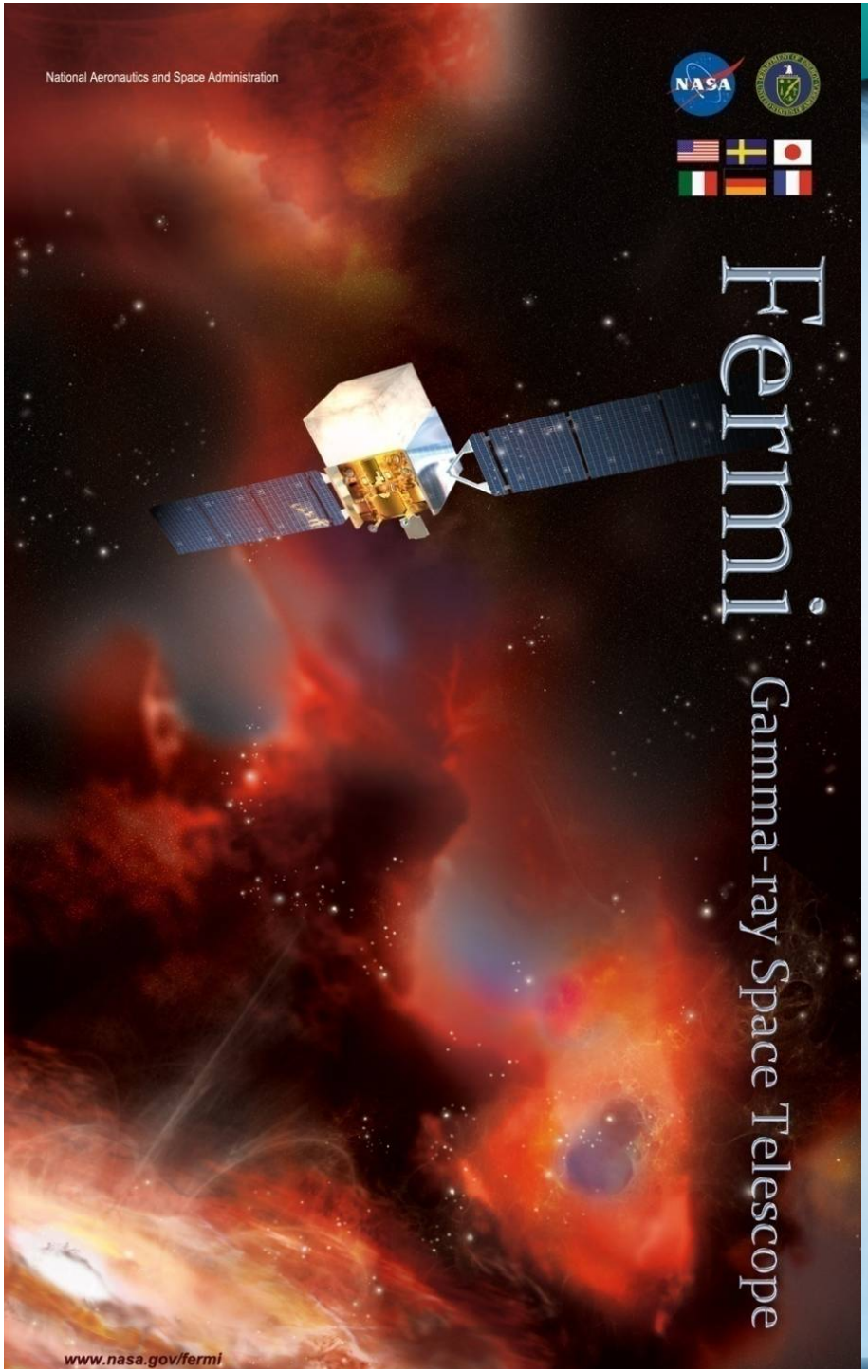
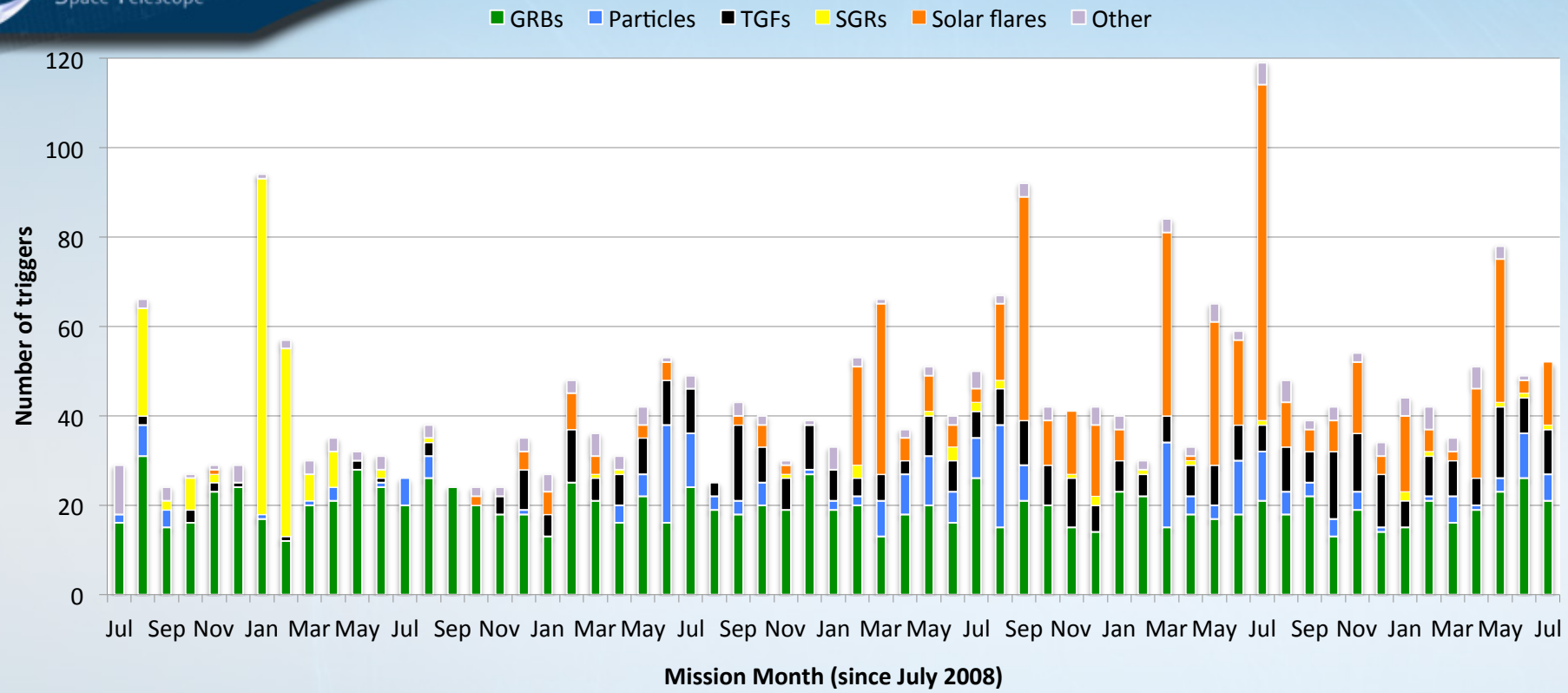


