Fermi GBM Status, Results, Plans

Colleen Wilson-Hodge
GBM PI, NASA/MSFC

Fermi Users Group
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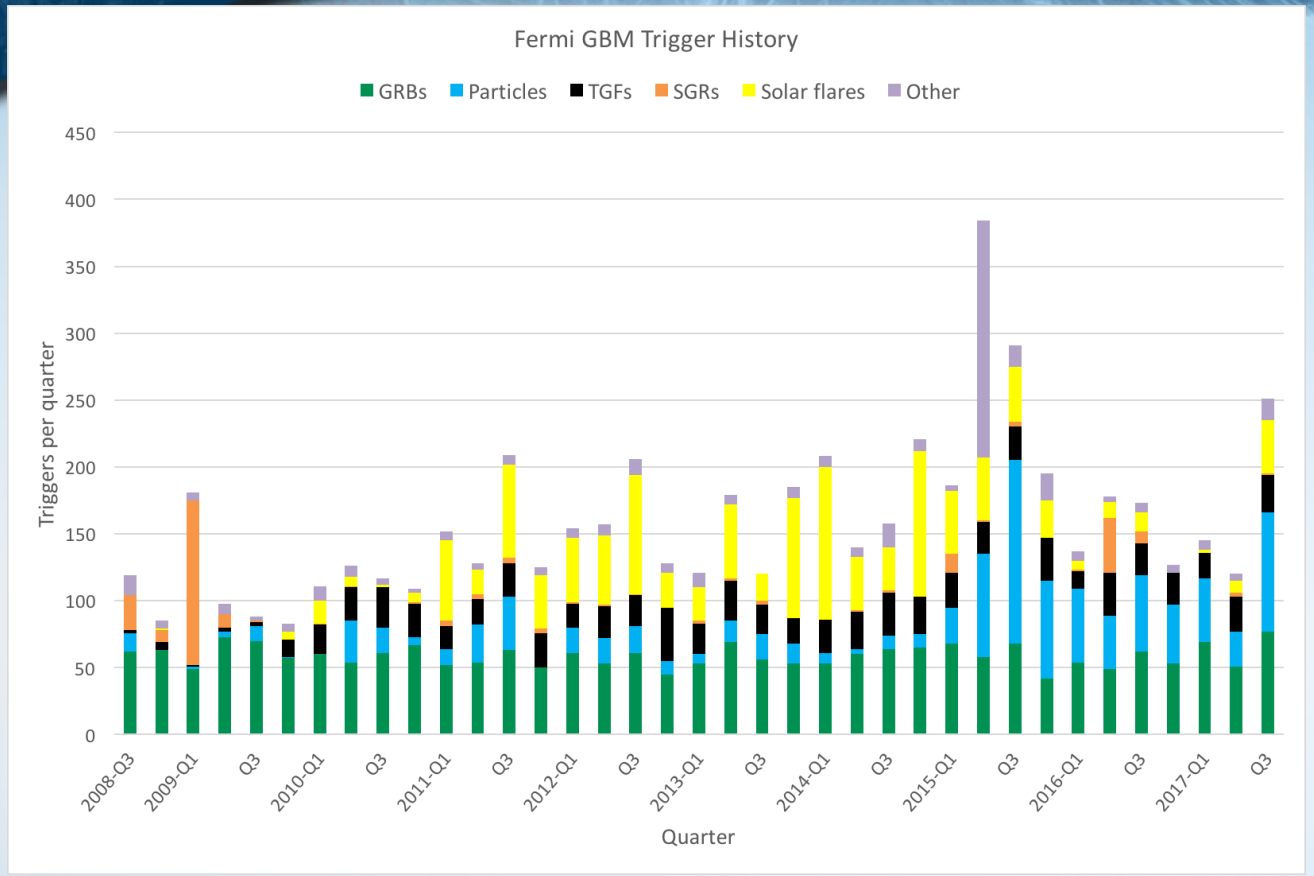
Outline

