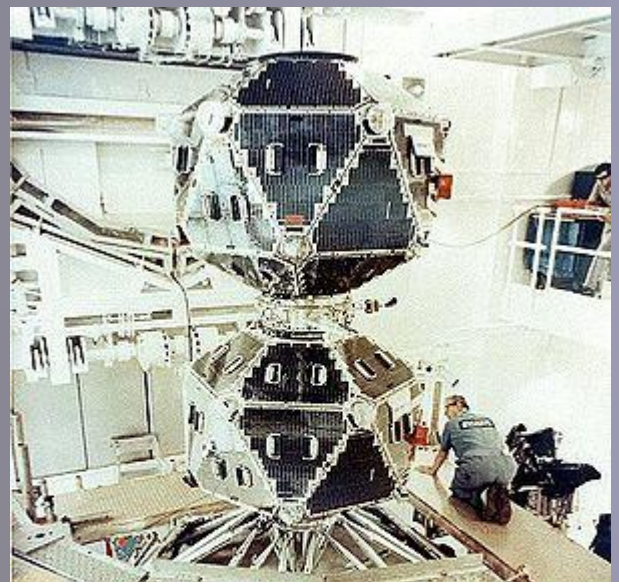
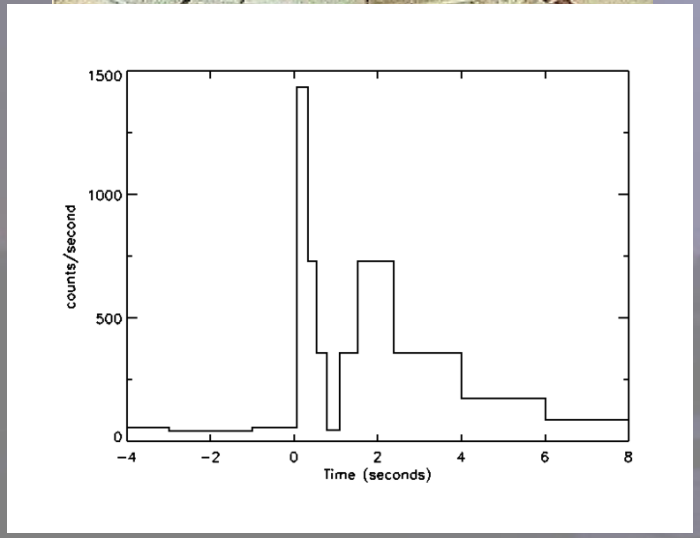
Terrestrial Gamma-ray Flashes

Gamma Ray Astronomy Beginning





started as a small budget research program in 1959

monitoring compliance with the 1963 Partial Test Ban Treaty by the Soviet Union, and other nuclear-capable states

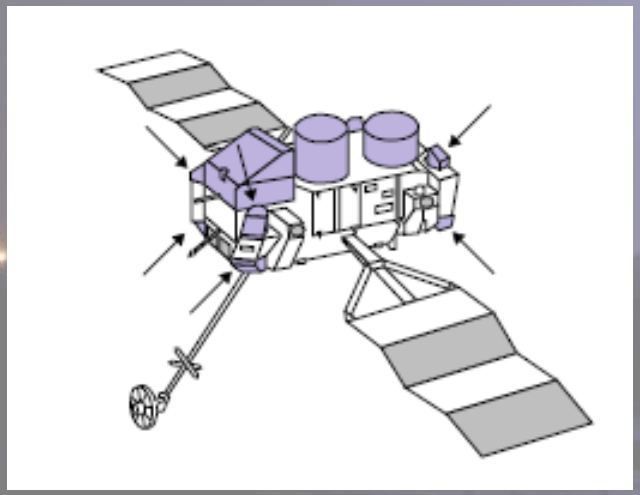
12 external X-ray detectors and 18 internal neutron and gamma-ray detectors

on July 2, 1967, at 14:19 UTC, the Vela 4 and Vela 3 satellites detected a flash of gamma radiation…

Compton Gamma Ray Observatory (CGRO)

Burst And Transient Source Experiment (BATSE, 1991-2000):

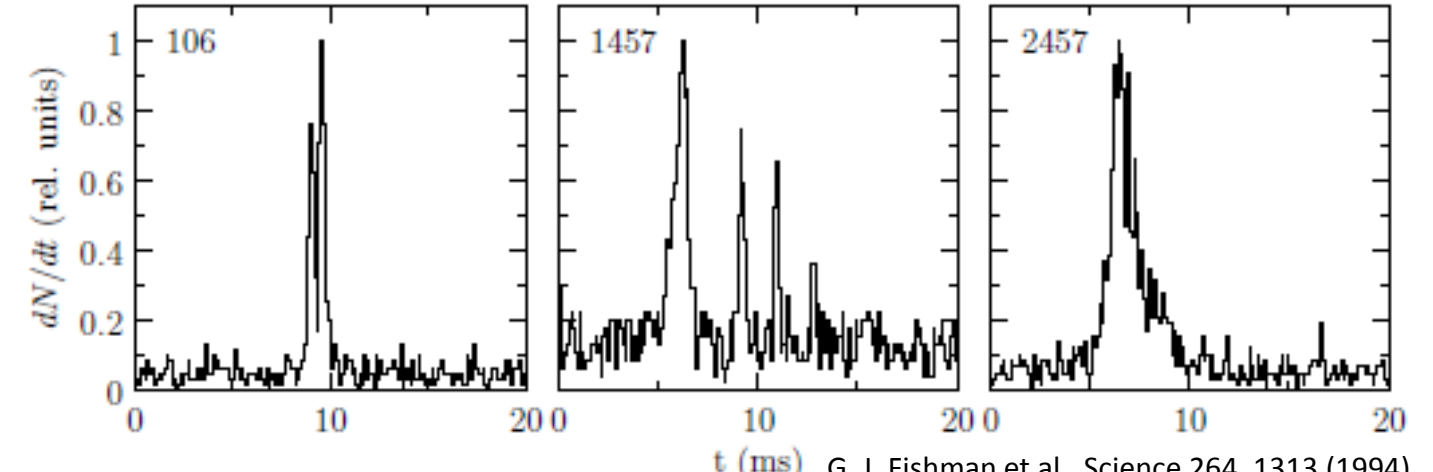
eight scintillator panels
each with effective area 2000 cm^2
energies from 25 keV to above 1MeV
mounted on the corners of CGRO (spatial information)