Fermi GBM Status, Results, Plans

Bill Paciesas
USRA/STI

Fermi Users Group
16 August 2013

GBM Trigger Rate



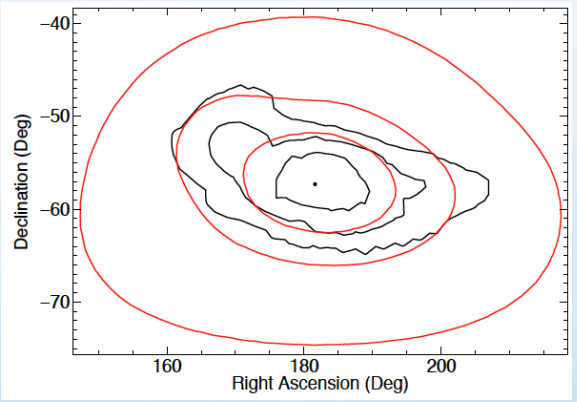
2730 triggers as of July 31, 2013 (excluding commanded)

- Gamma-ray bursts (GRBs): 1191 (two triggers were due to the same long GRB)
- Soft gamma repeaters (SGRs) aka magnetars: 195 (from 5 sources)
- Terrestrial gamma flashes (TGFs): 384 (at least 400 additional untriggered)
- Solar Flares: 538
- Others (particles, galactic XRBs, accidental, uncertain): 421

