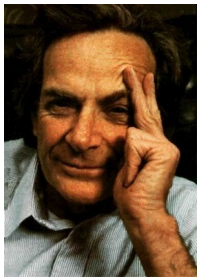
FULMINI E SAETTE

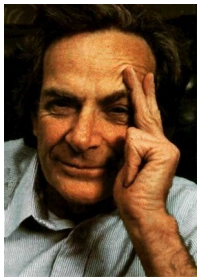
G.Barbiellini, G.Iafrate
University of Trieste and INFN Trieste

on behalf of the AGILE team

Thanks to M.Marisaldi,
F.Fuschino, F.Longo

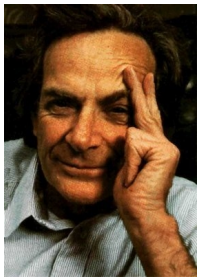


Feynman Festival - 17 aprile 2008

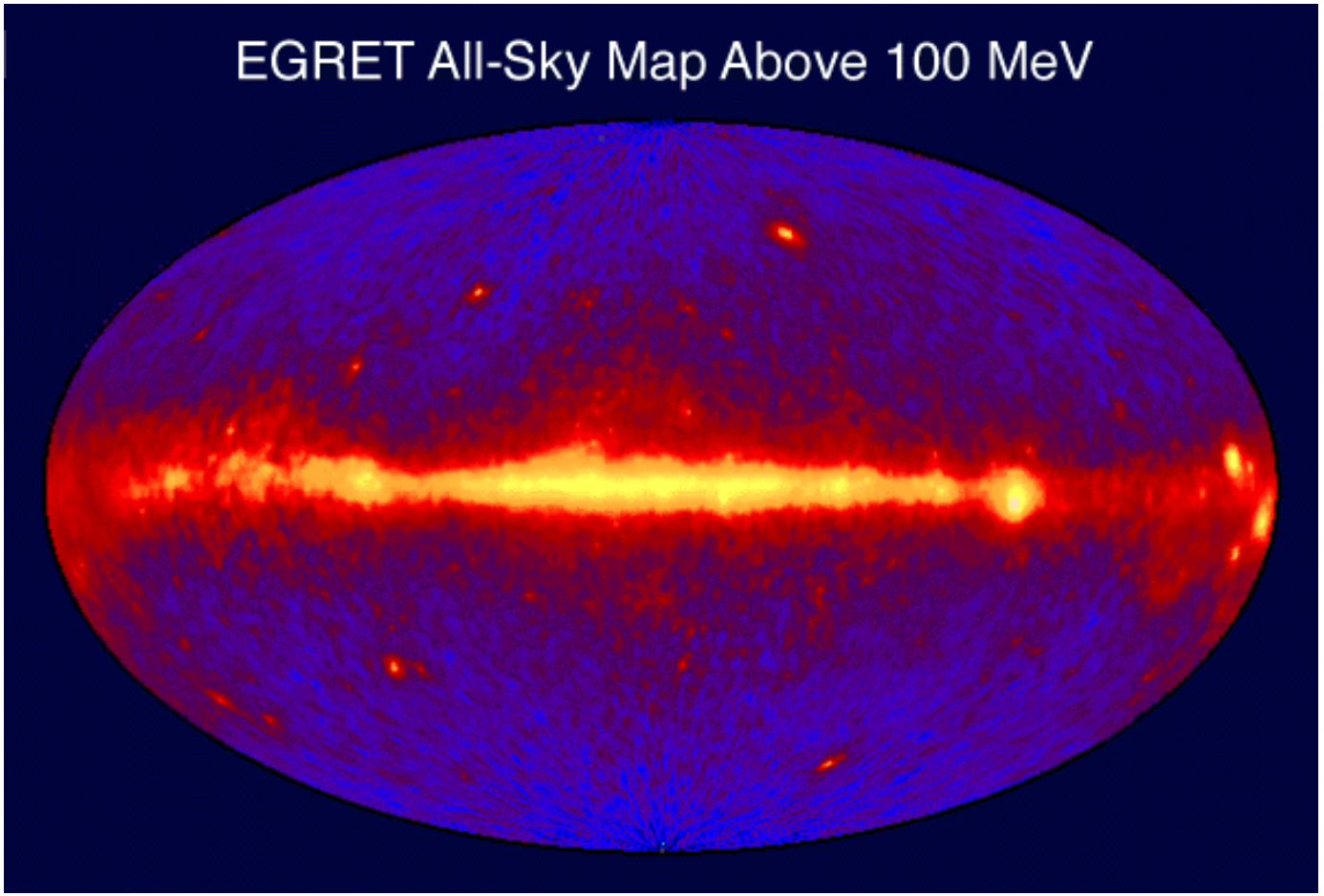


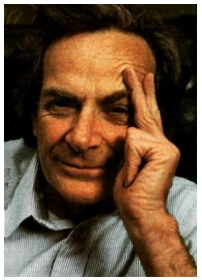
Outline

- Gamma-ray astrophysics and detection technique
- AGILE scientific mission and instrument
- AGILE in orbit: first results
- Terrestrial Gamma-ray flashes: introduction and history
- Sprites
- BATSE, RHESSI and AGILE observations
- Correlation with cosmic-rays

