



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.

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.

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

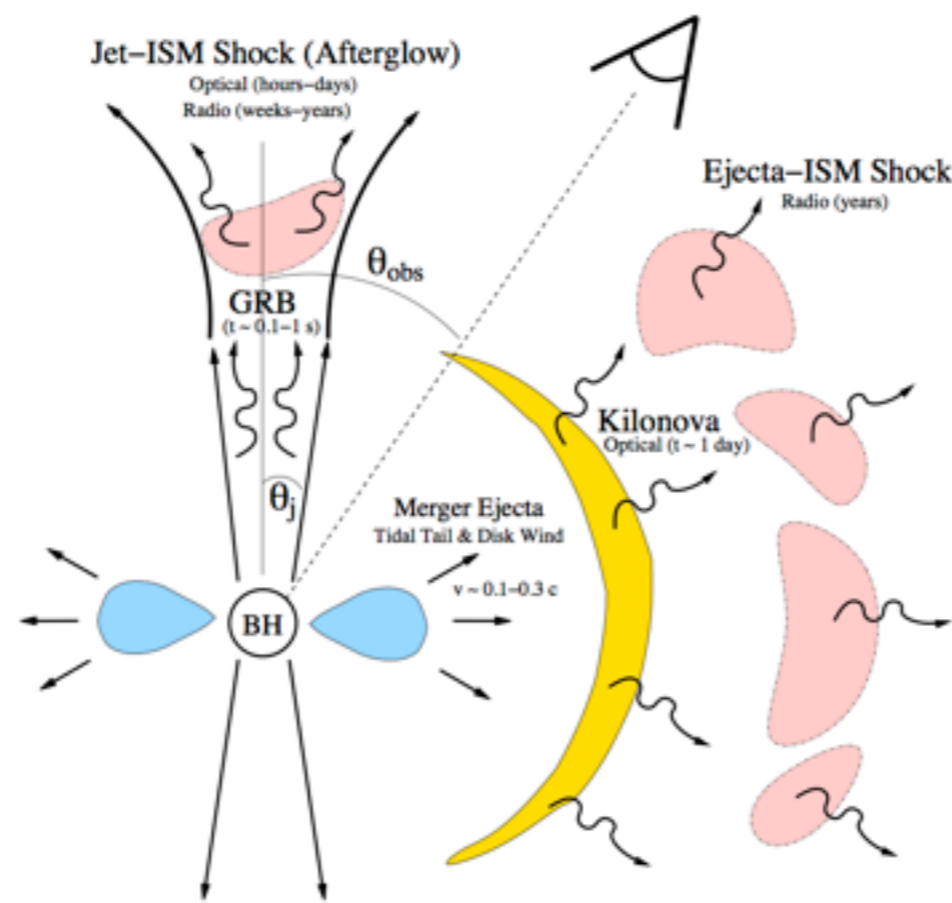
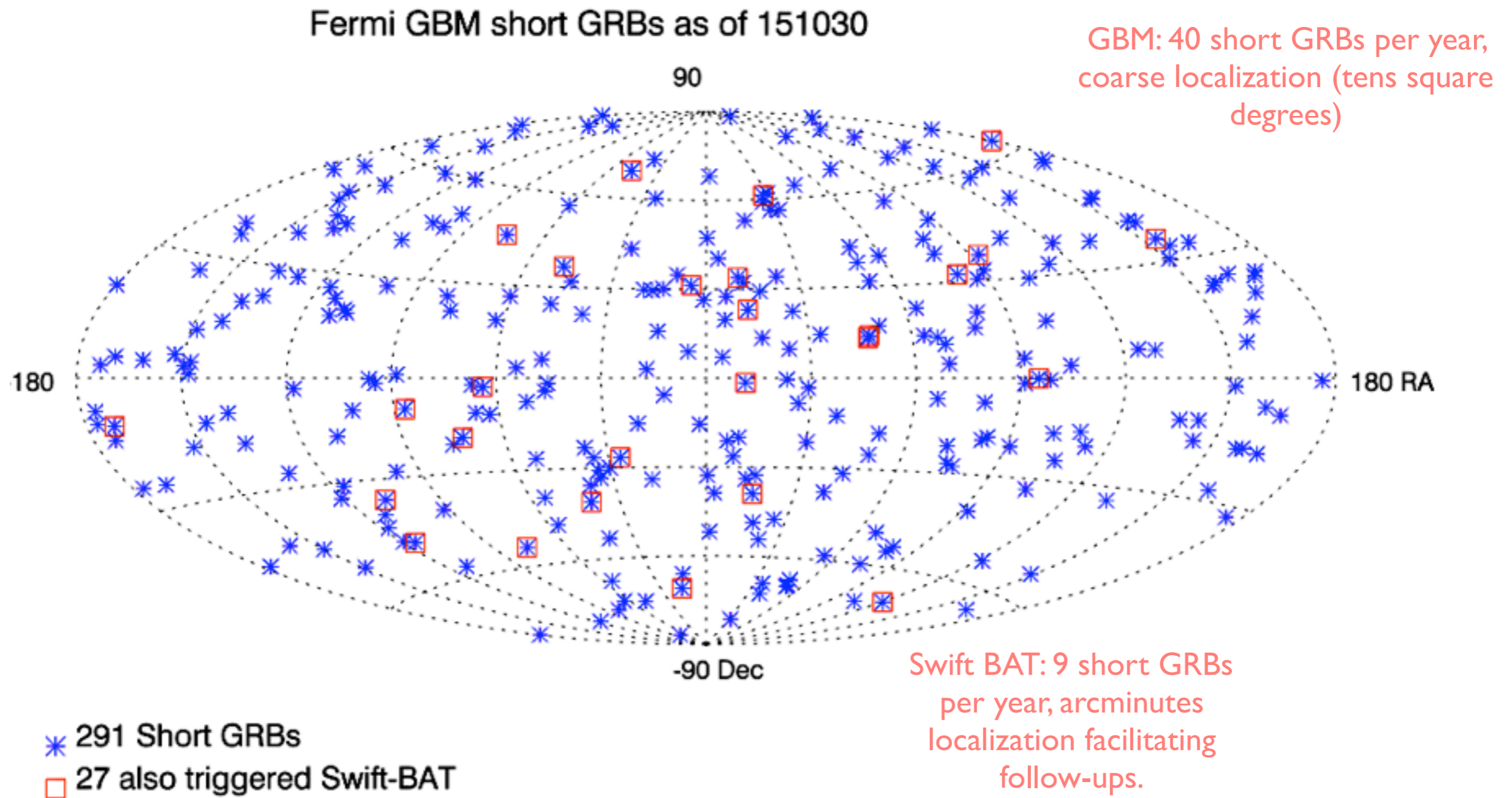