104 positive Autonomous Repoint Recommendations

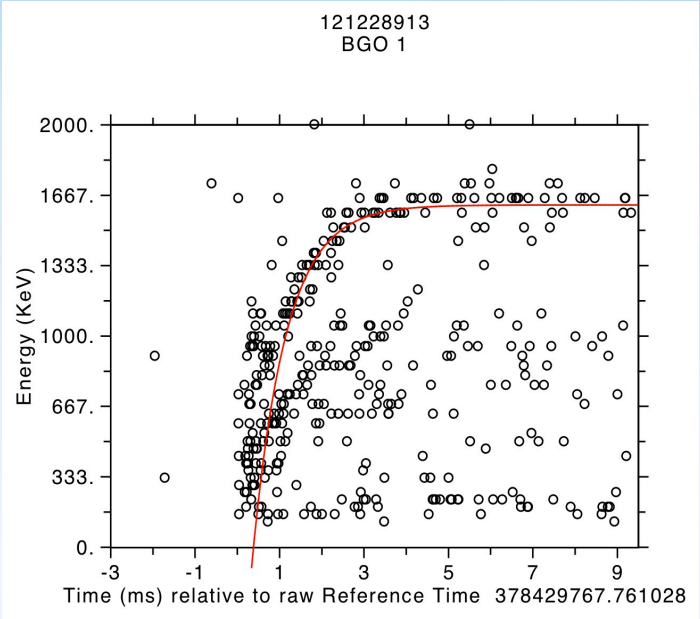
Operational Changes & Improvements

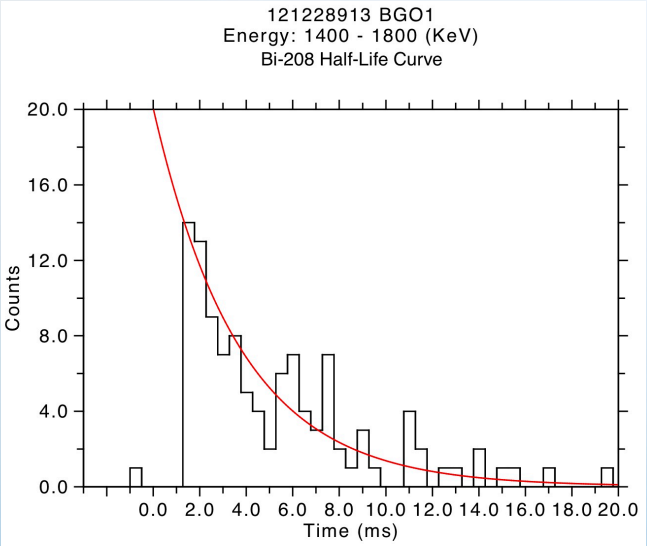
- Weekends & periods of high solar activity:
  - Disabled soft energy (22–50 keV) trigger algorithms
- Continuous TTE
  - FSW throttles back TTE data generation from solar-side NaI's in case of high solar activity
  - Has occurred 32 times since December 2012
  - Durations range from 26-3680 s (~0.3% of observing time)
- Software delivery: rmfit public release
  - GBM team standard spectral analysis package
  - Versions for Mac OS & Linux
  - http://fermi.gsfc.nasa.gov/ssc/data/analysis/rmfit/
- New data product: location contours
  - Distribute the χ^2 map convolved with an input systematic uncertainty model to return 1σ, 2σ, and 3σ contour maps for our localizations
  - Have general format & production process in place
  - Working on details with potential users
- Energy calibration
  - BGO spectral lines from cosmic ray activation
- High count-rate test
  - Lab tests with BGO EU and strong ^{137}Cs & ^{60}Co sources
  - planned later this month
- Konus cross-calibration
  - Awaiting more data from Konus

