Terrestrial Gamma-ray Flashes (TGFs): Nearby Particle Acceleration

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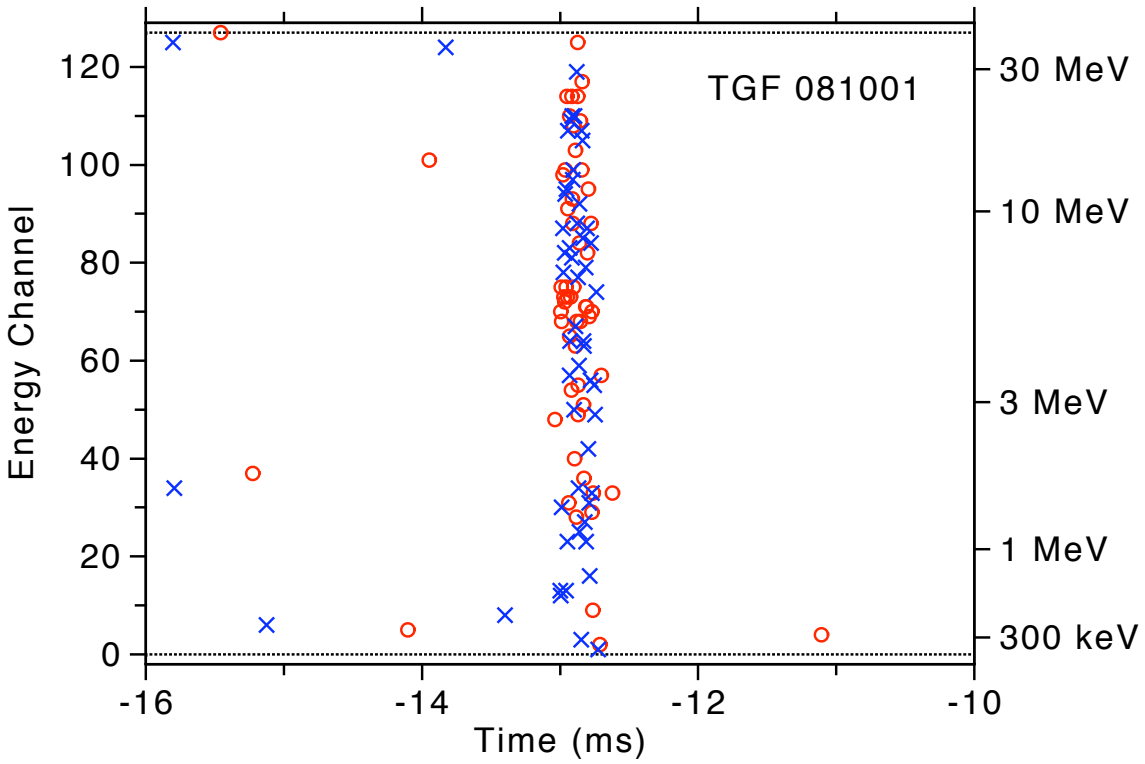


