Short GRB from compact mergers: the role of *Fermi* GBM in the identification of advanced LIGO/Virgo detections.

V. Pelassa, V. Conaughton, M.S. Briggs, A. Goldstein, B.-B. Zhang, E. Burns (UAH) for the *Fermi* GBM team,
E. Troja (NASA/GSFC) for the *Swift* team

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

« Gamma-Ray Bursts in the multi-messenger era », Paris, June 19 2014

Outline

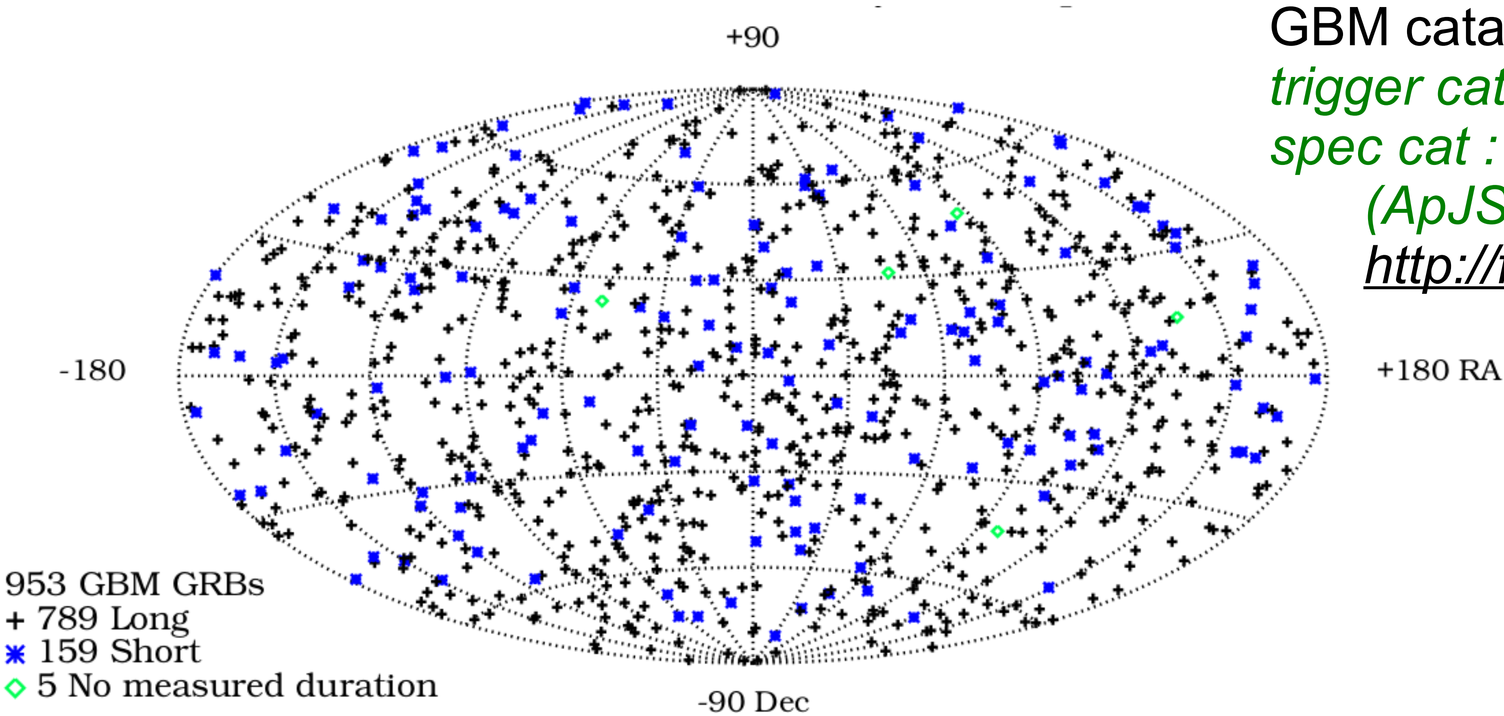
Short GRB observations

Short GRB from compact mergers : detection rate prediction

Increasing the short GRB detection rate through ground search

GBM GRB localization performance and follow-up

Fermi short GRB detections



GBM catalog (07/08 –07/12)
trigger cat : von Kienlin et al. 2014
spec cat : Gruber et al. 2014
(ApJS 211, articles 12 & 13)
http://fermi.gsfc.nasa.gov/ssc/