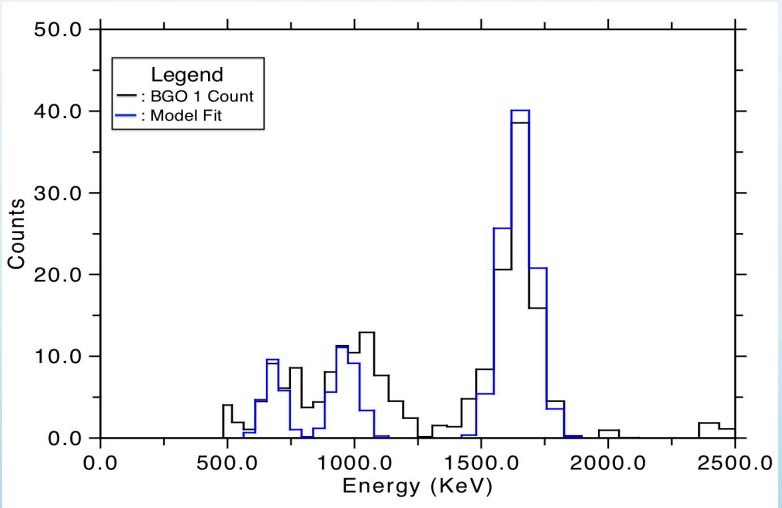


Energy calibration using cosmic rays

- Cosmic ray events that have struck a single detector allow us to check BGO calibration
- Multiple lines visible despite initial gain shift
- Spectral line @ ~1.7 MeV consistent with ^{208m}Bi decay
- Possible Production Mechanism: ^{209}Bi (p, d) → ^{208m}Bi
- Estimated gain correction ~4% (preliminary)







Burst Location Accuracy

Connaughton et al, in preparation

- Compared GBM locations with reference sample of 203 precisely localized GRBs
  - Ground-automated GBM localizations distributed as GCN notices within ~1 minute after the trigger time lie within 7.6°of the true location 68% of the time and within 17.2° 90% of the time.
  - For GRBs with small statistical localization uncertainties of 1°this improves to 2.9°and 7.9°for the 68% and 90% containment levels, respectively.
  - Localizations produced with human intervention distributed as Final Position GCN notices within a few hours after the trigger are within 5.3° and 10.1°of the true position for 68% and 90% of GRBs, respectively. For GRBs with statistical localization uncertainties of 1° the 68% and 90% containment radii are 3.4° and 5.8°, respectively.
  - The localization of short GRBs is poorer than long GRBs, with 68% localized within 8.7° of the true position and 90% within 16.1° when humans are involved. In the automated ground process, these numbers are 10.5° and 26.5°.
- Used a Bayesian analysis to compare GBM locations with reference sample plus ~100 IPN annuli
  - For localizations produced with human intervention, the distribution of systematic uncertainties is well represented (68% confidence level) by a 3.7°Gaussian with a non-Gaussian tail that contains ~10% of GBM-detected GRBs and extends to ~14°.
  - For ground-automated localizations, the core has a similar extent but the tail contains ~20% of the bursts.
  - Some dependence of the systematic uncertainty on the position of the GRB in spacecraft coordinates: GRBs in the quadrants on the Y-axis better localized than those on the X-axis
- Potential areas for improvement
  - Implement fluence localizations for ground automated notices
  - Explore inaccuracies in spacecraft mass model to explain dependence on spacecraft coordinates
  - Distribute error contour data product within a few hours

GBM Team Science Activity

- Papers in refereed journals (since Jan 2013)
  - Terrestrial Gamma-ray Flashes in the Fermi Era: Improved Observations and Analysis Methods (JGR)
  - Analytical modeling of pulse-pileup distortion using the true pulse shape; application to Fermi-GBM (NIM)
  - Anomalies in low-energy Gamma-Ray Burst spectra with the Fermi Gamma-Ray Burst Monitor (A&A)
  - The Interplanetary Network Supplement to the Fermi GBM Catalog of Cosmic Gamma-Ray Bursts (ApJS)
  - Long term variability of Cygnus X-1. V. State definitions with all sky monitors (A&A)
  - Radio signals from electron beams in terrestrial gamma ray flashes (JGR)
  - IACT observations of gamma-ray bursts: prospects for the Cherenkov Telescope Array (ExA)
  - Interplanetary Network Localizations of Konus Short Gamma-Ray Bursts (ApJS)
  - Evidence for a Photospheric Component in the Prompt Emission of the Short GRB 120323A and Its Effects on the GRB Hardness-Luminosity Relation (ApJ)
  - Quasi-periodic Oscillations and Broadband Variability in Short Magnetar Bursts (ApJ)
  - Multiwavelength Observations of GRB 110731A: GeV Emission from Onset to Afterglow (ApJ)
- Papers in press or submitted
  - Pulse Properties of Terrestrial Gamma-ray Flashes detected by the Fermi Gamma-ray Burst Monitor (JGR)
  - Time-resolved Analysis of Fermi GRBs with Fast and Slow-Cooled Synchrotron Photon Models (ApJ)
  - Fluence Distribution of Terrestrial Gamma-ray Flashes Observed by the Fermi Gamma-ray Burst Monitor (JGR)
  - The First Pulse of the Extremely Bright GRB 130427A: A Test Lab for Synchrotron Shocks (Science)
  - Fermi LAT Observations of the Extraordinary Gamma-ray Burst GRB 130427A (Science)
  - The Bright Optical Flash and Afterglow from the Extraordinary Gamma-Ray Burst GRB 130427A (Science)