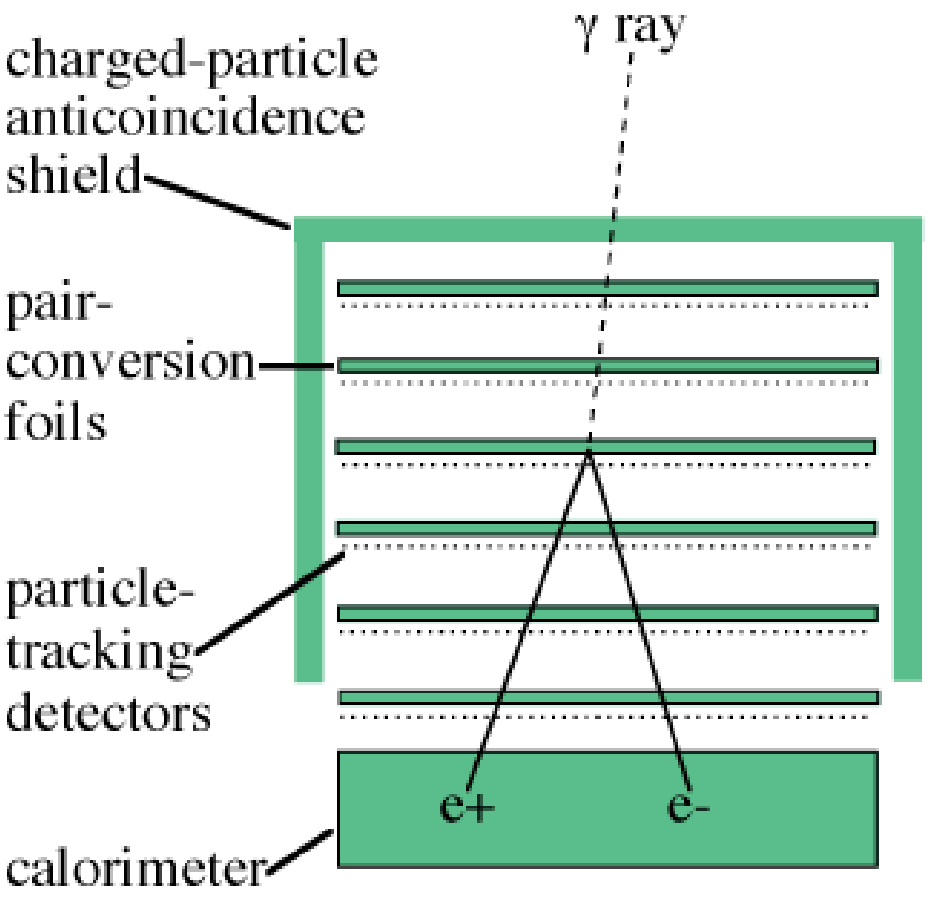


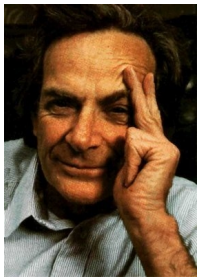
Gamma-Ray Astrophysics





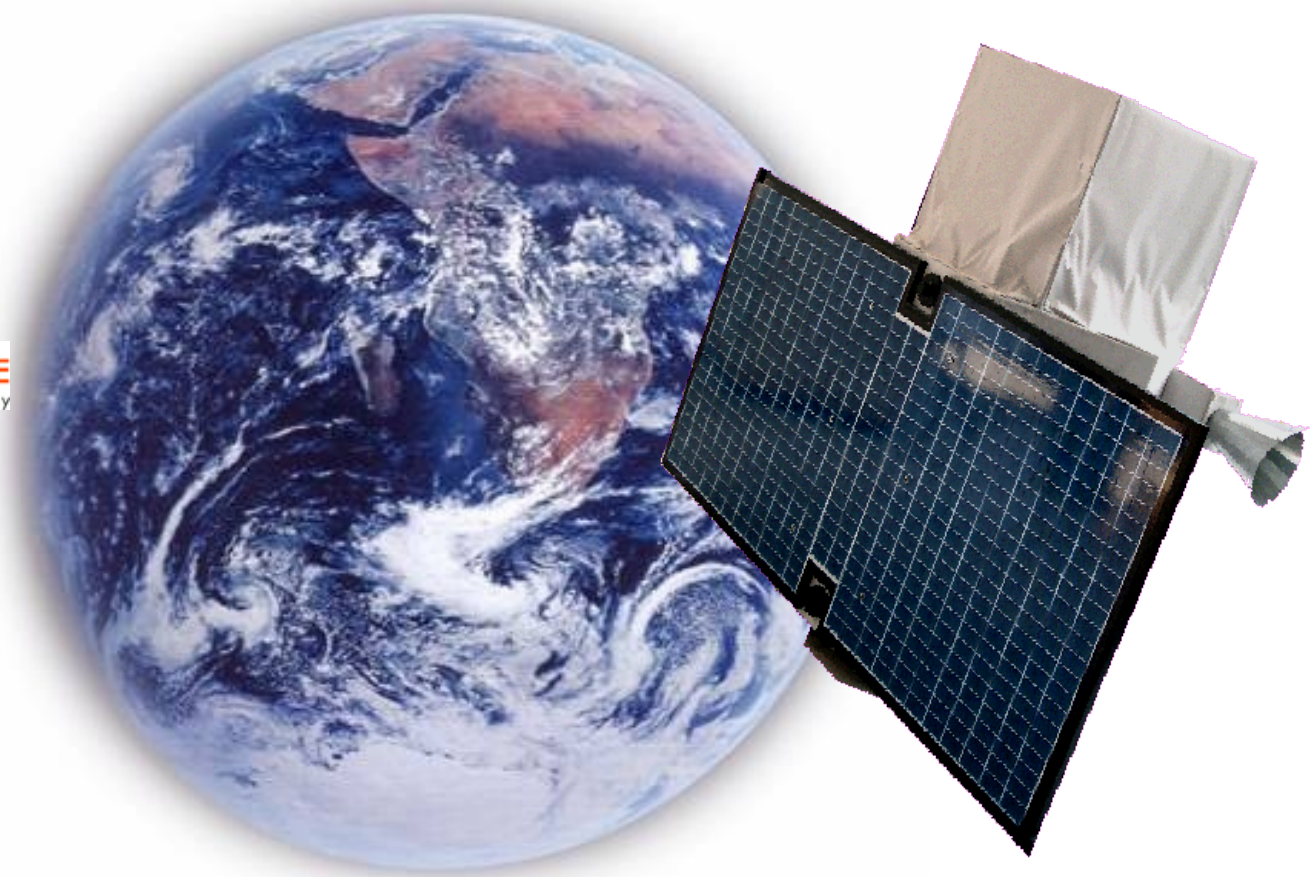
