Fermi GBM Counterparts to LIGO/Virgo Gravitational-Wave Candidates

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Mergers of binary neutron star systems produce both short Gamma-Ray Bursts (GRBs) and gravitational radiation.

Gamma ray radiation is seen in a jet as a short GRB detected by GBM if the jet is pointed at us. GBM can see very far.

Gravitational radiation is emitted isotropically and seen by LIGO/Virgo. LIGO can’t see very far (70 Mpc in O1, ~200 Mpc at design).

Joint GBM LIGO/Virgo events happen when the jet is pointed towards us and the merger happens nearby i.e., quite rarely ~1-- handful joint detections per year (model-dependent). It is very important to maximize the probability of joint GBM LIGO/Virgo detections and enable supporting observations that will provide the distance scale and energetics of the explosion.
Owing to all-sky coverage, Fermi GBM detects and localizes more short GRBs than other GRB detectors.

GBM: 40 short GRBs per year, coarse localization (tens square degrees)

Swift BAT: 9 short GRBs per year, arcminutes localization facilitating follow-ups.
Weak short GRBs are not necessarily more distant than bright short GRBs and may lie within the detection horizon of LIGO/Virgo.

GBM and Swift detect the same population of short GRBs (Burns et al. in press)

Extrapolating from sGRBs with known redshift gives <0.5 - 5 per year sGRB for GBM within LIGO/Virgo horizon (nearby $z$ uncertain).

This number is doubled with unseeded search for GRBs that do not trigger on-board.
Even a large banana and a large orange can help: using joint GBM-LIGO/Virgo detections and GBM non-detection to guide follow-up observers

Typical GBM GRB localization region for weak GRB

Typical LIGO localization region from http://www.ligo.org/scientists/first2years/ changes in 2016 with addition of Virgo

18 +/- 5 nearby galaxies (N. Gehrels et al. 2015, arXiv:1508.03608)

Typical reduction of 80% in sky region:
4 nearby galaxies: easier to follow up with XRT or optical telescopes.

- Using the non-detection of a GRB (triggered or untriggered) by GBM or Swift: limiting the sky region to that not viewed by either instrument reduces LIGO sky region by about 50%, assuming on-axis GW candidate with sGRB above detection threshold.

- Taken from E. Burns at Swift meeting (and in prep) http://www.clemson.edu/ces/physics-astro/conferences/Swift2015

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GBM can contribute in many ways to the breakthrough observations of gravitational wave radiation

- A detection by GBM of a short GRB in coincidence with LIGO/Virgo strengthens the significance of the GW detection

- Sub-threshold searches of GBM data for short GRBs may yield twice as many short GRBs within the LIGO/Virgo horizon

- Searches for LIGO/Virgo sub-threshold searches in the GBM data can find candidates that would otherwise go undetected, increasing LIGO sensitivity by 15-20% (Blackburn et al. 2015)

- Observing GBM localization regions of 10s sq degs has been successful (S. Kulkarni’s talk on ZTF)!

- GBM localization regions can greatly reduce (by 80%) the region of sky to be observed at lower energies

- The non-detection of GBM short GRBs can similarly limit the follow-up region for on-axis merger afterglows.