Sometimes bursts of radiation were observed only by detectors facing the Earth.

They were much shorter than the typical gamma-ray burst

Compton Gamma Ray Observatory (CGRO)



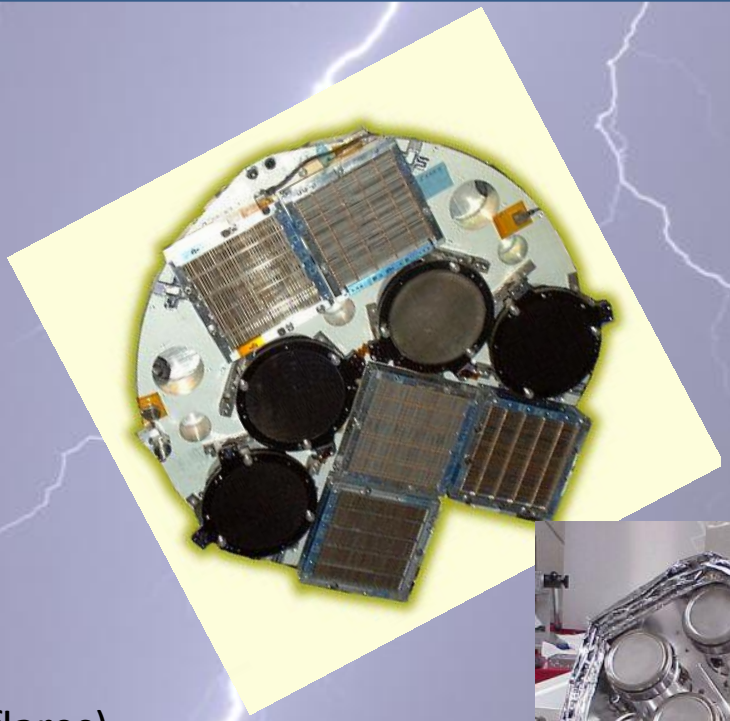
G. J. Fishman et al., Science 264, 1313 (1994)

The y axis represents count rate of 25-1000 keV photons

BATSE data shows TGFs as short bursts of up to 1000 photons with energies ranging from 25 keV up to above 1MeV.

About 70 events were detected during the entire mission

Ramaty High Energy Solar Spectroscopic Imager



Small Explorer (SMEX)

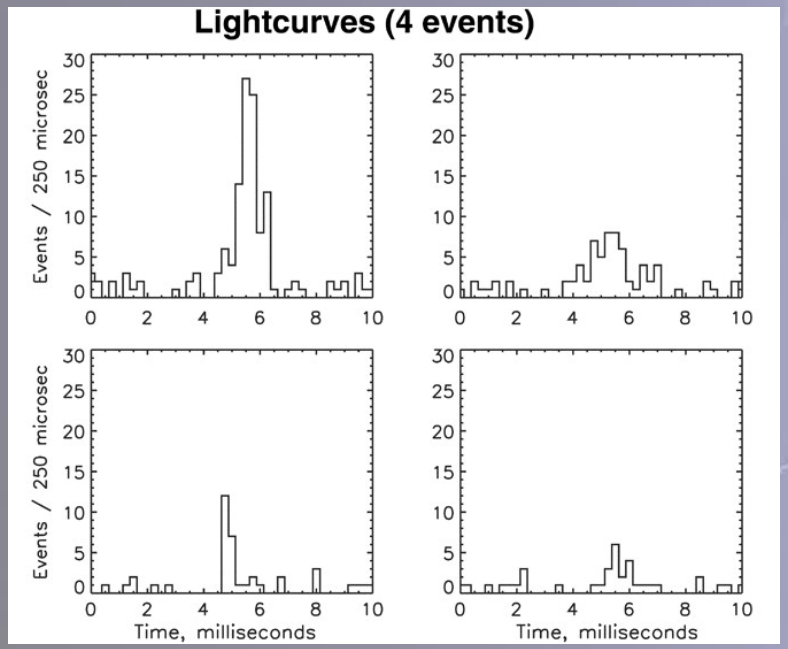
No shielding (good for TGF, bad for solar flares)

