AAAS Meeting
Fermi Session
Vancouver, Canada
February 18, 2012

Invited Talk

Terrestrial Gamma-ray Flashes (TGFs) Above Thunderstorms

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Abstract

Intense of gamma rays have been observed by five different space-borne detectors. The TGFs have hard spectra, with photons extending to over 50 MeV. Most of these flashes last less than a millisecond. Relativistic electrons and positrons associated with TGFs are also seen by orbiting instruemnts In a special mode of operation, the Fermi-GBM detectors are now detecting an average of about one TGF every two hours. The Fermi spacecraft has been performing special orientations this year which has allowed the Fermi-LAT instrument also detect TGFs.

The most likely origin of these high energy photons is bremsstrahlung radiation from electrons, produced by relativistic runaway electrons in intense electric fields within or above thunderstorm regions; the altitude of origin is uncertain. These TGFs may produce an appreciable radiation dose to passengers and crew in nearby aircraft. The observational aspects of TGFs will be the main focus of this talk; theoretical aspects remain speculative.

Terrestrial Gamma-Ray Flashes (TGFs) Above Thunderstorms

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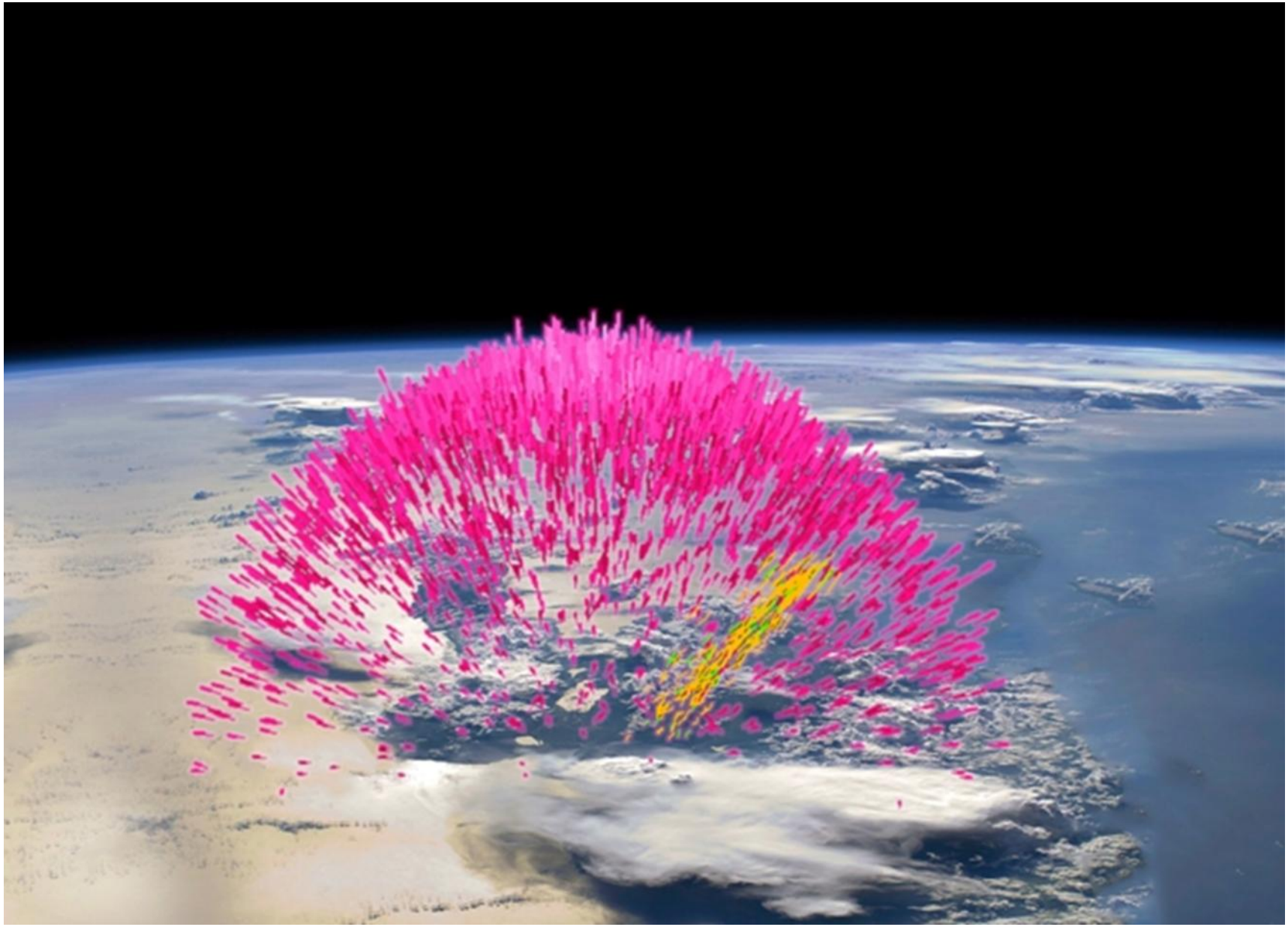
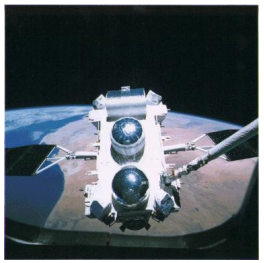
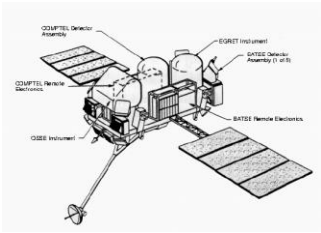


Four Orbiting Spacecraft Have Observed TGFs:

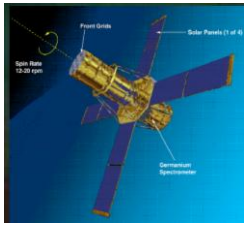
BATSE on the Compton Gamma-ray Observatory





- Discovered TGFs ; publ. in 1994
- Operational 1991-2000

RHESSI - Solar Spectroscopy Spacecraft



- Comprehensive TGF Observations
- On-line Catalog Available; still in-orbit

AGILE

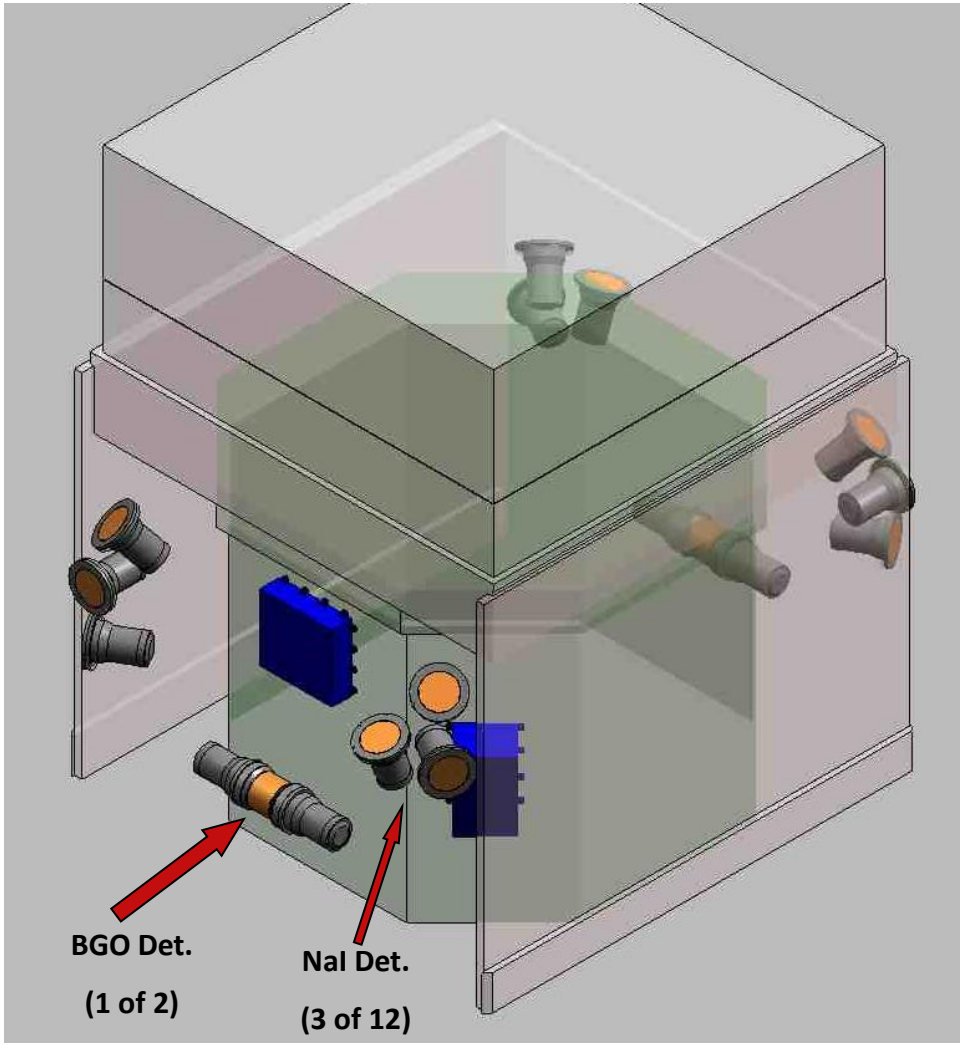
- Italian Gamma-ray Astronomy Mission
- Detects TGFs in calorimeter, still operational

The Fermi Gamma-ray Space Telescope

- This talk

GBM

Detector Locations on the Fermi Spacecraft



GBM Bismuth Germinate (BGO) Detectors (2)