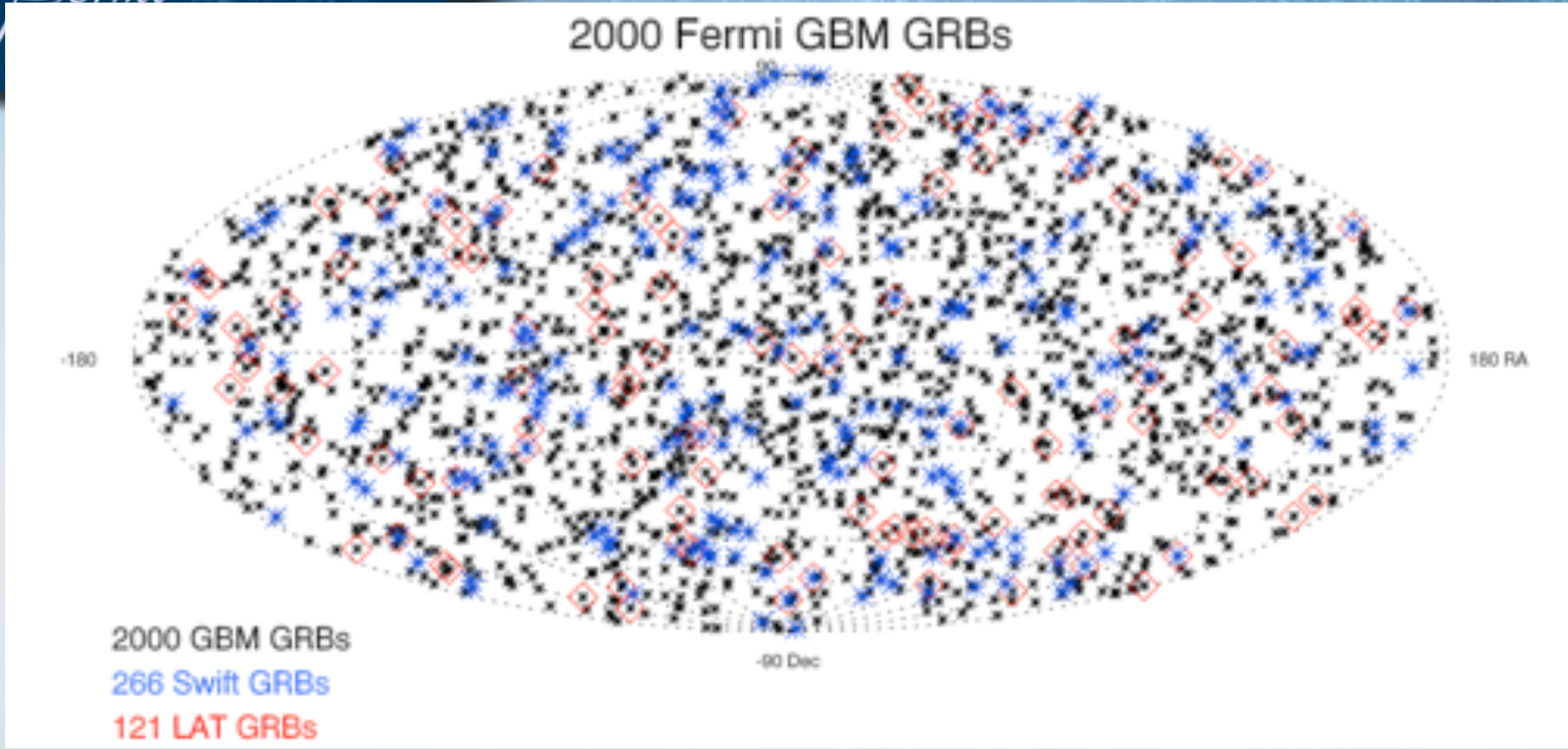
- GBM Status
- Operational changes and improvements
- Searches for gamma-ray counterparts to gravitational wave events and neutrinos
- Synergies between GBM and NICER
- New transient sources
- Summary

GBM Trigger Rate



5899 triggers as of October 3, 2017
Gamma-ray bursts (GRBs): 2180
Soft gamma repeaters (SGRs) aka magnetars: 274 (from 6 sources)
Terrestrial gamma flashes (TGFs): 802 triggered, ~5x more untriggered
Solar Flares: 1175
Particles: 1000
Others (galactic XRBs, accidental, uncertain): 468 (169 from V404 Cygni)
204 positive Autonomous Repoint Recommendations

GBM has now seen >2000 GRBs



To date GBM has triggered on 2180 GRBs since 2008.

- 200 long GRBs triggers/year → Massive star collapse
- 40 short GRB triggers/year → Compact merger event
- 13% also seen by Swift
- 6% also seen by Fermi LAT

Catalogs

2018

- GBM 8 yr GRB trigger + spectral catalogs (in prep)
- GBM 8 yr TGF catalog (Roberts et al. 2017, submitted to JGR)

- GBM 6 yr trigger catalog (3FGBM) (Bhat et al. 2016)
- GBM 5 yr magnetar catalog (Collazi et al 2015)

- GBM 4 yr time-resolved spectral catalog (Yu et al. 2016)
- GBM 4 yr GRB spectral catalog (Gruber et al. 2014)
- GBM 4 yr trigger catalog (2FGBM) (von Kienlin et. al 2014)

- GBM 3 yr X-ray burst catalog (Jenke et al. 2016)
- GBM 3 yr Earth occultation catalog (Wilson-Hodge et al. 2012)

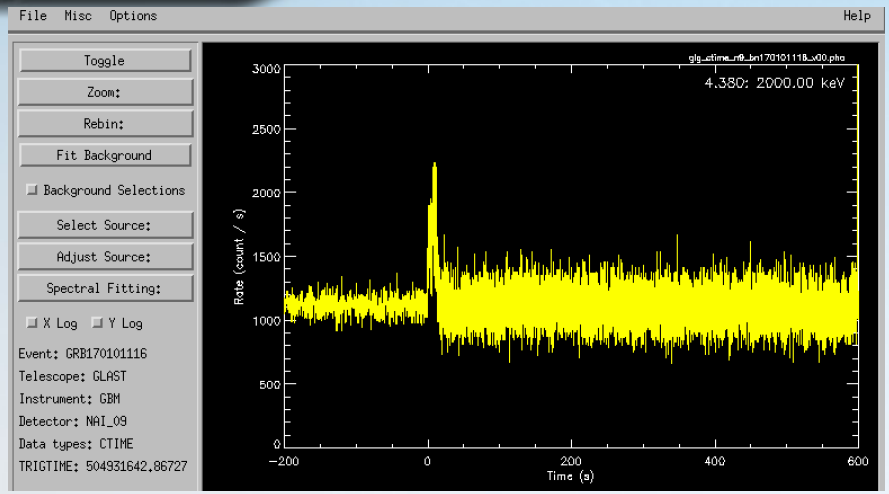
- GBM 2 yr GRB spectral catalog (Goldstein et al. 2012)
- GBM 2 yr GRB trigger catalog (Paciesas et al. 2012)