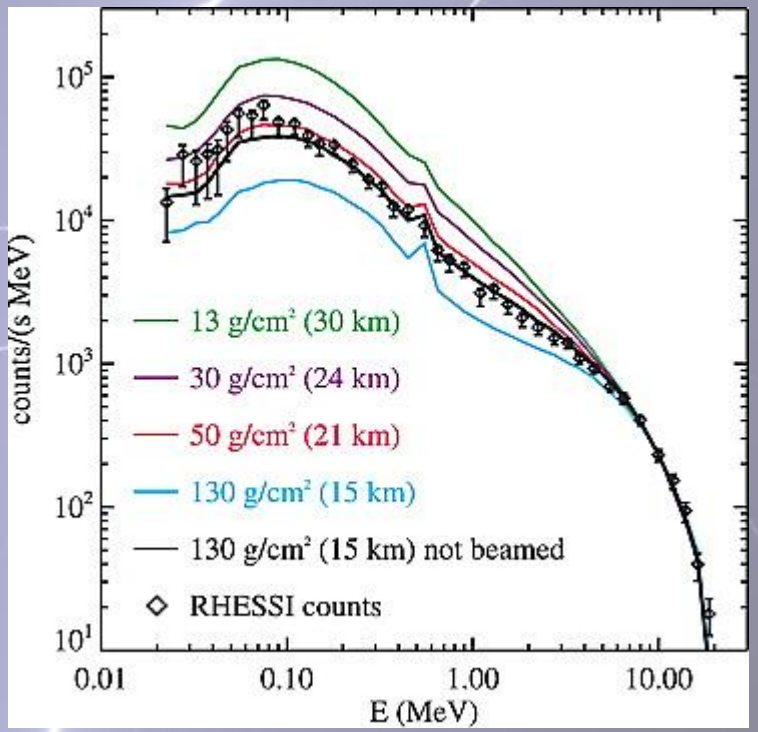
Each photon is counted – time and energy

TGFs recognized through time characteristic – duration less than 10 ms is much shorter than for typical GRB

RHESSI does not give spatial information concernig TGFs

Ramaty High Energy Solar Spectroscopic Imager





Worse sensitivity (effective area 200 cm^2)
Better time resolution

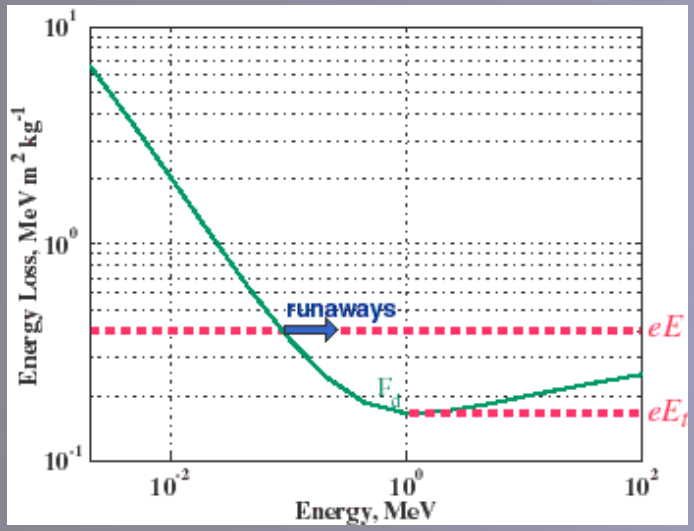
Over 800 events (years 2002 - 2008)

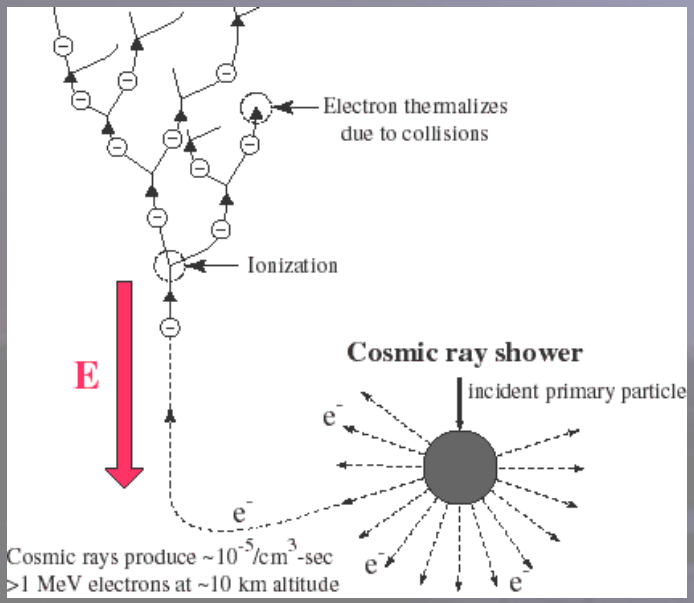
Accumulated spectrum of 85 RHESSI TGFs, with theoretical relativistic-runaway spectra

The only difference between the models is the altitude of the average TGF

Smith et al. Science 307 no. 5712, 1085 (2005)

Runaway Breakdown Mechanism





Gurevich et al., Phys. Letters A 165, 463 (1992)

Energy loss due to collisions decrease with increasing energy

Electrons with sufficient initial energy can be accelerated by electric fields

Accelerated electrons collide with atmospheric molecules, ionize them and produce more relativistic electrons.

