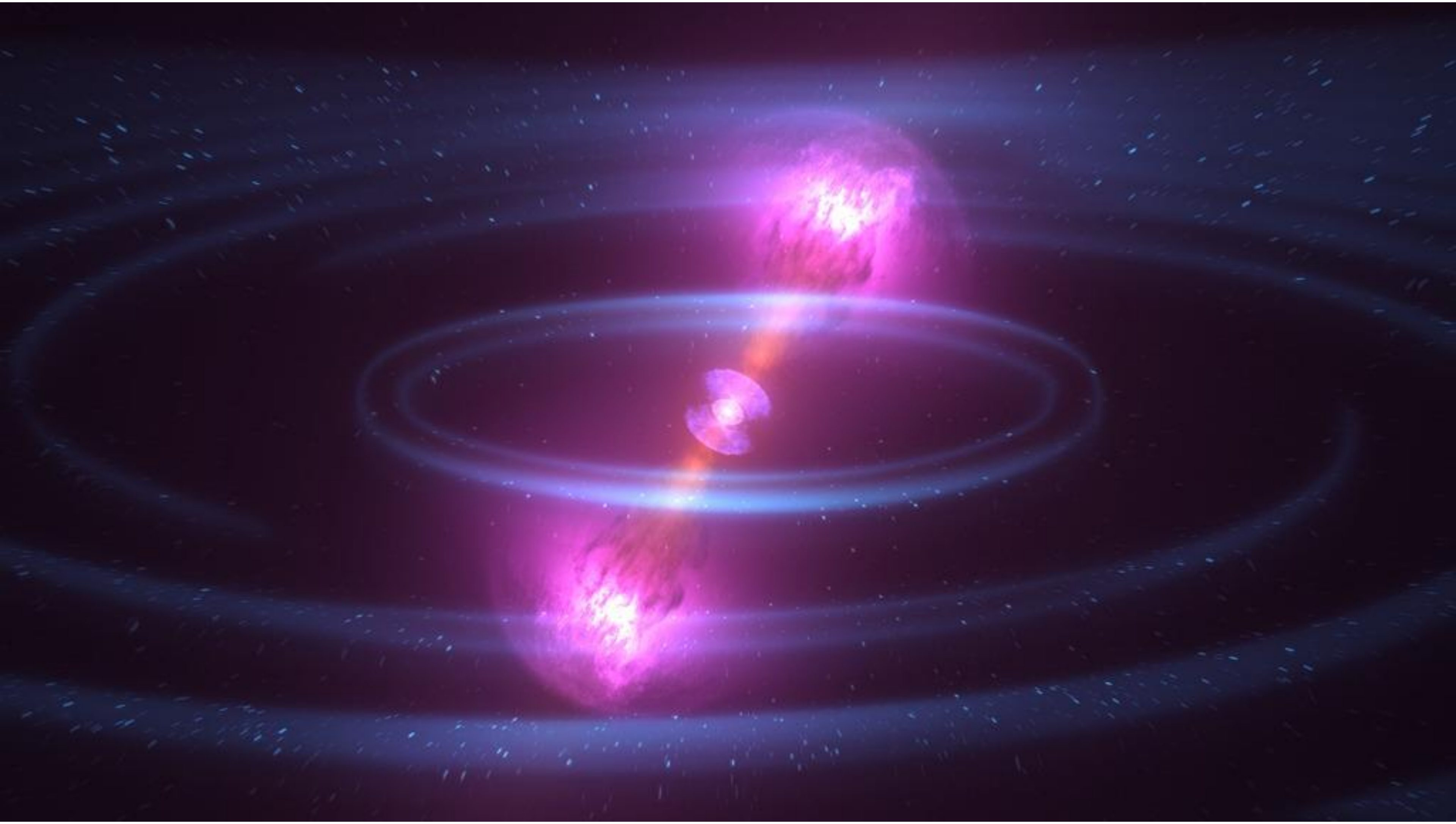
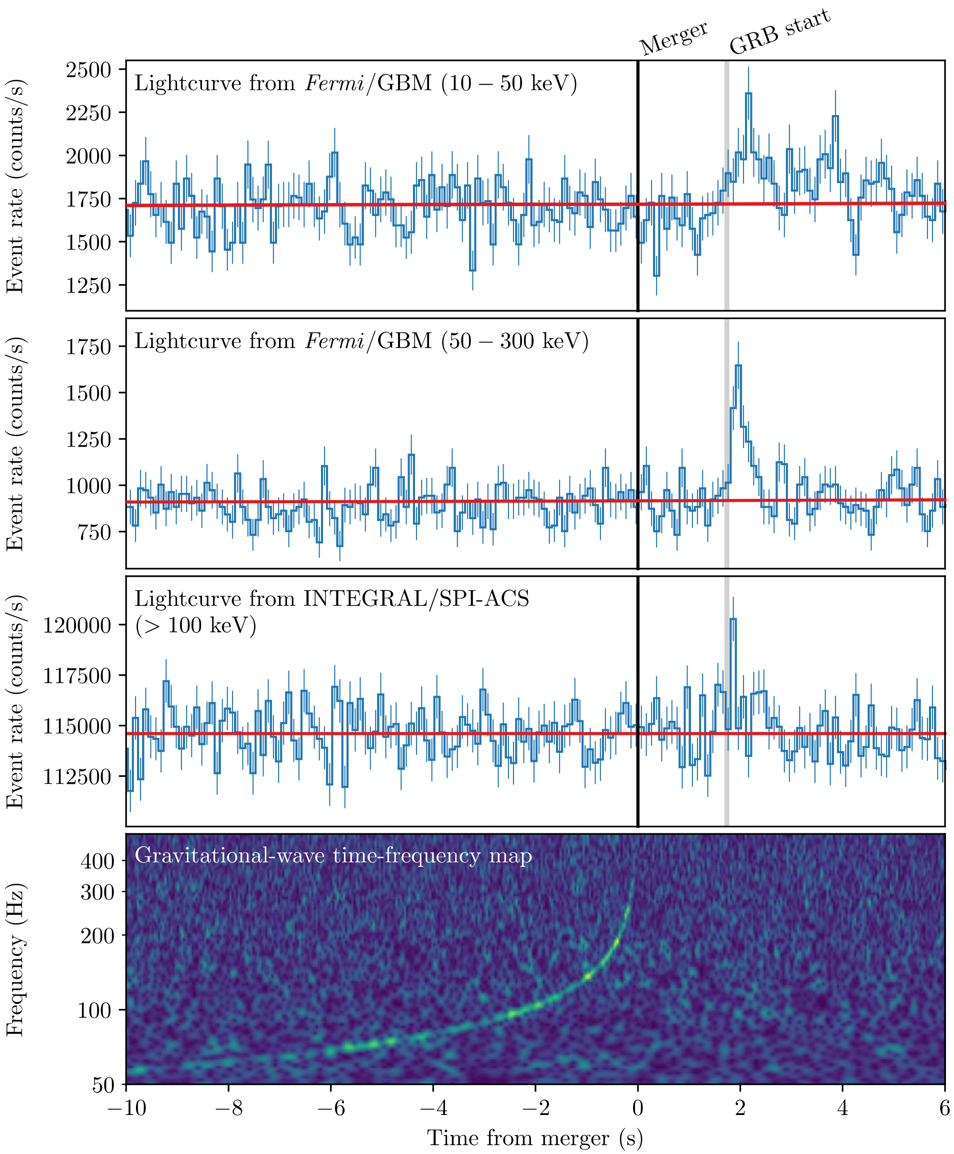
GRB 170818A and future missions