GBM (8keV – 40MeV) : ~240 GRB/yr, ~40/yr are short.
~1/2 GRB occur within the LAT FoV

LAT (20MeV – 300GeV) : ~10 GRB/yr, i.e. ~8% of GBM GRB located in the LAT FoV. 5 short GRB in 4yrs *(LAT GRB catalog, Ackermann et al ApJS 209:11, 2013)*

(see talks about Fermi GRB by F.Piron, S.Guiriec, L.Nava, H.F.Yu, ...)

Short GRB as seen by Fermi or Swift

Short GRB mostly associated to compact mergers (with a few collapsars).

Since the classification criterion (T90 < 2s) depends on an instrument's characteristics, different instruments could see very different populations : 40 % Swift (15 % of Fermi) sGRB could be collapsars *(Bromberg et al, 2012)*.

Analysis of sGRB populations observed by Swift and Fermi GBM *(see poster 22 by E. Burns et al) :*
→ Swift sGRB seen by Fermi are nearly all classified as short by GBM (22 out of 23)
→ offline search shows that both Swift and GBM detect most of the others' sGRB that are observable.

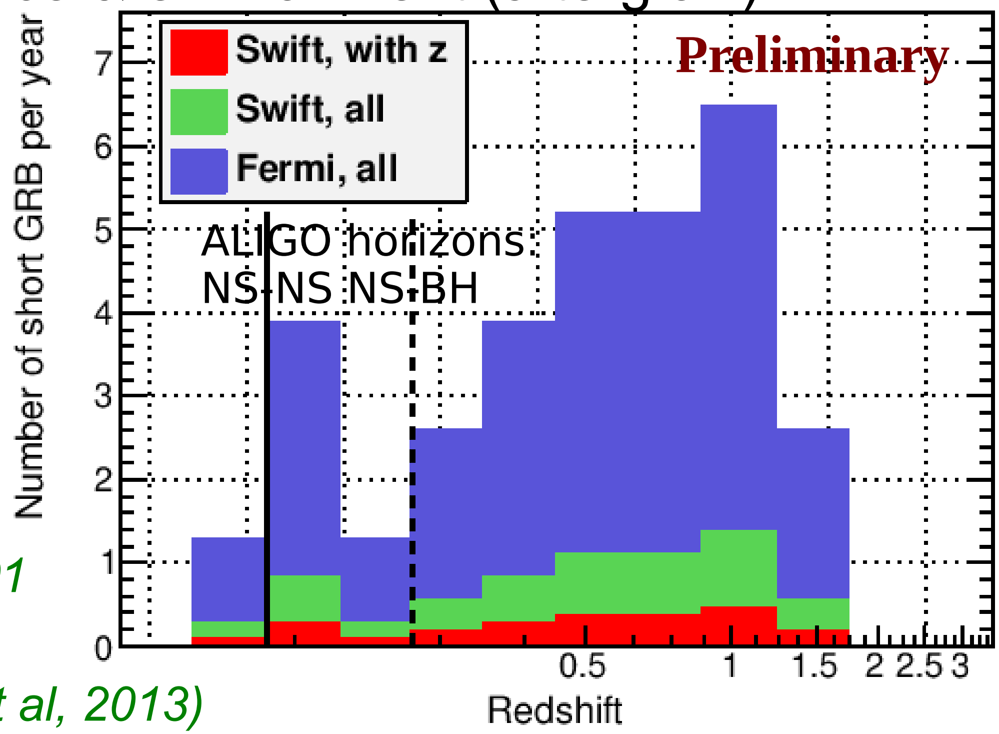
Swift and Fermi see the same population of short GRB, and ~80 % of them are likely mergers.