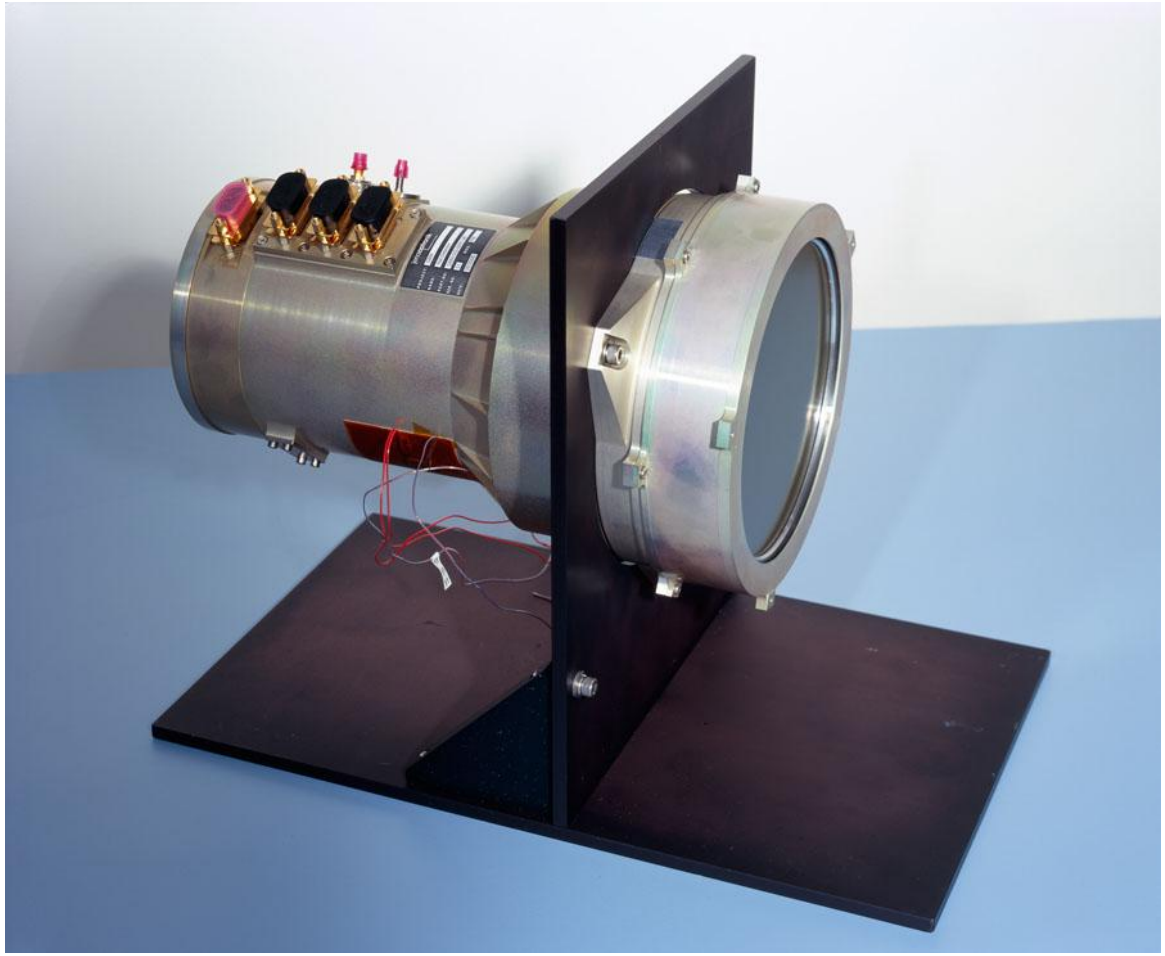
12.7 cm thick
12.7 cm dia.

150 keV to 45 MeV

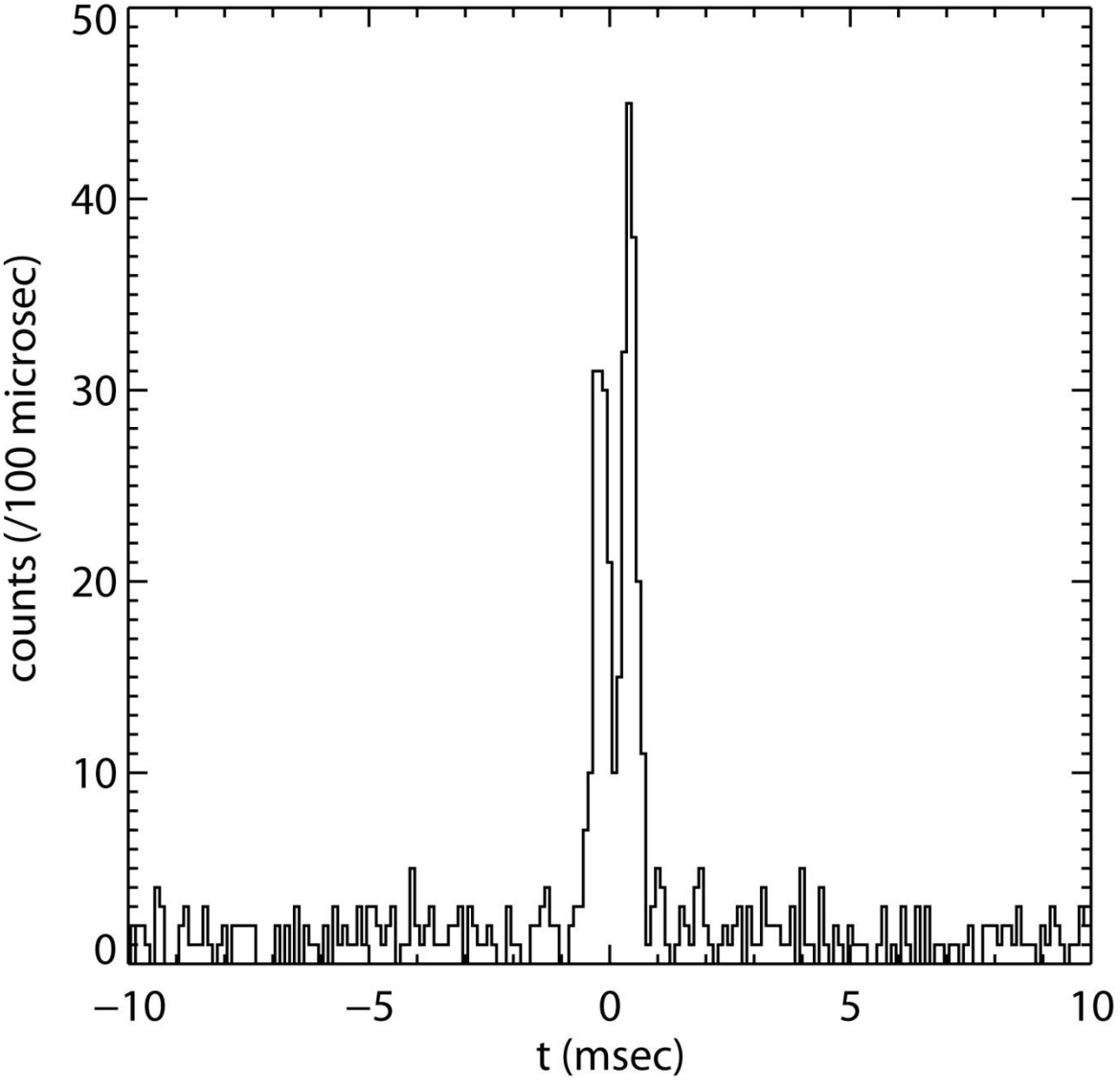
Gamma-Ray Burst Monitor (GBM) Sodium Iodide (NaI) Detectors (12)

1.27 cm thick
12.7 cm dia.

8 keV to 1 MeV



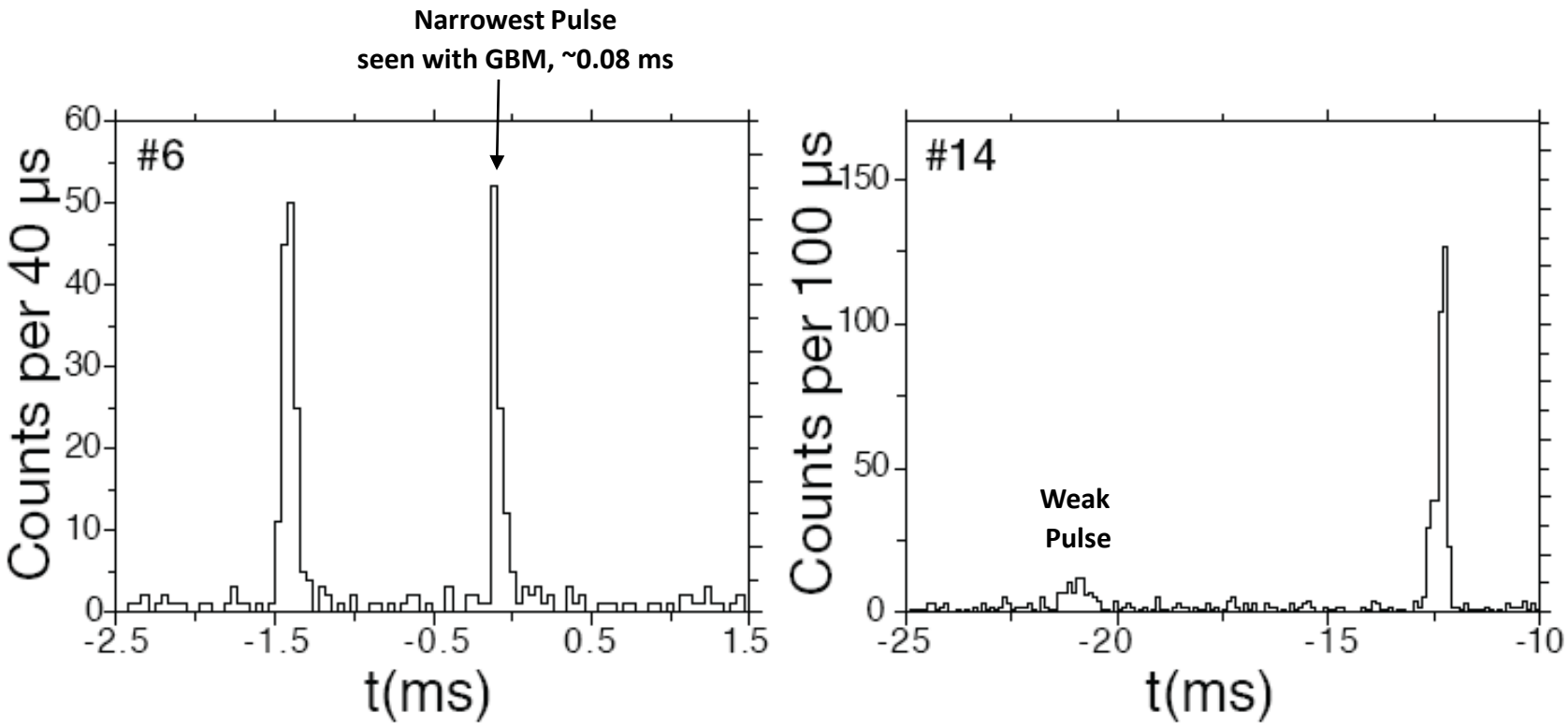
CGRO/BATSE Terrestrial Gamma-ray Flash (TGF)
(Fishman *et al*. 1994)