Colleen A. Wilson-Hodge (NASA/MSFC)

GRB 170817A and GW170817

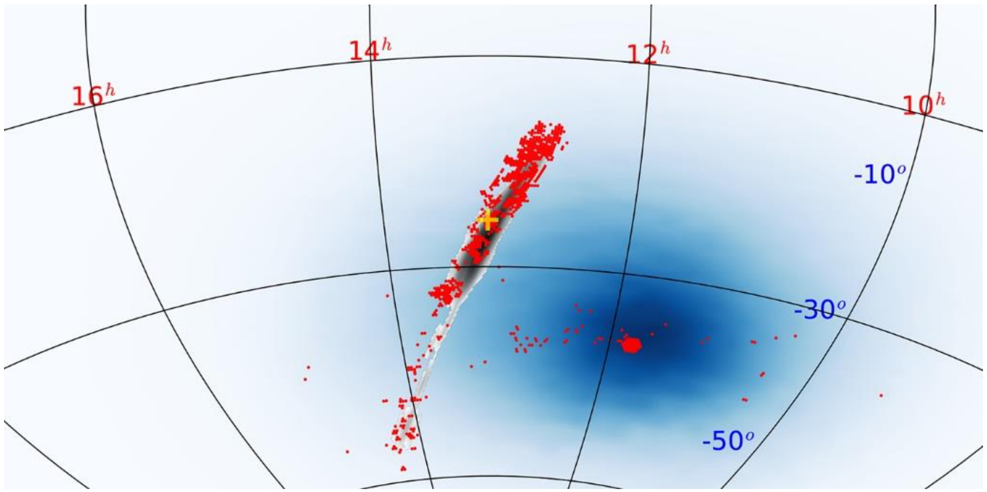


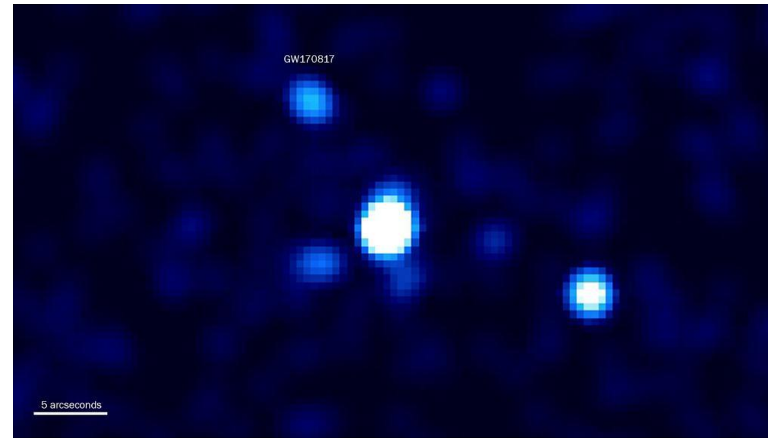
Abbot et al. 2017, ApJ, 848, L13

<u>GBM T0 = GBM Trigger Time</u>

- T0-2 s: LIGO recorded the GW signal
- T0+14 s: First GBM trigger notice
- T0+25 s: First GBM automated localization
- T0+6 min: LIGO trigger (via software) of the single IFO event
- T0+40 min: LIGO announcement of a trigger possibly associated with GBM trigger
- T0+45 min: Human-in-the-loop localization of GRB
- T0+7 hr: Public GCN establishing name

