Fermi Gamma-ray Burst Monitor (GBM)
and
Inter-Planetary Network (IPN)
Data Pipelines

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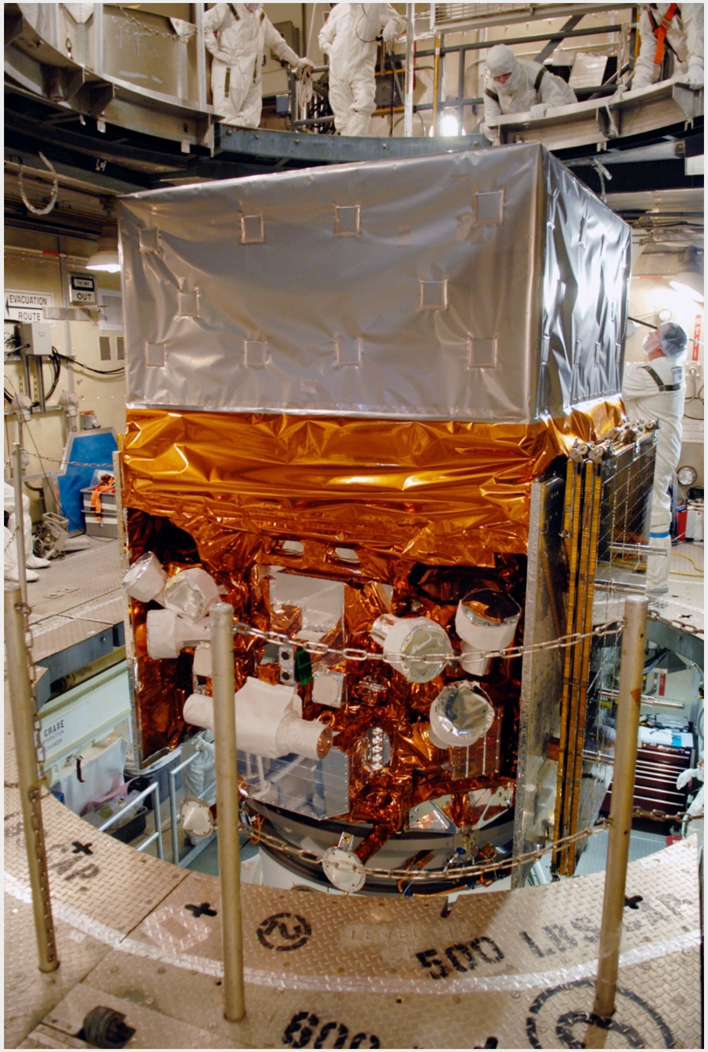


Neither Fermi nor GBM are small!

GBM has many Data Pipelines

Real time / trigger data

GBM/Fermi opens TDRS Demand Access channel within ~10 seconds. Transmitted at ~1 kbit s^{-1} over 10 minutes.

Generated on-board: TRIGDAT:
trigger information, detector rate data, Max Rates, background, localization and classification, supporting information.

Detector rate data has various resolutions and time ranges to provide GRB light curves and allow creation of background models:

resolution	Time range (s) relative to trigger time
64 ms	-1/4 to +½
256 ms	-1 to +2
1 s	-3 to +61
8 s	-131 to -8 & 57 to 478

Pipeline 1: Real Time Data:
Automatic output of GCN Notices.

Complicated system for reliability ... two computers at different locations listen for the TRIGDAT packets.

One is Primary, one Secondary.   Both receive the telemetry.

Normally the Primary sends the GCN Notices. Should the Secondary lose contact with the Primary, it will send GCN Notices.

Pipeline 2: Real Time Data: RoboBA
Automatic processing of Trigger data

Runs after end of the TRIGDAT (~10 minutes after trigger)

Identifies optimum signal and background intervals from the TRIGDAT detector rate data, then runs localization software: outputs localization and skymap via GCN Notice.

Pipeline 3: Real Time Data:
Rapid Human (Burst Advocate) Evaluation of Triggers

Evaluation of important triggers: bright or observed by other instruments:
Generate GCN Circulars with temporal and spectral parameters.
Improved localization performed by human.

Correct classification of non-GRBs that were incorrectly classified as GRBs with GCN Circulars.

Science Data

Large volume data (~8 GB per day) / Many datatypes
Scheduled high-bandwidth downlink via TDRS.
A few downlinks per day – latency of hours.

Primarily the continuous data. Also trigger science data.