Detection Technique

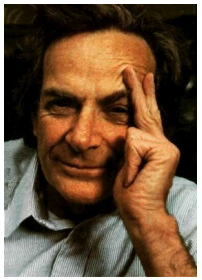




AGILE

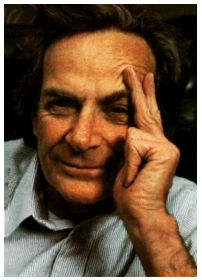
AGILE



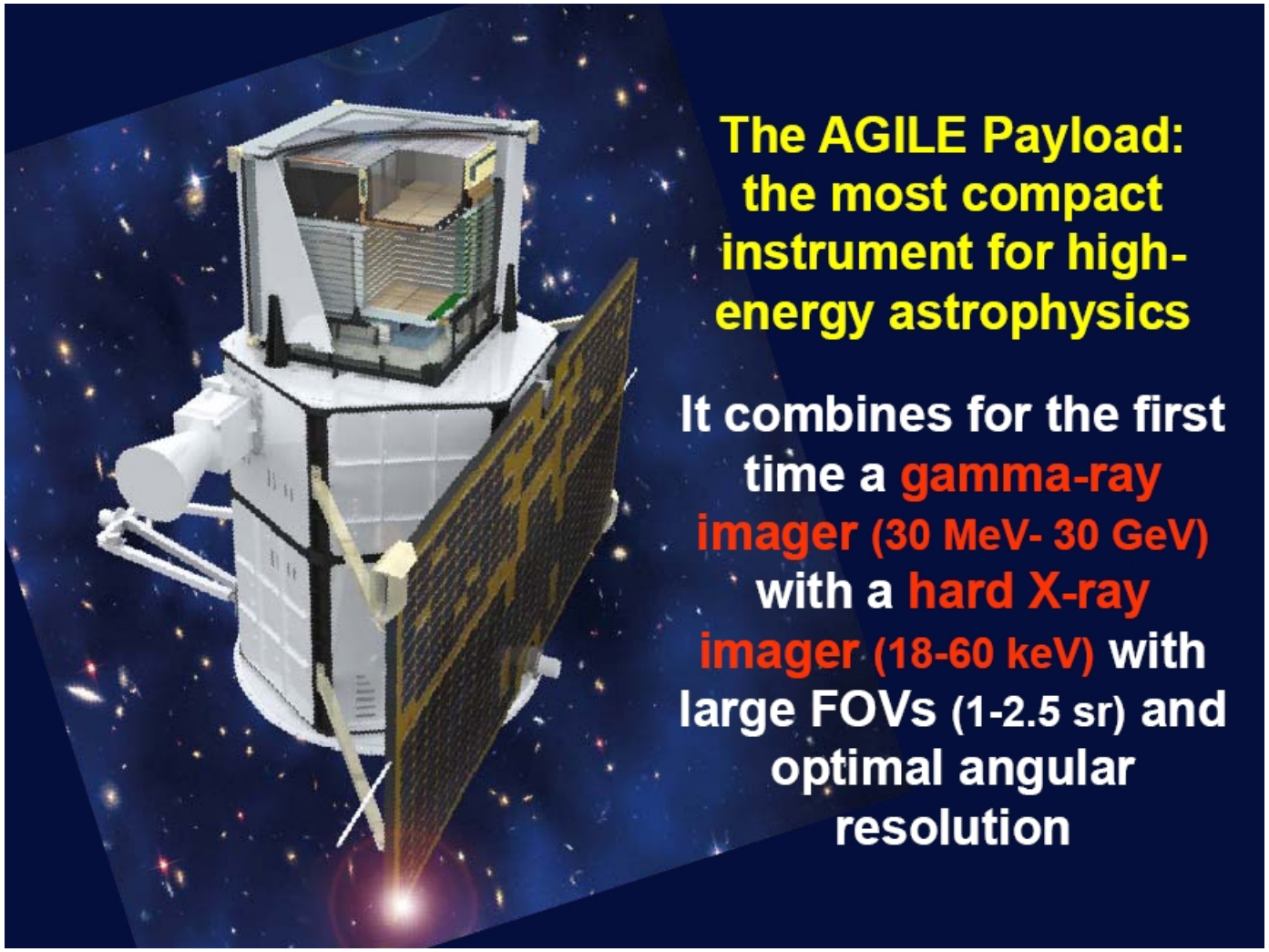


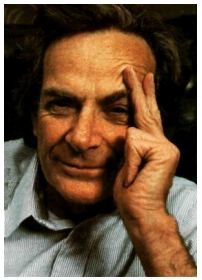
Scientific Institutes involved in the development of AGILE