Searches for X-ray afterglow





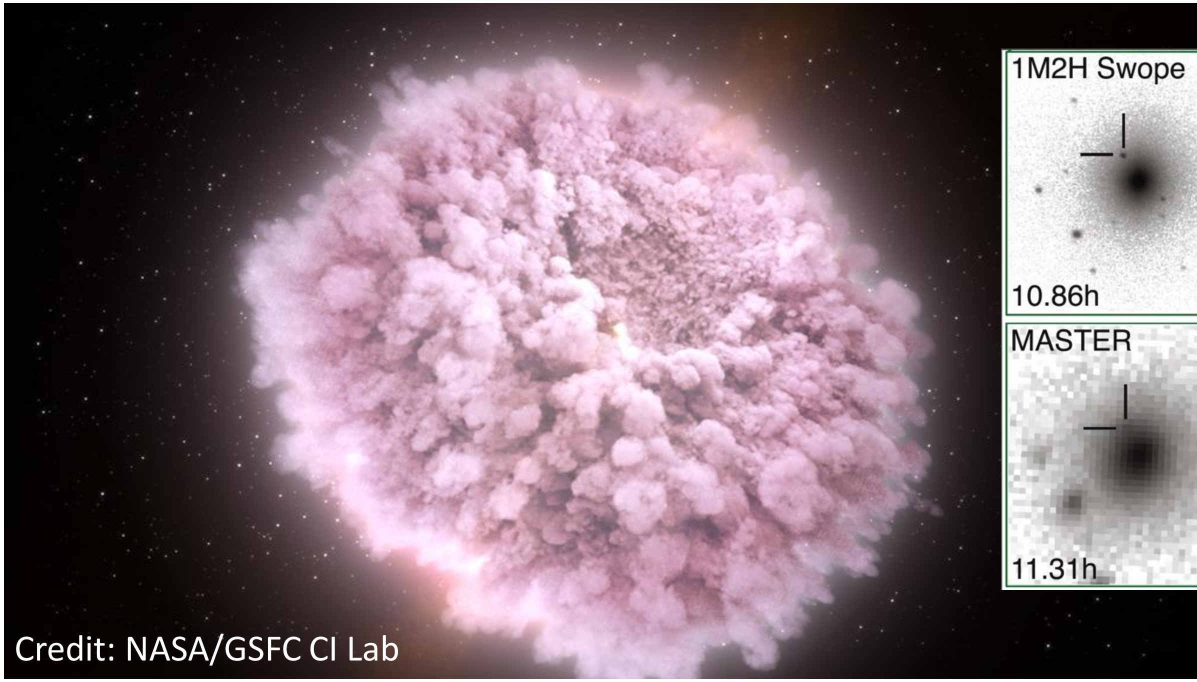
P.A. Evans et al. Science 10.1126/science.aap9580 (2017)

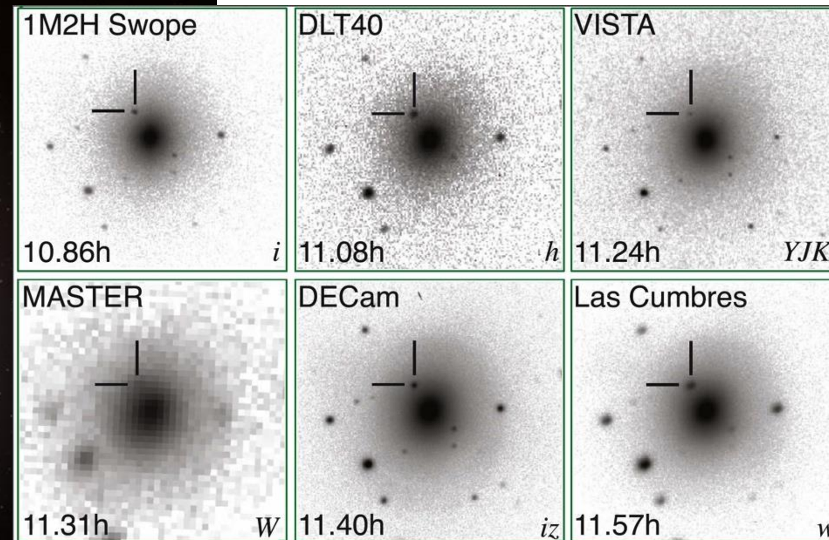
- Swift XRT started searching the GBM error box ~1 hour after the GW
- Tiled 93% of the LVC error circle 0.2 d after GW
- First observed optical transient location 0.6d after GW with Swift and NuSTAR (0.7 d)
- Swift UVOT detected a bright UV transient at 0.6 d
  - UV transient highly inconsistent with observed GRB afterglows

- Early Chandra observtions (GW+2d) yielded non-detections
- Afterglow detected w/ Chandra 9 days after GW
- Consistent with afterglow from off-axis SGRB (>23 deg) or cocoon emission