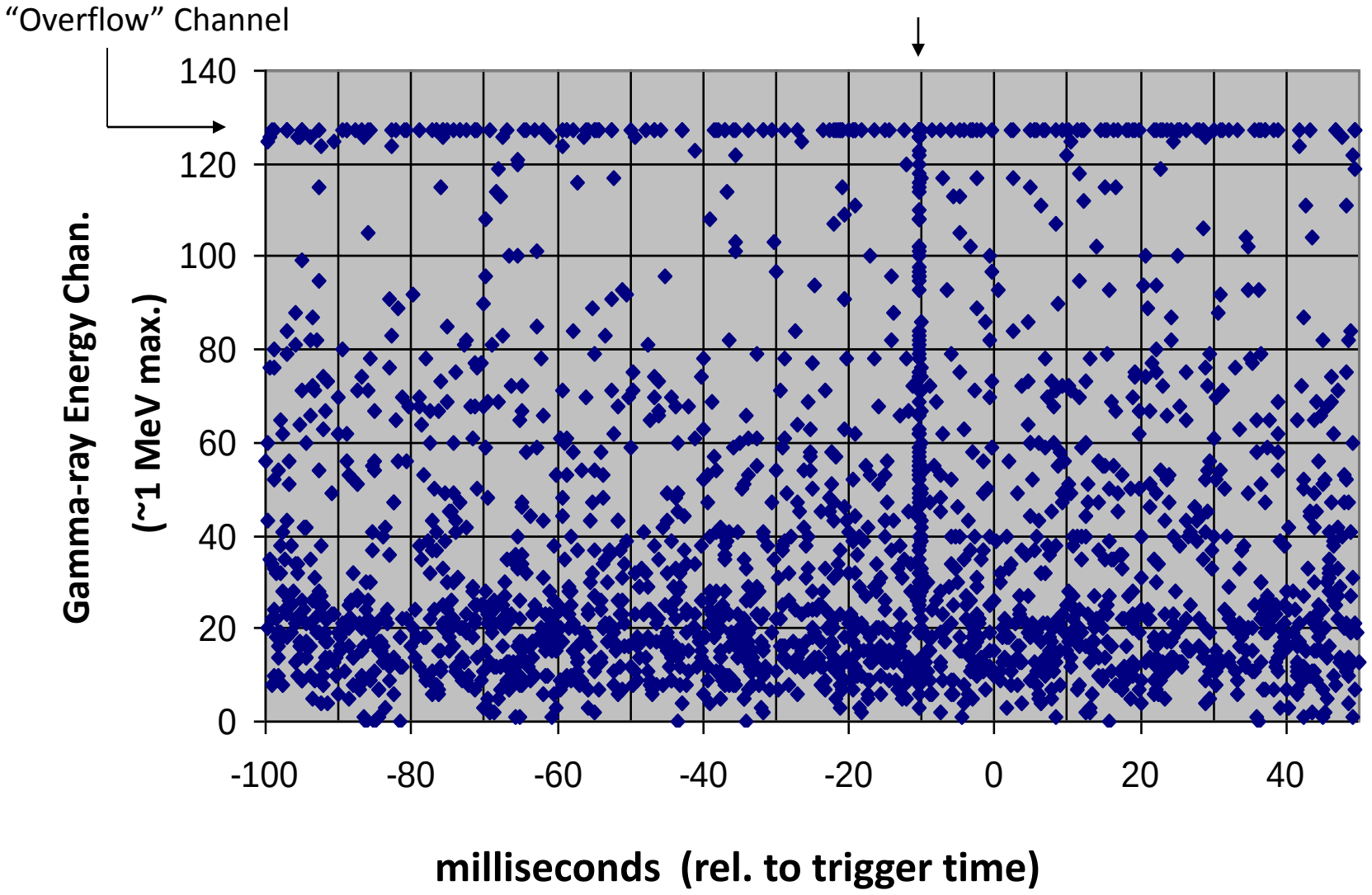
http://www.batse.msfc.nasa.gov/batse/tgf/

Two Well-separated, Double-Pulse TGFs

seen with GBM, All Detectors – Time Profiles

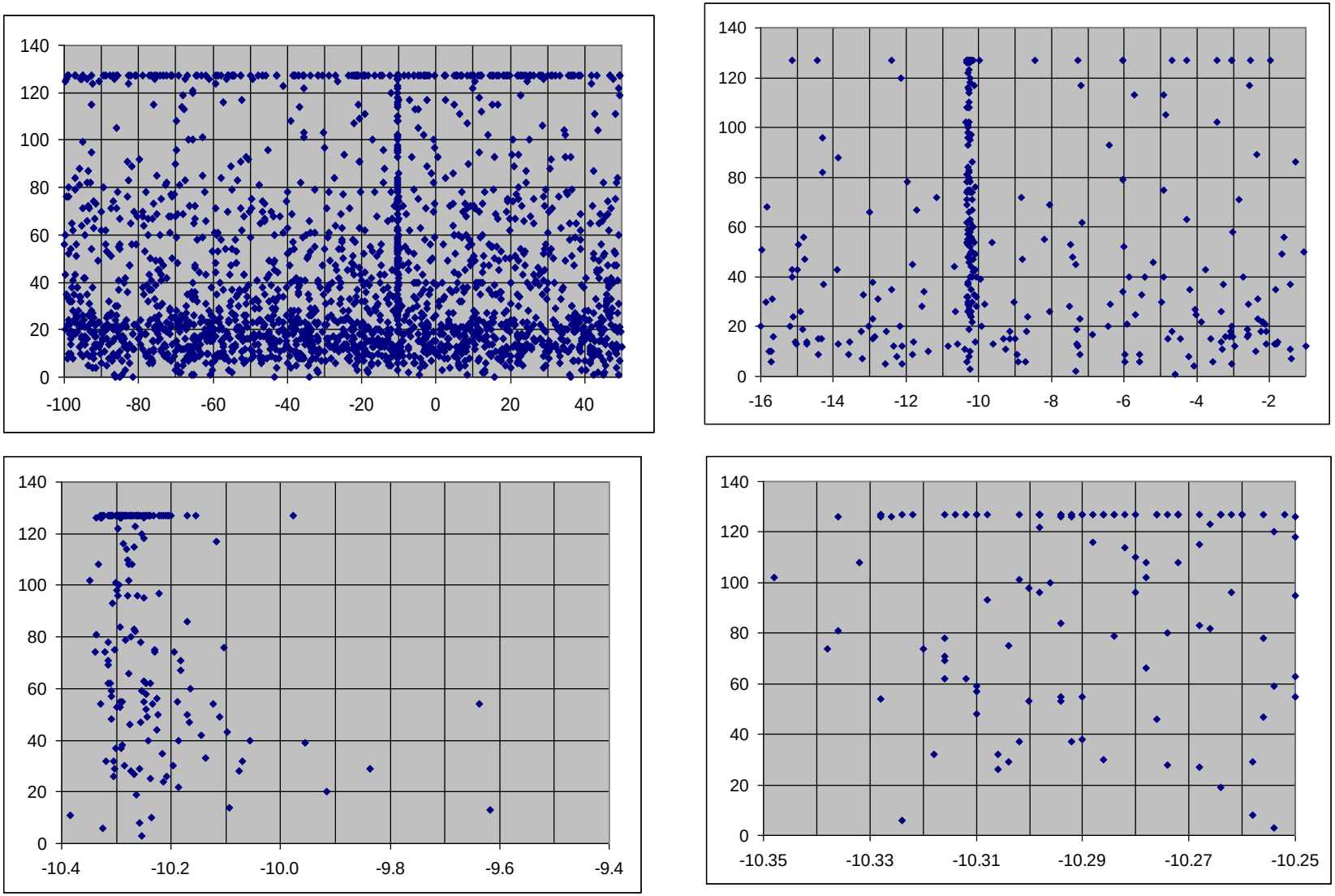


NaI Detectors – Showing Background & TGF (at 10ms)



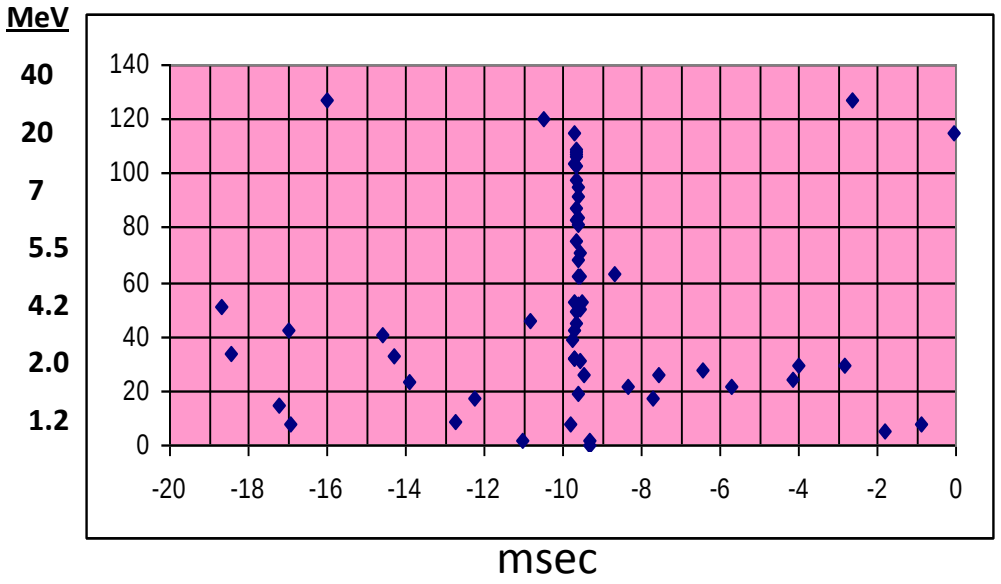
TGF #7, Nov. 23, 2008 Fermi – GBM

NaI Detectors (12, combined)



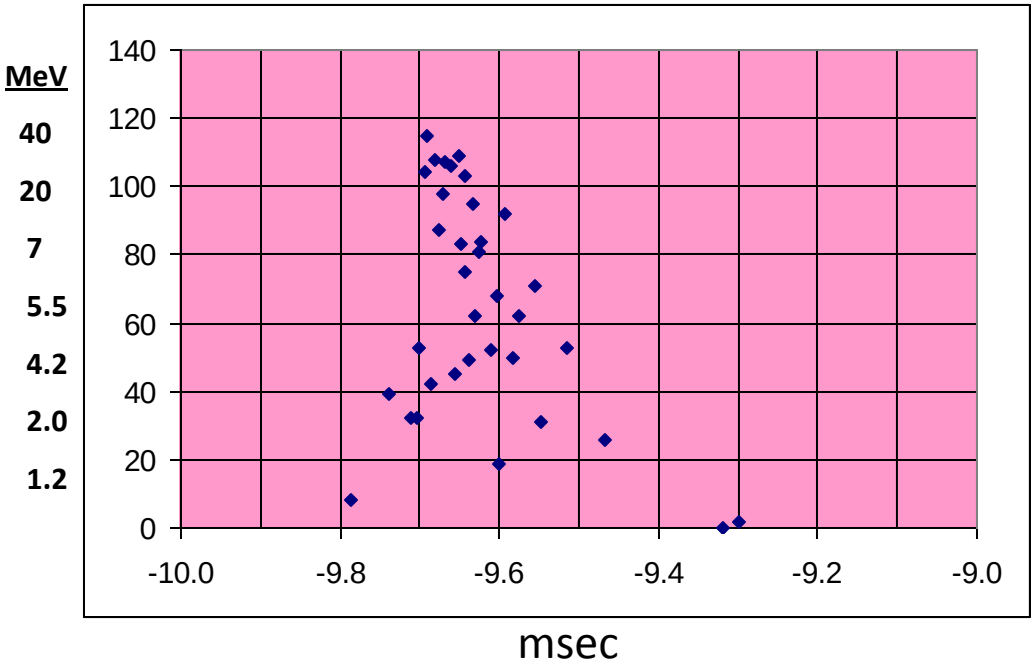
TGF_#5

BGO 0



Duration

~150 microsec



What Causes them?