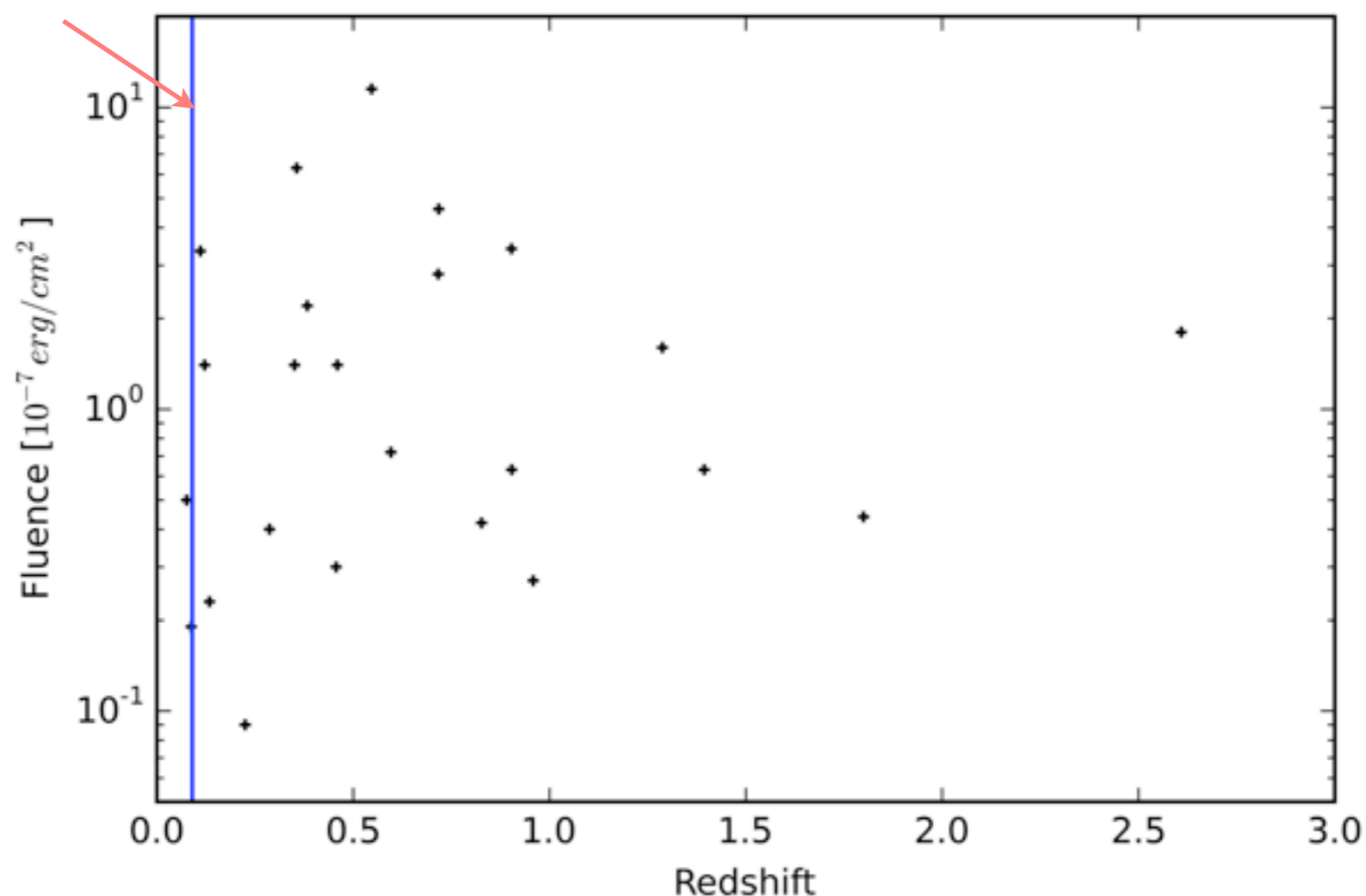
Figure 1 of Meztger & Berger 2012

Owing to all-sky coverage, Fermi GBM detects and localizes more short GRBs than other GRB detectors.



Weak short GRBs are not necessarily more distant than bright short GRBs and may lie within the detection horizon of LIGO/Virgo.