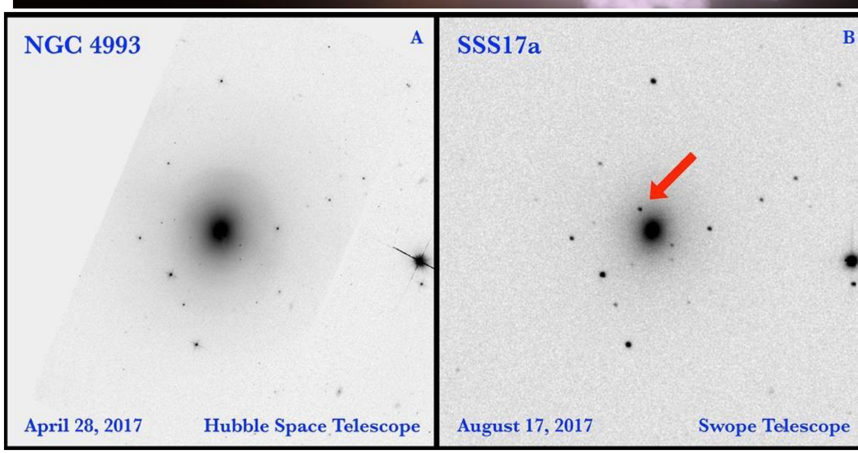
(Margutti et al 2017; Troja et al 2017; Haggard et al 2017)