CTIME: 8 energy channels / 0.256 s (trigger: 0.064 s)
CSPEC: 128 energy channels / 8.192 s (trigger: 1.024 s)

CTTE (since late 2012): individual counts:
128 energy channels, 2 μs resolution, several μs accuracy.
(originally only 330 s of TTE per trigger)

Spacecraft Position History

Pipeline 4: Conversion of Science Data

Automatically from raw data to FITS files for scientific use: calibrations, merging of data, etc.

Also higher level products: Detector Response Matrices for GRB triggers

Delivered to Fermi Science Support Center (FSSC)

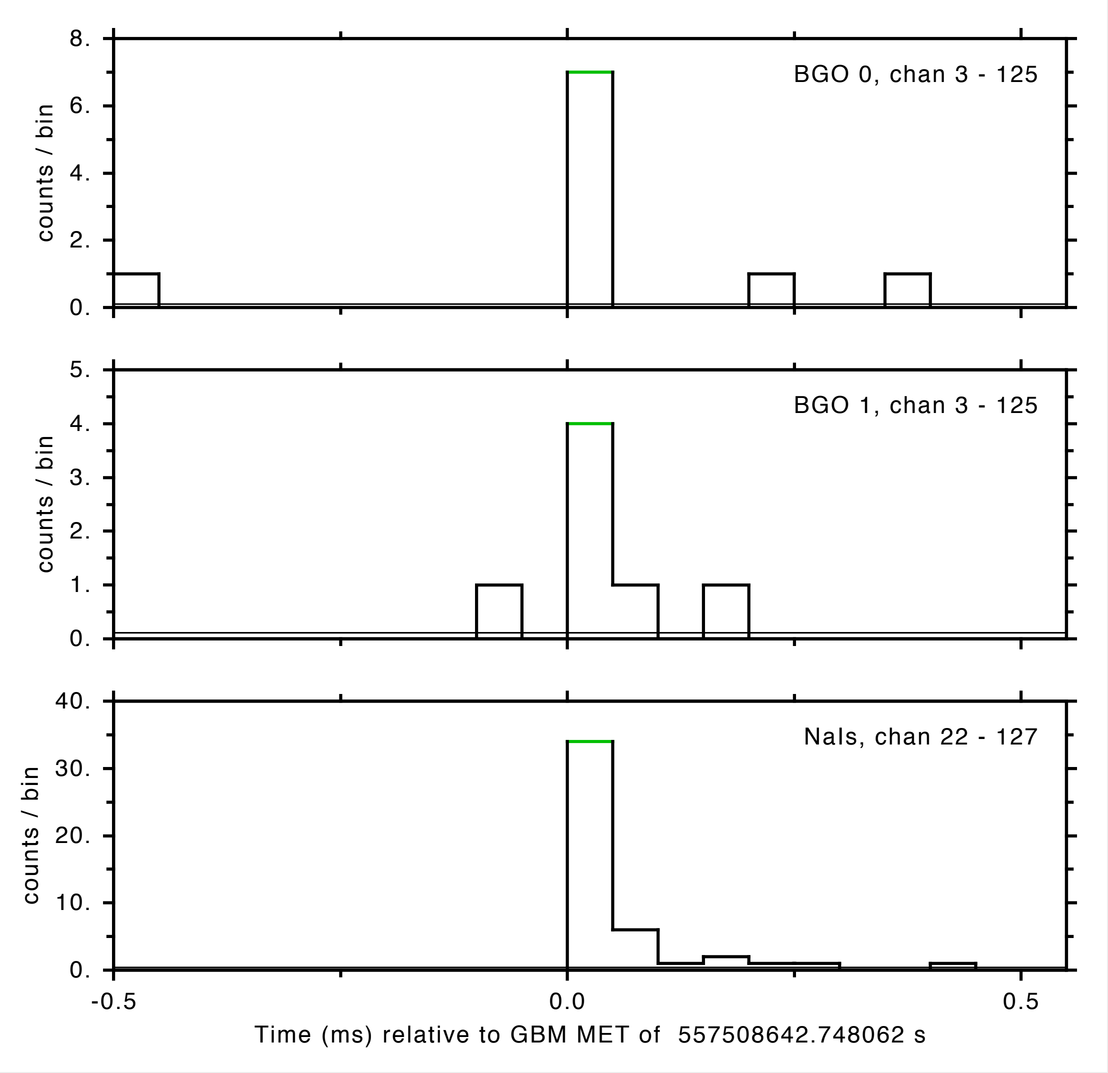
Pipelines 5, 6 and 7: Automatic sub-trigger threshold Searches

All based on the Continuous Time Tagged Event (CTTE) Data

5: Terrestrial Gamma-ray Flash
Runs daily to process CTTE, binned on timescales from 25 μs to 16 ms. Finding ~800 TGFs per year.
Through 2016 July 31: published in a catalog at the FSSC and Roberts et al., JGR (2018). Current TGFs: contact me.