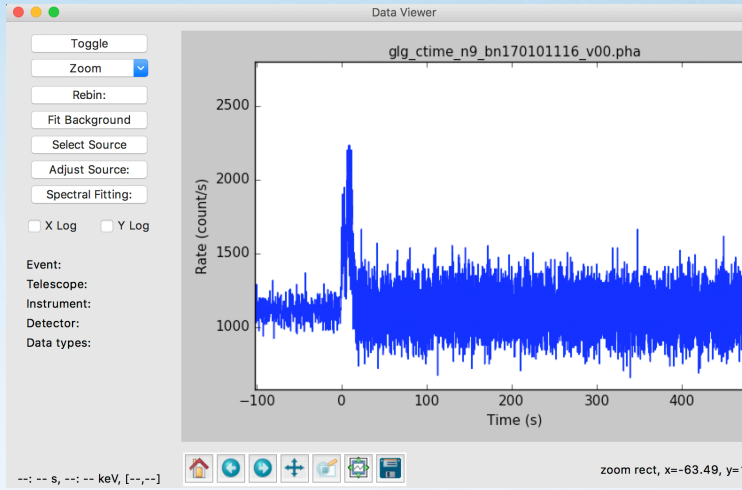
2008

Operational Changes & Improvements

- GBM response generator
  - Pre-made responses are available as always for GRB triggers
  - Allows users to generate custom responses for any location and time
  - Available through the FSSC for download and installation
  - https://fermi.gsfc.nasa.gov/ssc/data/analysis/rmfit/
  - Work is underway to replace the perl code with a more portable python version
- Hourly CTTE data files
  - Available at FSSC for current data since Sep 7, 2017.
  - Backfill data for Jul 27-Sep 6, 2017 delivered & will be available once FSSC has archived and replaced the old TTE files (all of 2017 by Jan 2018)
  - Removes timing glitches and improves latency for untriggered searches.
  - Convenient: simpler to predict which file contains an event
  - Plan to deliver all back data to Nov 2012 when CTTE was turned on.

GSPEC: A modern replacement for RMfit





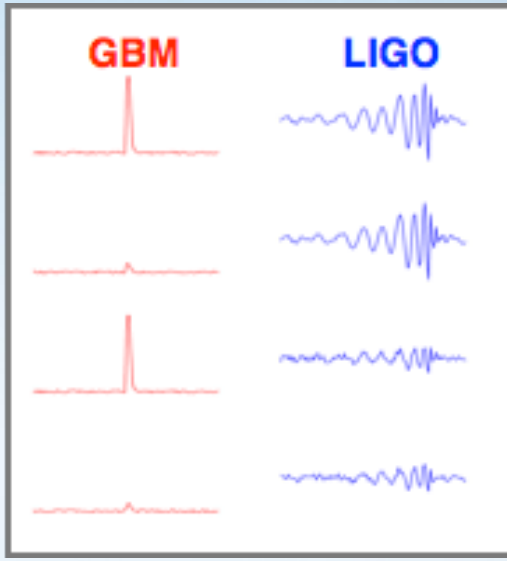
- Python based replacement for Rmfit with an interface (and backend) to XSPEC
- Enables both GUI and script based usage
- Allows users to fit background and make selections interactively
- Enables efficient time-resolved spectral fitting using GBM data with XSPEC
- Allows for scripted catalog reanalysis
- Expected availability in early 2018!

Searching GBM data for LIGO/Virgo EM counterparts

- Under an MOU with the LIGO/Virgo consortium, GBM has implemented searches of GBM data for short GRB as counterparts of candidate gravitational wave (GW) events
  - A Targeted search (Blackburn et al 2015, ApJS, 217,8; Goldstein et al 2016, arXiv:1612.02395) of GBM CTIME (O1) and CTTE (O2) data, respectively, for prompt emission
  - An untargeted search of CTTE data for sub-threshold short GRBs (provides candidates used to search LIGO data)
  - A search for persistent emission using the Earth Occultation technique with CTIME data
- These techniques are also used to follow-up neutrino events and Fast Radio Bursts.

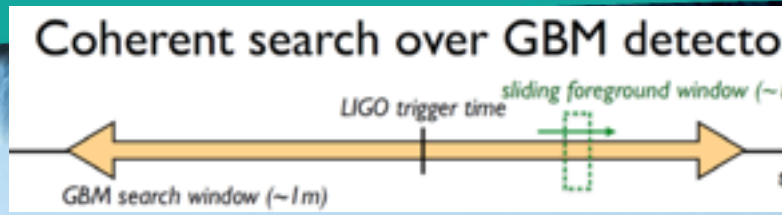
Need for sub-threshold searches

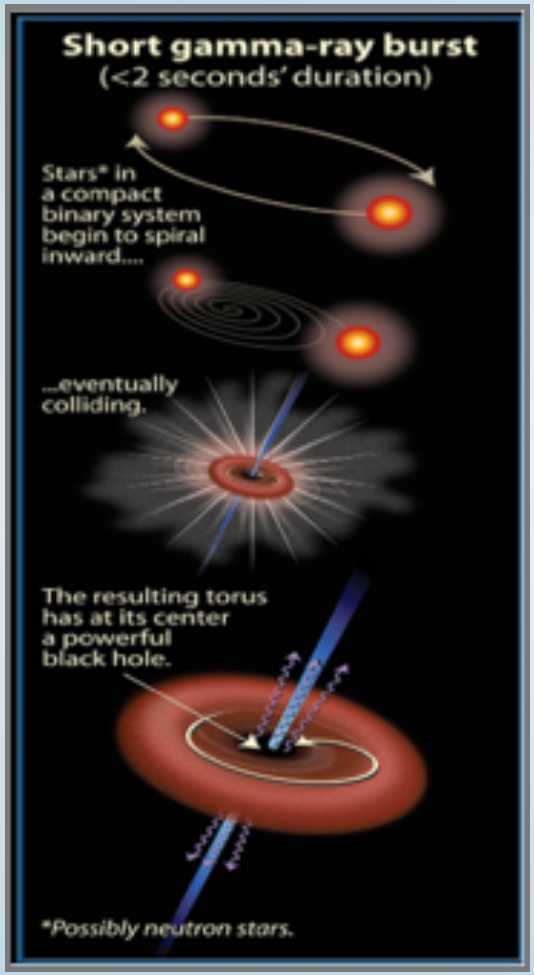
Ideal Scenario	Bright GBM	Bright LIGO
GW150914 Scenario	Sub-threshold GBM	Bright LIGO
Typical more distant short GRB	Bright GBM	Sub-threshold LIGO
Both Sources Faint	Sub-threshold GBM	Sub-threshold LIGO



