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Laser Interferometer Gravitational-Wave Observatory
A Proposal to NASA for a Burst Monitor (GBM) for the GLAST Mission

Volume I.
Science Investigation and Technical Description

Version 2
March 20, 2000

Submitted by
Space Science Department
Science Directorate
Marshall Space Flight Center
Alabama 35812
Large Area Telescope
Gamma-ray Burst Monitor

NaI Detector
8 keV-1 MeV

BGO Detector
200 keV-40 MeV
Incoming Gamma-ray

Scintillation Crystal

Gamma-ray absorbed; light emitted

Photomultipliers detect light
6222 Fermi GBM triggers

2238 GRBs

1176 Solar Flares

668 Others, including 189 from Swift J0243.6+6124 and 169 from V404 Cyg; 1041 particles

275 Magnetars

875 TGFs
GBM Triggered GRBs

2218 GBM GRBs
293 Swift GRBs
139 LAT GRBs
Types of GRBs

Long GRBs
- 200 per year triggered with GBM

Short GRBs
- 40 per year triggered with GBM
- >80 per year found in searches for weak GRBs
GRB 170817A: a short GRB

- GRB 170817A is a short GRB—predicted to originate from mergers
GRB 170817A:
A short GRB with a weak low-energy tail

traditional “spike” but also a weak lower-energy tail

GRB 170817A: Faintest GRB with known distance
80 weak short GRBs per year
GBM could see GRB 170817A twice as far away
Expect to see about \(~1\) coincident event per year when LIGO/Virgo reaches design sensitivity

Other weak short GRBs in GBM data
Counterpart to a Black hole merger?
gamma rays
Gamma-Ray Bursts
Example Spectrum

[Graph showing a spectrum with different energy flux measurements for various satellite missions, including BATSE SD0, BATSE SD1, BATSE LAD0, BATSE SD4, OSSE, COMPTEL Telescope, COMPTEL Burst Mode, and EGRET TASC. The x-axis represents Photon Energy (MeV) and the y-axis represents Flux (photons cm$^{-2}$ s$^{-1}$ MeV$^{-1}$). The graph is labeled GRB 990123.]
Example Time History
Where & When
Duration Distribution

 BATSE 4B Catalog

NUMBER OF BURSTS

T_{90} (seconds)
No Milky Way band:

- GRBs farther away than our Galaxy
- Extremely high energies
- Due to energy and source size (from variability), gamma rays should self absorb, but …
Solution: Relativistic Jet
Two origins?
Hubble images of host galaxies of long GRBs (Andrew Fruchter, STScI)
Long GRBs: Collapsar: Jet Breakout

simulation: Woosley and Zhang, Lawrence Berkeley Laboratory
Short GRBs: Merger of Binary Neutron Stars
Questions

Are there more than two origins for GRBs?

The rate of GRBs varies with cosmic distance (age) and heavy element abundance. How common (rare) are GRBs near to us?
Questions

Can we fully explain the spectra of GRBs?

Especially for short GRBs: what are the opening angles of the jet beams? And thus, what are their true energies?
Lightcurve from *Fermi/GBM* (10 – 50 keV)

Lightcurve from *Fermi/GBM* (50 – 300 keV)

Gravitational-wave time-frequency map

Merger  GRB start

Time from merger (s)

Frequency (Hz)
GCN/FERMI NOTICE

NOTICE_DATE: Thu 17 Aug 17 12:41:20 UT
NOTICE_TYPE: Fermi-GBM Alert
RECORD_NUM: 1
TRIGGER_NUM: 524666471
GRB_DATE: 17982 TJD; 229 DOY; 17/08/17
GRB_TIME: 45666.47 SOD {12:41:06.47} UT
TRIGGER_SIGNIF: 4.8 [sigma]
TRIGGER_DUR: 0.256 [sec]
E_RANGE: 3-4 [chan] 47-291 [keV]
ALGORITHM: 8
DETECTORS: 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0
LC_URL:
COMMENTS: Fermi-GBM Trigger Alert.
COMMENTS: This trigger occurred at longitude, latitude = 321.53, 3.90 [deg].
COMMENTS: The LC_URL file will not be created until ~15 min after the trigger.

https://gcn.gsfc.nasa.gov/other/524666471.fermi
Automated On-ground Localization and classification

