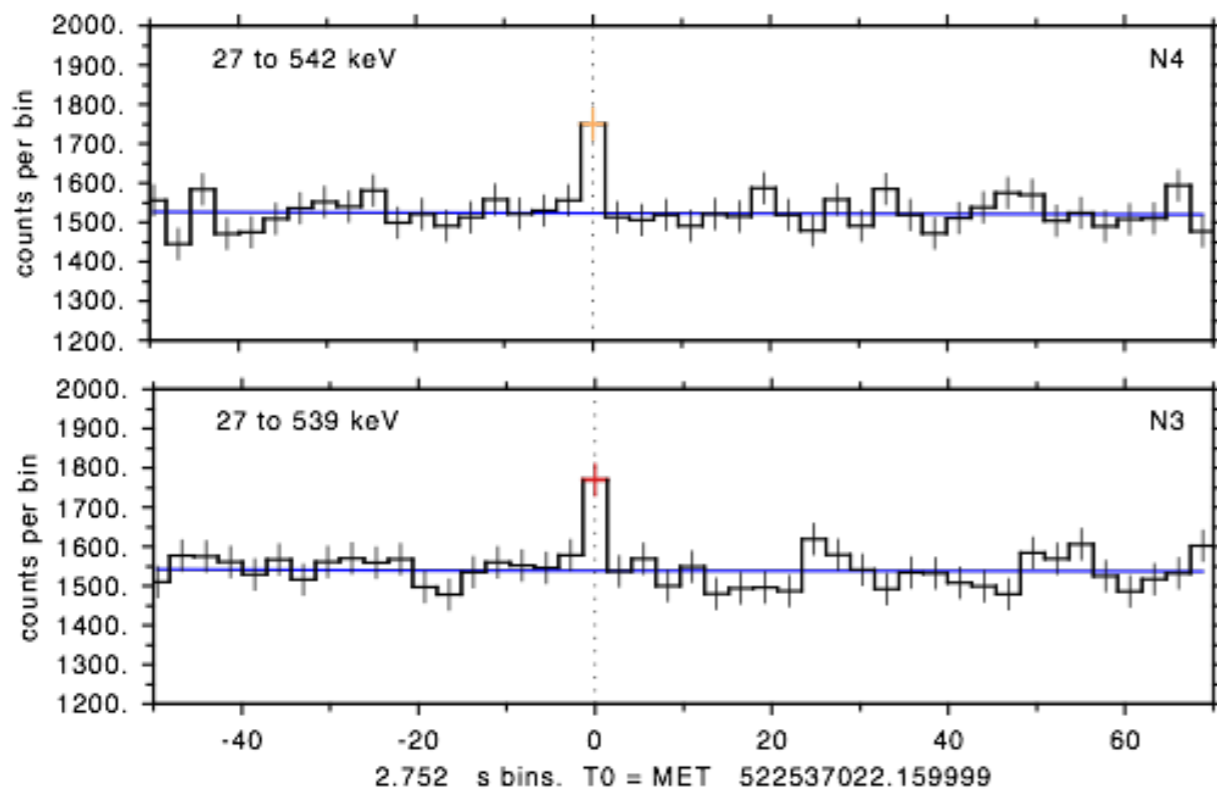
GRB 170817A/GW170817

- Reported GRB automatically 14 s after on-board GBM trigger
- Associated GRB unambiguously with GW170817: chance probability 5.0×10^{-8}
- Confirmed BNS mergers as a progenitor of short GRBs
- Measured delay of 1.74 ± 0.005 s
- Constrained speed of gravity to $-3 \times 10^{-15} < \Delta v/v_{EM} < 7 \times 10^{-16}$
- Run-of-the-mill short GRB in gamma-rays
- Weak for such a close by GRB