Coincident signals in GBM and LIGO/Virgo increase the confidence in a detection

Targeted Search





- Looks for coherent signals in all detectors given an input time and optional skymap.
- Calculates likelihood ratio of source and background.
- Searches +/- 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 and/or comptonized function: soft, normal, and hard.
- Uses CTTE data (Blackburn et al 2015; Goldstein et al 2016, arXiv:1612:02395)

GBM Targeted Search

sliding foreground window (~1s)

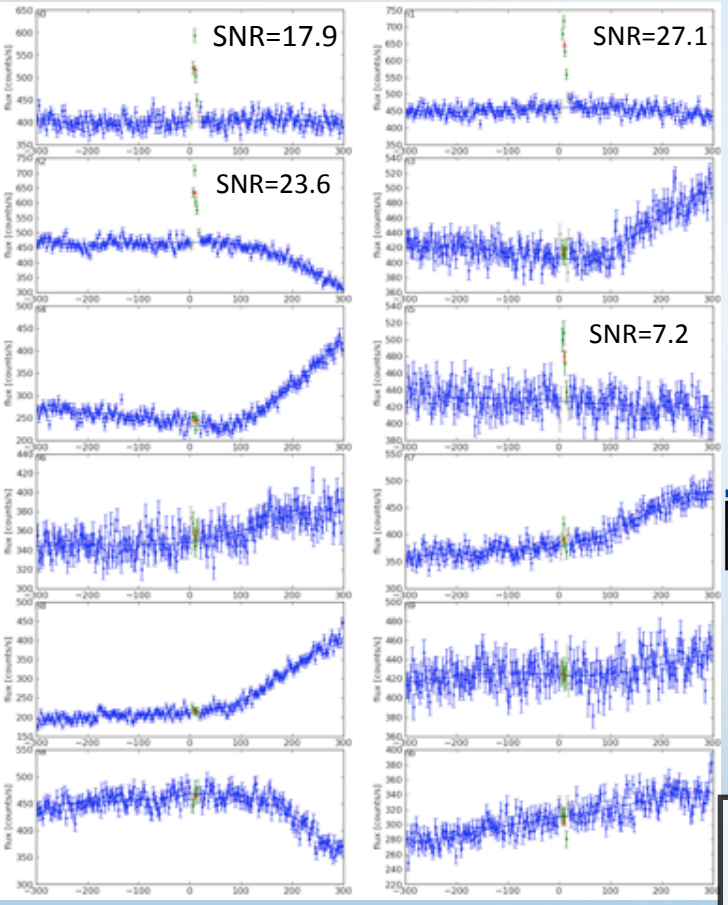
LIGO trigger time

time

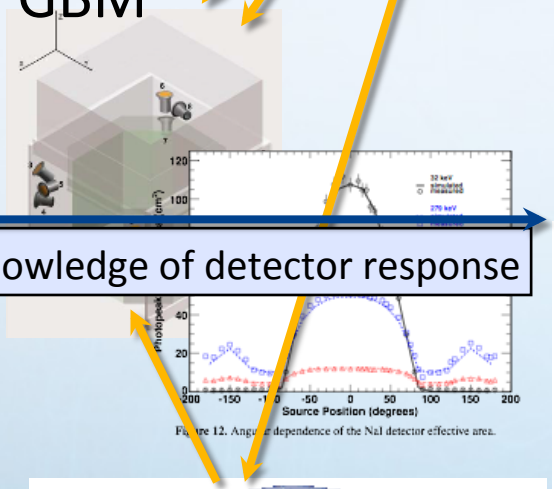
GBM search window (~1m)

sGRB

Individual GBM detector data

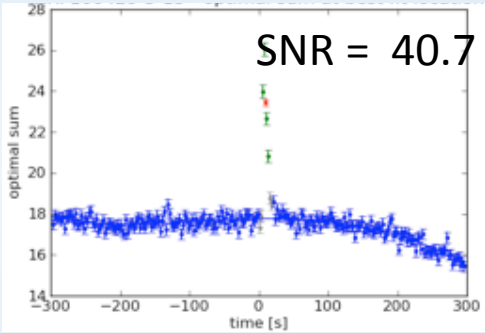


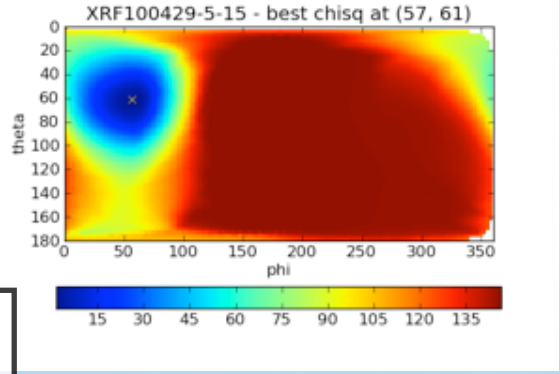
GBM



knowledge of detector response

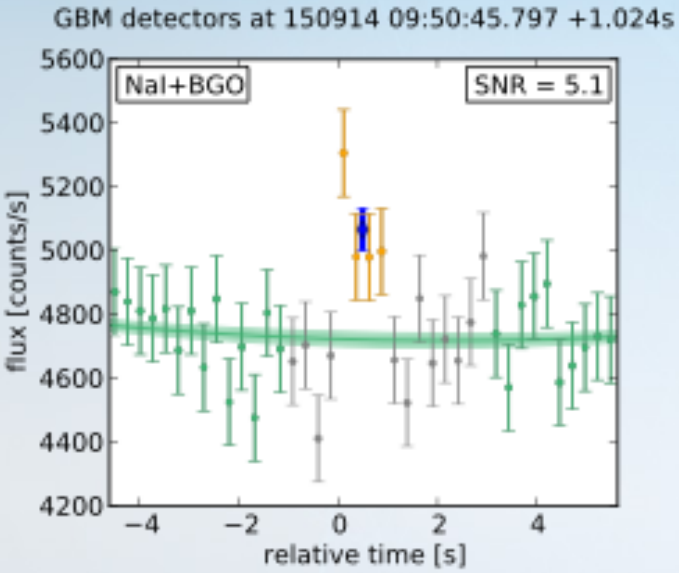
Likelihood-ratio characterizes event as originating from model vs noise alone