An example TGF found at 50 μs binning of the CTTE.

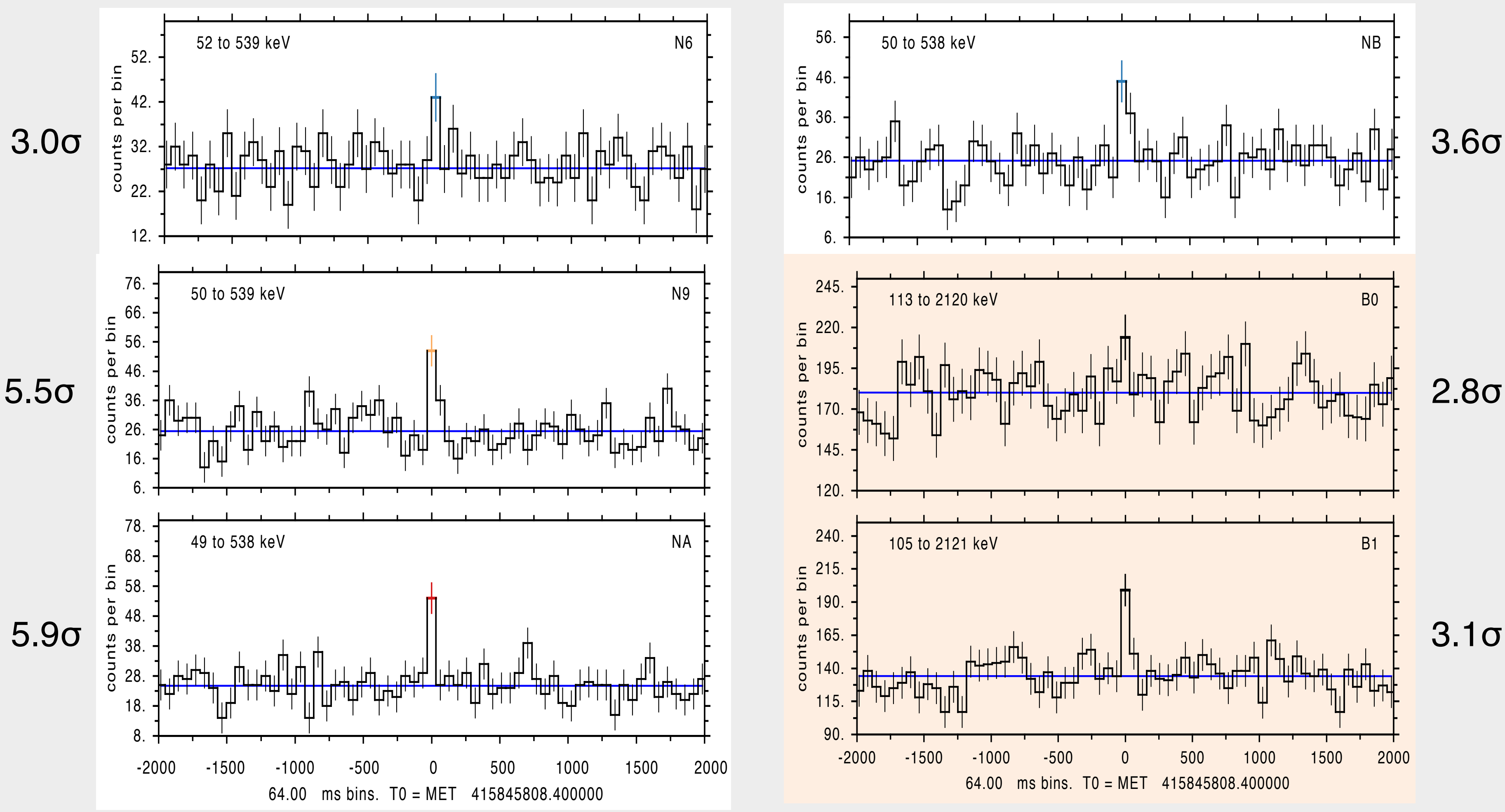
The change probability for the joint signal, corrected for trials in day, is 1E-68.