- INAF-IASF Milano
- INAF-IASF Bologna
- INAF-IASF Roma
- INFN- Sez. Trieste
- INFN- Sez. Roma I
- INFN- Sez. Roma II
- INFN- Sez. Pavia
- Università di Trieste
- Università di Roma “Tor Vergata”
- Università “La Sapienza”
- CIFS - Consorzio Interuniversitario per la Fisica Spaziale (Torino)



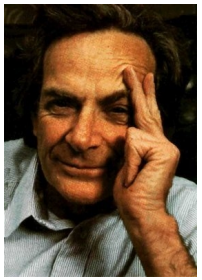
AGILE instrument





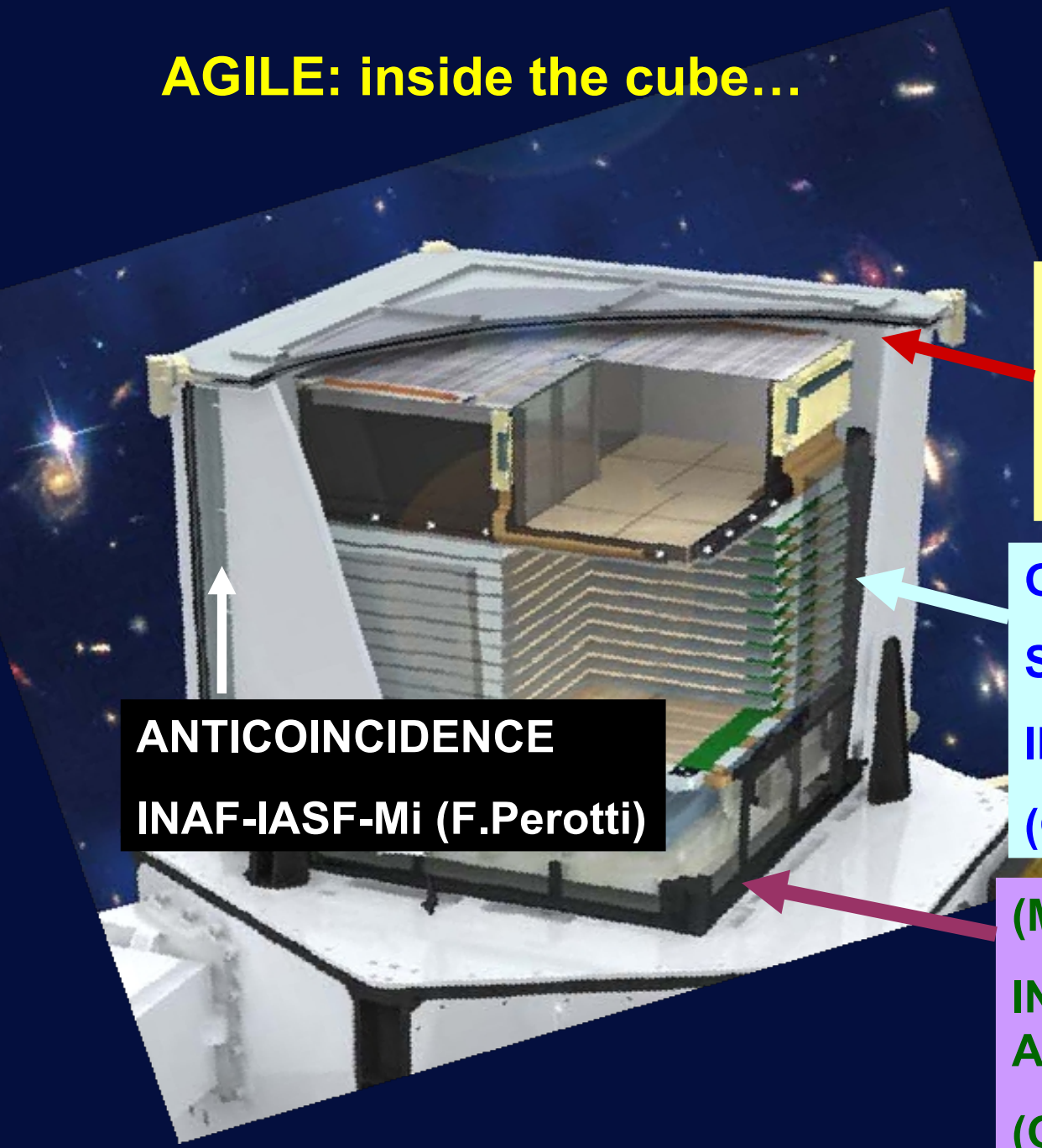
AGILE in orbit…

- First ASI Small Scientific Mission
- Scientific Mission dedicated to gamma-ray and X-ray astrophysics
- Around 5000 orbits.
- Healthy Scientific Instrument
- Satellite Commissioning Phase completed (May-June)
- Science verification phase and in-orbit calibrations completed (July-September: Vela & Crab PSRs)
- Very promising scientific performance



The AGILE Instrument

AGILE: inside the cube…



HARD X-RAY IMAGER
(SUPER-AGILE)

INAF-IASF-Rm
(E.Costa, M. Feroci)

GAMMA-RAY IMAGER

SILICON TRACKER

INFN-Trieste

(G.Barbiellini, M. Prest)