Search for compact mergers

Expected complementarity of Gravitational Wave (GW) and Electromagnetic (EM) observations of compact mergers :
GW → inspiral characteristics (mass, radial distance, inspiral rate)
EM → jet physics (prompt γ-ray) ; distance & environment (afterglow)

GBM short GRB within aLIGO horizons:
N(z<0.11) ~ 1.3 (+1 -0.6) /yr
N(z<0.22) ~ 6.5 (+8 -3.5) /yr

aLIGO horizons for face-on mergers :
z=0.11 (neutron star (NS) + NS)
z=0.22 (NS + black hole (BH) $10M_{Sun}$)
Abadie et al 2010, Class. Quant. Grav 27, 173001

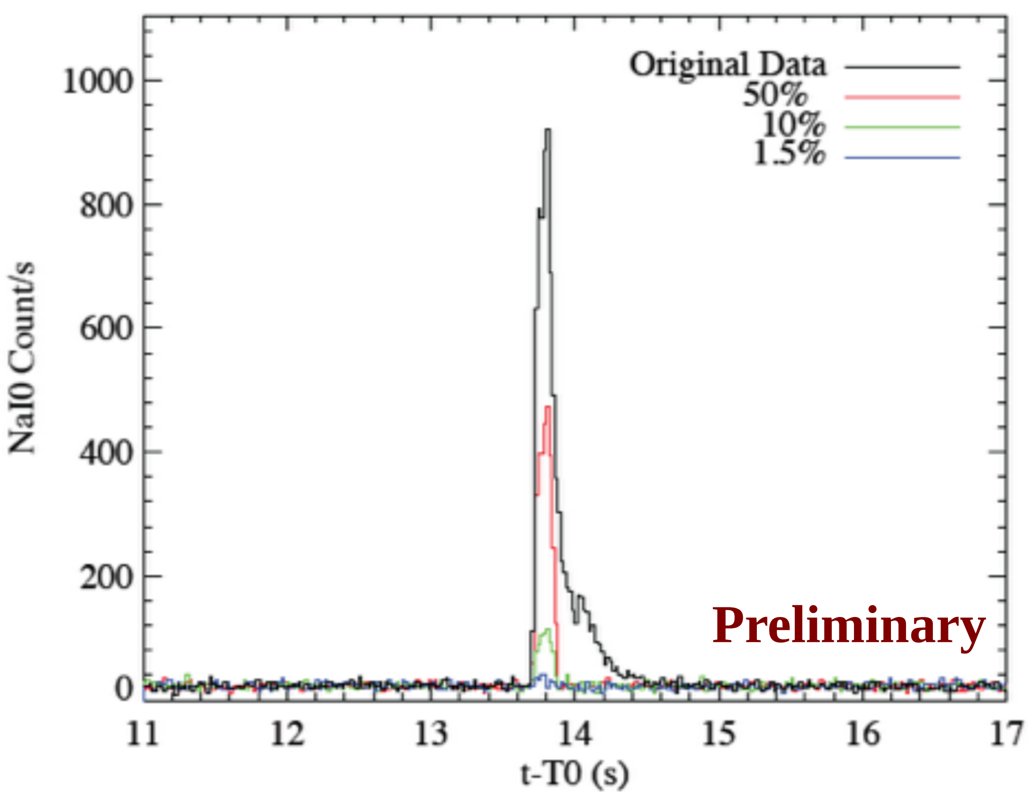


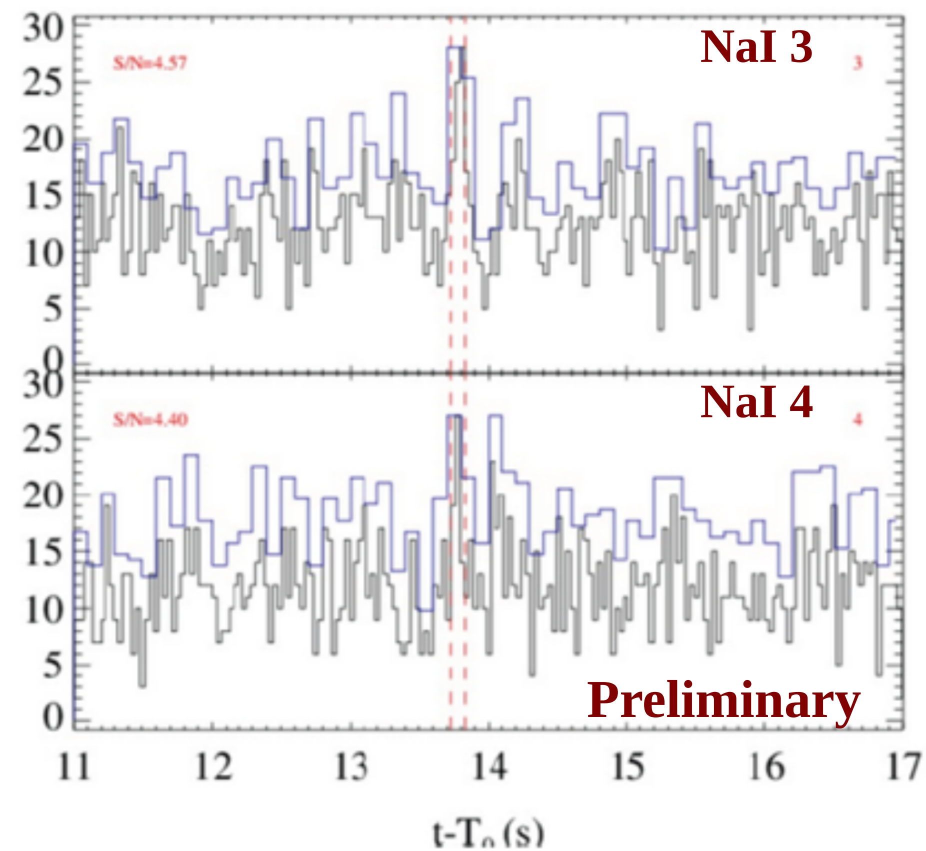
Consistent with other works *(e.g. Siellez et al, 2013)*

GBM and aLIGO should either see coincident GW and gamma-ray transients or rule out NS-BH mergers as the progenitors of sGRB.

