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)

Counts (/100 microsec) vs. Time (msec)

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)

Counts/0.1 ms

#106  #868  #1433  #1457

#2144  #2185  #2223  #2348

#2370  #2457  #2465  #2573

$\text{t (ms)}$
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:
Map of RHESSI TGFs (820 events)
Gamma-ray Burst Monitor (GBM)
Detector Locations on the Fermi Spacecraft – Launched June 2008
Nal Detectors (all 12 combined)

"Overflow" Chan. (127)

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

milliseconds (rel to trigger time)
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, \(~ 50 \mu s\)
Fermi – GBM
Locations of 85 TGFs
Triggered TGF Rate in GBM: \( \sim 1/\text{mo.}, \) prior to 11 Nov. 2010
\( \sim 8/\text{mo.}, \) after " "

Annotated graph showing the number of TGF (Triggered Growth Factor) events over time. The x-axis represents days after 2 August 2008, and the y-axis represents TGF events. A note indicates that the trigger algorithm changed on 10 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 15μs
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

Binned Data 20μs/bin

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

bn090627274
All 14 GBM Detectors
Channels 0 to 127

TGF

Full-Width: ~0.25ms
Total cts above bkgrnd: ~35 cts
Peak ct. rate: ~20kcps
(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

Plot by M. Briggs
TGF #1, Individual Detectors, 0.1ms bins

BGO (2)

NaI (12)

Counts per 100 μs

t(ms)
Properties of 10 Short TGF Pulses

Time Profiles –
All Detectors Combined

Energies of Single Counts -
BGO Detectors Only
Four Longer TGF Pulses (~1-3 ms)

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Energies of Single Counts -
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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