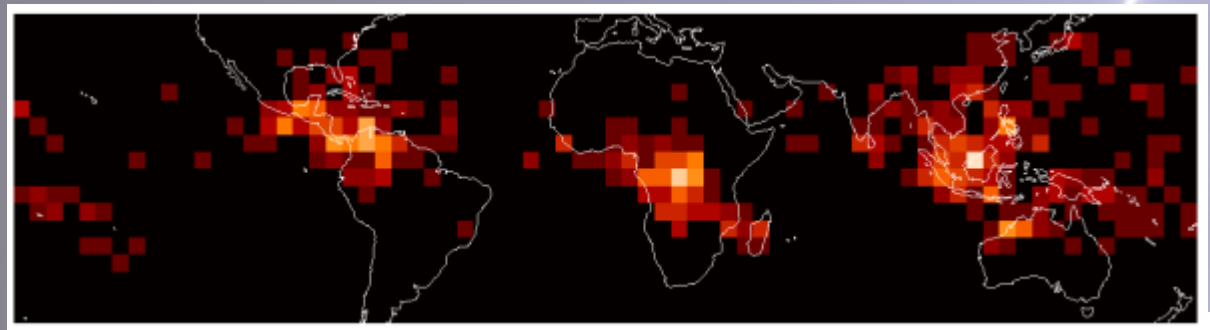
Most newly produced electrons thermalize because of collisions (gamma ray emission), but some accelerate and contribute to the avalanche

Spark: cosmic ray particle

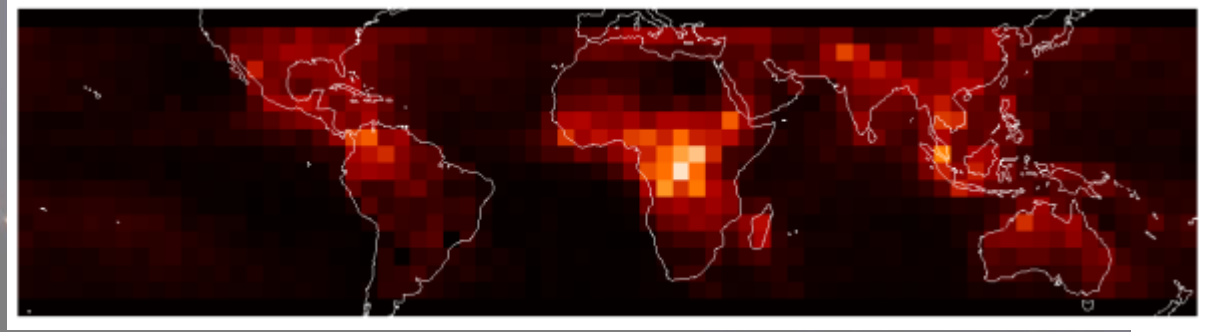
http://www-star.stanford.edu/~vlf/runaway/

RHESSI TGFs and Lightnins

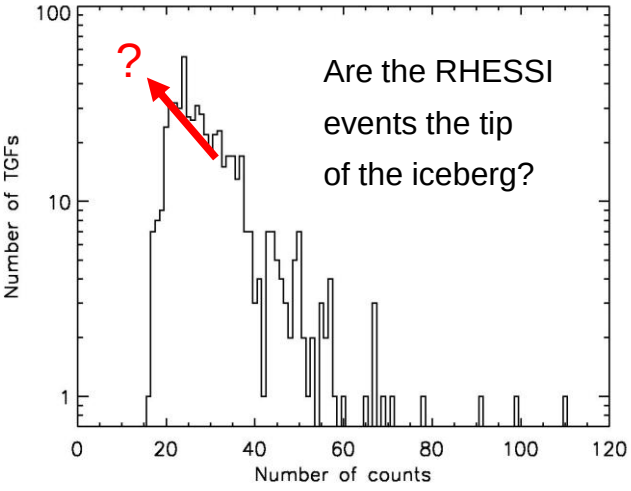
RHESSI TGF Positions



Visible Lightning Positions



RHESSI TGFs for which lightning data is available show coincident lightning activity within several milliseconds for 76% of TGFs



Smith et al. Science 307 no. 5712, 1085 (2005)

Ramaty High Energy Solar Spectroscopic Imager

http://svs.gsfc.nasa.gov/

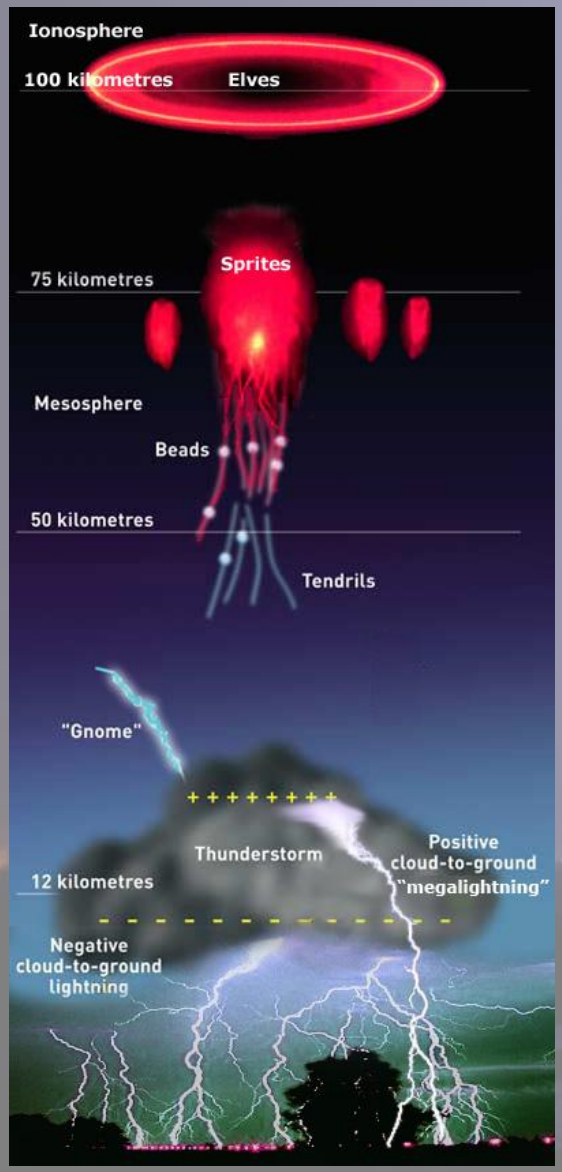
What do You know about lightnings?

