Time-domain Astronomy with Fermi GBM
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The Fermi Gamma-ray Burst Monitor (GBM) is an all-sky monitoring instrument sensitive to energies from 8 keV to 40 MeV. Over the past 8 years of operation, the GBM has detected over 240 gamma-ray bursts per year and provided timely GCN notices with localization to few-degree accuracy for follow-up observations. In addition to GRBs, Galactic transients, solar flares, and terrestrial gamma-ray flashes have also been observed. In recent years we have also been searching the continuous GBM data for electromagnetic counterpart to astrophysical neutrinos and gravitational wave events, as these are believed to be associated with gamma-ray bursts. With continuous data downlink every few hours and a temporal resolution of 2 microseconds, GBM is well suited for observing transients and supporting EM followup in the era of multi-messenger astronomy.

![GBM instrument](image)

**The GBM instrument**

- 12 NaI detectors, sensitive from 8 keV to 1 MeV.
- 2 BGO detectors, sensitive from 200 keV to 40 MeV.
- > 8 steradians field of view and sample entire sky every ~90 minutes.
- 120 distinct triggers are possible, from a combination of 4 energy ranges (25+ keV to >300 keV), 10 timescales (16ms — 8.192s).
- Available data products:
  - CTIME data (256ms temporal resolution and 8 energy channels)
  - CSPEC data (4s temporal resolution and 128 energy channels)
  - CTTE data (2us temporal resolution and 128 energy channels)

**Gamma-ray Bursts**

- 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% is also seen

**Terrestrial Gamma-ray Flashes**

- Intense and short (millisecond timescale) gamma rays produced in Earth’s atmosphere.
- Associated with electrons accelerating in electric fields at the top of thunderstorm clouds.
- Present in triggered events and dedicated offline data search.
- Online catalog has 4144 TGFs between 2008 and 2016. https://fermi.gsfc.nasa.gov/ssc/data/access/gbm/tgf/

![GBM triggered TGFs](image)

**Pulsar Monitoring**

- Accelering pulsars are detected by the frequency modulation.
- Currently monitoring:
  - 8 persistent pulsars
  - 28 transient pulsars
  https://gammaray.nsstc.nasa.gov/gbm/science/pulsars.html

**Monitoring by Earth Occultation Technique**

- 200+ sources are monitored, from X-ray binaries to Active Galactic Nuclei
  - 102 detections, 9 at >100 keV
  https://gammaray.nsstc.nasa.gov/gbm/science/earth_occ.html

![Crab Nebula flux variations](image)

**X-ray Bursts**

- Over a period of 13 days, 4U 0614+09. The aFXPs are shown as blue circles and are largely in three clusters centered the known type I XRBs. There is a smaller cluster of events consistent with the location of Vela X-1, A0535+26, the green curve is the index distribution for the uGRBs. Contributions from Sco X-1 and the total model. Right: Separation of indices by class of event. The red curve is the index model fit to the data and the dashed and dotted lines are the two gaussian components of the best-fit model. Left: Diamonds are the data points for all the XRB events. The solid line is a

Briggs et al. JGR 118, 3805 (2013)
Roberts et al JGR, in prep.

![Black hole binary system V404 Cyg](image)

Wilson-Hodge et al. in prep.