NASA EM Followup of LIGO-Virgo Candidate Events

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Abstract

We present a strategy for a follow-up of LIGO-Virgo candidate events using offline survey data from several NASA high-energy photon instruments aboard RXTE, Swift, and Fermi. Time and sky-location information provided by the GW trigger allows for a targeted search for prompt and afterglow EM signals. In doing so, we expect to be sensitive to signals which are too weak to be publicly reported as astrophysical EM events.

EM detectors:

- **Mission**
- **Instrument**
- **Energy**
- **FOV**
- **Transit**

<table>
<thead>
<tr>
<th>Mission</th>
<th>Instrument</th>
<th>Energy</th>
<th>FOV</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXTE</td>
<td>ASM</td>
<td>1–10 keV</td>
<td>3%</td>
<td>&lt;1°  1.5 hr</td>
</tr>
<tr>
<td>SWIFT</td>
<td>BAT</td>
<td>20–150 keV</td>
<td>15%</td>
<td>&lt;1°  n/a</td>
</tr>
<tr>
<td>FERMI</td>
<td>GBM</td>
<td>20 keV–40 MeV</td>
<td>65%</td>
<td>&gt;5°  3 hr</td>
</tr>
<tr>
<td>FERMI</td>
<td>LAT</td>
<td>20 MeV–300 GeV</td>
<td>20%</td>
<td>1–5°  3 hr</td>
</tr>
</tbody>
</table>

* FOV: fraction of sky observed, Δθ: source localization resolution, Transit: time required for full-sky coverage

LIGO-Virgo GW network:

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Frequency</th>
<th>Optimal NS/NS–NS/BH Range</th>
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<tbody>
<tr>
<td>H1L1V1</td>
<td>50–6000 Hz</td>
<td>~30–70 Mpc</td>
</tr>
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</table>

Searches

Prompt search

- Search for prompt signal in GBM detectors (0.256 s bins, 8 energy channels) of GW event. Time-resolution and energy ranges are similar to those used on board to target GBM's. Use GW source localization to aid in combining GBM detector data and background rejection. Tune for a 2×1 coincidence probability per GW event.

Afterglow search

- Search for a prompt signal in BAT using time-resolved data (0.256 s bins, 3 sub-bands) about time of GW event. Only searching BAT detection (Δθ > 1°) to improve with GW source localization. Tune for a 2×1 coincidence probability per GW event.

- Search for a prompt signal in LAT using time-resolved data (0.256 s bins, 3 sub-bands) about time of GW event. Only searching LAT detection (Δθ > 1°) to improve with GW source localization. Tune for a 2×1 coincidence probability per GW event.

- Detect search for afterglow in LAT using time-resolved data (0.256 s bins, 3 sub-bands) about time of GW event. Only searching LAT detection (Δθ > 1°) to improve with GW source localization. Tune for a 2×1 coincidence probability per GW event.

FERMI Gamma-ray Burst Monitor (GBM)

GBM offline data includes count rates (0.256 s bins, 8 energy channels) of the 12 NaI (8 keV–1 MeV) and 2 BGO (200 keV–40 MeV) detectors.

GBM10005010: a strong short GRB observed in the GBM detectors. The on-board trigger increases the time-resolution of the bursted detector counts immediately following the event.

The NaI detectors are semi-directional (-cos θ response) and can be used for source localization and consistency checks. The GW location can be used as a basis for a coherent sum of the 12 data streams, increasing the overall response of the network compared to a single-detector approach.

SWIFT Burst Alert Telescope (BAT)

- BAT lightcurve data contains total flux counts at 64 ms resolution in various energy bands.
- For un-triggered (low threshold) events, imaging is only available offline for 5 minute time-series.

RXTE All Sky Monitor (ASM)

The ASM aboard RXTE provides a 90 s 1–10 keV (3 sub-bands) snapshot of an area in the sky as often as every 90 minutes. Localization of <0.1° is achieved by use of three cameras each equipped with a shadow mask.

The analysis method of fitting the amplitudes of a small number of point sources in the FDV to the masked data is generally used to produce position and light curve information. The method makes use of the same technique as the Finkle sky-coverage of the GW trigger in the low data following the event to search for X-ray afterglows. The 90 s dwell is divided into 5 s "test" point analysis 6.5 s dwell. AIC is fit to the data along with a catalog of known active sources. The quality of the fit is dumped to 20 s (4×10^4 m/s) and can be improved by averaging measurements over a region of interest. This method of analyzing a region of the sky more sensitive than the standard un-triggered all-sky search for ASM transient, which uses FFT deconvolution to create an image from the masked data.

FERMI Large Area Telescope (LAT)

- LAT completes individual photon data available for offline analysis.
- Likelihood statistic used by LAT team to identify significant clusters of photons.