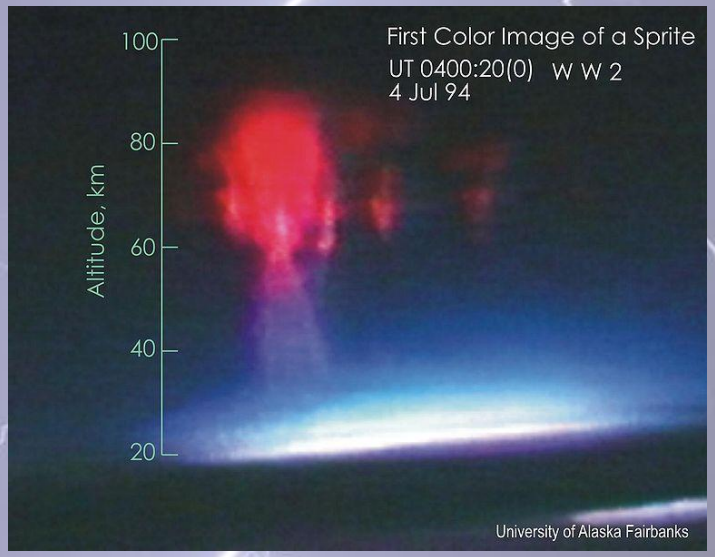
Blinding	oh, Yeah
Hit the ground	are You sure?
Short duration	well, but...
Relatively simple shape	definately not
Additional effects: thunder	not only

What do You know about lightnings?

What do You know about lightnings?