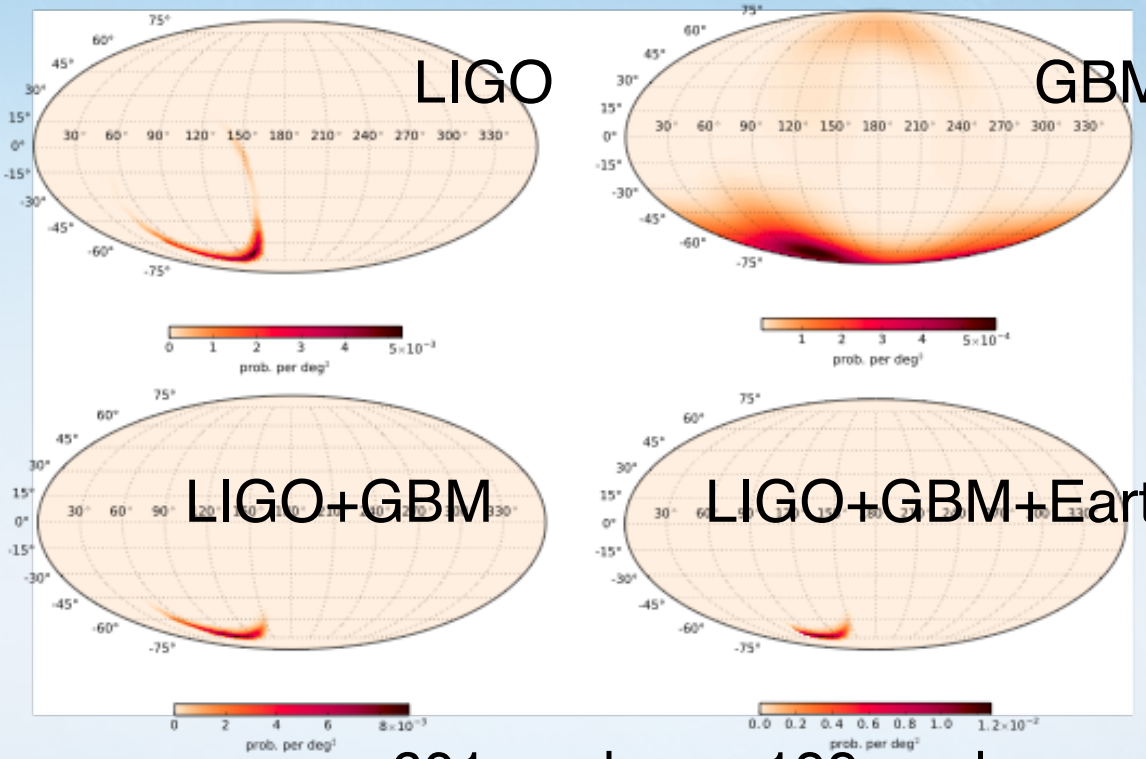




predicted counts depend on:
amplitude, light-curve, spectrum, source position, Earth position

GW150914-GBM





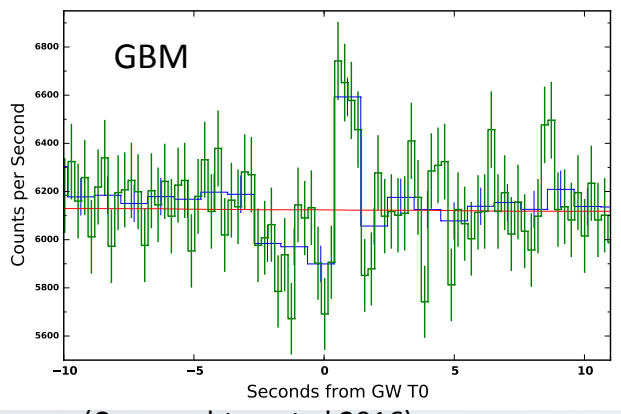
601 sq deg ➡ 199 sq deg

- Targeted search found a signal 0.4 s after GW150914
- Consistent with low-fluence short GRB coming from behind Fermi
- Poorly localized but consistent with LIGO localization
- 0.2% post trials probabilty in statistical fluctuation
- GW150914 was a BH-BH merger, so no EM counterpart was expected