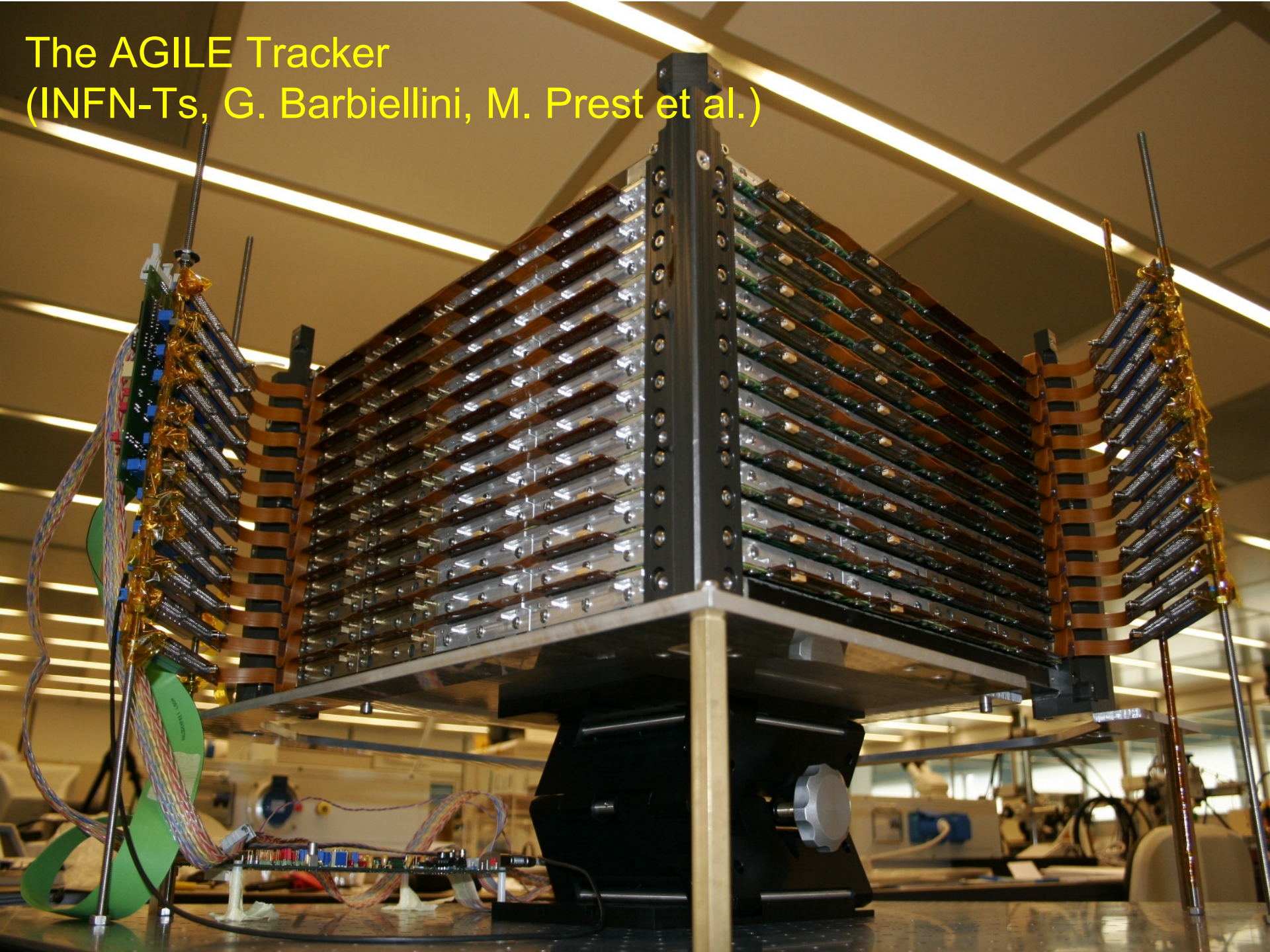
ANTICOINCIDENCE

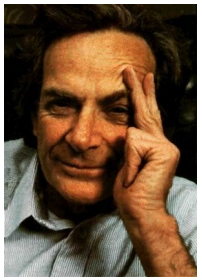
INAF-IASF-Mi (F.Perotti)