Sprites, Elves, Gnomes…





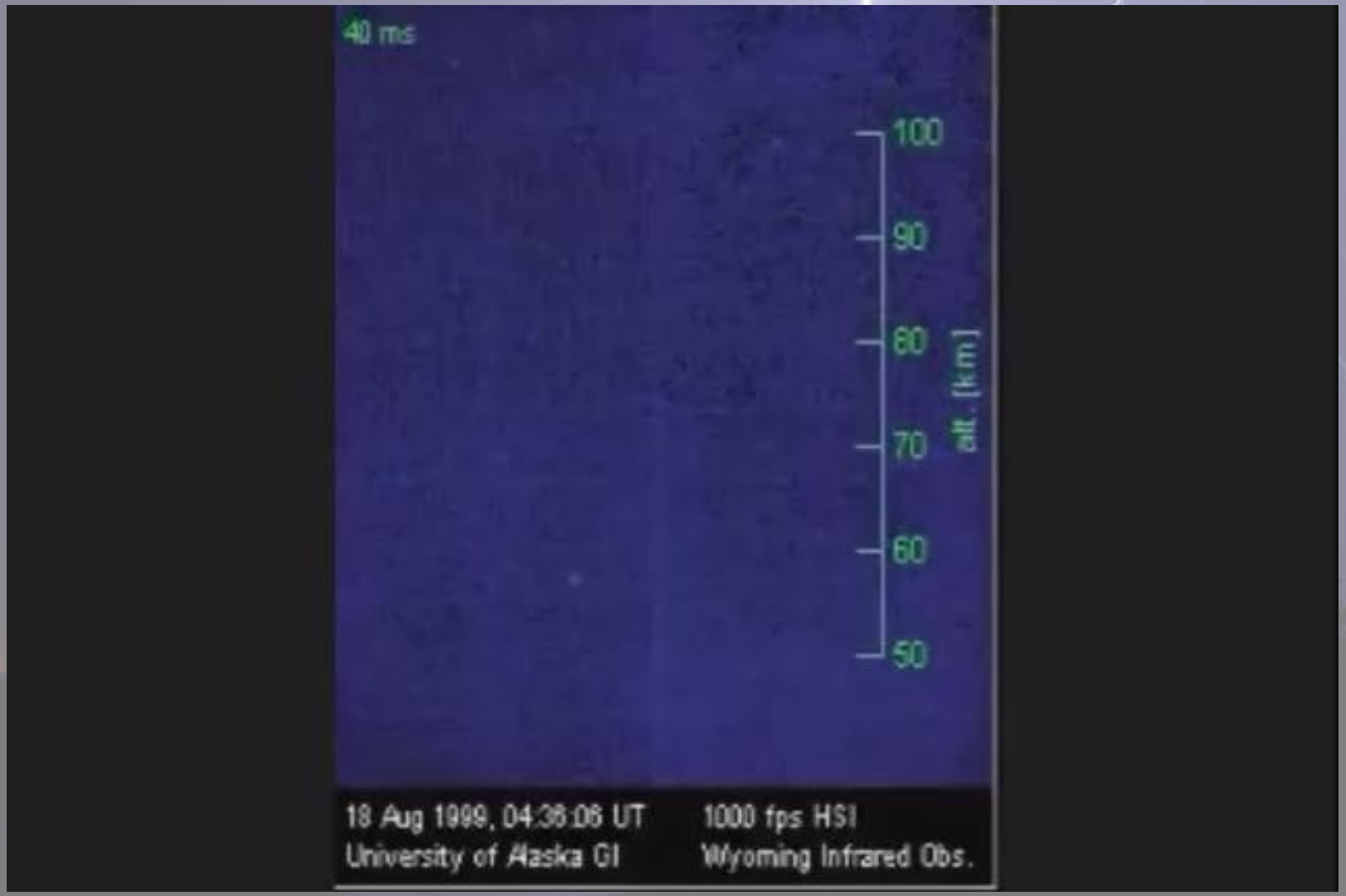
first photographed on July 6, 1989

observed above thunderstorms

extremely short

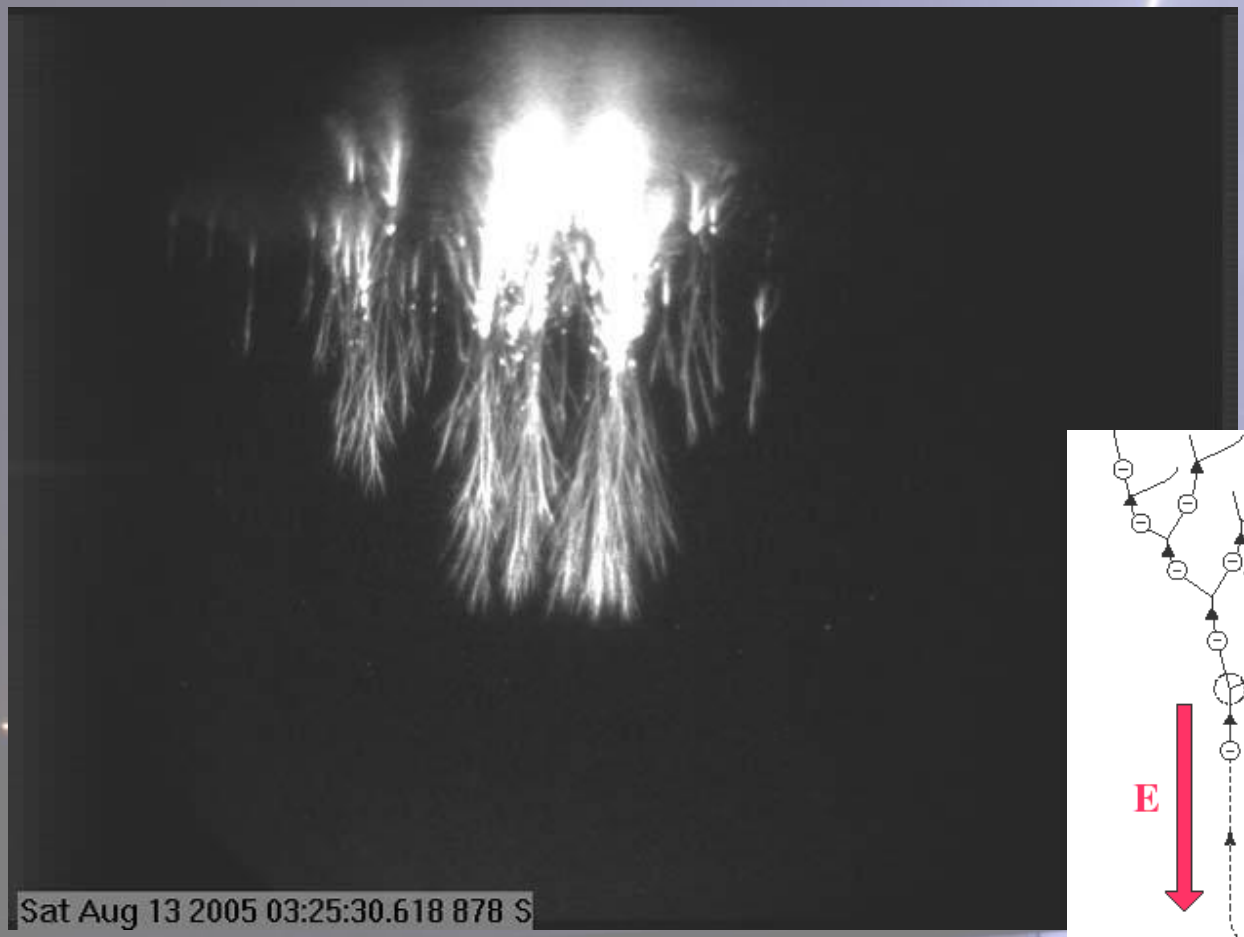
observed few miliseconds after lightning

Sprites


40 ms
100
90
80
70
60
50
alt. [km]
18 Aug 1999, 04:36:06 UT
University of Alaska GI
1000 fps HSI
Wyoming Infrared Obs.

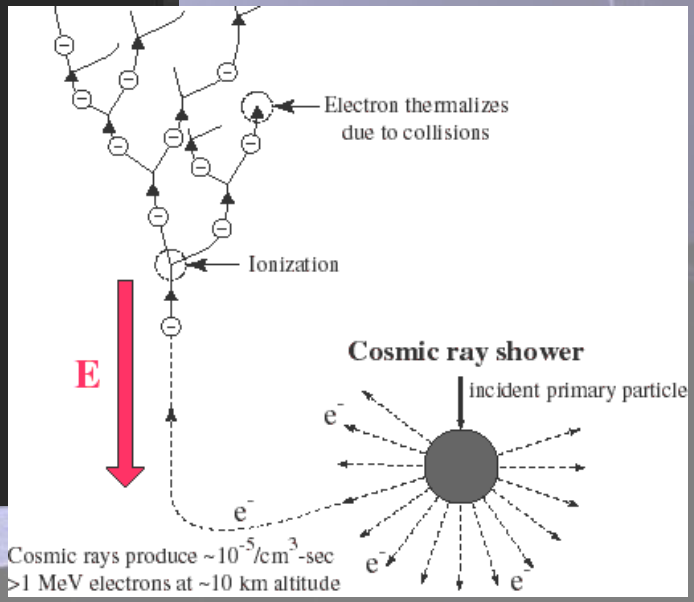
Sprites

Sprites



Consistent with running breakdown mechanism

The source of TGFs?