Connaughton et al 2016

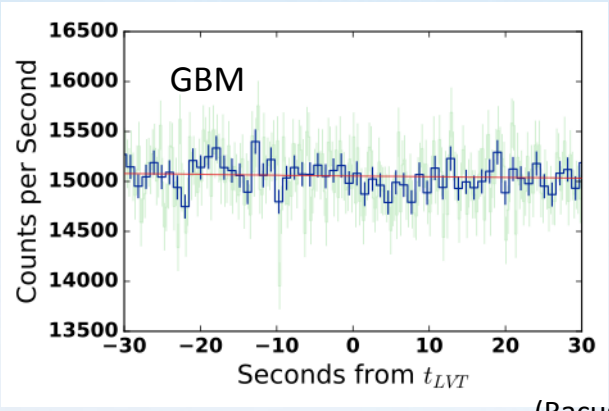
GBM Observations of GW Events

GW150914
(Abbot et al. 2016a)
- BH+BH Merger
- 36 and 29 M_{sun}
- 410 Mpc

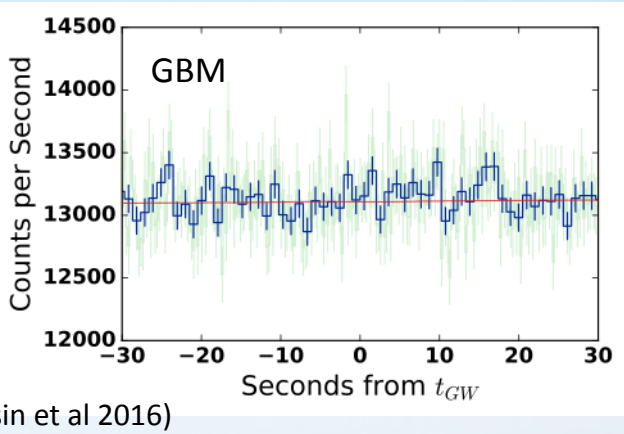


(Connaughton et al 2016)

LVT151012
(Abbott et al 2016a)
- Candidate BH+BH
- 23 and 13 M_{sun}
- 1100 Mpc



GW151226
(Abbott et al. 2016b)
- BH+BH Merger
- 14 and 7.5 M_{sun}
- 440 Mpc



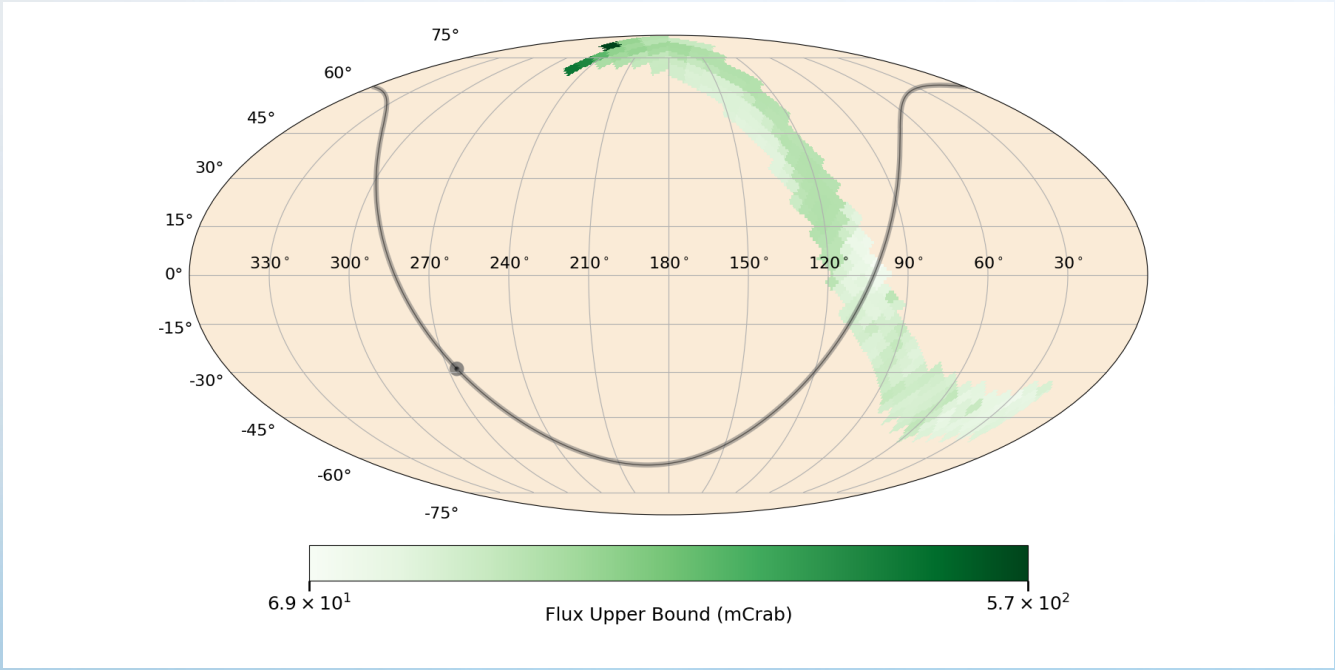
(Racusin et al 2016)

- GW150914-GBM, a 2.9σ event consistent with a short GRB
  - Not predicted by theoretical models
- No gamma-ray detections for LVT151012 or GW151226 – not constraining
  - 32% and 17% of LIGO localization region blocked by Earth for GBM
  - Backgrounds were 18% and 3% higher in GBM
  - Distance for LVT151012 was 3x larger
  - If gamma-ray emission is in a jet, only 15-30% would be pointed toward Earth
- Need more events before we can say more!

GW follow-up with Earth Occultation Technique

- https://gammaray.nsstc.nasa.gov/gbm/science/earth_occ.html
- 200+ known sources are routinely monitored
- Sky positions mapping out LIGO region are monitored fo +/- 1-day for GW events to search for longer term emission

GW170104 Upper limits map



Untargeted Search

- Searches CTTE data for sub-threshold events
- Similar to FSW – looks for simultaneous excesses in 2 or more NaI detectors
- Better background model, more timescales, more phase steps, more energy ranges than FSW
- Run autonomously and candidates released automatically within minutes of data receipt
- Candidates automatically classified (duration & reliability)
- Per month low: 70, medium 6, and high 2.5
- Localizaton uncertainites are typically 10-40 deg (68% containment)

Untargeted Search (2)

