Joint GW-GRB Localizations with Fermi GBM

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On behalf of the Fermi GBM Team
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The Fermi Gamma-ray Burst Monitor

- Trigger on many different sources: GRBs, Solar Flares, SGRs, X-ray Binaries
  - ~2300 GRBs (~40 triggered short GRBs/year)
- Triggers are classified and communicated to the ground/public within seconds
- GRBs are localized within seconds—10 minutes
- Sub-threshold searches for signals below triggering threshold (latency ~2–5 hours):
  - Un-targeted blind search for short GRBs sends out GCN notices*
  - Targeted follow-up search of known multi-messenger events

*https://gcn.gsfc.nasa.gov/fermi_gbm_subthreshold.html
Example: Initial GBM Localization for GRB 170817A

Typical weak triggered short GRB

HLV, GBM initial, GBM-INTEGRAL SPI/ACS timing annulus
Updated Localizations

Standard GBM Human-in-the-Loop

Initial

Sub-threshold Targeted Search

Final
If We Combine Localizations….
GBM initial+HL

Combined Localizations, 2 GW Detectors

-15°
-30°
210° 180°

In 2005, the Fermi satellite detected the first electromagnetic counterpart of a gravitational-wave event. This was a kilonova associated with the binary neutron star merger GW170817. The neutron star merger scenario has been one of the key challenges in high-energy astrophysics, as it remains elusive.

In the mid-1960s, gamma-ray bursts were first established to be extragalactic. The absence of associated electromagnetic counterparts to these events was a significant puzzle. However, subsequent sGRB discoveries have shown that supernova kicks or with black holes. These hints included:

- Associated with mergers of neutron stars with other neutron stars
- Experienced a breakthrough in following up gravitational-wave detections
- Radio and multi-wavelength observation

The detection of gravitational and electromagnetic radiation from a single source has been a significant breakthrough. An optical transient was detected in the host galaxy NGC 4993. The source was detected across the infrared, and radio bands—over hours, days, and weeks. These observations support the hypothesis that GW170817 was the result of a binary neutron star merger.

The kilonova, interpreted as the signature of r-process nuclei synthesized in the ejecta, was detected minutes after the sGRB. The decay of these nuclei powered the kilonova. The long-lived radioactive r-process nuclei synthesized in the ejecta are expected to produce a neutron star.

For a compilation, see Jin et al. 2016.
Upshot and Deliverables

• Combining GBM w/ GBM-ACS annulus -> up to factor 2–3 localization improvement
• GBM w/ single IFO -> Actual localization on sky with distance information
• GBM w/ 2 IFOs -> factor ~3 (or more?) localization improvement

• Working on improving GBM “initial” localizations to be as accurate as the GBM “Final”
• Current known sky map latencies:
  • GBM triggers: ~10 minutes
  • LVC online trigger: ~few minutes
  • INTEGRAL SPI-ACS data downlink: ~1 hour
  • GBM sub-threshold triggers/searches: ~2–5 hours

• Working on a pipeline to automatically combine and deliver the sky maps via GraceDB? VOEVents? etc.
Localization is performed by comparing the relative observed rates from the GRB in each detector to the expected rates on a 1 degree grid. This requires an assumption of the spectrum, and the sky grid limits to a statistical minimum uncertainty of 1 degree radius (systematic uncertainty is > 1 deg).