(MINI) CALORIMETER

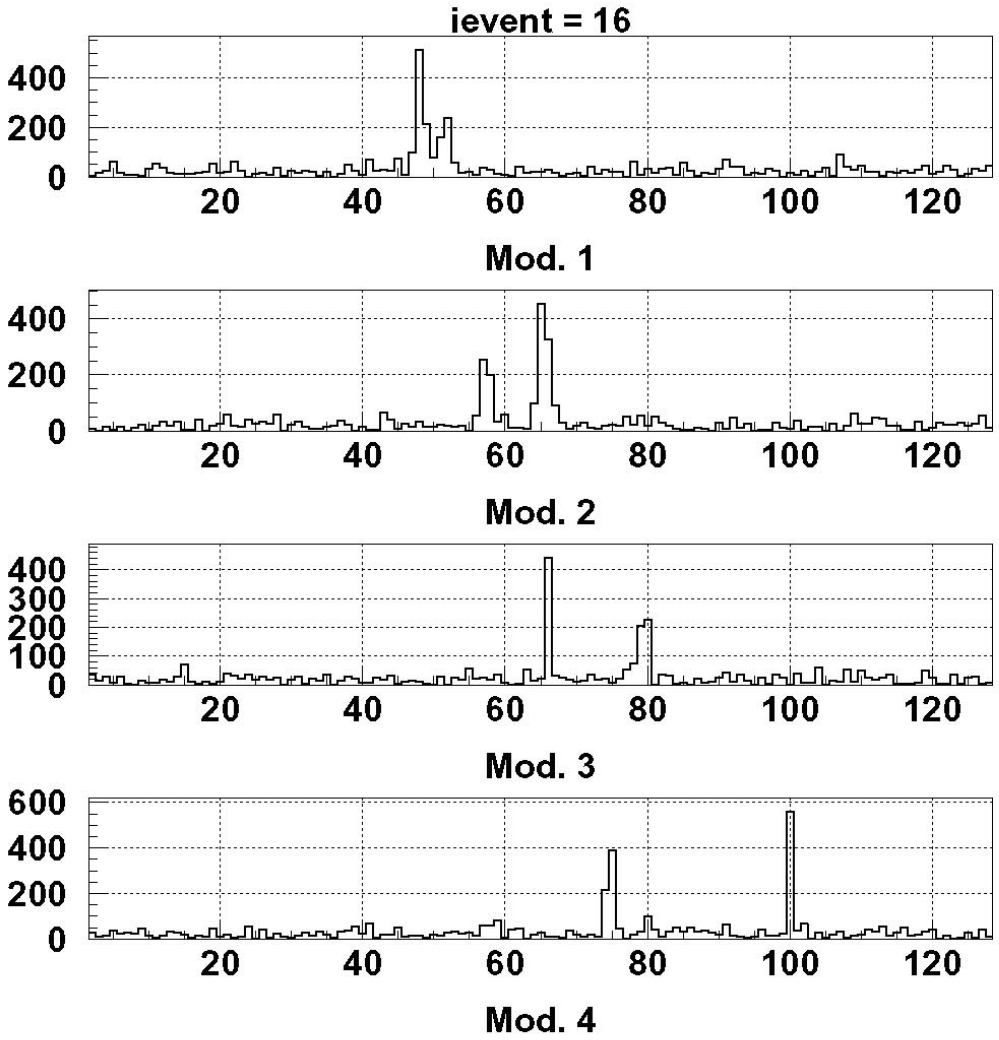
INAF-IASF-Bo, Thales-Alenia Space (LABEN)

