The hunt for gamma-ray counterparts to gravitational-wave sources

Tyson B. Littenberg (NASA/MSFC)
Gamma Ray Bursts
Gamma Ray Bursts
2704 BATSE Gamma-Ray Bursts

Fluence, 50-300 keV (ergs cm\(^{-2}\))

Count

Observed Duration: \(\log(T_{90} \text{ [s]})\)

- 1966 BATSE GRBs
- 1366 BATSE LGRBs
- 600 BATSE SGRBs

Traditional dividing line:

\(T_{90} \sim 3 \text{ [s]}\)

(e.g., Kouveliotou et al. 1993)
traditional dividing line: $T_{90} \sim 3$ [s] 
(e.g., Kouveliotou et al. 1993)
Short gamma-ray burst (<2 seconds' duration)

Stars in a compact binary system begin to spiral inward...

...eventually colliding.

...becoming so dense that it expels its outer layers in a supernova explosion.

The resulting torus has at its center a powerful black hole.

*Possibly neutron star.

Long gamma-ray burst (>2 seconds' duration)

A red-giant star collapses onto its core...

Torus

Jet

Gamma rays
GBM
GBM
GBM

Incoming gamma-ray

Scintillation crystal

Gamma-ray absorbed, light emitted

Photomultiplier tube
GBM

Incoming gamma-ray

Scintillation crystal

Gamma-ray absorbed, light emitted

Photomultiplier tube
GBM

Incoming gamma-ray

Scintillation crystal

Gamma-ray absorbed, light emitted

Photomultiplier tube

"Typical" Prompt GRB Spectrum

\[ E^2 N_E (\text{erg cm}^{-2} \text{s}^{-1}) \]

Photon Energy (MeV)

NaI  BGO
GBM

>2K GRBs

>1K Solar Flares

>200 Magnetar Flares

~1K TGFs
Short gamma-ray burst
(<2 seconds' duration)

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...eventually colliding.

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Short gamma-ray burst
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GBM

Onboard triggered search

Sub-threshold un-targeted search

Sub-threshold targeted search

LVC

All Sky “Burst” search

All Sky “CBC” search

Targeted GRB Follow-up

Targeted GRB Follow-up
GBM

Onboard triggered search

Sub-threshold un-targeted search

Sub-threshold targeted search

All Sky “Burst” search

All Sky “CBC” search

Targeted GRB Follow-up

LVC

Onboard triggered search

Sub-threshold un-targeted search

Sub-threshold targeted search

All Sky “Burst” search

All Sky “CBC” search

Targeted GRB Follow-up
Advanced LIGO Observing Runs
GW150914
GW150914

LIGO-only sky map
LIGO-only sky map + Earth occultation for GBM
Joint LIGO-GBM sky map
Advanced LIGO Observing Runs
Advanced LIGO Observing Runs

GW170608
GW170817/GRB170817A

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Relative</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:41:06.474598</td>
<td>0</td>
<td>Trigger Time: End of 0.256 s interval containing statistically significant rate increase</td>
</tr>
<tr>
<td>12:41:06.477006</td>
<td>+2.4 ms</td>
<td>Triggered: Autonomously detected in-orbit by the <em>Fermi</em> GBM flight software</td>
</tr>
<tr>
<td>12:41:20</td>
<td>+14 s</td>
<td><em>Fermi</em> GBM Alert Notice sent by the GCN system at NASA/GSFC</td>
</tr>
<tr>
<td>12:41:31</td>
<td>+25 s</td>
<td>Automatic location from GBM flight software sent by the GCN: RA=172.0, Dec=-34.8, err=32.6 deg</td>
</tr>
<tr>
<td>12:41:44</td>
<td>+38 s</td>
<td>More accurate automatic location by ground software sent by GCN: RA=186.6, Dec=-48.8, err=17.4 deg</td>
</tr>
<tr>
<td>13:26:36</td>
<td>+44.9 min</td>
<td>More accurate human-guided localization sent by GCN: RA=176.8, Dec=-39.8, err=11.6 deg</td>
</tr>
<tr>
<td>13:47:37</td>
<td>+66.5 min</td>
<td><em>LVC</em> GCN Circular reporting localization and consistency of signal with a weak short GRB (<em>Connaughton et al. 2017</em>)</td>
</tr>
<tr>
<td>20:00:07</td>
<td>+7.3 hr</td>
<td><em>Public</em> GCN Circular establishing GRB name and standard GBM analysis (<em>von Kienlin et al. 2017</em>)</td>
</tr>
<tr>
<td>00:36:12</td>
<td>+11.9 hr</td>
<td><em>LVC</em> GCN Circular reporting updated spectral analysis, energetics, and association significance (<em>Goldstein 2017</em>)</td>
</tr>
</tbody>
</table>

Adapted from LVC, Fermi and INTEGRAL, ApJL (2017)
If GRB170817A brightness reduced to:

- ~70%...no onboard trigger
- ~50%...at untargeted search threshold
- ~40%...at targeted search threshold

Adapted from LVC, Fermi and INTEGRAL, ApJL (2017)
Chandra X-Ray Observatory

Giant Meterwave Radio Telescope


Misra et al, arXiv:1803.02768
Median (full range) O3 detections

BNS: ~5-10 (0-30)
BBH: ~30 (10-100)
NSBH: < ~1 (if they exist)

C. Pankow, private communication, (2018)
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