Terrestrial Gamma-Ray Flashes (TGFs)

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TGFs - Overview &
Some New Results

- History; Spacecraft observations
- Observations from Fermi-GBM
- Future Space Missions
CGRO/BATSE Terrestrial Gamma-ray Flash (TGF)

30 keV – 1 MeV
Observations of TGFs with Four Spacecraft:


II. Solar Spectroscopic Imager

III. AGILE Gamma-ray Telescope

IV. Gamma-ray Burst Monitor (GBM) on the Fermi Gamma-ray Space Telescope
BATSE TGFs:

- Determined rough spectral properties (extremely energetic)
- Associated with thunderstorms
- Observed 78 in 9 years
TGFs from BATSE  (showing saturation at \(~300,000\) cps)
RHESSI Observations:

- Doesn’t require trigger; all data are transmitted
- Detected many more TGFs than BATSE, but they were much weaker
- Determined very hard spectra (> 20 MeV)

Time Profiles of some RHESSI TGFs:
Hi Bkgnd - Low Sensitivity Region

SAA Region

High Background, Low Sensitivity Region

Map of RHESSI TGFs (820 events)
Gamma-ray Burst Monitor (GBM)
Detector Locations on the
Fermi Spacecraft – Launched June 2008
NaI Detectors (all 12 combined)

“Overflow” Chan. (127)

Gamma-ray Energy Chan. (~1 MeV max.)

milliseconds (rel. to trigger time)
Spectral Differences

TGF #1:
Low energies dominate

TGF #7:
High energies dominate
Two Well-separated, Double-Pulse TGFs seen with GBM, All Detectors – Time Profiles

Narrowest Pulse seen with GBM, ~ 50 μs

Counts per 40 μs

Counts per 100 μs

#6

#14

Weakest Pulse
Fermi – GBM
Locations of 85 TGFs
Triggered TGF Rate in GBM: \(~1/\text{mo.}, \text{ prior to } 11 \text{ Nov. } 2010\)

\(~8/\text{mo.}, \text{ after } \)

\[ \text{Trigger algorithm changed: } 10 \text{ November } 2009 \]
First 50 GBM TGFs

Media TGF Pulse Duration = 0.11ms

- Does not include 5 longer “electron” TGFs
- Solid column – includes 10 possible un-resolved pulses
Time-of-Day Occurrence of TGFs

- shows afternoon enhancement
Five “Electron” TGFs
(in the first 50)

Characteristics:

- Longer than usual
- Fast rise, then decaying
- Some are not over thunderstorms
Overlapping Double Pulses

- 3 in the first 50 TGFs

(∼7 others are less obvious)
6 of the fastest TGFs

Show variations (risetimes & falltimes) of
~7 to 15 μs
July 2010 – Implemented “un-triggered” TGF capability

Over selected “America’s Region”:

- RHESSI TGFs

- RHESSI TGFs, May-November

est.: ~several TGFs per day in this Region
First look at a GBM an Un-triggered TGF

bn090627274
Both GBM BGO Detectors
Channels 0 to 127 = 110. keV to infinity

Treating the data as binned into 20 μs time bins, we observe:

- Full-Width: ~0.25 ms
- Total counts above background: ~35 counts
- Peak count rate: ~20 kcps

(Spectrum appears similar to strong TGFs)
TGFs –

Major Observational Questions:

- Altitude of origin?
- Extent & volume of the emitting region?
- Beaming properties of the emission?
- What is the intensity distribution of TGFs?
- Are TGFs related to Gigantic Blue Jets?
What Causes TGFs?
Ans.: *Relativistic Runaway Electron Avalanche*

What is their physical relationship to storm systems & lightning?
- *Temporal?*
- *Spatial?*

- to be covered by V. Connaughton
Future Spacecraft to Study TGFs:

- Firefly – NSF cubesat; GSFC; Siena Coll.
- ASIM – on ISS; ESA, led by Danish
- TIRANIS – French & others
- CHIBIS-M – Russian (IKI) & others
End
Back-up Slides
TGF #5, Individual Detectors, 0.1ms bins

BGO (2)

Counts per 100.0 us

Time (ms)

Nal (12)

Counts per 100.0 us

Time (ms)

Plot by M. Briggs
TGF #1, Individual Detectors, 0.1ms bins
Properties of 10 Short TGF Pulses

Time Profiles –
All Detectors Combined

Counts per 20 μs

Energy Channel

Energies of Single Counts -
BGO Detectors Only

t(ms)
Four Longer TGF Pulses (~1-3 ms)

Time Profiles –
All Detectors Combined

Energies of Single Counts -
BGO Detectors Only
Properties of 10 Short TGF Pulses

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Counts per 20 μs

Energy Channel

\( t(\text{ms}) \)
Four Longer TGF Pulses (~1-3 ms)

Time Profiles –
All Detectors Combined

Energies of Single Counts -
BGO Detectors Only
Four Orbiting Spacecraft Have Observed TGFs:

- **BATSE on the Compton Gamma-ray Observatory**
  - Discovered TGFs; publ. in 1994
  - Operational 1991-2000

- **RHESSI - Solar Spectroscopy Spacecraft**
  - Comprehensive TGF Observations
  - On-line Catalog Available; still in-orbit

- **AGILE**
  - Italian Gamma-ray Astronomy Mission
  - Detects TGFs in calorimeter, still operational

  - This talk and the next one