Ans.: *Relativistic Runaway Electron Avalanche (RREA)*

Early work (1992):

RREA Model of

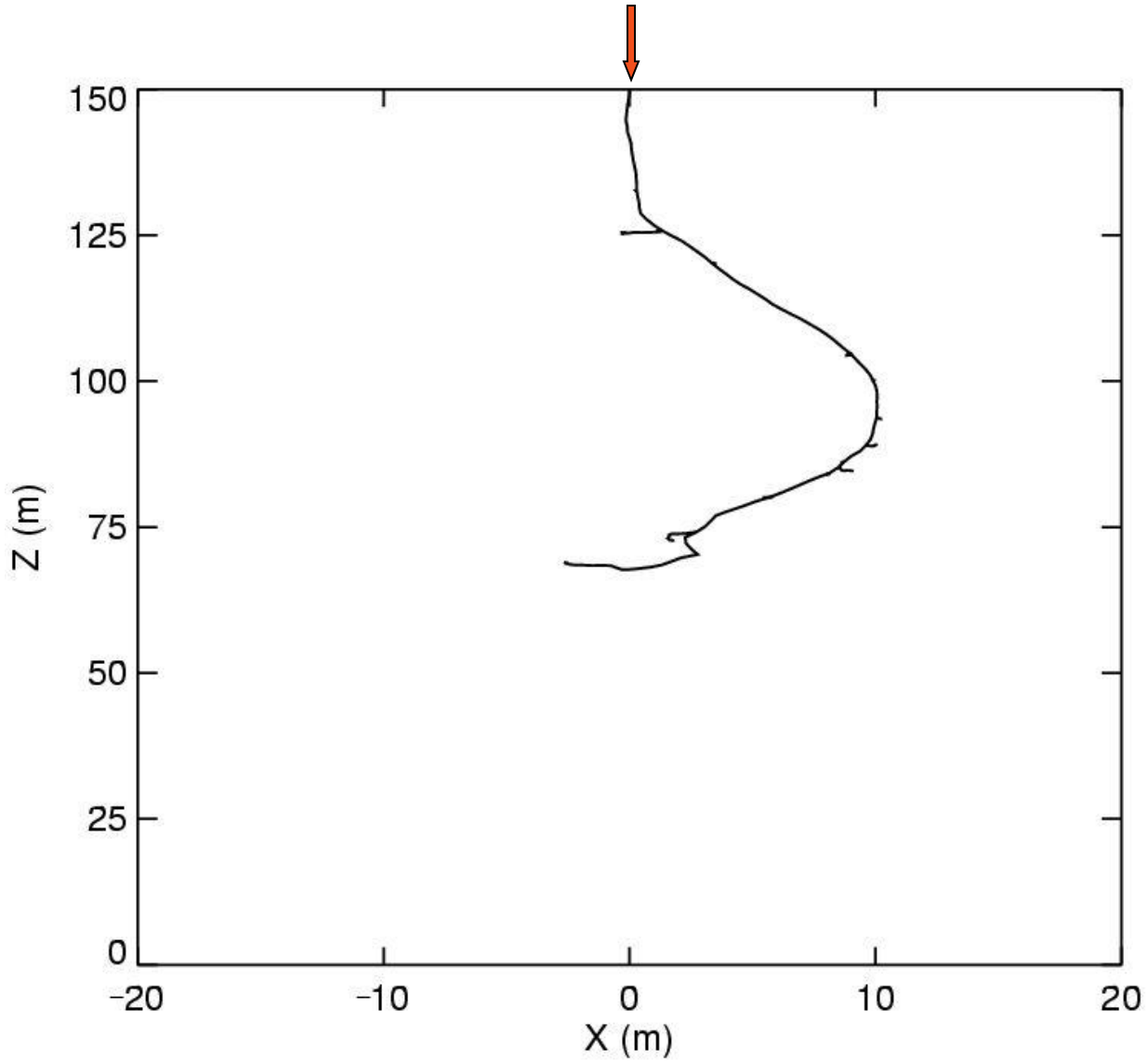
Gurevich, Milikh & Roussel-Dupre

Recent Work:

Dwyer; Milikh; Babich; Stanford U. group

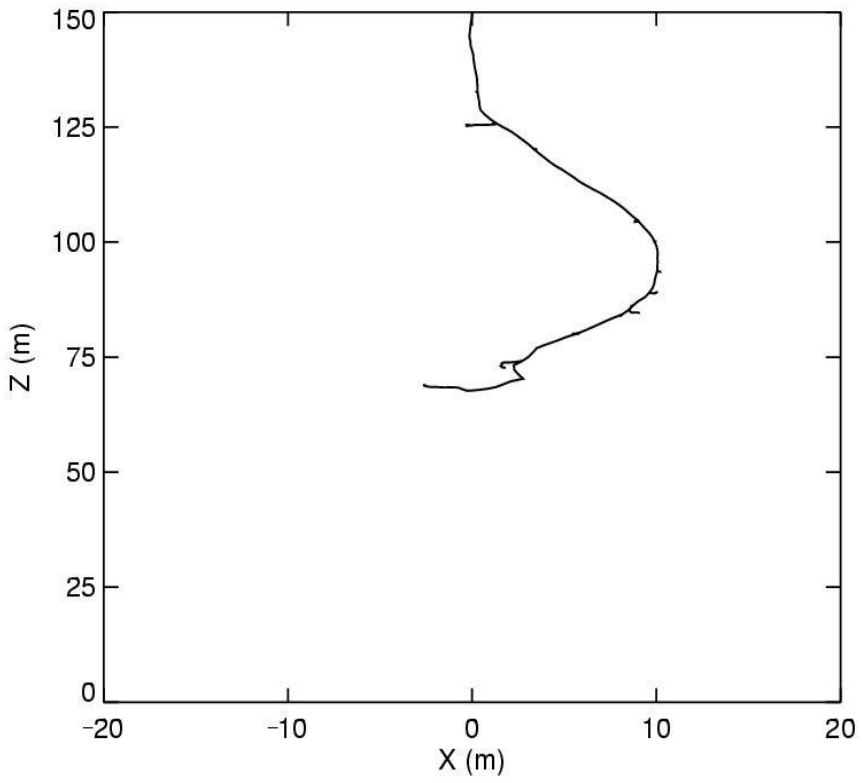
(Note: very early work: C.T.R. Wilson -1925!)