GBM Team Science Activity

- Conferences with presentations
  - AAS Heineman Prize Lecture: C. Kouveliotou (Long Beach)
  - Fermi-LIGO Workshop (DC)
  - AAS HEAD meeting (Monterey)
  - 7th Huntsville GRB Symposium (Nashville)
  - MORIOND : Very High Energy Phenomena in the Universe (La Thuile, Italy)
  - Multi-Messenger Transient Astrophysics Workshop (Beijing)
  - 4th Fermi Asian Network Workshop (Hong Kong)
  - Explosive Transients: Lighthouses of the Universe (upcoming Santorini, Greece)
- Papers for near-term submission
  - Localization of Gamma-Ray Bursts using the Fermi Gamma-Ray Burst Monitor
  - The 2nd Fermi GBM Gamma-Ray Burst Catalog: The First Four Years
  - The Fermi GBM Gamma-ray Burst Spectral Catalog: Four Years Of Data
  - A New Correlation between Thermal and Non-Thermal Emission in Gamma-Ray Bursts
  - The 5-year GBM magnetar Catalog
  - Time-resolved spectroscopy of SGR J1550-5418 bursts
  - Insight into the prompt emission period with simultaneous *γ*-ray/NIR wavelength observations of *γ*-ray burst 121217A
- Upcoming press activity
  - GRB 130427A media briefing (~September)