Goldstein et al 2017; Abbot et al. 2017

Offline GRB search

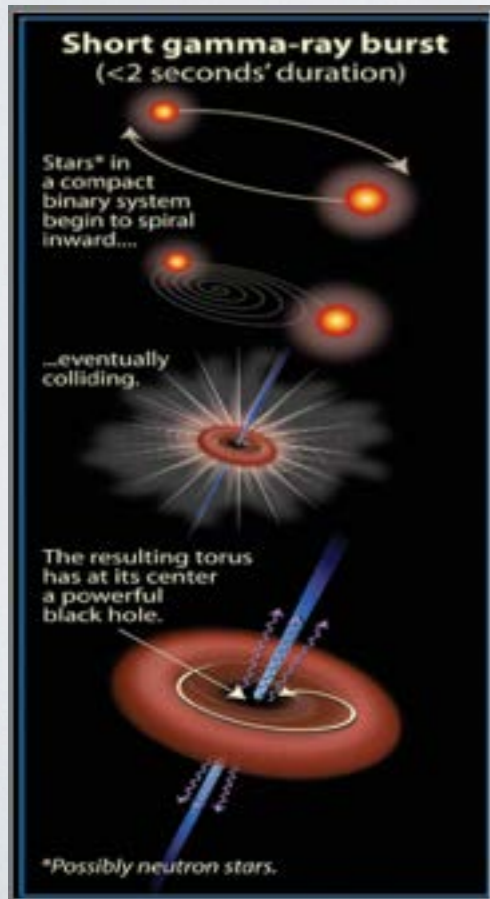
- **Untargeted** search in the Continuous Time Tagged Events (CTTE) data.
 - 18 timescales: 64ms to 32 s
 - Four energy ranges
- GCN now available, more info at https://gcn.gsfc.nasa.gov/fermi_gbm_subthreshold.html
 - Currently short timescale pipeline is released, long (2.8+s) pipeline is in progress.
 - Expected rate is ~70/month (during periods of Cyg X-1 activity, it may increase by 4x).
 - Current time delays range from 0.5 to 6 hours due to ground processing and data downlink.
 - Location uncertainties are in the range of 10 to 40 deg (68% containment radius).
- List of candidates from older data (2013 and on) are available. http://gammaray.nsstc.nasa.gov/abm/science/sarb_search.html



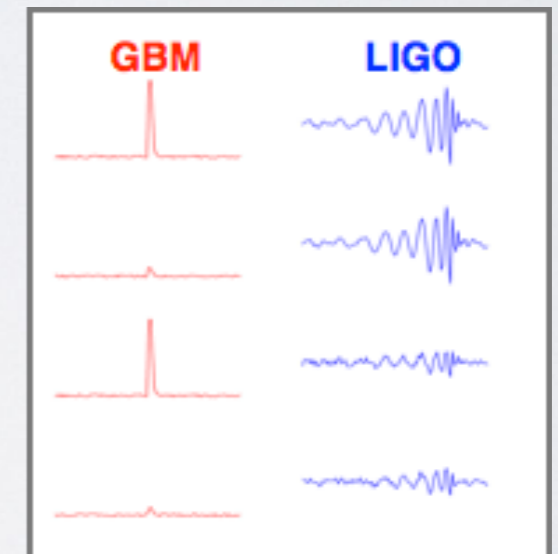
Offline GRB search



- **Targeted** search in the Continuous Time Tagged Events (CTTE) data. (Blackburn et al. 2015, Goldstein et al. arXiv:1612:02395)
 - Looks for coherent signals in all detectors given an input time and optional skymap.
 - Calculate likelihood ratio of source and background.
 - Search +/- 30 seconds of input event time.
 - Sliding timescales from 0.256s to 8s (capable down to 0.064s) with a factor of 4 phase shift.
 - 3 source spectral templates using Band function: soft, normal, and hard.



Ideal Scenario	Bright GBM	Bright LIGO
GW150914 Scenario	Sub-threshold GBM	Bright LIGO
Typical more distant short GRB	Bright GBM	Sub-threshold LIGO
Both Sources Faint	Sub-threshold GBM	Sub-threshold LIGO