25 MeV electron moving through air at 1 atm

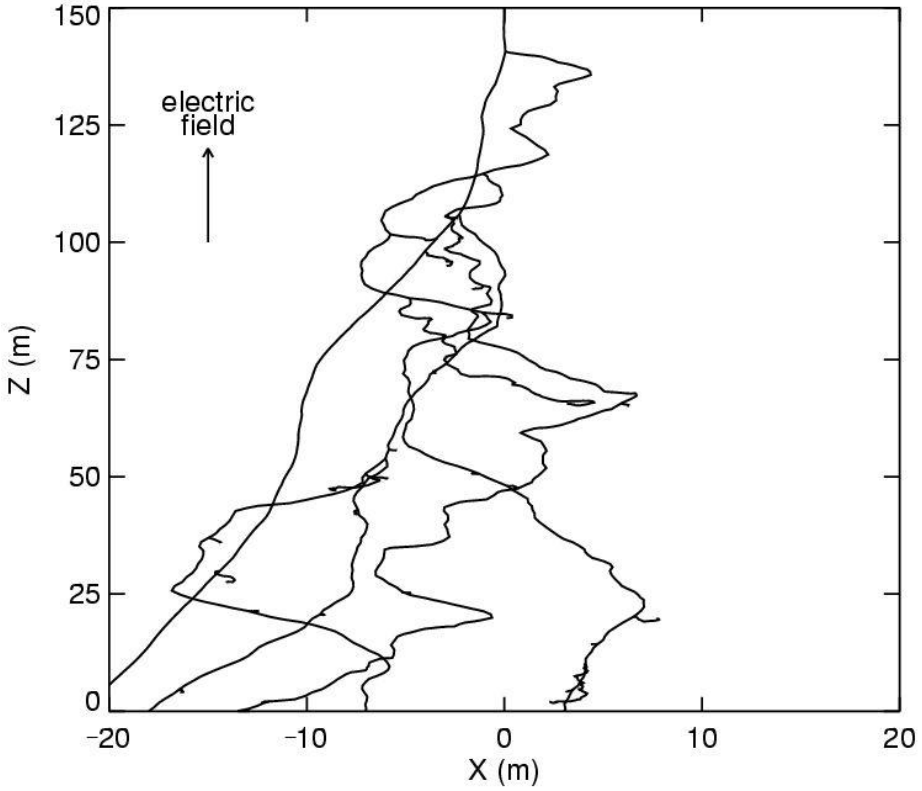


25 MeV electron moving through air at 1 atm

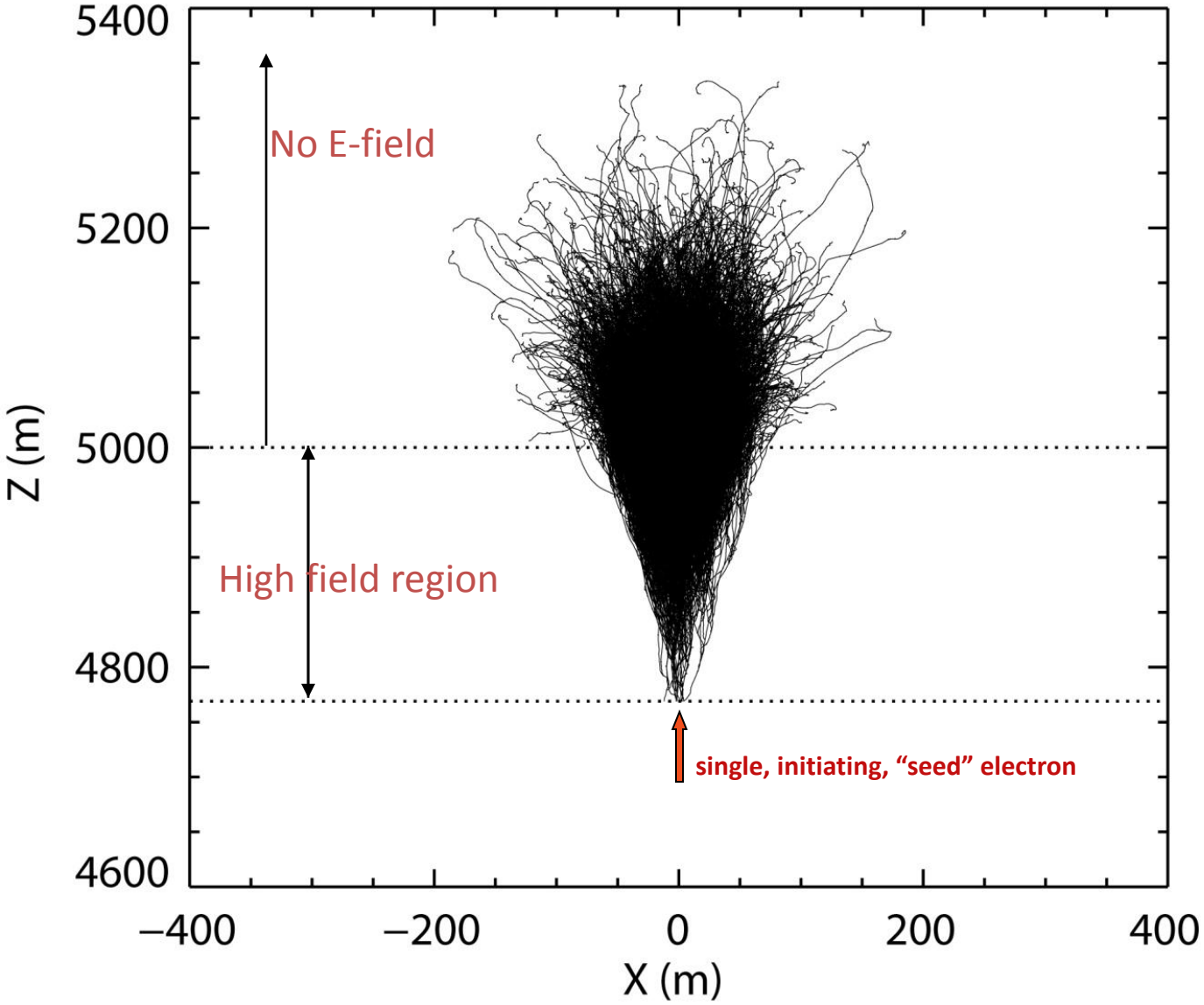
No electric field



In a 300 kV/m electric field

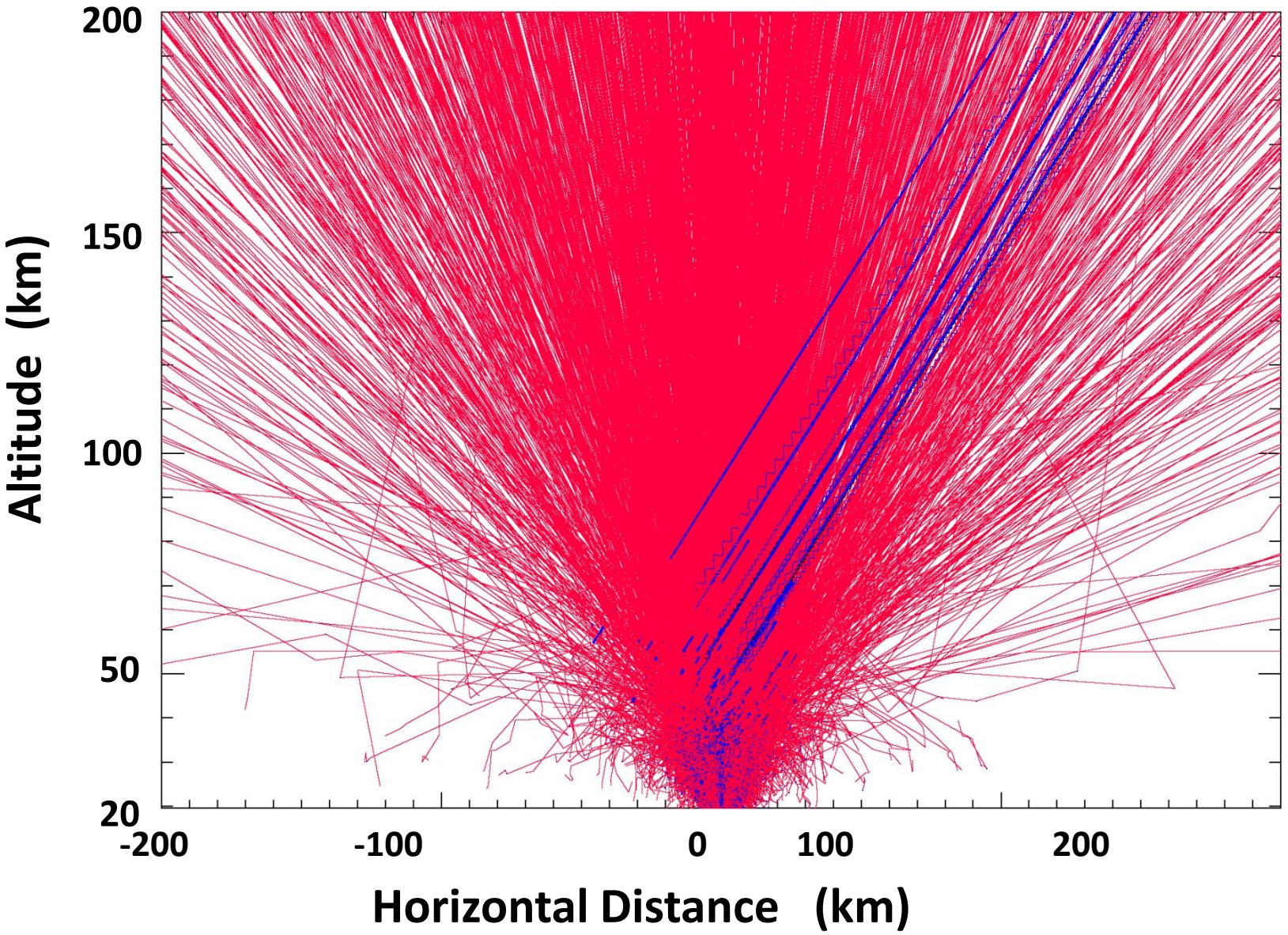


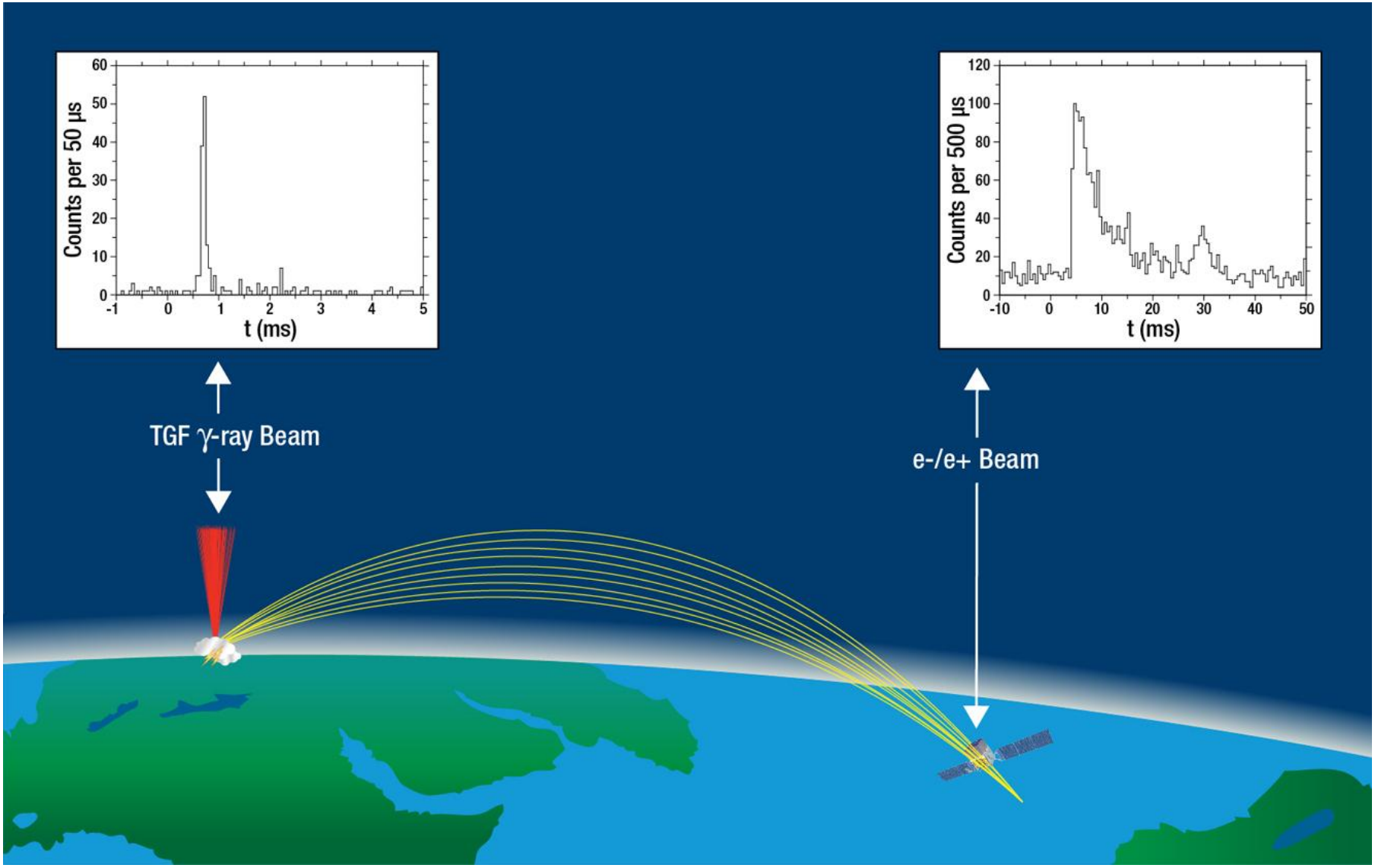
Monte Carlo simulation showing runaway electron trajectories, inside a thundercloud at 5 km altitude



TGF Simulation

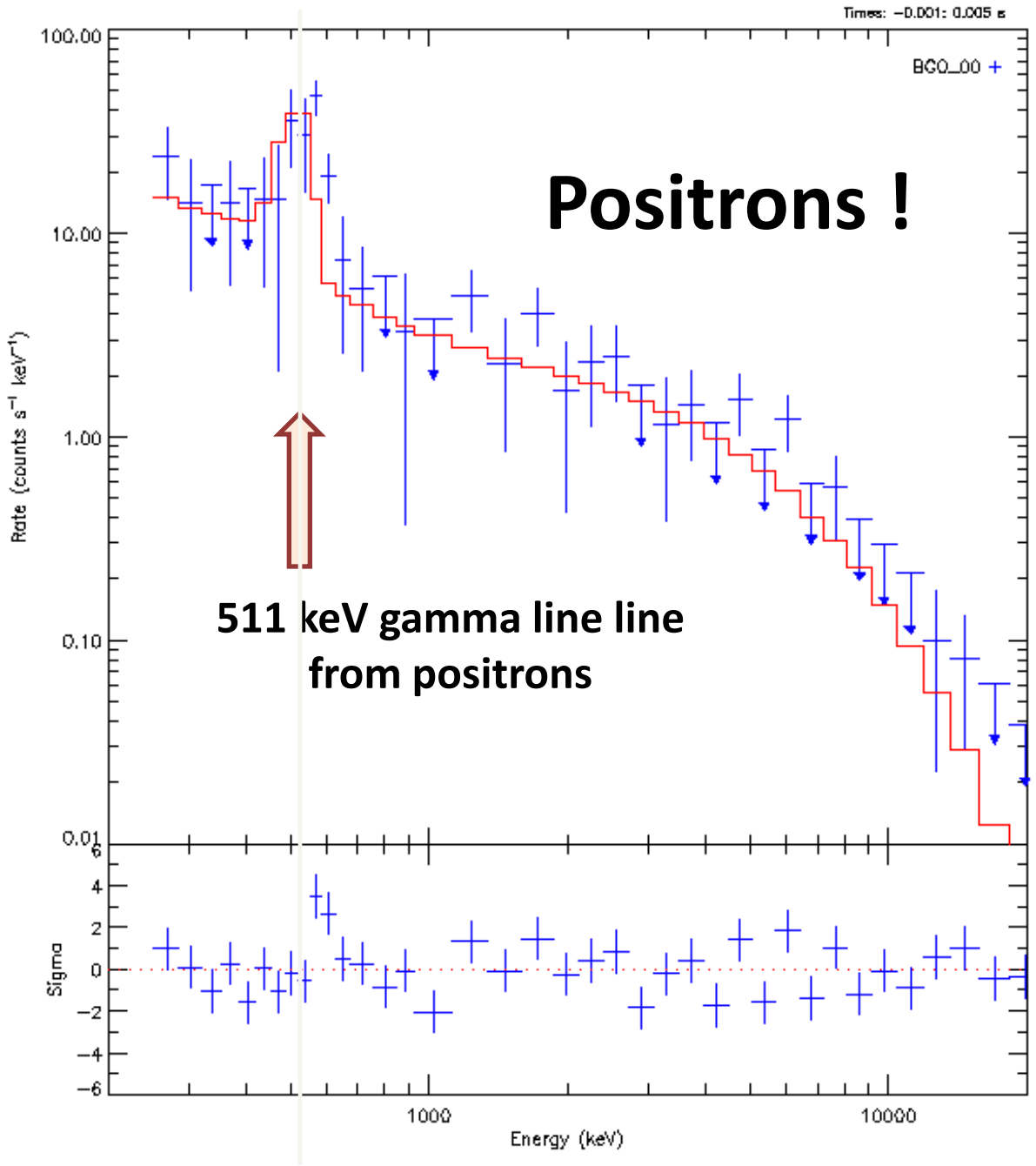
Gamma-rays (red); Electrons (blue)