Discovery of a Kilonova 12 hours later

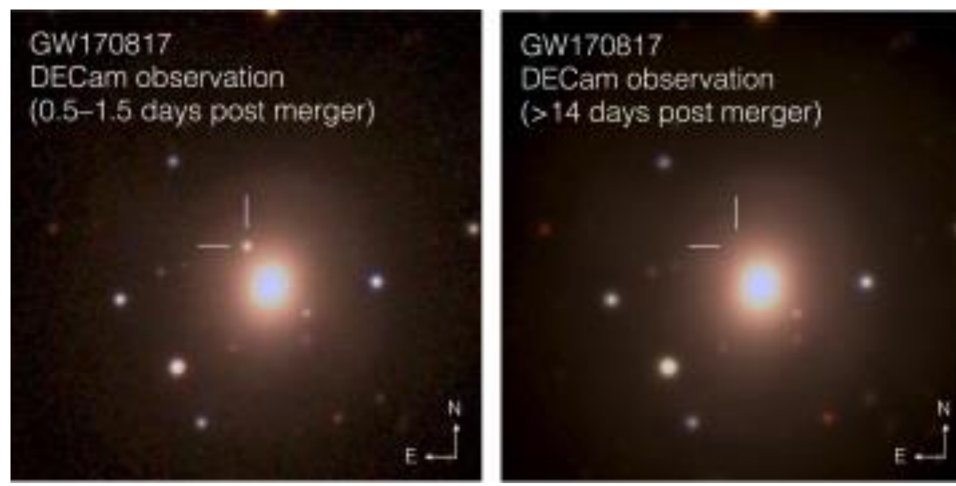

Credit: NASA/GSFC CI Lab



Abbot et al 2017, ApJL, 848, L12

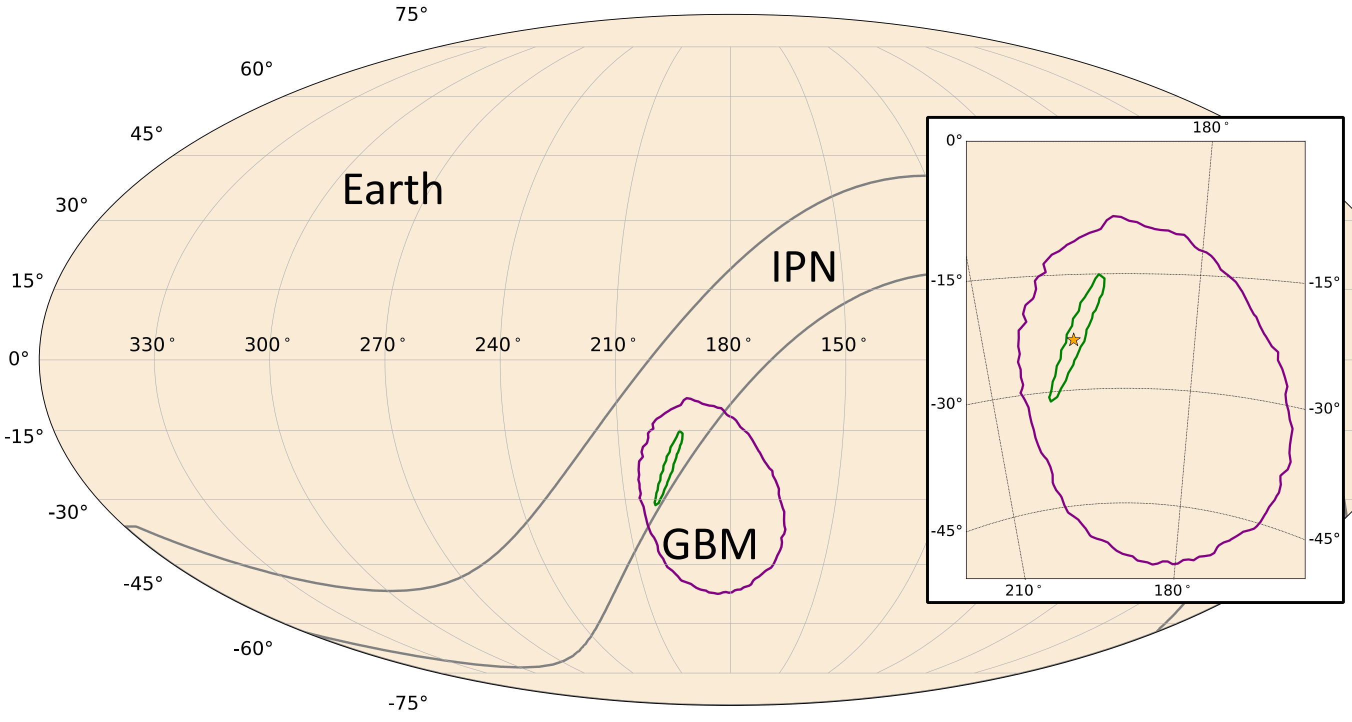


Coulter et al. 2017, 10.1126/scienceaap9811



Soares-Santos et al. 2017, ApJ, 848, L16