GBM Magnetar Team Update

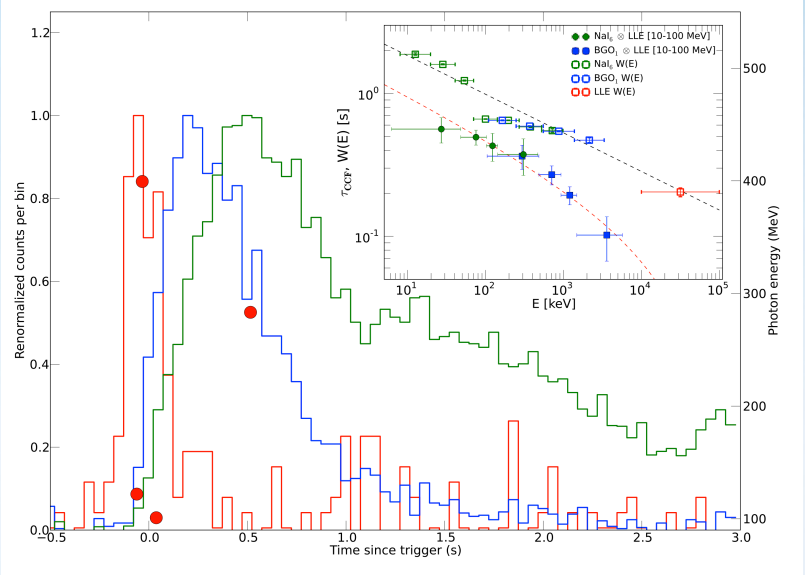
C. Kouveliotou

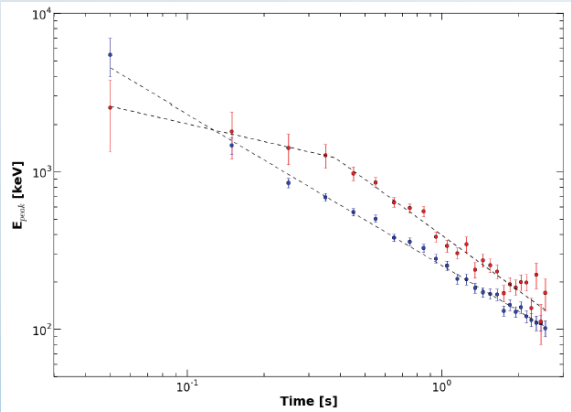
- The GBM Magnetar team has produced thus far 12 papers in refereed publications (since launch). The team is working on the next level of the data interpretation, namely:
  - theoretical models
  - the GBM magnetar catalog after the first 5-years of the mission,
  - searches of untriggered magnetar bursts,
  - comprehensive searches for quasi-periodic oscillations in magnetar bursts,
  - comparisons of spectral and temporal properties of magnetars across several sources,
  - correlative studies between GBM and NuSTAR data,
  - correlative studies between GBM and LOFAR, MWA data
- Near-term:
  - The final paper in the series of burst spectroscopy of SGR J1550-5418 to be submitted by the end of August: time-resolved spectroscopy on 60 bursts. The 2BB fits reveal two well-separated emitting regions interpreted as an adiabatically expanding region (hot BB) and emission from the outer layer of a fireball (cold BB).
  - The GBM 5-year magnetar catalog to be submitted by the end of September. All SGR-like bursts detected with GBM from known and unknown sources and their properties are listed, compared and discussed.
  - A comprehensive paper on the comparison of properties across different magnetars mostly geared towards theoretical interpretation

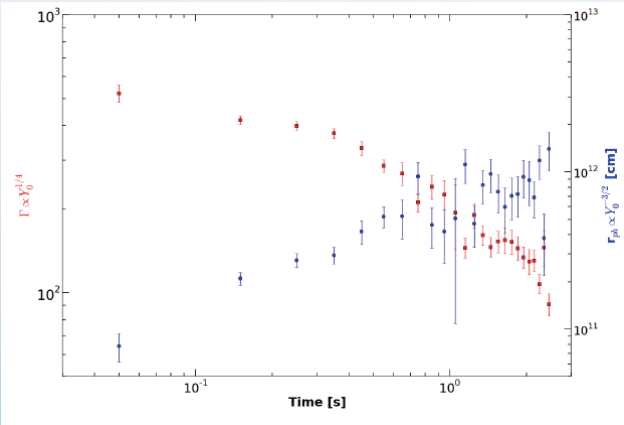
GRB 130427A

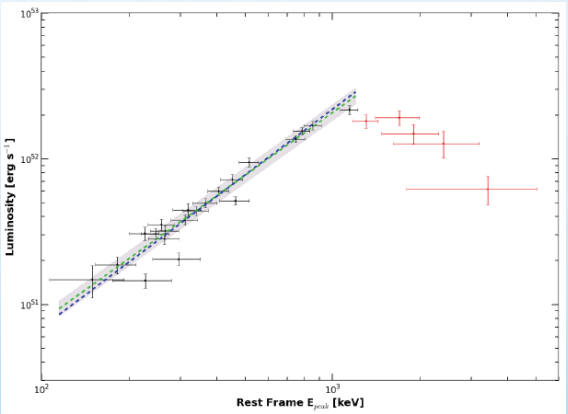
Preece et al, Science submitted

- Brightest GRB in more than 20 years
  - GBM had severe pulse pile-up during main emission episode (4.5 – 11.5 s post-trigger)
  - First pulse (< 2.5 s) was not piled-up but still among the brightest few GBM bursts
- Spectral evolution on minimum variability timescale using physical model: synchrotron plus blackbody
  - Peak energy evolves as power-law, consistent with internal synchrotron shocks
  - Correlation between rest-frame peak energy and isotropic luminosity is inconsistent with curvature effects in relativistic outflow