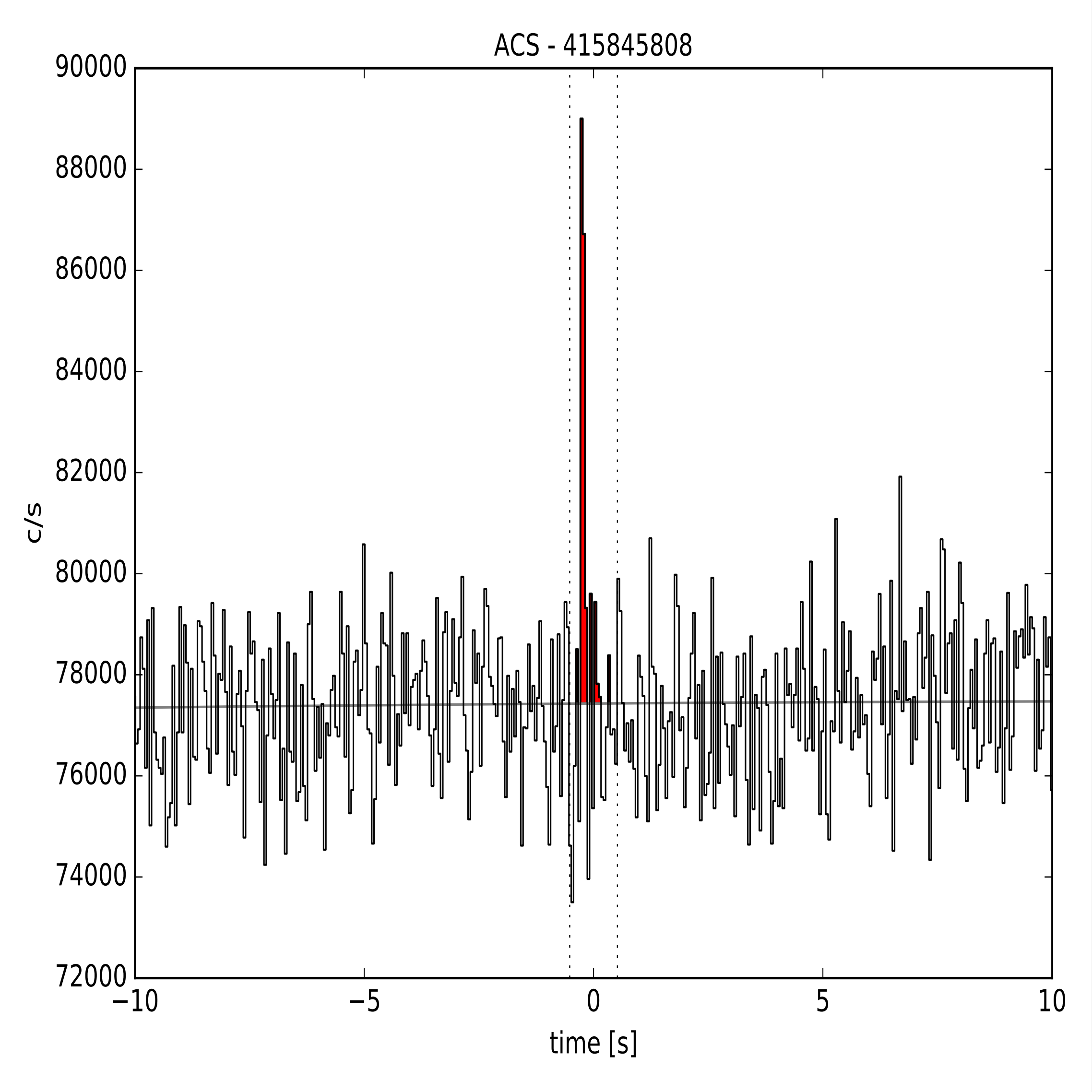
Pipelines 5, 6 and 7: Automatic sub-trigger threshold Searches

6: Untargeted
Runs when CTTE is available. Agnostically searches for rate increases in two or more GBM detectors. Compared to the flight trigger algorithm, has lower threshold and other improvements, such as a more sophisticated background model.   Results are automatically published as GCN Notices.
Doubling the short GRB rate.