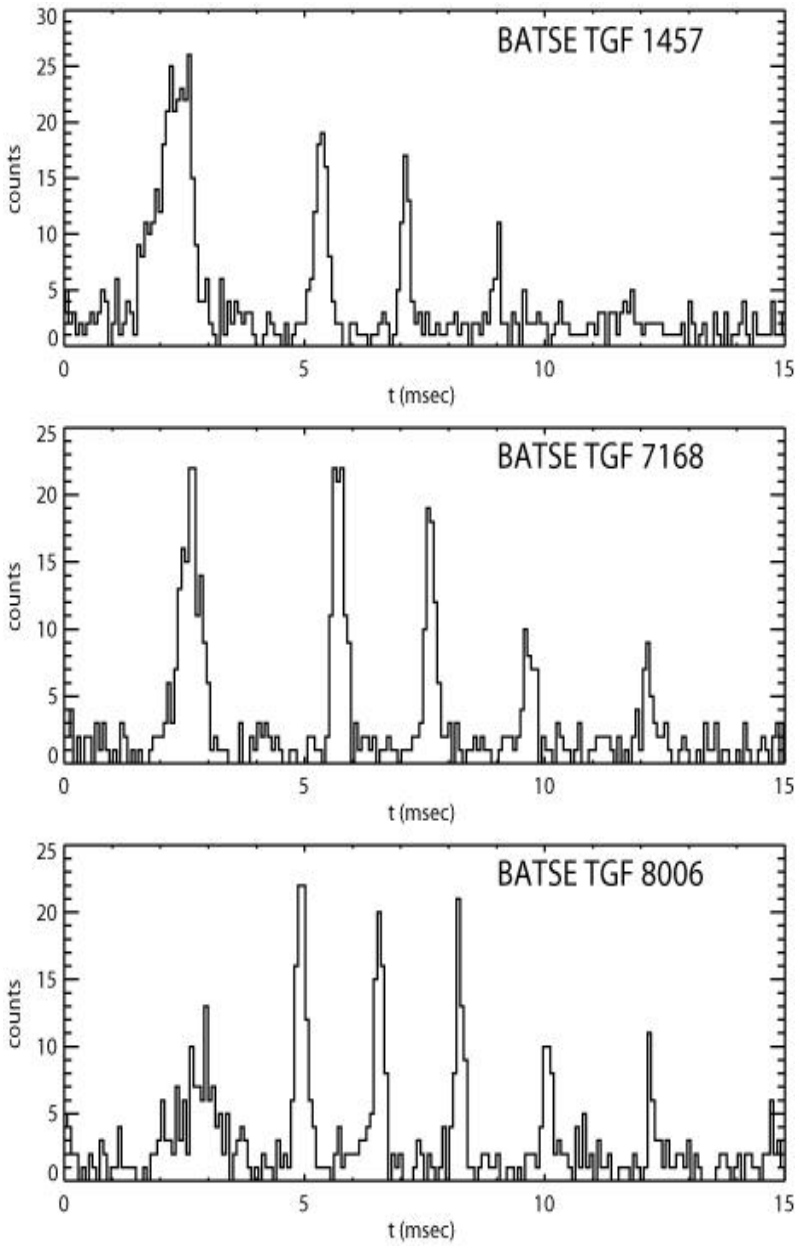
TGF: Gamma-ray Beam (left) **Electron/positron beam (right)**