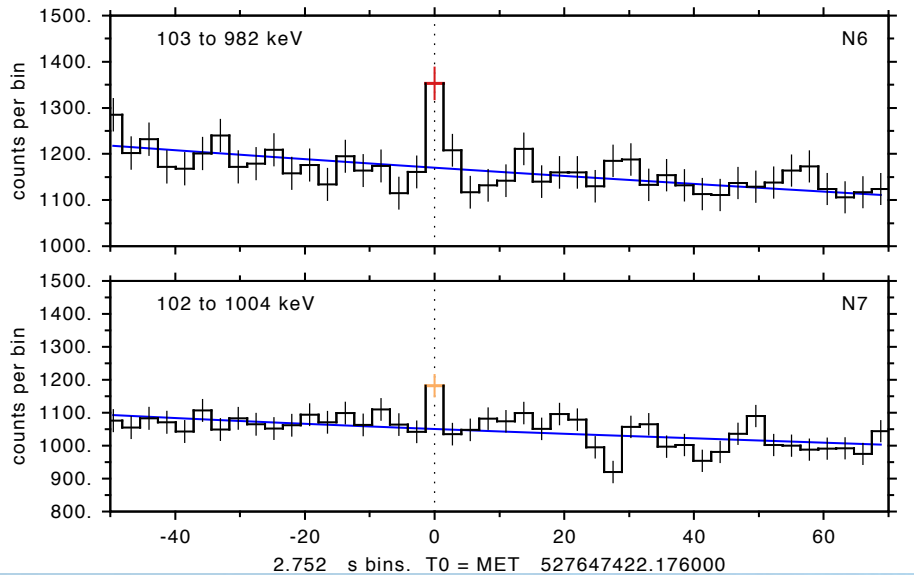
- Older candidates on GBM website

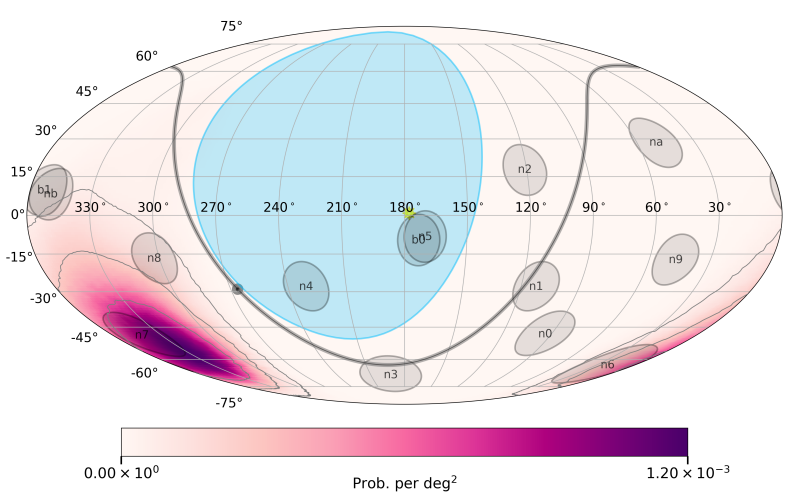
https://gammaray.nsstc.nasa.gov/gbm/science/sgrb_search.html

- Short candidates reported through GCN since 17 Jul 2017 https://gcn.gsfc.nasa.gov/admin/fermi_gbm_subthreshold_announce.txt
- https://gcn.gsfc.nasa.gov/fermi_gbm_subthresh_archive.html
- Provides input to searches of LIGO/Virgo data for coincident events

Untargeted Search (3)

- A small fraction are confirmed by other instruments: Swift/BAT, INTEGRAL/ACS, MAXI and recently Insight-HXMT
  - GCN Circular 21919 on GRB 170921A from Insight-HXMT team member S. Xiong confirmed GBM sub-threshold candidate





Ice Cube Neutrino Follow-up

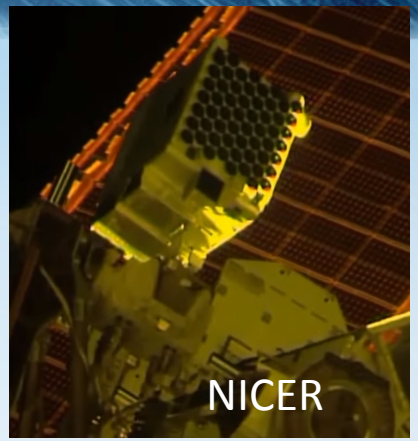
- Uses all search methods:
  - On-board triggers.
  - Targeted search using event time.
  - Untargeted search within the hour.
  - Earth occultation technique.
- Good follow-up observation for IceCube-161103, upper limit published in GCN 20127.
- Other followup with limited GBM coverage: IceCube-170321A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

Future Plans for GW Followup Effort

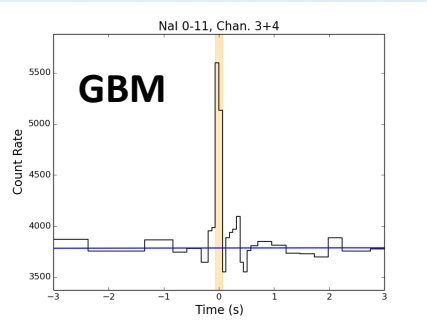
- We expect many more GW triggers in O3
- Improve targeted search in coincidence with triggers, produce joint localization maps in real time (with trigger data)
- Have targeted search run automatically and have burst advocate duty to review the results
- Improve untargeted search to allow weaker signals common to more than two detectors

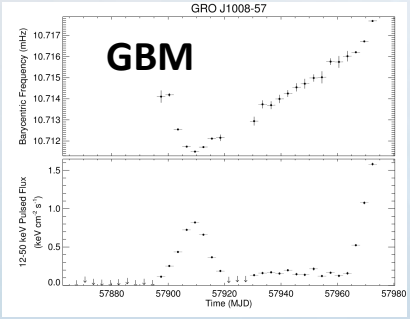
Fermi GBM Synergy with NICER

- The Neutron star Interior Composition Explorer (NICER) launched in June 2017 and began science operations in July 2017.
- Fermi GBM has contributed to three of NICER's early Target of Opportunity (ToO) observations.