Candidate with ACS Confirmation



P = 8E−8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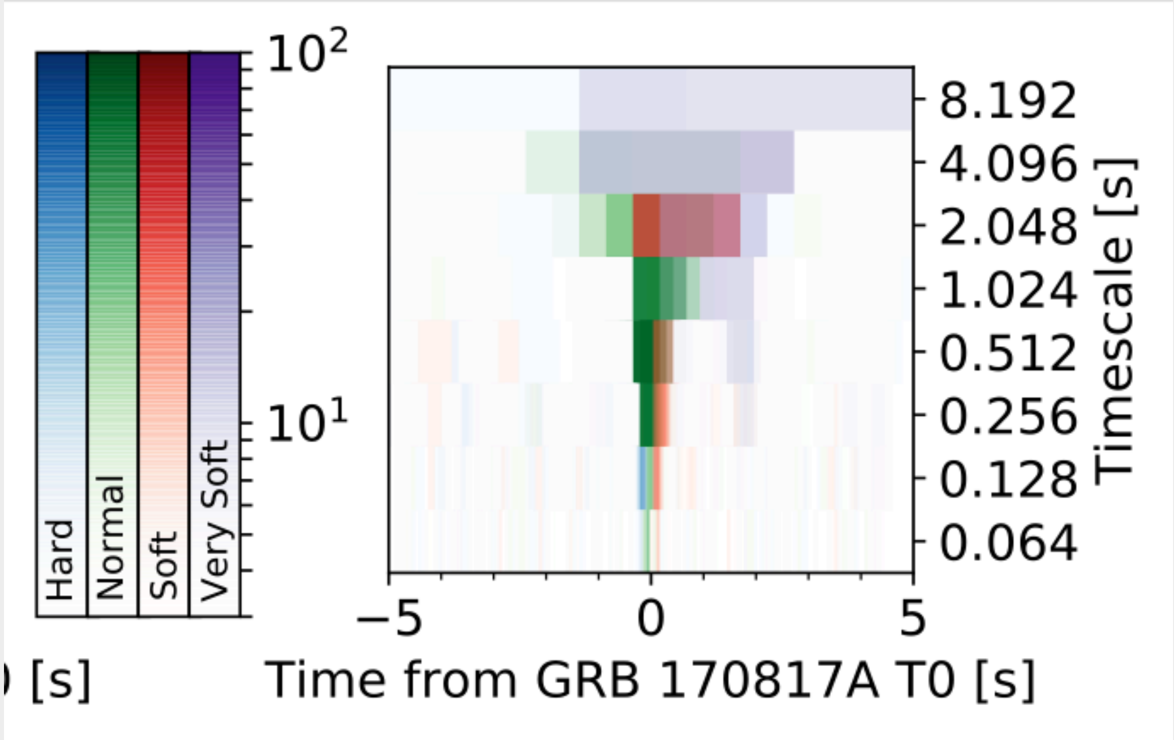
Pipelines 5, 6 and 7:
Automatic sub-trigger threshold Searches

7: Targeted
Runs when CTTE becomes available. Bayesian test for GBM detection using information (time/location) from another detection, such as a gravitational wave or neutrino signal.   Three spectral templates and the detector responses are used so that the detectors are tested for a consistent deconvolved signal.   Soon: After human evaluation, significant events will be released via GCN Circulars.

Likelihood Ratio for a coherent signal



Burns et al., ApJ
(2018)

Interplanetary Network (IPN)

GBM emails TTE data for each GRB to Kevin Hurley.

Typically the first data arrives to Kevin Hurley by email.
Data from additional instruments are obtained from servers or requested by email.
Currently typical latencies are hours to ~day.

Currently since the instrument pairs are so different, the analysis is manual.   In the past there some instrument pairs were automatically analyzed.
Results are published via GCN Circulars.

Lessons Learned

Software tends not to be neglected compared to hardware and not (fully) ready by launch. A bigger problem for SmallSats with shorter mission durations?

The GBM example has too many pipelines for SmallSats – typically smaller budgets – unless code sharing.

Lessons Learned: Data Types

Compton had less telemetry and memory then Fermi … a challenge to fit the data into the telemetry ... and some problems with its data design.   Telemetry is typically an issue for SmallSats ...

BATSE Time-to-Spill (TTS): too complicated.
BATSE HERB / SHERB background types: temporal resolution was too coarse.
BATSE TTE for Large Area Detectors: time coverage too short.
Between instruments: different time binnings (widths and phases) greatly hindered time-resolved analysis of GRBs.

Fermi: LAT always individual photons; GBM has TTE for triggers for entire mission ➔ total analysis flexibility for GRBs.
mid 2010: GBM gets additional TTE for TGFs;
late 2012 full Continuous TTE:
enables sub-threshold searches for weak transients.