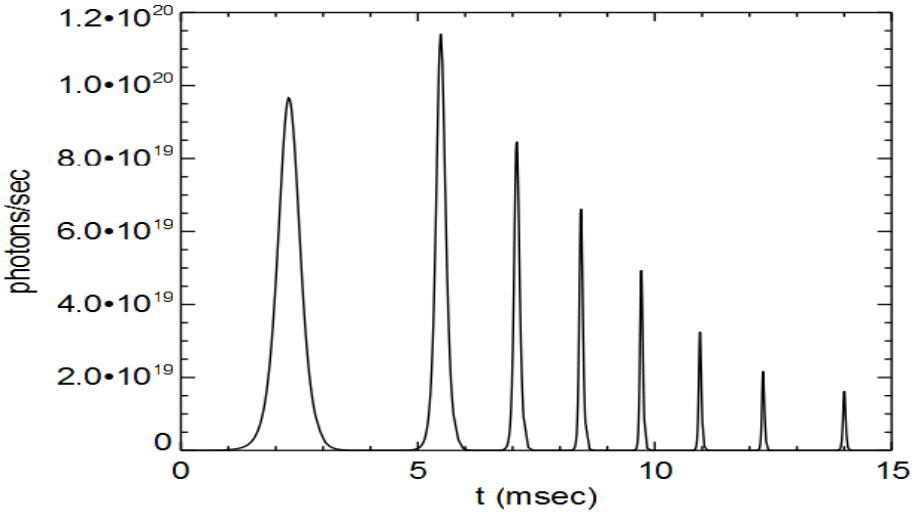
Spectrum of TGF



Multi-pulsed TGFs

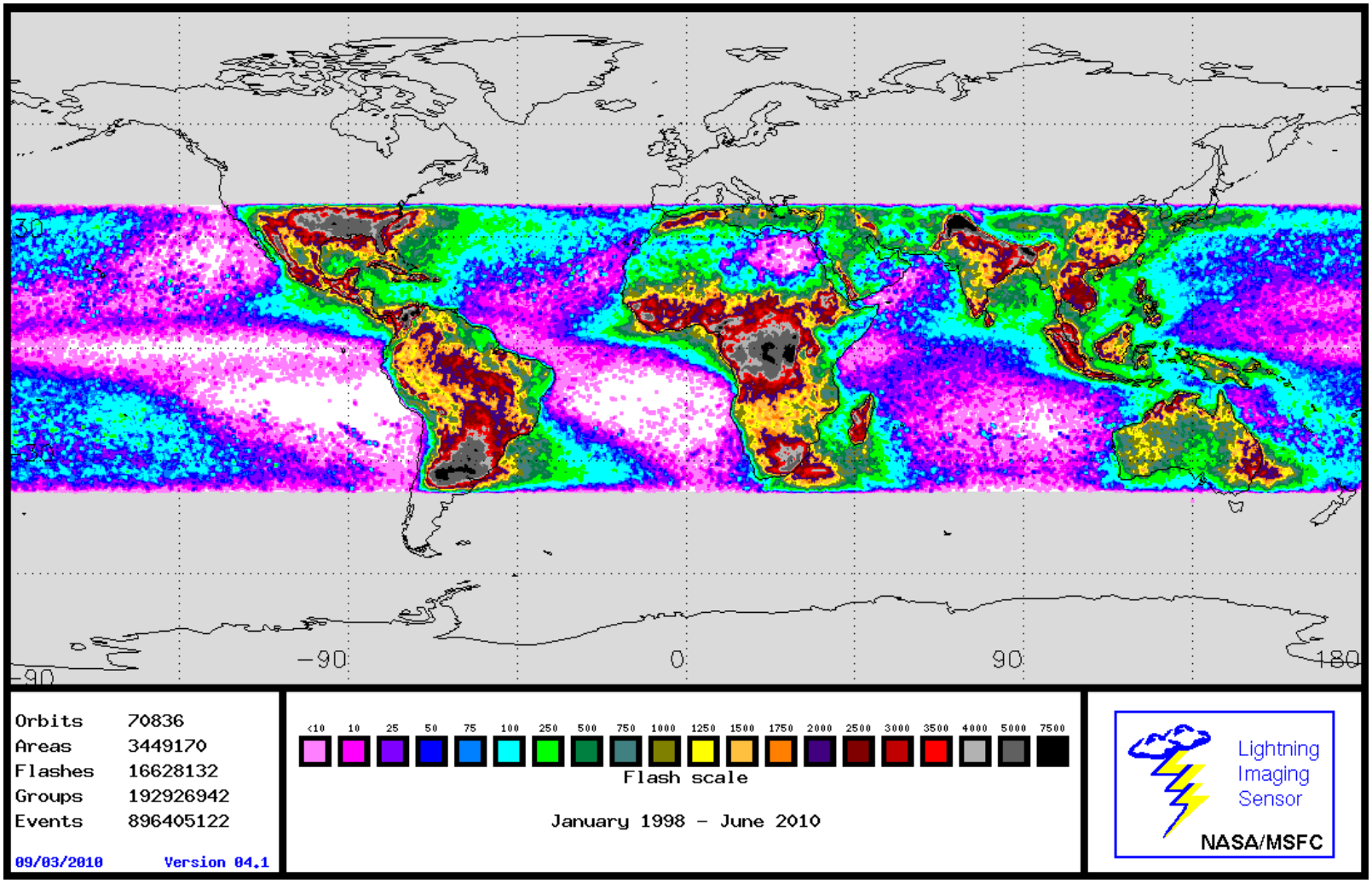
CGRO/BATSE TGFs





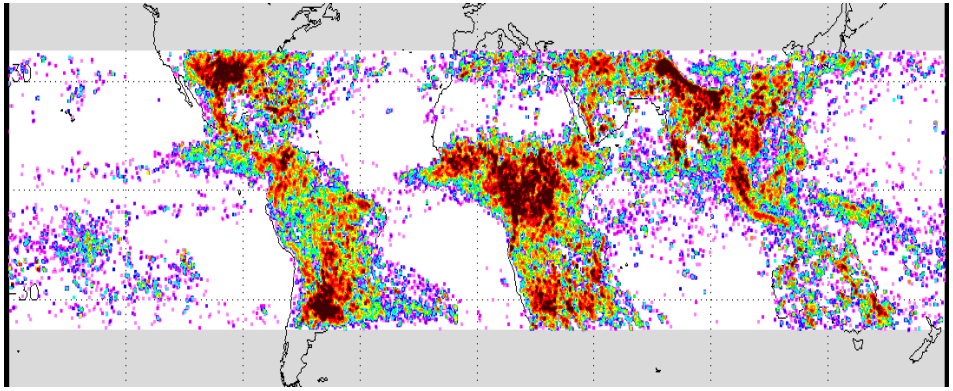
New Simulation Model: Dwyer 2012

Global Thunderstorm Regions

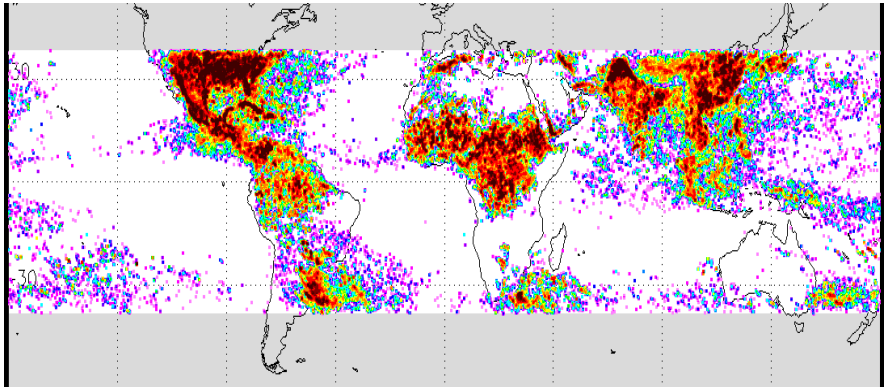


Global Lightning – by Season

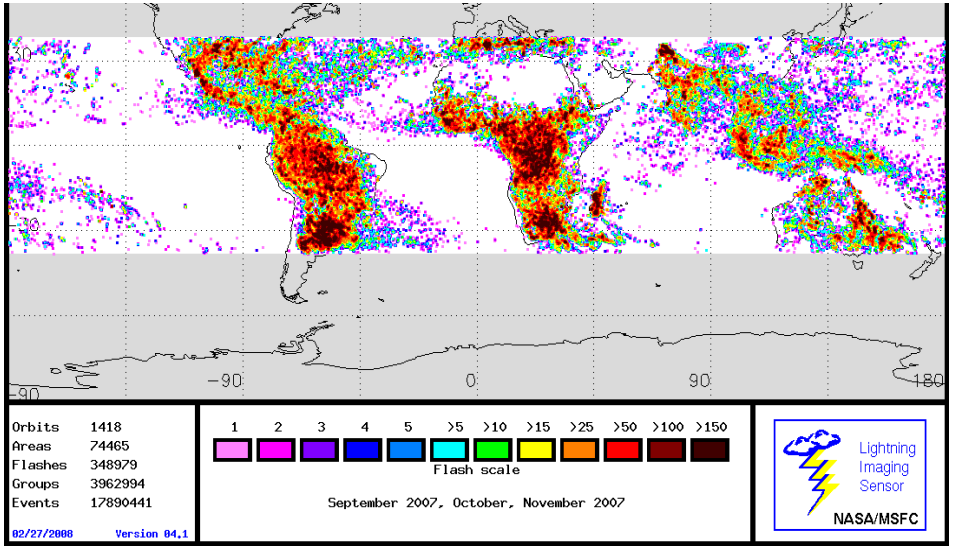
(NASA/MSFC - LIS data, 2007)



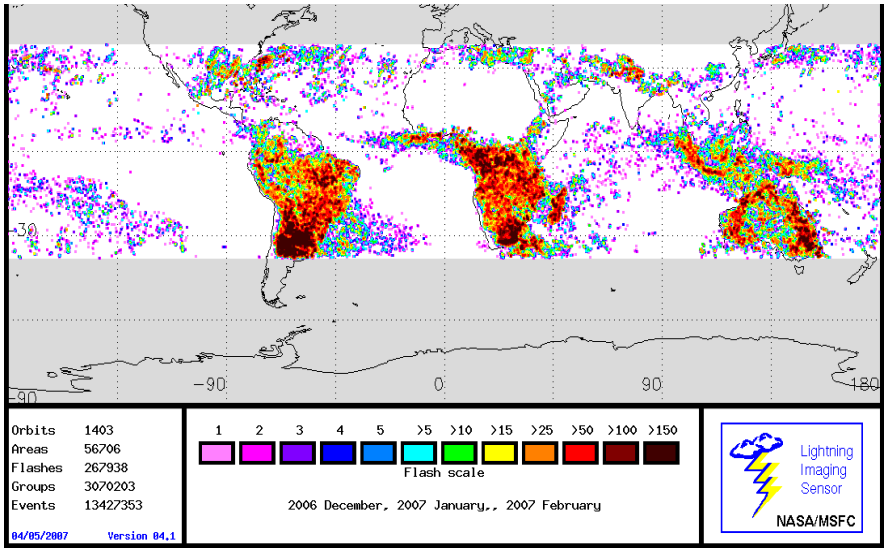
Spring



Summer

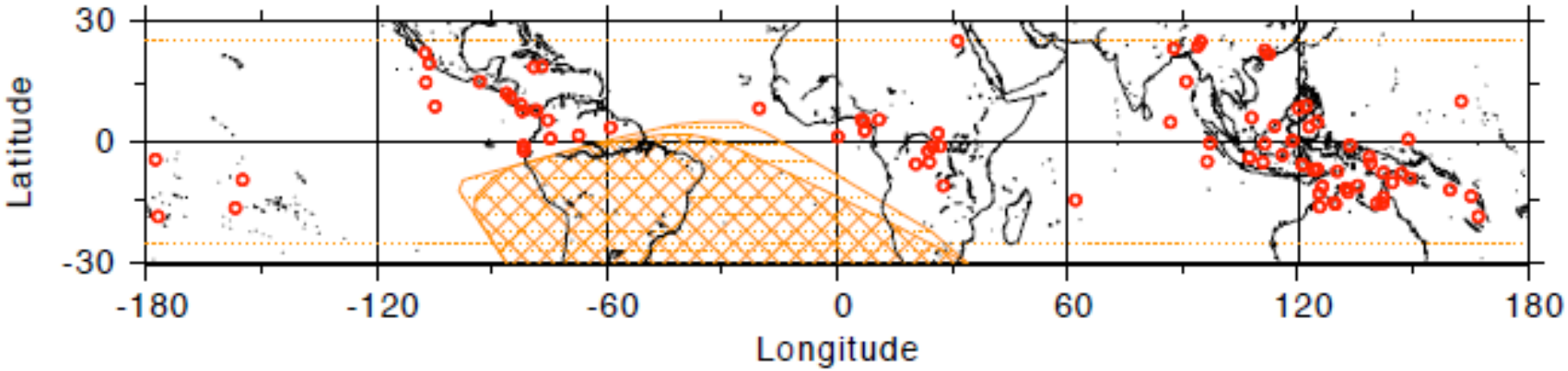


Fall



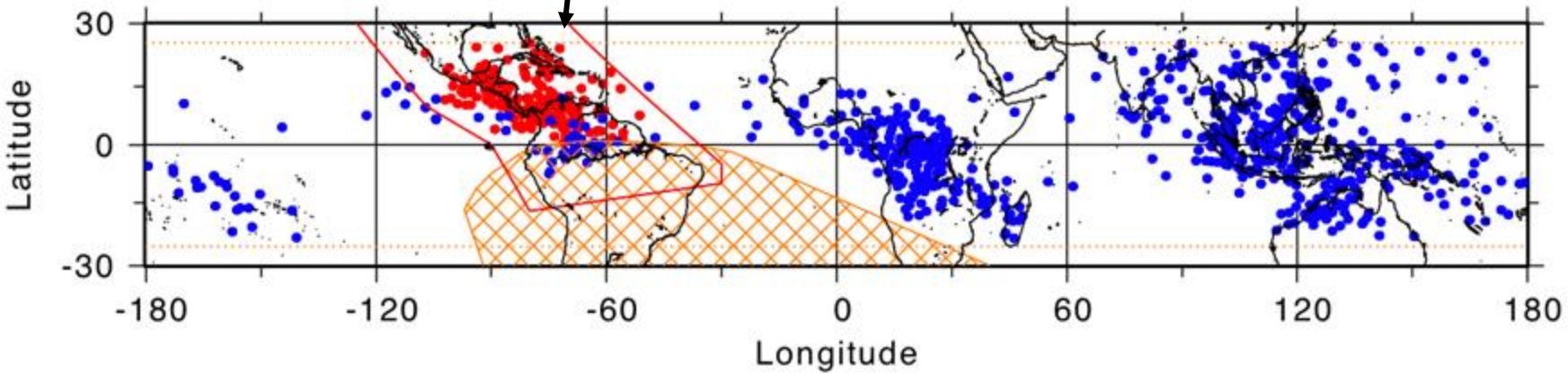
Winter

Fermi – GBM
Locations of 85 TGFs



New Capability: "Un-triggered" TGFs

"America's Region"

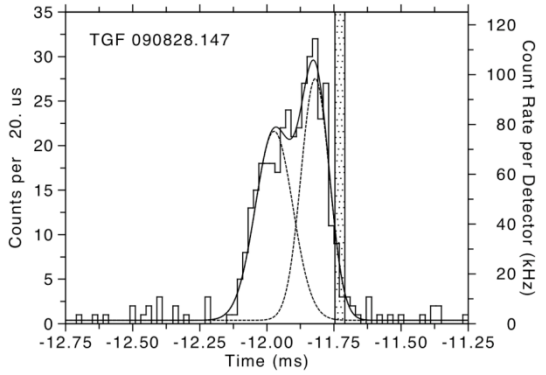


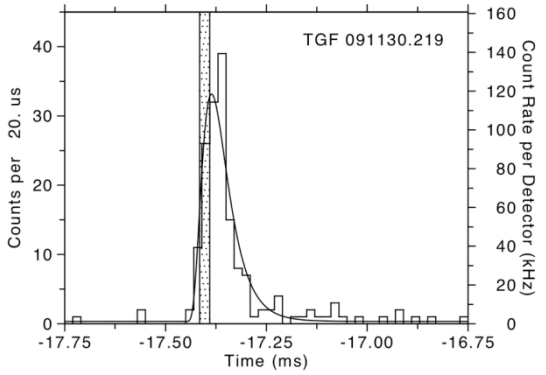
● - RHESSI TGFs

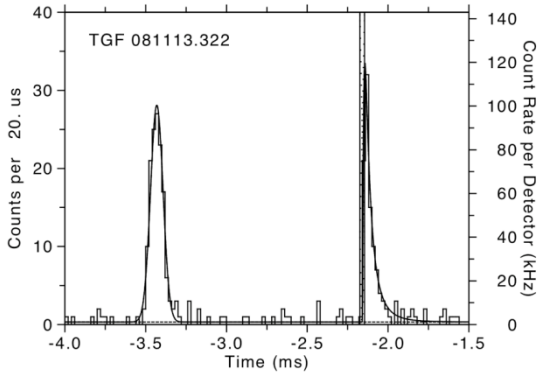
● - RHESSI TGFs, May-November

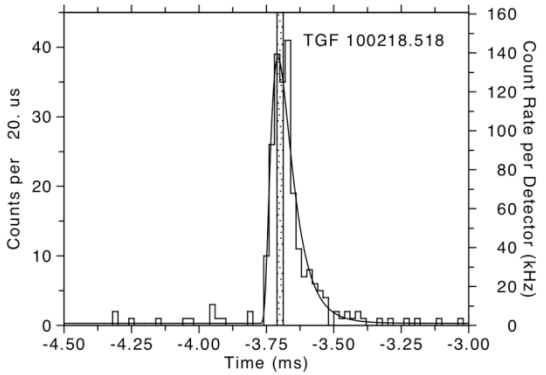
~2 TGFs per day in "America's" Region - untriggered TGFs