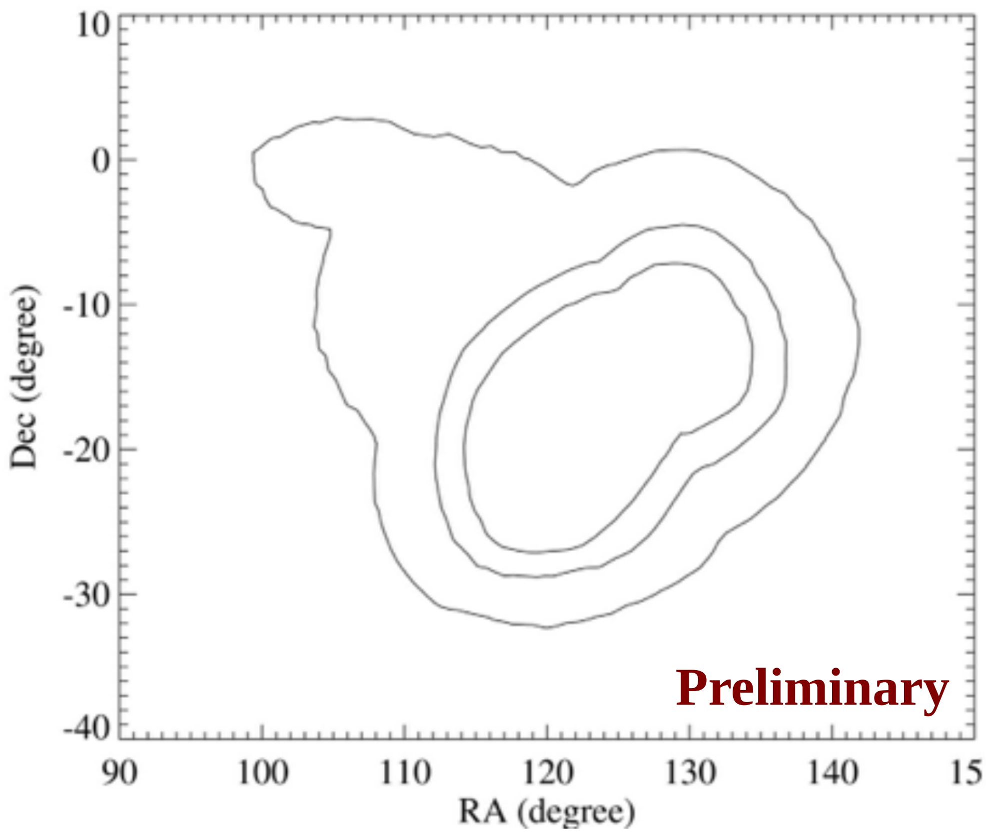
Fermi GBM offline search

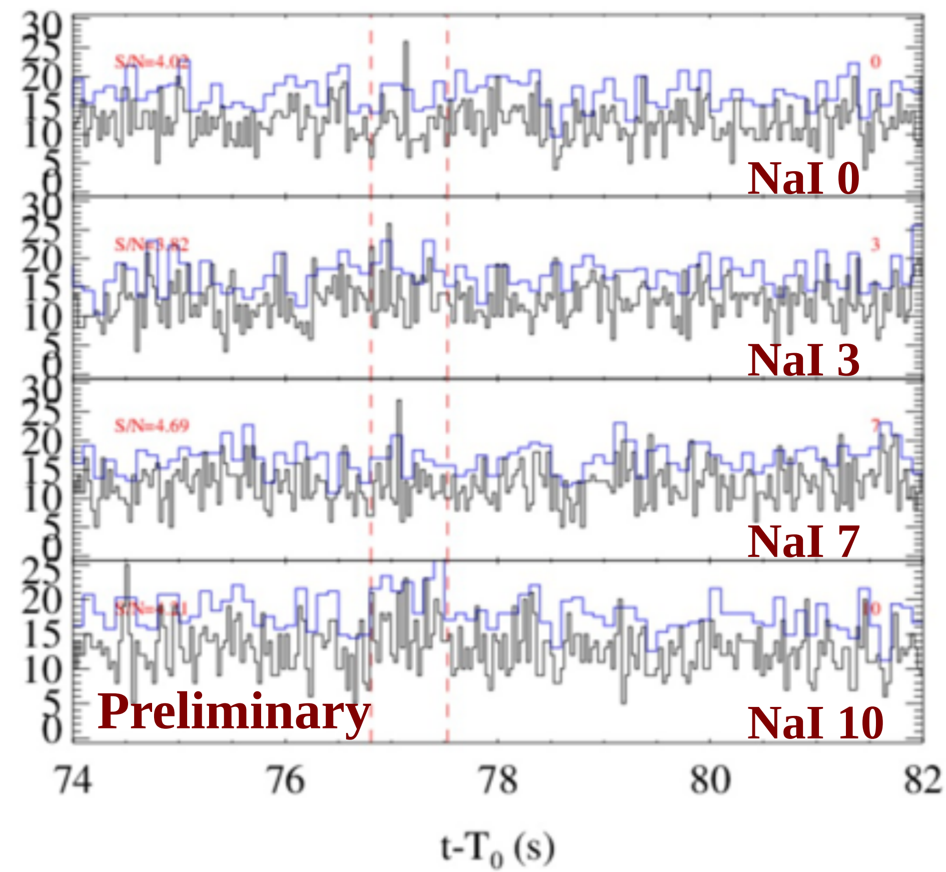
TTE (Time-Tagged Events) data recorded continuously since November 2012 (previously recorded over 350s windows upon on-board trigger).
→ enables offline search for undetected short transients
Improved sensitivity : sGRB can be found offline, which are 1/3 intensity of the weakest on-board detected sGRB *(Zhang B-B et al, in prep)*.