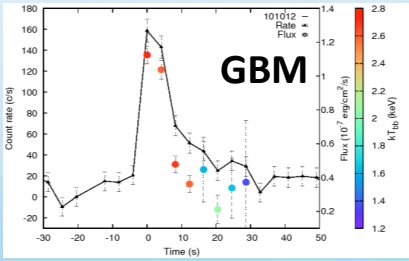


- On July 13, 2017, GBM triggered on a 0.1-second burst from 4U0142+61 (Hamburg et al. 2017), the first seen since 2015.
- 4U0142+61 has a magnetic field 10^{15} times Earth's.
- This GBM observation resulted in NICER's first ToO observation.



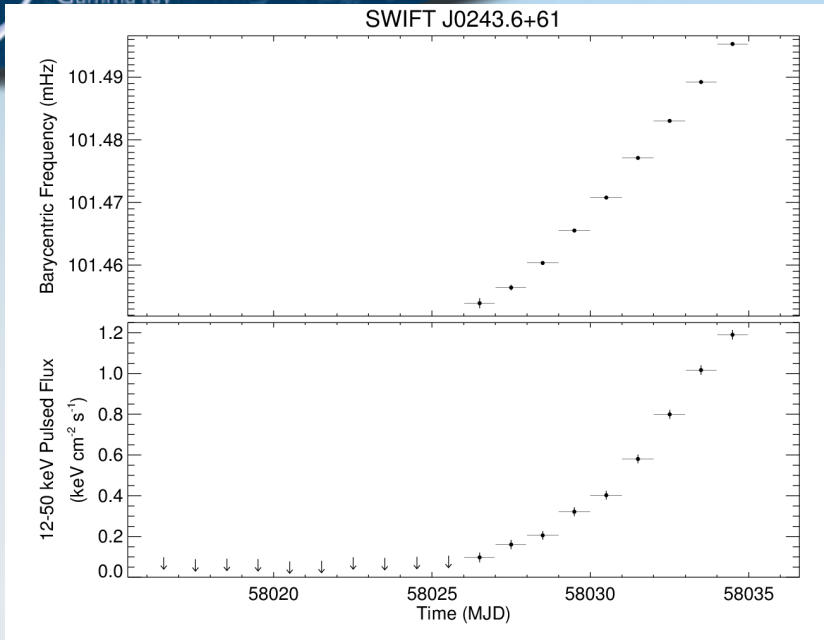


- GRO J1008-57 is an accreting pulsar with a 93.5 s period
- It is undergoing a rare giant outburst where it emits X-rays throughout its orbit rather than just near its closest approach to its companion. NICER has triggered a ToO observation to study the low-energy behavior during this outburst.



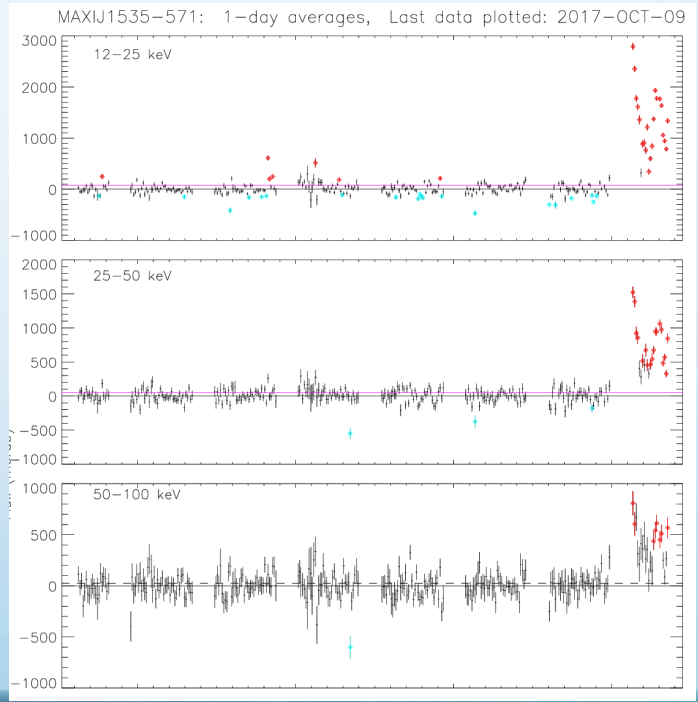
- Swift J181723.1-164300 is a newly discovered X-ray burster.
- Swift saw two X-ray bursts from this object and GBM has seen 6 so far.
- NICER is performing a ToO of this source to look for burst oscillations.

New Galactic Transients with GBM



SWIFT J0243.6+61

- Discovered with Swift (Kennea et al. 2017)
- 9.86 s Pulsations reported from Swift and GBM (Kennea et al 2017; Jenke et al 2017)
- Be star companion (Kouroubatzakis et al 2017)
- Shows rapid spin-up and strongly increasing pulsed flux in GBM data
- Detected in pulsar monitoring and Earth occultation data
- Also observed with NICER



MAXI J1535-571

- Discovered with MAXI in September (Negoro et al 2017)
- Likely new LMXB/BH
- Low frequency QPO detected with Swift XRT (Mereminskiy et al 2017) and NICER (Gendreau et al 2017)

GBM Summary

- GBM is operating well and continues to observe many exciting transient events
- Work is underway on a modernized replacement to RMFIT
- Continued improvements are underway for Targeted and Untargeted searches for LIGO/ Virgo O3 and neutrino searches
- GBM is finding new synergies with newly launched instruments