First On-board Localization and classification

T0+27 s

T0+40 s
LIGO Report on GW Trigger
Coincident with GRB

Subject: [gbm+ligo] WAKE UP
Date: Thu, 17 Aug 2017 13:23:13 +0000
From: Littenberg, Tyson B. (MSFC-ST12)
To: GBM+LIGO

ivo://nasa.gsfc.gcn/Fermi#GBM_Gnd_Pos_2017-08-17T12:41:06.47_524666471_57-431

this morning’s GBM trigger has a friend….
T0+77 min

Lightcurve from *Fermi*/GBM (10 – 50 keV) 

Lightcurve from *Fermi*/GBM (50 – 300 keV) 

Lightcurve from INTEGRAL/ SPI-ACS (> 100 keV)
T0+5 hr
T0+7 hr

TITLE: GCN CIRCULAR
NUMBER: 21520
SUBJECT: GRB 170817A: Fermi GBM detection
DATE: 17/08/17 20:00:07 GMT
FROM: Andreas von Kienlin at MPE <azk@mpe.mpg.de>
T0+11 hr
Overnight...
Get ready for something awesome!

We definitely just found a BNS within 2 seconds of a GRB.

WHAT. NO WAY. Which GRB?!!

Was it at 12:41 UTC time?

Today

Yessssss

Wait for the alert, we're just about to send it.

AHHHHH. I am freaking out right.

Ok

So are we, people literally can't stop rambling between each other.

Like my adviser was shaking too badly to start an alert process at first.
Focus on the Electromagnetic Counterpart of the Neutron Star Binary Merger GW170817

Multi-messenger Observations of a Binary Neutron Star Merger
B. P. Abbott et al. 2017 ApJL 848 L12
[View abstract] [View article] [PDF]

Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A
[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]
Low flux --> weak burst

Near median fluence
GW170817 / GRB 170817A
Upper Limits on Gamma-ray Flux

Table 4
3σ 24 hr Flux Upper Limits (Units of $10^{-9}$ erg s$^{-1}$ cm$^{-2}$) Over the HLV Map

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>12–27</td>
<td>0.84</td>
<td>2.06</td>
<td>1.31</td>
</tr>
<tr>
<td>27–50</td>
<td>0.93</td>
<td>2.28</td>
<td>1.42</td>
</tr>
<tr>
<td>50–100</td>
<td>1.58</td>
<td>3.95</td>
<td>2.37</td>
</tr>
<tr>
<td>100–300</td>
<td>3.34</td>
<td>8.73</td>
<td>5.14</td>
</tr>
<tr>
<td>300–500</td>
<td>7.29</td>
<td>20.6</td>
<td>11.4</td>
</tr>
<tr>
<td>12–100</td>
<td>1.45</td>
<td>1.80</td>
<td>1.59</td>
</tr>
</tbody>
</table>
TITLE: GCN CIRCULAR
NUMBER: 21505
SUBJECT: LIGO/Virgo G298048: Fermi GBM trigger 524666471/170817529:
LIGO/Virgo Identification of a possible gravitational-wave counterpart
DATE: 17/08/17 13:21:42 GMT
FROM: Reed Clasey Essick at MIT <ressick@mit.edu>

The LIGO Scientific Collaboration and the Virgo Collaboration report:

The online CBC pipeline (gstlal) has made a preliminary
identification of a GW candidate associated with the time
of Fermi GBM trigger 524666471/170817529 at gps time 1187008884.47
(Thu Aug 17 12:41:06 GMT 2017) with RA=186.62deg Dec=-48.84deg and an
error radius of 17.45deg.

The candidate is consistent with a neutron star binary coalescence with
False Alarm Rate of ~1/10,000 years.

An offline analysis is ongoing. Any significant updates will be provided
by a new Circular.

[GCN OPS NOTE(17aug17): Per author's request, the LIGO/VIRGO ID
was added to the beginning of the Subject-line.]
JOINT SUB-THRESHOLD SEARCHES

➤ On-call Burst Advocate

➤ Targeted search
JOINT SUB-THRESHOLD SEARCHES

➤ On-call Burst Advocate

➤ Targeted search

➤ Untargeted search
SO MANY QUESTIONS...

➤ How do we explain the soft tail of GRB 170817A?

➤ Do all short GRBs come ~2s later?

➤ How wide are GRB jets?

➤ Neutrinos?
Happy 10th, Fermi!@nasafermi