Fermi GBM offline search

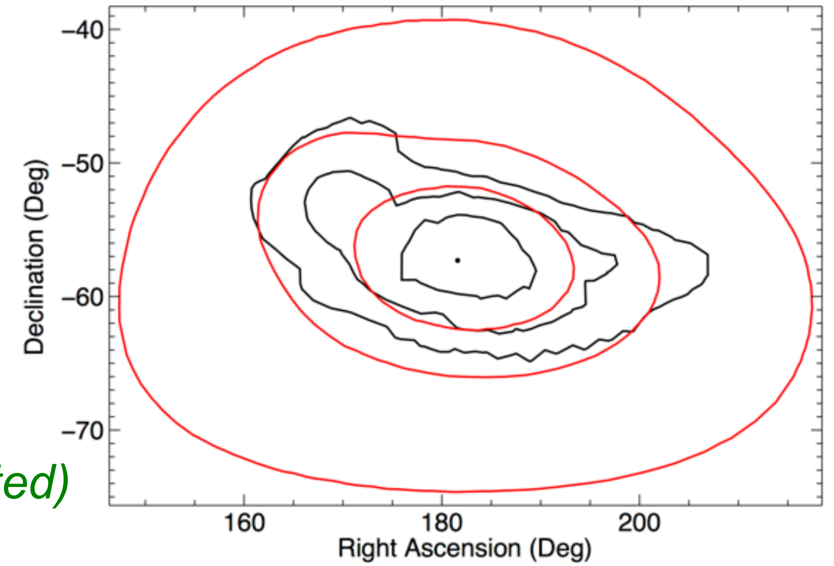




A short GRB candidate on Jan 24 2012.
Signal to noise ratio > 4.5 in only one detector (onboard trigger requires 2).
Statistical localization error radius : 8 degrees