New Instrumentation

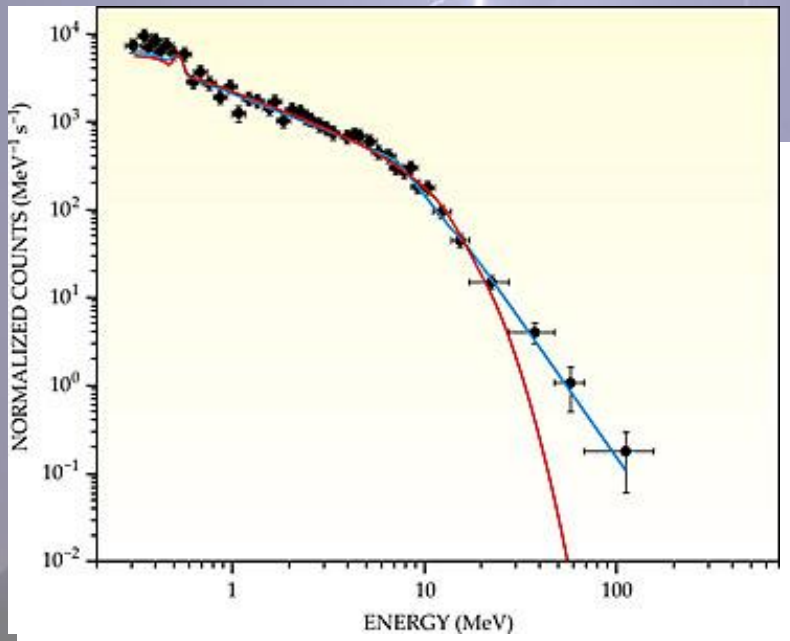
AGILE (Astro-rivelatore Gamma a Immagini LEggero)

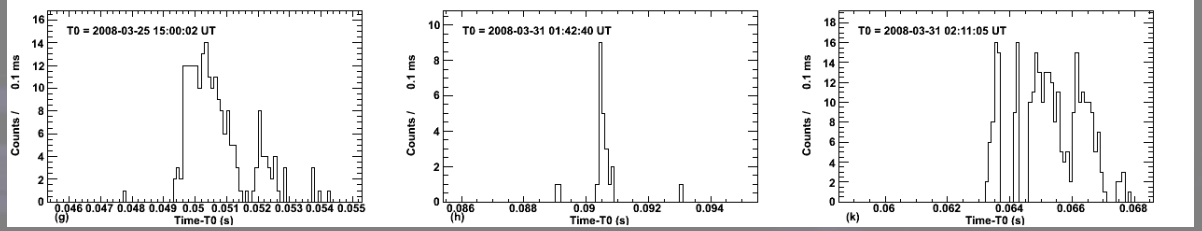
combines gamma-ray imager (30 MeV- 30 GeV) with a hard X-ray imager (18-60 keV) with large FOVs (1-2.5 sr) and optimal angular resolution

detects ~10 TGFs/month

AGILE and RHESSI TGF samples are consistent concerning longitude, local time distribution and spectral shape

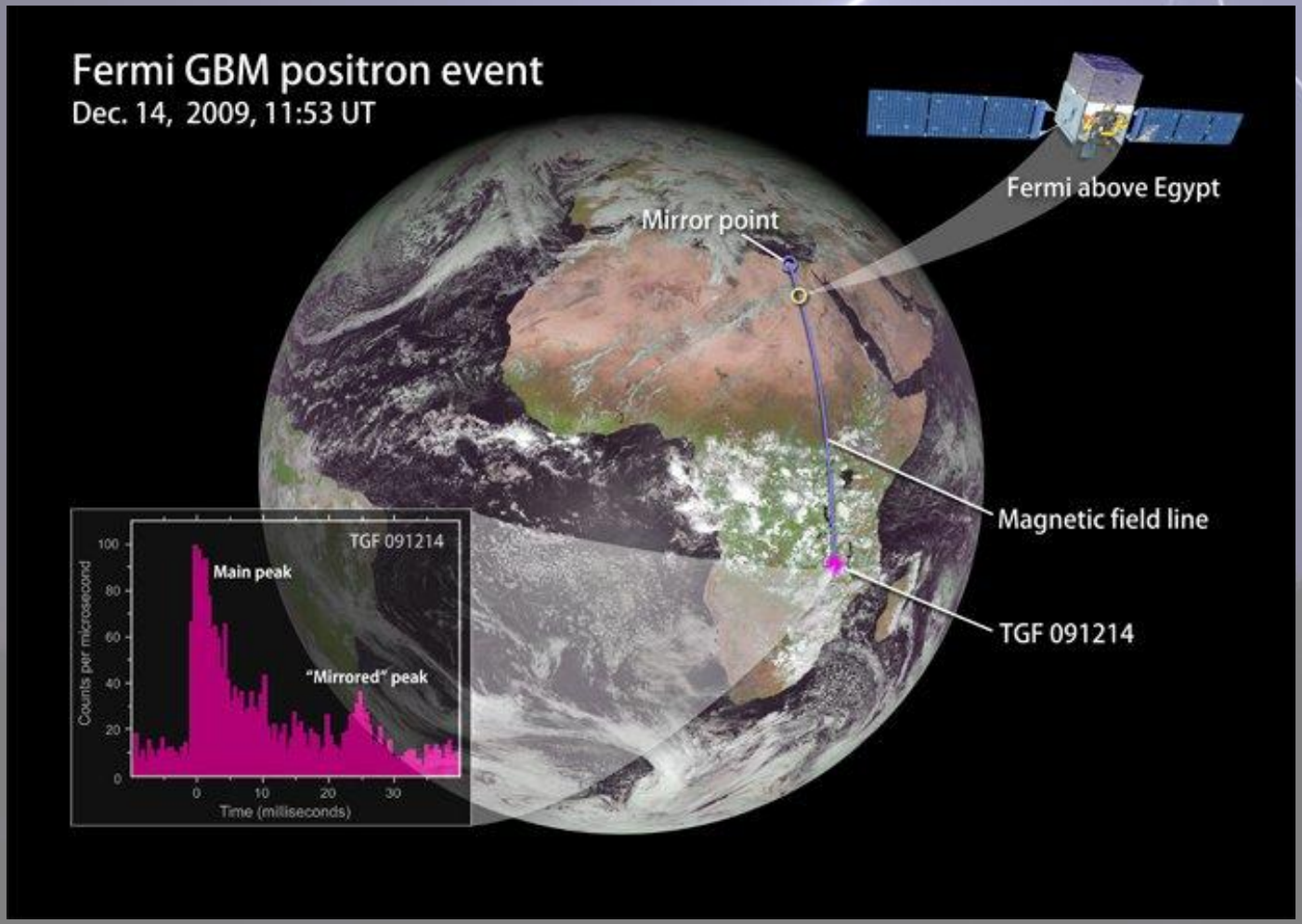
cumulative spectrum with significant detection above 40 MeV