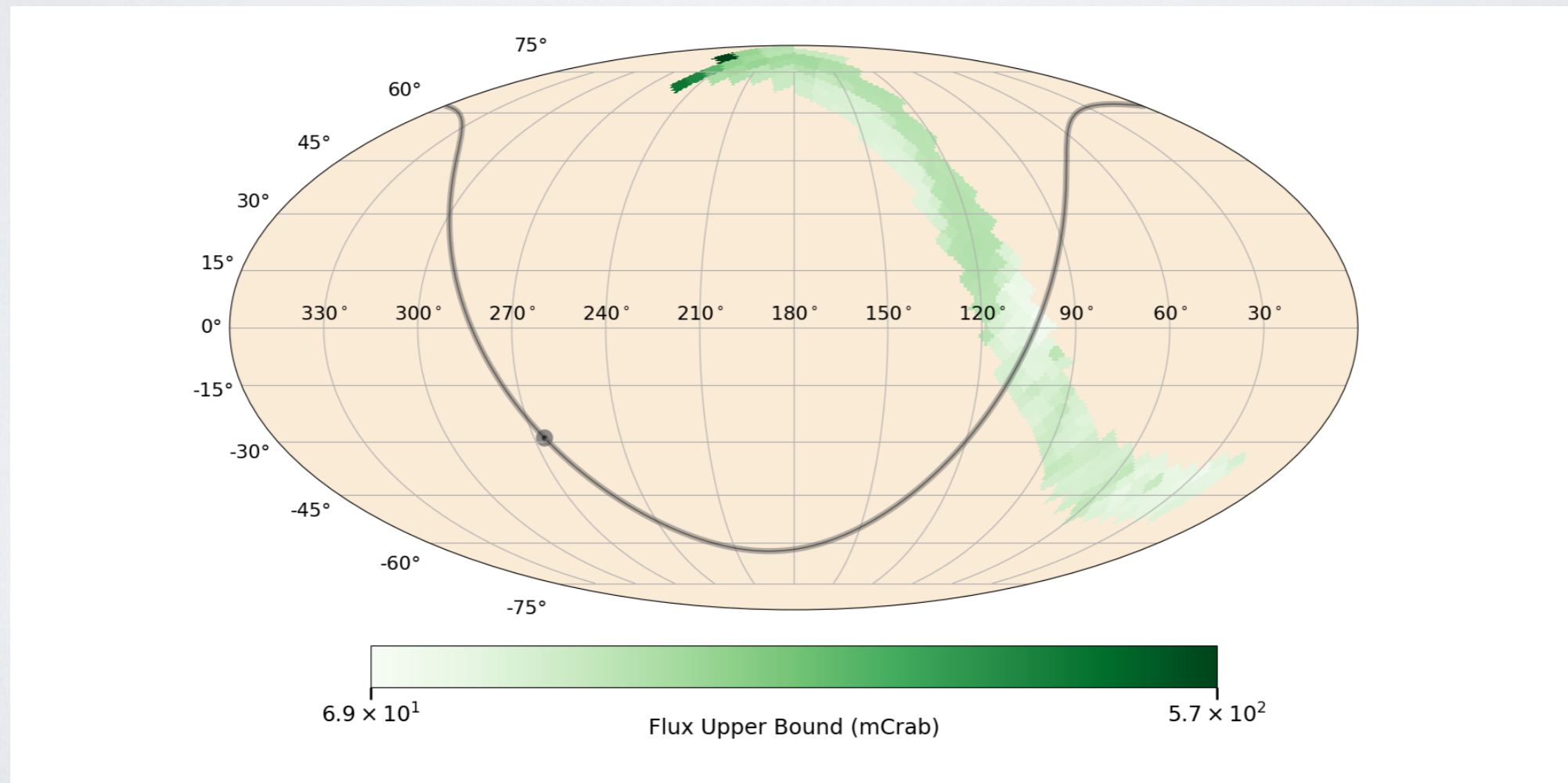
Talk by E. Burns – this session 10:50am

Monitoring by Earth Occultation technique

https://gammaray.nsstc.nasa.gov/gbm/science/earth_occ.html

- 200+ sources are monitored from X-ray binaries to Active Galactic Nuclei.
 - 102 detections, 9 at >100 keV.
- Earth occultation technique can be used to search for longer term emission from GW candidates

GW 170104 upper limits map (+/- 1 day)