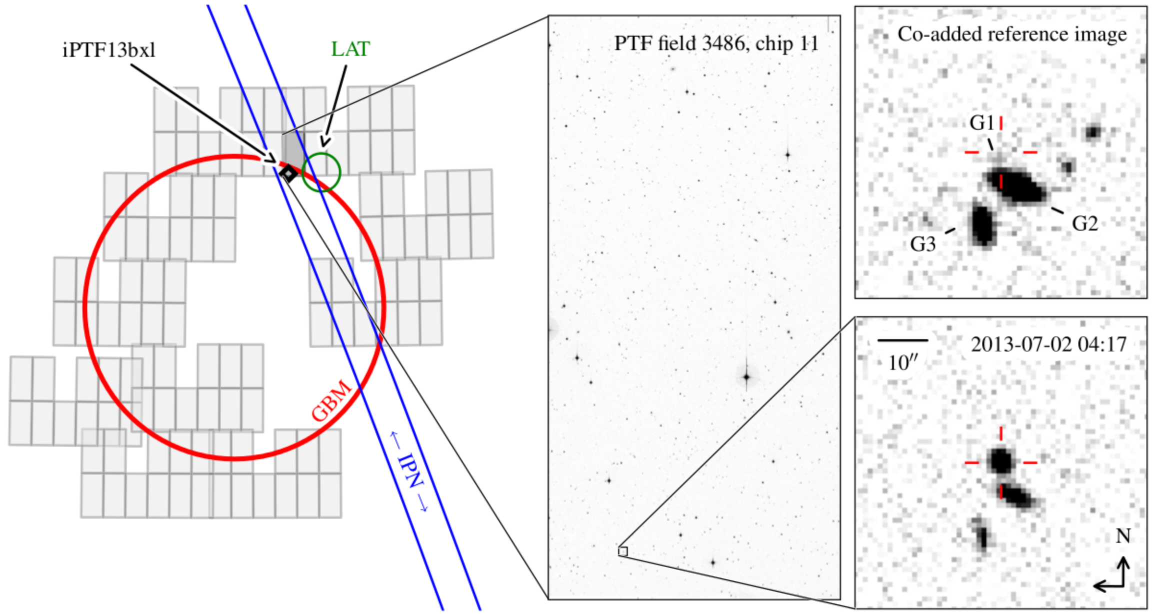
Follow-up of GBM localized GRB

GBM GRB localization accuracy
- Automated localization ~10 – 45s :
  - 1° – 26° (68 % stat)
- Human processed localization 30min – 2h :
  - 1° – 14° (68 % stat)
- Systematic errors :
  - 2° – 4° for 90 % GRBs
  - *(full characterisation : Connaughton et al, submitted)*



Facilitating follow-up :
- More accurate & reliable automated localizations (under work)
- Probability maps combining stat and syst errors now available at FSSC (since January 2014)
- Collaboration since June 2013 with intermediate Palomar Transient Factory (iPTF) on optical follow-ups.
- Additional interest from IPN, TAROT, RAPTOR, MASTER, aLIGO, IceCube...

Successful tiling observations (iPTF)



~30 follow-up. 5 afterglows found, leading multi-wavelength follow-up :
GRB 130702A *(Singer et al, ApJL 776 :34, 2013)* → z=0.145, supernova, radio AG

GRB 131011A *(Kasliwal et al, GCN 15324)* → z=1.874 *(Rau et al, GCN 15325)*
GRB 131231A *(Singer et al, GCN 15643)* → z=0.642 *(Xu et al, GCN 15645)*
GRB 140508A *(Singer et al, GCN 16225)* → radio AG *(Gorosabel et al, GCN 16227)*,
1.03<z<2.1 *(Moskvitin et al, GCN 16228, Malesani et al GCN 16229)*
GRB 140606B *(Singer et al, GCN 16225)* → z=0.384 *(Perley et al, GCN 16365)*

Summary

Fermi GBM detects ~45/yr short GRB (on-board), and a near-real time offline search will yield more localized short GRB.