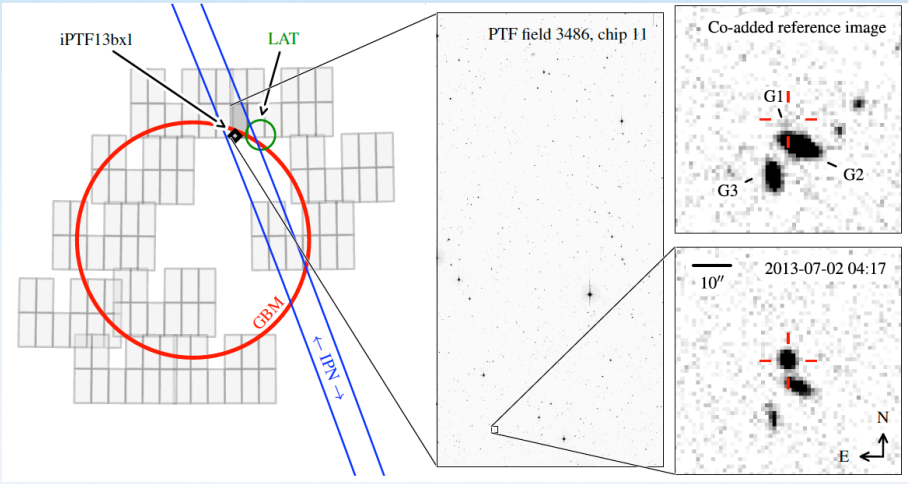


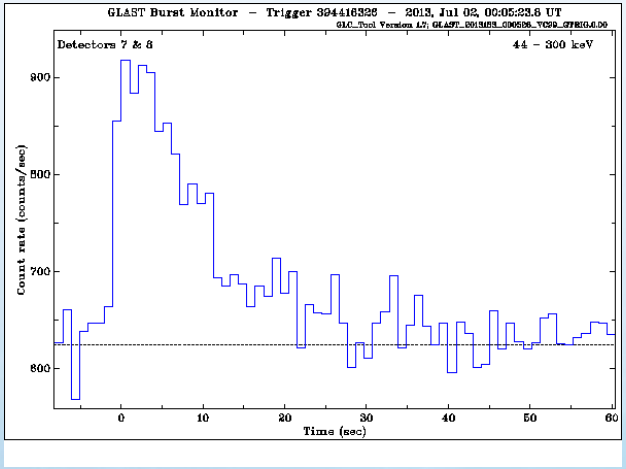
Other GBM-Related Papers

- On the Correlation of Low-Energy Spectral Indices and Redshifts of Gamma-Ray Bursts (ApJ)
- Short Versus Long and Collapsars Versus Non-Collapsars: A Quantitative Classification of Gamma-Ray Bursts (ApJ)
- Minimum variability time-scales of long and short GRBs (MNRAS)
- Average power density spectrum of long GRBs detected with BeppoSAX/GRBM and with Fermi/GBM (MNRAS)
- Diffuse PeV Neutrinos from Gamma-Ray Bursts (ApJ)
- Prompt thermal emission in gamma-ray bursts (A&A)
- GRB 090227B: The Missing Link between the Genuine Short and Long Gamma-Ray Bursts (ApJ)
- Cosmology with Gamma-Ray Bursts: status and perspective (AstRv)
- Photospheric emission throughout GRB 100507 detected by Fermi (MNRAS)
- Two distinct phases in the first 13 seconds of GRB110731A prompt emission (Ap&SS)
- The average GeV-band emission from gamma-ray bursts (A&A)
- Discovery and redshift of an optical afterglow in 71 square degrees iPTF13bxl and GRB 130702A (ApJ submitted)
- An Anti-Glitch in a Magnetar (Nature)

GRB 130702A

- First afterglow discovered solely based on a GBM localization (Singer et al, ApJ submitted)
- Confirmed by Swift XRT, CARMA, VLA
- Redshift $z = 0.145$
- $E_{iso} = 2.4 \times 10^{50}$ erg
- Associated Type Ic supernova
- GBM light curve looks relatively ordinary





Multi-wavelength Initiative

- Encourage collaborative studies using GBM Earth occultation monitoring
  - Facilitated by Dave Thompson
- Five contacts so far
  - H. Steinle (MPE)
    - Potential use of GBM as high-energy trigger for Cen A flaring?
  - O. Kargaltsev (U Florida):
    - Non-accreting pulsars
    - Referred him to Bhat/Finger
  - A. Vovach (Crimean Astrophysical Observatory)
    - Correlative studies with Simeiz 22-M radio telescope
  - A. Sadun (U Colorado)
    - Provide optical monitoring of Mrk 421, possibly other sources
  - Gopal Bhatta (Jagiellonian U, Poland)
    - Interested in blazar micro-variability
    - GBM has limited sensitivity

Summary & Near-term Plans

- GBM operations and performance are nominal
  - Full-time untriggered TTE data collection proceeding smoothly
- No significant operational changes planned for next few months
- Work on validating energy calibration & understanding high-rate behavior
- GRB localization
  - Characterization of systematic errors
  - Distribution of location contours
  - GRB 130702A: PTF discovery of optical afterglow using GBM localization
- Science results continue
  - GRB 130427A
  - GRB & SGR catalogs
  - GRB multi-component spectral analysis, GRB theoretical model fitting, TGF/lightning, magnetars, etc.
- Multi-messenger/multi-wavelength coordination
  - LIGO, CTA, LOFAR, etc