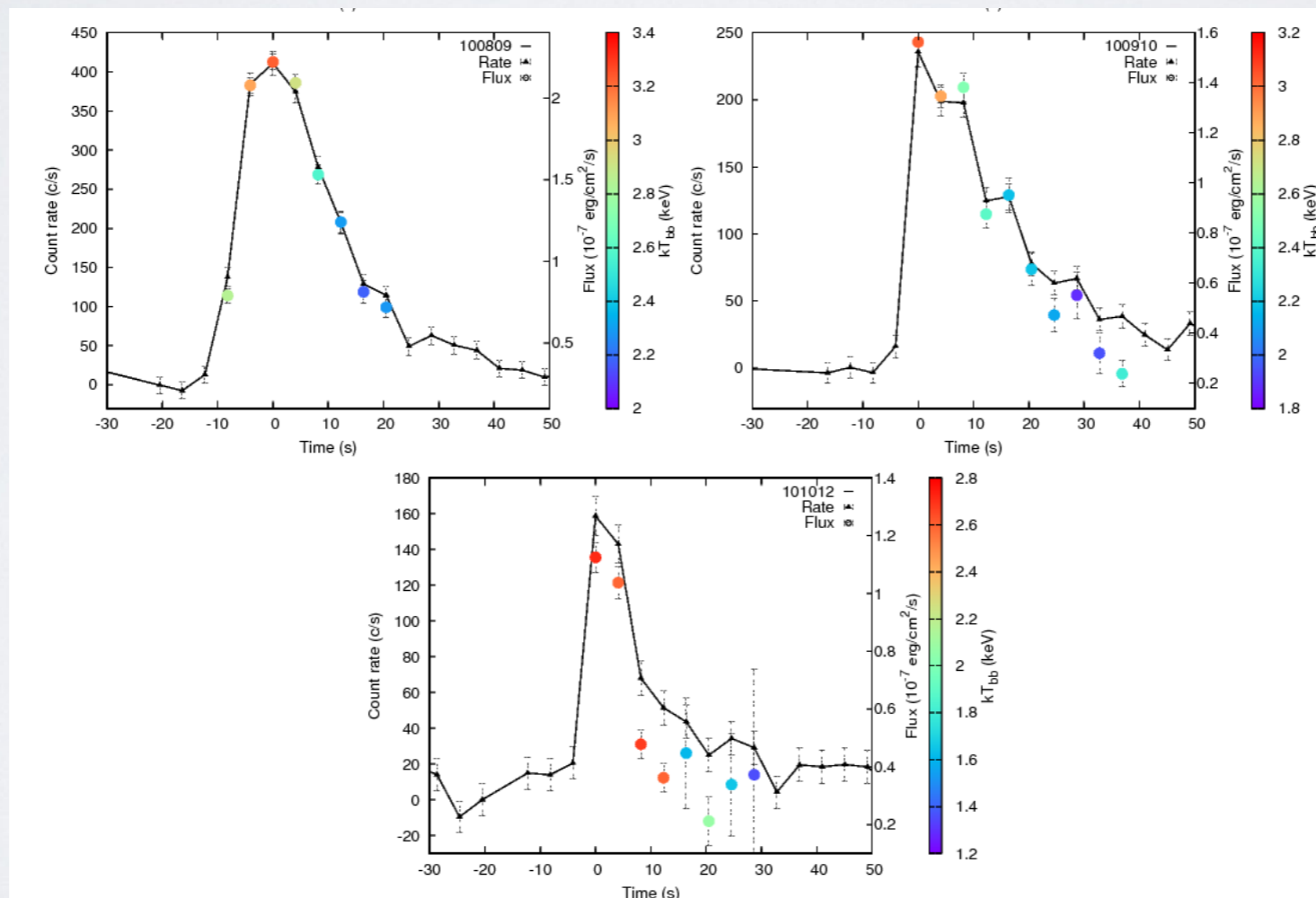
Follow-up to IceCube neutrino Events

- Utilizes all search methods:
 - On-board triggers.
 - Targeted search using event time.
 - Untargeted search within the hour.
 - Earth occultation technique.
- Good follow-up observation for IceCube-161103, upper limit published in GCN 20127.
- Other followup with limited GBM coverage: IceCube-170321A (GCN 20932).
- Also can use these techniques to search for counterparts to Fast Radio Bursts

X-ray Bursts

- 1084 Type I X-ray bursts detected between 2010 and 2013 (Jenke et al. 2013)
- GBM is particularly sensitive to photospheric expansion bursts
- Average of 1.4 bursts from all bursters <10 kpc
- Average blackbody temperature is 3.2 ± 0.3 keV
- <https://gammaray.nsstc.nasa.gov/gbm/science/xrb.html>