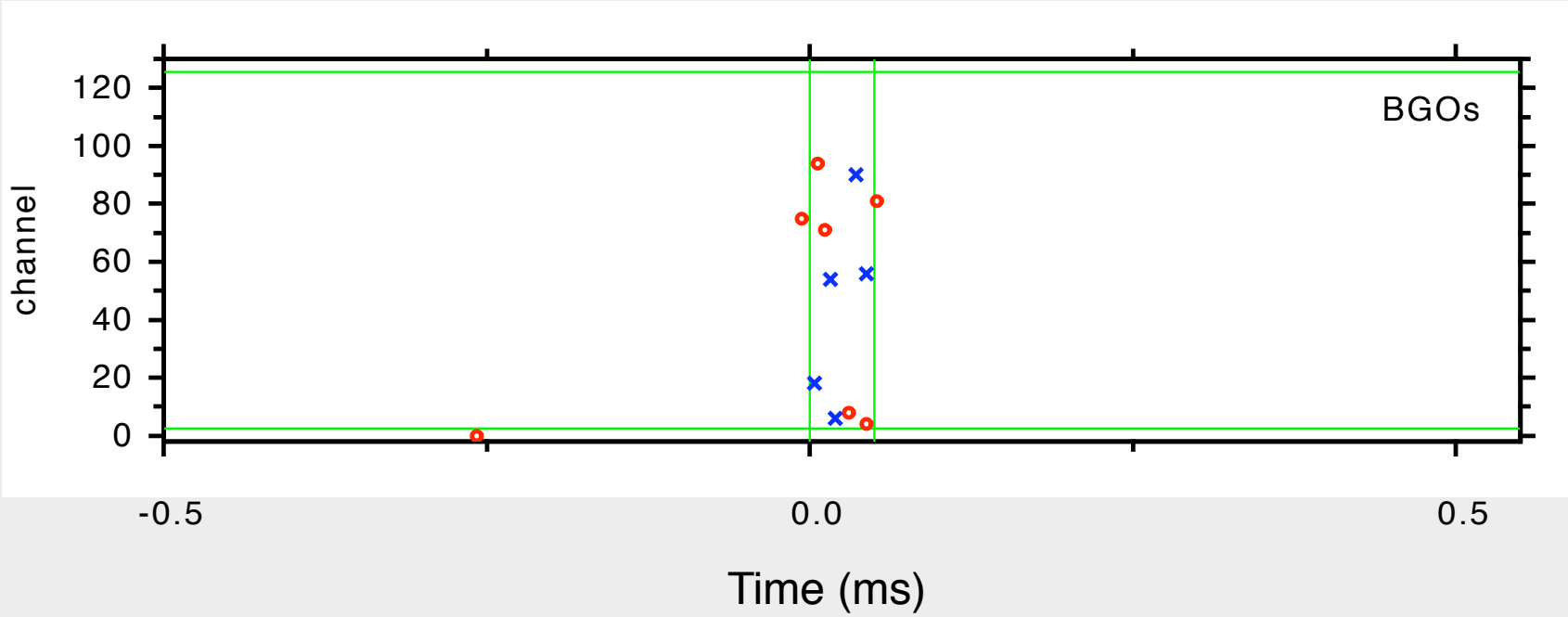
Individual photons detected with the two (red & blue) GBM BGO detectors for a bright TGF:
99 ϒ-rays in ¼ μs

RHESSI: “super TGFs” that saturate the detectors.

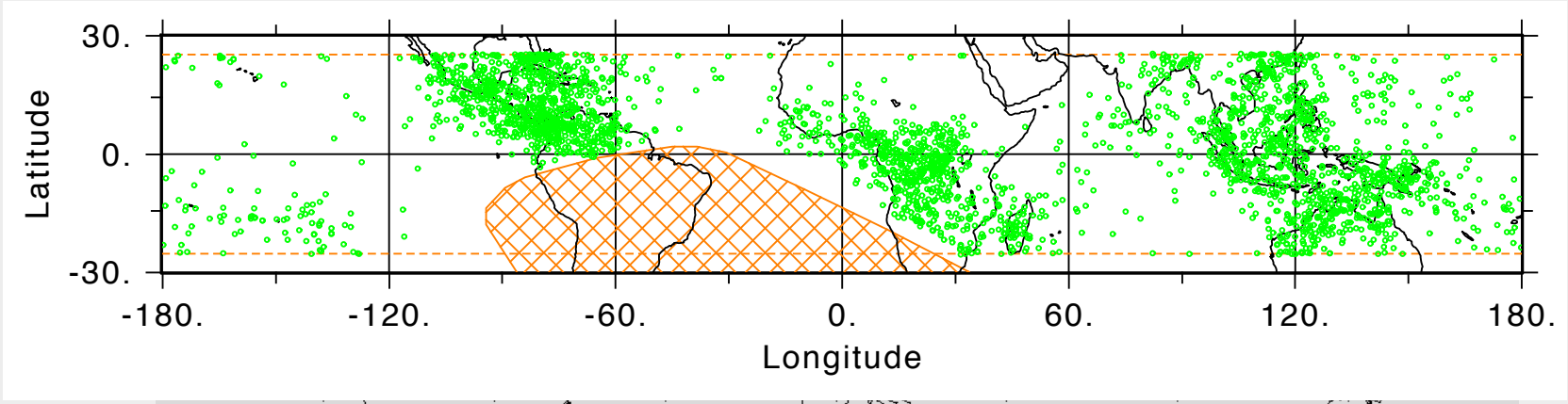
The brightest TGFs are
>~1 ϒ cm^{-2} in ~¼ μs, observed from 600 km altitude