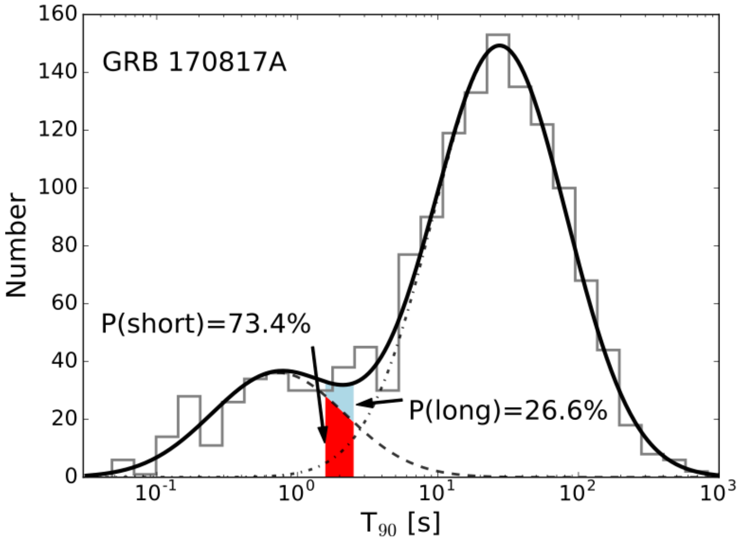
Localization

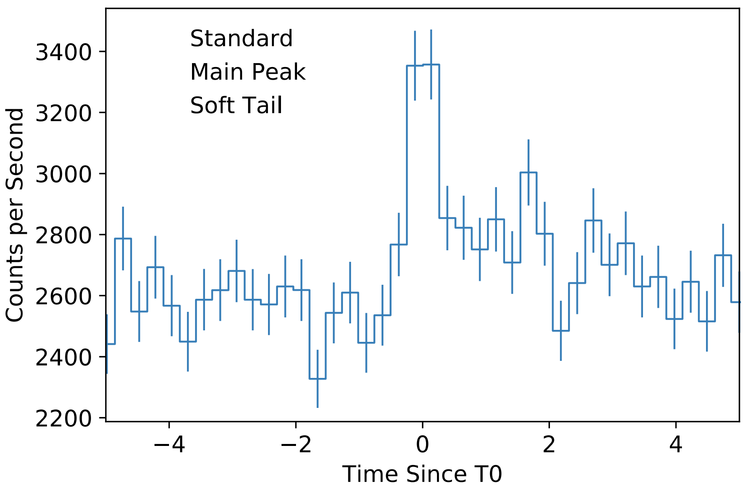


Abbot et al. 2017, ApJ, 848, L13

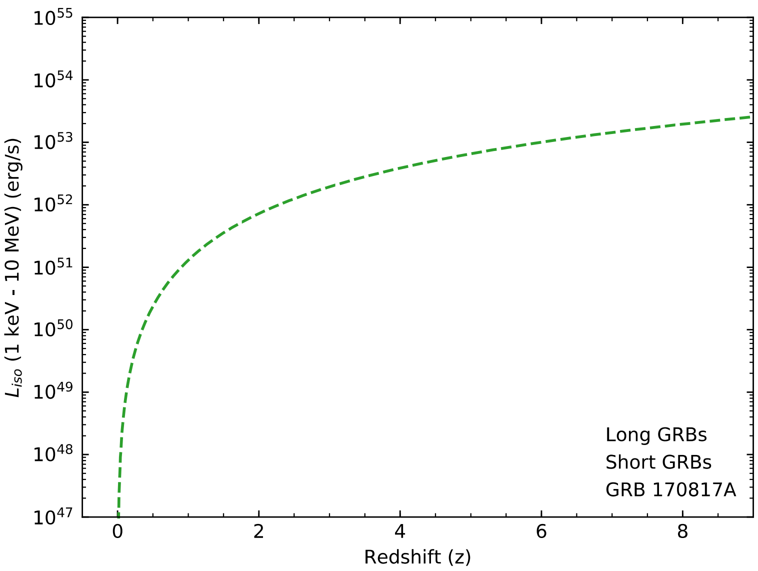
Chance temporal and spatial coincidence of GRB 170817A and GW170817: 1 in 20,000,000

A weak short GRB with a low-energy tail