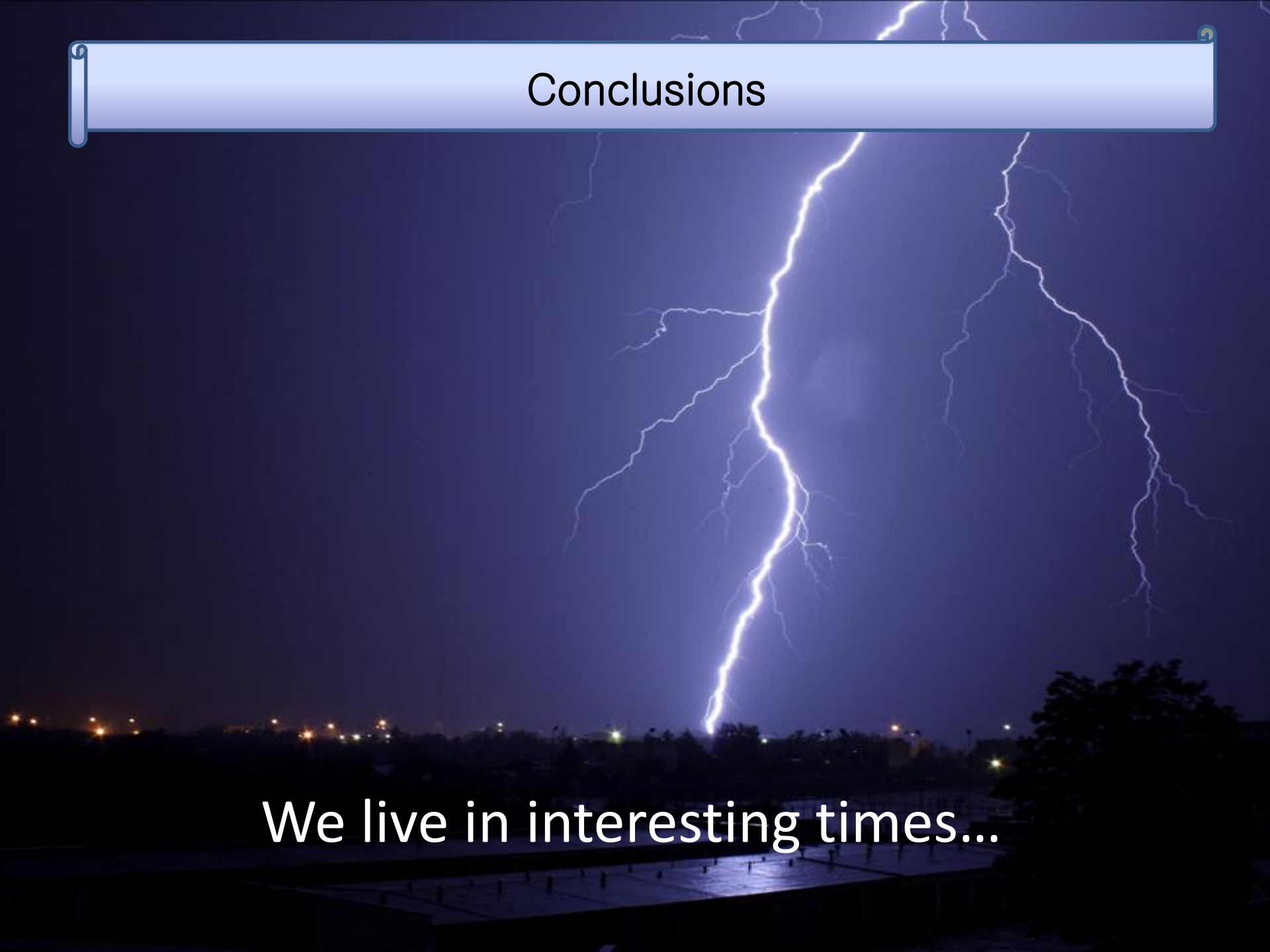


New Instrumentation

Fermi Gamma Ray Space Telescope and new discovery



Conclusions



We live in interesting times…