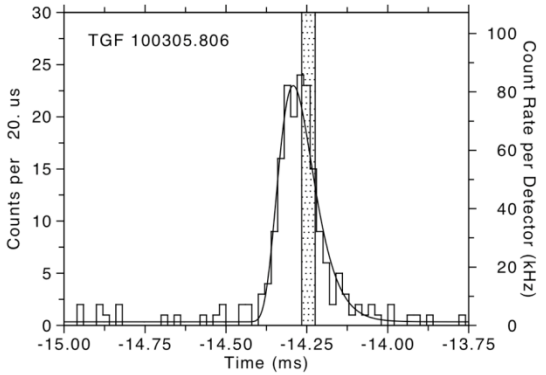
TGF & Lightning are *usually* Simultaneous

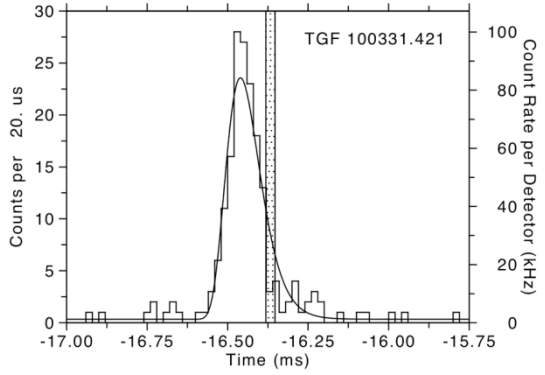












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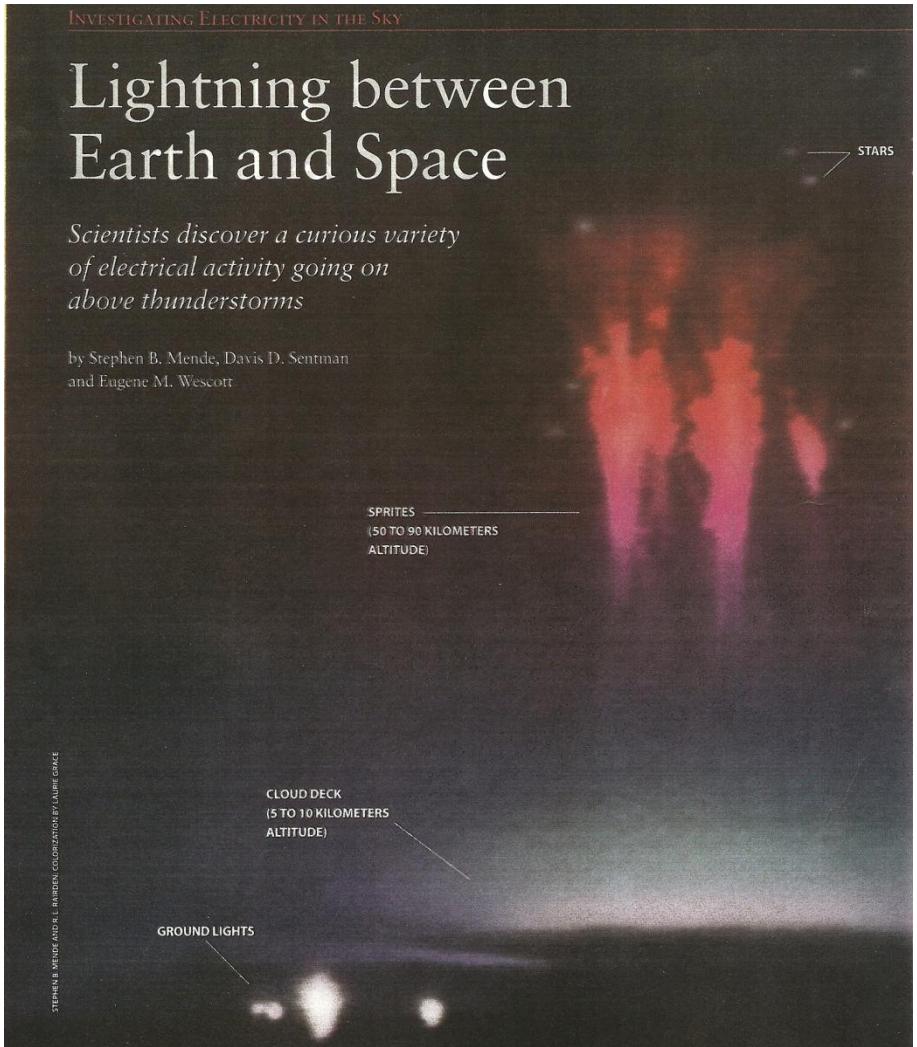
AGE AND ENERGY
HOW SUBTLE MUTATIONS IN CELLULAR DYNAMOS SLOWLY WEAKEN THE BRAIN AND MUSCLES

Bolts arc between clouds and the earth, but also from clouds toward space

Lightning between Earth and Space

Scientists discover a curious variety of electrical activity going on above thunderstorms

by Stephen B. Mende, Davis D. Sentman and Eugene M. Wescott



SPRITES are high-altitude luminous flashes that take place above thunderstorms in a part of the atmosphere called the mesosphere. Although sprites are usually rare, some storms can spawn them frequently. Typically the upper parts of clouds are charged positively and the lower parts negatively. Most often, it is the negative base of the cloud that flashes to the ground. But at times the upper, positive part can discharge directly to the earth, producing a lightning flash of exceptional intensity. About one out of 20 such positive cloud-to-ground lightning bolts are sufficiently energetic that they spawn sprites. These examples, recorded from the ground with a monochromatic video camera, have been colorized to match a color image obtained from an aircraft.

TGFs –

Major Observational Questions:

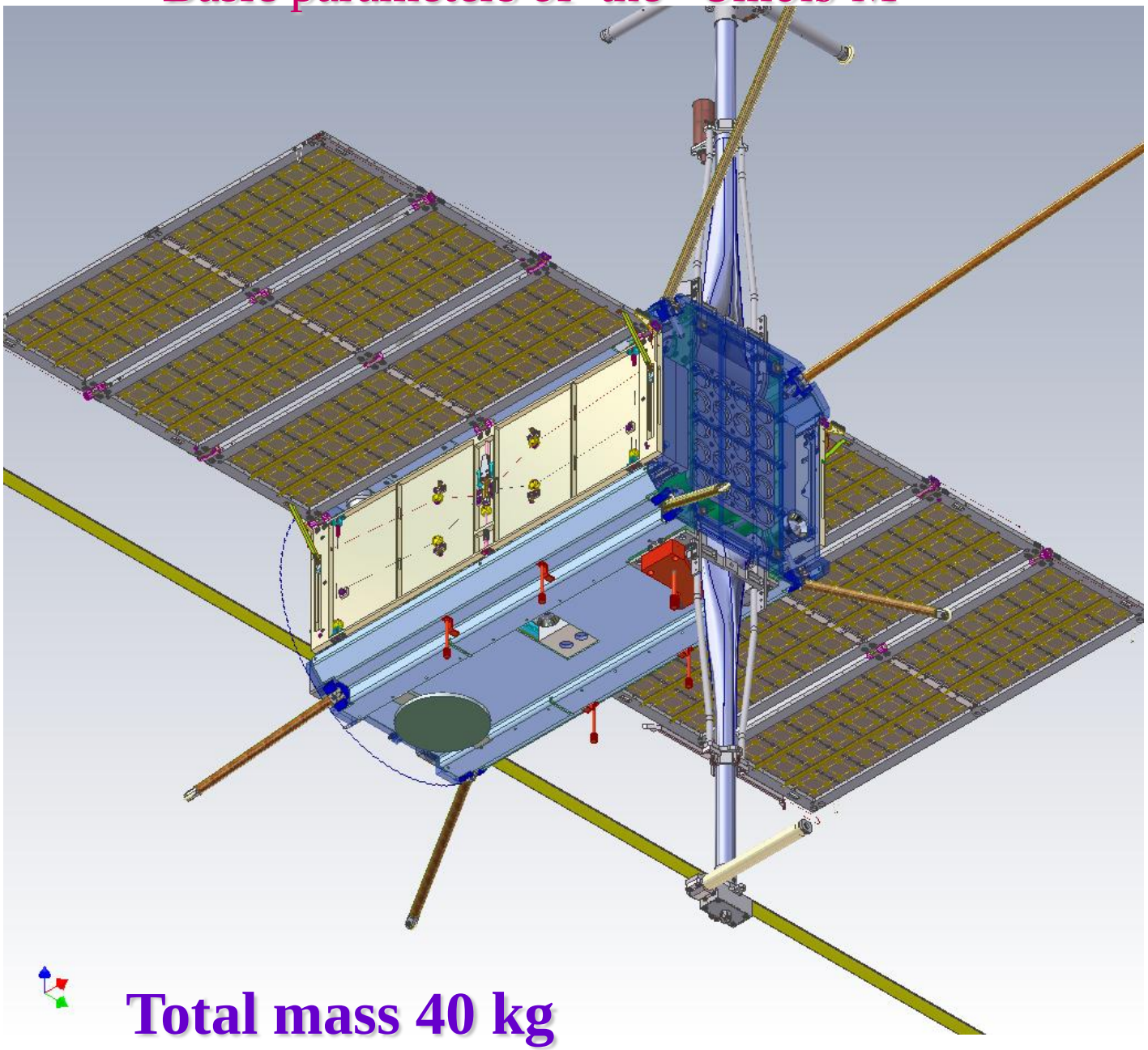
- **Altitude of origin?**
- **Extent & volume of the emitting region?**
- **Beaming properties of the emission?**
- **What is the intensity distribution of TGFs ?**
- **Are TGFs related to the rare Gigantic Blue Jets ?**
- **Are TGFs dangerous to airline crew & passengers ?**

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**

The End

Basic parameters of the “Chibis-M”



Total mass 40 kg