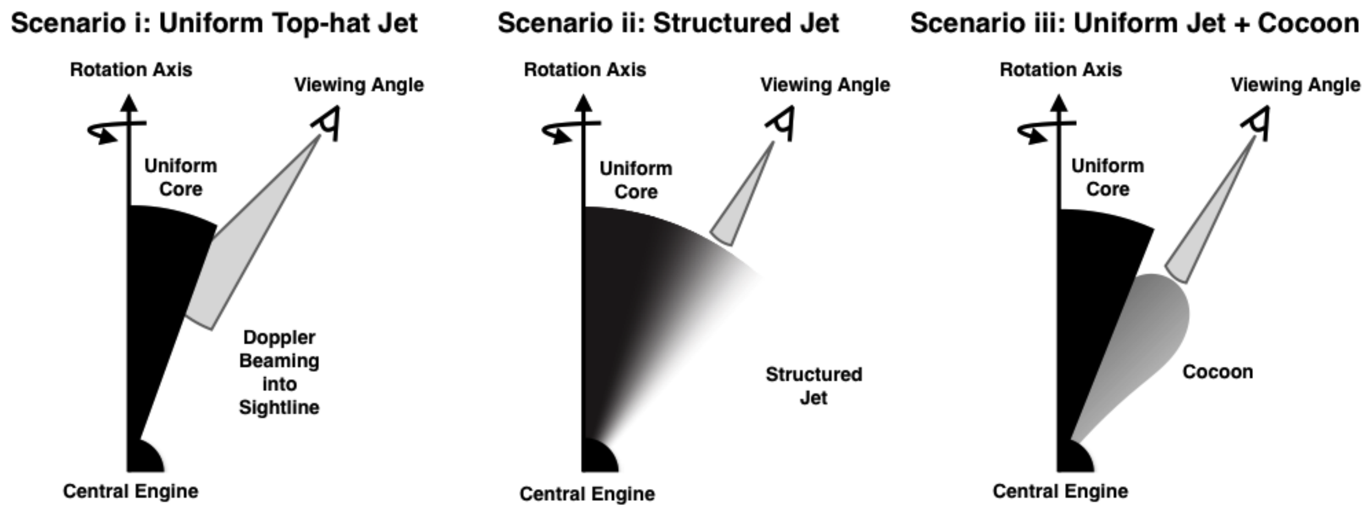


- GRB 170817A is a short GRB—predicted to originate from mergers
- It appears to have the traditional "spike" but also a weak lower-energy tail
- It appears intrinsically less luminous than any other GRB with measured distance