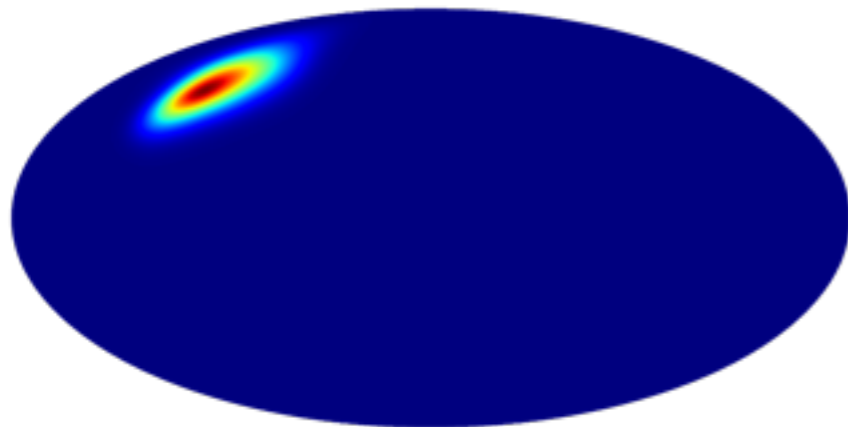
LIGO/Virgo detection horizon for on-axis events with favorable sky position



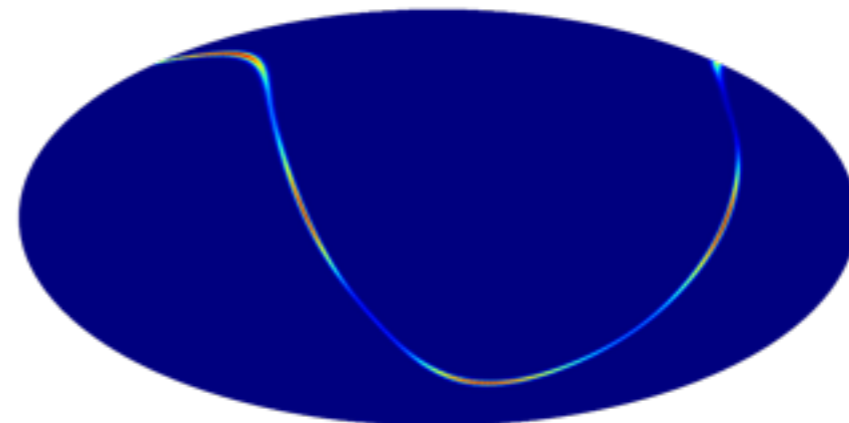
- ▶ GBM and Swift detect the same population of short GRBs (Burns et al. in press)
- ▶ Extrapolating from sGRBs with known redshift gives $<0.5 - 5$ per year sGRB for GBM within LIGO/Virgo horizon (nearby z uncertain).
- ▶ This number is doubled with unseeded search for GRBs that do not trigger on-board.

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



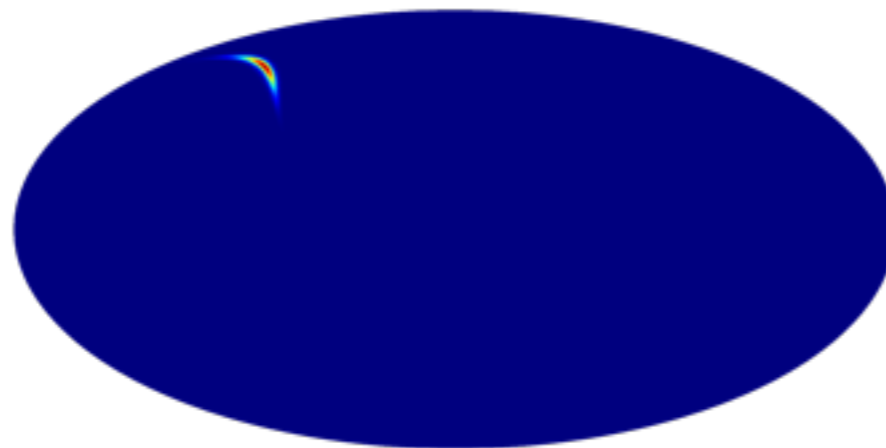
Typical LIGO localization region from <http://www.ligo.org/scientists/first2years/>: changes in 2016 with addition of Virgo



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

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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>

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.

- ▶ **Next Huntsville GRB workshop: 24 - 28 October 2016, in Huntsville AL. Organizers: VC, Neil Gehrels, Adam Goldstein. Details soon!**