4U 0614+09

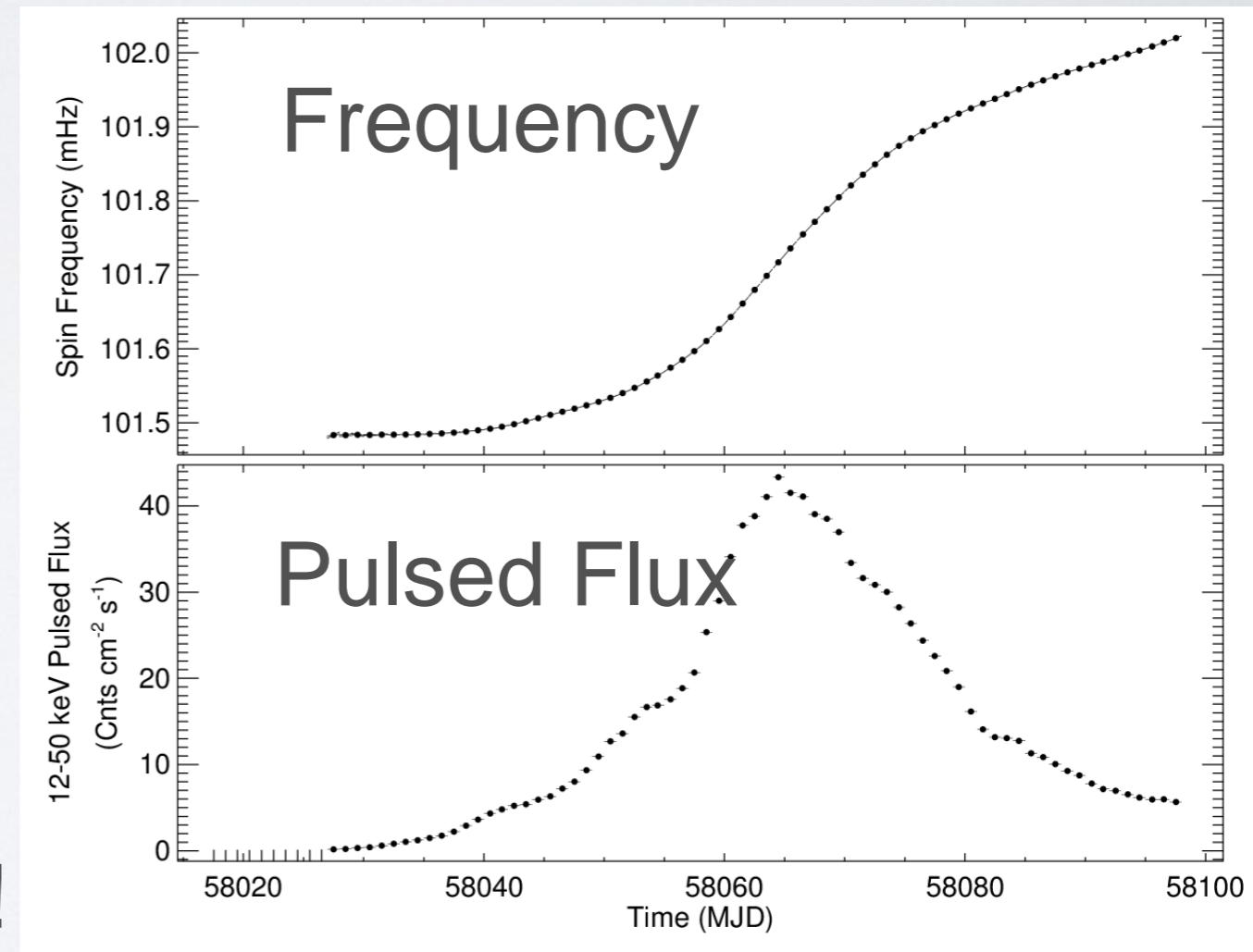
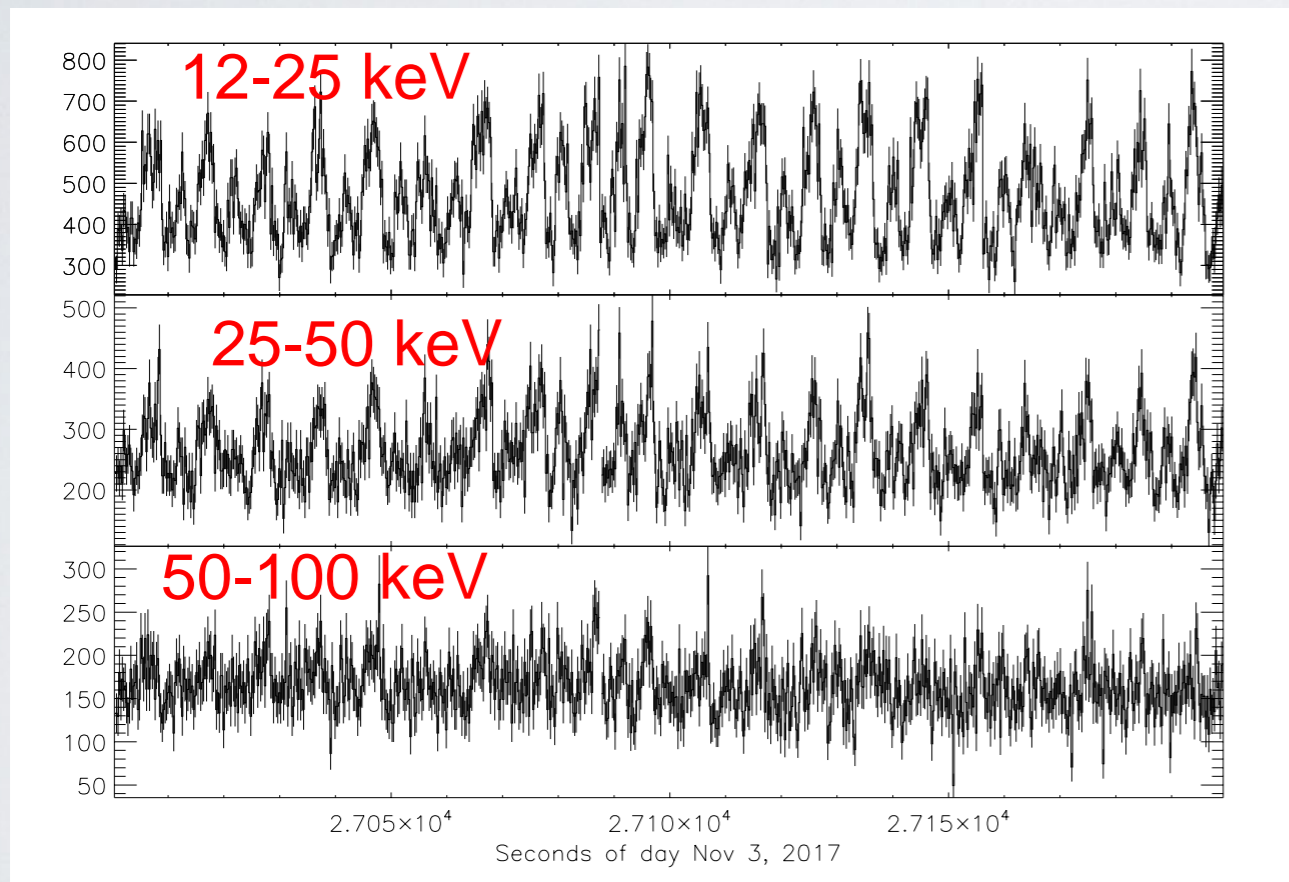


Linares et al. 2012

Accretion Powered Pulsar Monitoring

- Daily blind searches for new pulsars and new outbursts
- Epoch folded searches for 39 systems (36 detected to date)
- <https://gammaray.nsstc.nasa.gov/gbm/science/pulsars.html>

Swift J0243.6+6124: 9.8 s pulsar - brightest ever seen by GBM



189 triggers: 42 on Nov 3, 2017!

Summary

- GBM continues to be prolific in detecting GRBs and monitoring pulsars and Galactic transients.
- GCN notices of subthreshold GRB candidate events are now available.
- Continued development of offline data searches for joint detection of astrophysical transients with neutrinos and gravitational waves.