Goldstein et al. 2017, ApJ, 848, L14; Abbot et al. 2017, ApJ, 848, L13

GRB Observing Scenarios



Abbot et al. 2017, ApJ, 848, L13

- Simplest model is just a uniform Lorentz factor jet with sharp edges
- Possible that we are looking off the center of the jet, which does not have a uniform Lorentz factor
- For the low-energy emission after the initial GRB spike, there may be a "cocoon" of surrounding material that is pulled along by the interior jet

Science from the joint GW/GRB (Abbot et al. 2017, ApJ, 848, L13)

- Fundamental Physics:
  - Directly measure the speed of gravitational waves:
    - It is the speed of light to within one part in one quadrillion

      $$-3 \times 10^{-15} \leqslant \frac{\Delta v}{v_{\mathrm{EM}}} \leqslant +7 \times 10^{-16}.$$
  - Set Limits on Lorentz Invariance Violation
  - Test the Equivalence Principle (Shapiro delay)
  - Probe the Neutron Star Equation of State: the properties of the most highly compressed matter in the universe
- GRB Physics
  - Provide a unique view into the emission physics of relativistic jets and the engine that produces the short GRB jet
  - Estimate the rate of these events throughout the universe
  - First direct evidence for cocoon emission

Characteristics of GRB 170817A

- Nearby
- No immediate X-ray afterglow
- Slightly softer than typical short GRB
- Possibly off-axis
- Blackbody emission during/after the initial peak
- Likely a population of nearby weak events.
- How does this impact future missions?

Implications for current & future missions

- Need Sky coverage – in LEO, observing fraction is ~60%
- All Sky Monitoring
  - GRBs/GW come from any direction
  - Pointed observations require considerable resource allocation
    - To repoint quickly and to monitor for several days
  - GBM would have seen this event if it was twice as far away (optimal conditions)
  - Predict GBM GRB/GW 0.1-1.4/yr during LV03 and 0.3-1.7/yr at design sensitivity
- Energy coverage well above 50 keV
  - GRB was >5 sigma (10 -1000 keV), only ~3 sigma (8-50 keV)
  - 25% of Swift SGRBs have no detected X-ray afterglow
- Localization capability
  - To confirm spatial coincidence and to improve localizations in cases of 1-2 interferometers observing a GW event.

Current and Future Missions

- Near term: Keep Fermi, Swift, and INTEGRAL going as long as possible
- Medium term:
  - SmallSAT ideas – BurstCube has been approved, several others being proposed or considered (e.g. MoonBEAM)
  - ISS TAO – Mission of opportunity on space station in phase A.
- Longer term:
  - THESEUS – Proposed ESA M5
  - AMEGO – Probe class - use shield and calorimeter as GRB detectors
  - TAP – Transient Astrophysics Probe – includes GBM-like detectors
  - STROBE-X – Probe class – WFM instrument
  - Multiple Smallsats

Conclusions

- Current and (most) proposed instruments are limited by a gamma-ray detection horizon for weak SGRBs that is closer than LIGO/VIRGO design sensitivity
- Need a large area dedicated all-sky monitor
- Possible solution – GBM/BATSE-like w/ larger effective area, all-sky coverage, hard bandwidth, quick downlink, not in LEO

GRB 170817A publications

OPEN ACCESS

Multi-messenger Observations of a Binary Neutron Star Merger

B. P. Abbott *et al.* 2017 *ApJL* **848** L12

+ View abstract View article PDF

OPEN ACCESS

Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A

B. P. Abbott *et al.* 2017 *ApJL* **848** L13

+ View abstract View article PDF

An Ordinary Short Gamma-Ray Burst with Extraordinary Implications: *Fermi*-GBM Detection of GRB 170817A

A. Goldstein *et al.* 2017 *ApJL* **848** L14

+ View abstract View article PDF

INTEGRAL Detection of the First Prompt Gamma-Ray Signal Coincident with the Gravitational-wave Event GW170817

V. Savchenko *et al.* 2017 *ApJL* **848** L15