Fermi GBM Observations of Terrestrial Gamma-ray Flashes


Photo Credit: NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory (NSSL)
Fermi Gamma-ray Burst Monitor

- **Fermi**
  - Launched June 11, 2008
  - 565 km orbit
  - 26.5 deg inclination

- **GBM**
  - 12 NaI detectors
    - 8keV - 1 MeV
  - 2 BGO detectors
    - 150 keV - 40 MeV

- **Triggers**
  - BGO triggers for TGFs
  - Implemented Nov 2009
  - 87 TGF triggers as Aug 27
  - TGF trigger every ~4 days
Lightning & GBM TGF Maps

- Which comes first, lightning or TGF?
- Does one cause the other?
- Or do they have a common cause?
- Do they have a consistent time order?

"Associations between Fermi GBM Terrestrial Gamma-ray Flashes and sferics from the WWLLN", V. Connaughton, et al, JGR in press.
WWLLN

- World-Wide Lightning Location Network.
- 10% of lightning worldwide, 30% lightning with peak current > 30 kA.

- Timing accuracy (with 5+ stations) 30 μs, geolocation ~ 10 km.
- No information on lightning type, discharge size, shape.
- [http://wwlln.net](http://wwlln.net) headed by Bob Holzworth.
Detection distance

• In first 50 GBM TGFs (July 2008-March 2010)
  – 30% of GBM gamma-ray TGFs have a match with individual sferic within 5 ms of TGF peak and 1000 km of sub-spacecraft position.
  – Blind searches reveal the false positive rate is very small (1-7 per 1000).
• All 15 matched sferics are within 300 km of sub-spacecraft point.

- **Red** - Fermi sub-spacecraft location with a 300 km radius
- **Green** - WWLLN lightning strokes within 10 minute of the GBM trigger time
- **Blue Square** – Exact match – sferic within 5ms and 300 km
TGF-lightning are Simultaneous!

- GBM light curves corrected for light travel time and clock drift (histogram)
- WWLLN stroke time and uncertainty band (dotted vertical bar)
• Peak times of simultaneous TGFs and sferics agree to within ~40 μs.
• No indication of preferred order.
• Two exceptions (not shown)
  • Within 5ms and 300km, but occur ms before or after the TGF peak.
  • Likely explanation: TGF and sferic are associated with the same storm but not with each other.
Storms ... almost always!

- In absence of sferic matches, (almost) always have storms within 300 km of sub-spacecraft position.
- Suggests 30 deg opening angle (including scattering) for detection from gamma-ray TGFs.
No coincidence - no storm

- In 3 of 4 cases with no storm under spacecraft, storm activity at one of the geomagnetic footprints. All 4 cases look like electron TGFs.
Electron TGFs with GBM

- 4 seen to date with GBM
- Long duration (> 1ms)
  - Electrons with low pitch angles arrive at spacecraft first
- Low maximum energy ≈ 10 MeV
- Lightning activity within 50 km of magnetic footprint.
Sferic with Electron TGF!

Cohen et al. 2010, to appear in GRL.
Positron Features Detected with GBM

- Spectra fitted by separately simulating electrons and positrons along the field lines.
- Fits require both electron and positron components
- Exponential continuum spectrum with Ecutoff=2-4 MeV.

TGF 080807  TGF 090813  TGF 091214
Summary

• TGFs and lightning are simultaneous with no preferred order.
• This supports lightning leader models for TGFs.
• GBM detects gamma-ray TGFs within 300 km of Fermi’s sub-spacecraft location.
• GBM detected electron TGFs within ~50 km of geomagnetic footprint.
• Positron features detected with GBM from electron TGFs are direct evidence for relativistic phenomena in Terrestrial lightning.
GBM TGF Papers

- “First Results on Terrestrial Gamma-ray Flashes from the Fermi Gamma-ray Burst Monitor”, M. S. Briggs, et al., J. Geophysical Res., in press,

- “Associations between Fermi GBM Terrestrial Gamma-ray Flashes and sferics from the WWLLN”, V. Connaughton, et al., to appear in JGR,

- “Catalog of Terrestrial Gamma-ray Flashes from the Gamma-ray Burst Monitor on the Fermi Observatory”, G. J. Fishman, in preparation,

- “Positrons observed from Terrestrial Lightning with Fermi GBM”, M. S. Briggs, et al., in preparation,

http://gammaray.nsstc.nasa.gov/publications/tdgjournal.html