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)
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:
Map of RHESSI TGFs (820 events)
Gamma-ray Burst Monitor (GBM)

Detector Locations on the Fermi Spacecraft – Launched June 2008
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, \( \sim 50 \, \mu s \)
Fermi – GBM
Locations of 85 TGFs
Triggered TGF Rate in GBM: ~1/mo., prior to 11 Nov. 2010

~8/mo., after “ “

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**Graph Description:**

- **X-axis:** Days after 2 August 2008
- **Y-axis:** TGF No.
- **Note:** Trigger algorithm changed: 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

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

Binned Data 20μs/bin

bn090627274
All 14 GBM Detectors
Channels 0 to 127

TGF

Full-Width: ~0.25ms
Total cts above bkgrd: ~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

BGO (2)

Nal (12)

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

Time Profiles –
All Detectors Combined

Energies of Single Counts -
BGO Detectors Only

Counts per 20 μs

Energy Channel
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(ms)

t(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