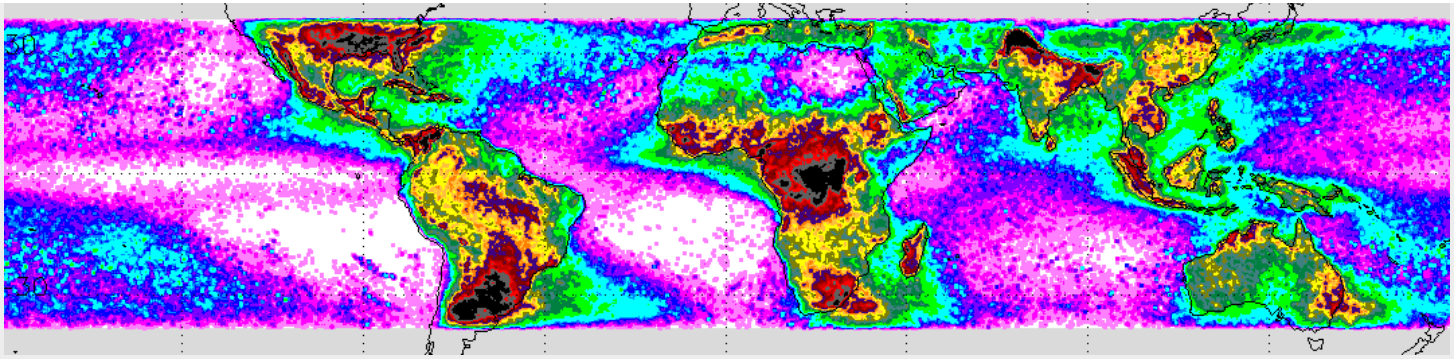
Cummer et al., 2014: 10^18 runaway electrons in the source to produce the observed ϒ-rays

50 µs



Fermi Locations at the times of 2700 GBM TGFs





Lightning Activity, as observed with the Lightning Imaging Sensor (LIS)

Fermi GBM: ~850 TGFs per year. Ratio: 1 TGF: 2600 LIS lightning.
AGILE, with anti-coincidence shields disabled: ~1100 TGFs per year (M. Marisaldi, priv. comm.).

Key Questions

- Acceleration Mechanism: large-scale (Relativistic Runaway Electron Avalanche) or small-scale (lightning leader) electric fields. Tests:
  - spectral shape: exponential cutoff or power-law extension to ~100 MeV
  - Pulse profile: smooth or sub-pulses with ~μs spacing
- How many? Faintest?
- Do extremely short (1 to 10 μs) TGFs exist?

More Questions

- True intensity: radiation dose
- Number and intensity: source of particles to the magnetosphere
- precise relationship to lightning, lightning physics, convection and charging mechanisms
- Multi-wavelength: optical / radio observations that can't be made of astrophysical particle acceleration
- Connections to astrophysical acceleration processes...

Instrument Requirements

- low Earth orbit
- low deadtime (<< μs), extremely high throughput (>≈1 ϒ cm in 100 μs)
- Large effective area:
  - To test the shape of the light curve
  - To provide a high TGF detection rate so that a ground-based instrument will obtain a useful number of co-observations.
- transmit all photons (or short-timescale, highly configurable trigger)
- Energy coverage to 100 MeV
  - to test acceleration mechanism and measure potential difference.
- How to distinguish TGFs from HE cosmic rays that create a shower in the spacecraft?

Particle acceleration is interest to astrophysics, but TGFs are terrestrial.

How do we accomplish this “Bonus Science”, which could be a low-cost addition to some gamma-ray astrophysics instruments, within the NASA division structure?