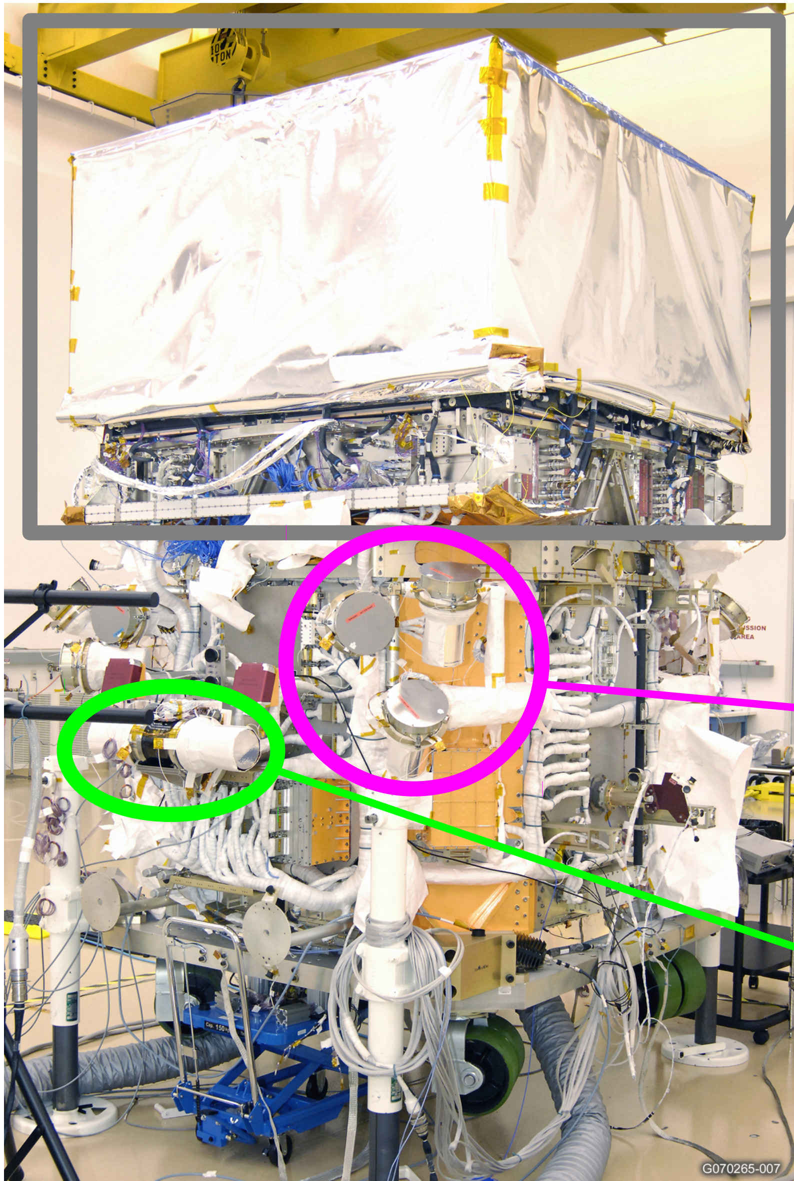
GBM and aLIGO should either see coincident GW and gamma-ray transients or rule out NS-BH mergers as the progenitors of sGRB :
~1.3 (+1 -0.6) NS-NS mergers/yr ~6.5 (+8 -3.5) NS-BH mergers/yr.

Follow-up of GBM-located GRBs facilitated by probability maps (68 %, 90 % and 99 % C.L. contours now available, detailed maps in preparation).

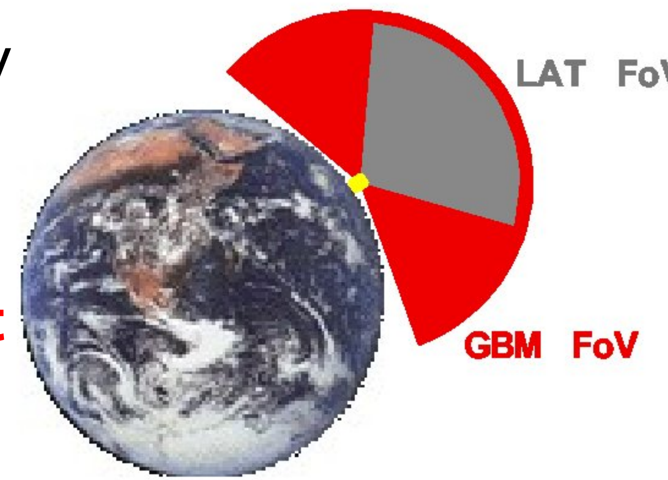
Several cases of successful tiling observations of (large) GBM error boxes by iPTF yielded multiple AG observations, redshift measurements.
And it is a good training for following up on the future (larger) aLIGO/AdvVirgo error boxes.

Thank you for your attention !

Fermi instruments



Large Area Telescope :
Pair conversion
Spectroscopy, timing, transients trigger & localization
20 MeV – 300 GeV
W. Atwood et al 2009, ApJ 697, 1071



Gamma-ray Burst Monitor : 14 PMT
12 NaI
Transients trigger & localization, timing, spectroscopy
8 keV – 1 MeV
2 BGO
Timing and spectroscopy
200 keV – 40 MeV
C. Meegan et al 2009, ApJ 702, 791