(G. Di Cocco, C. Labanti)

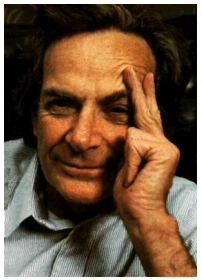

The AGILE Tracker
(INFN-Ts, G. Barbiellini, M. Prest et al.)



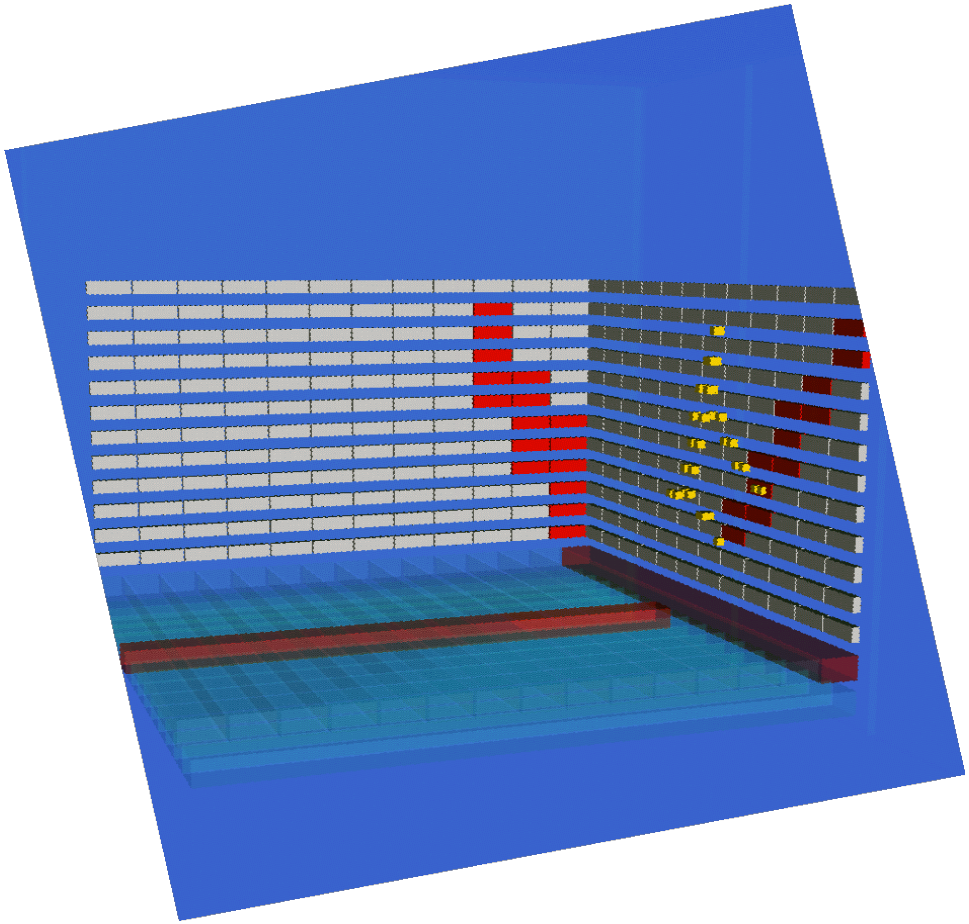
The AGILE instrument



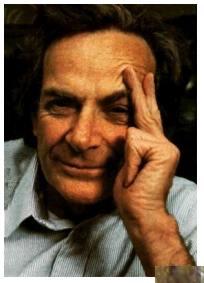
Gamma-ray detected by the AGILE Tracker



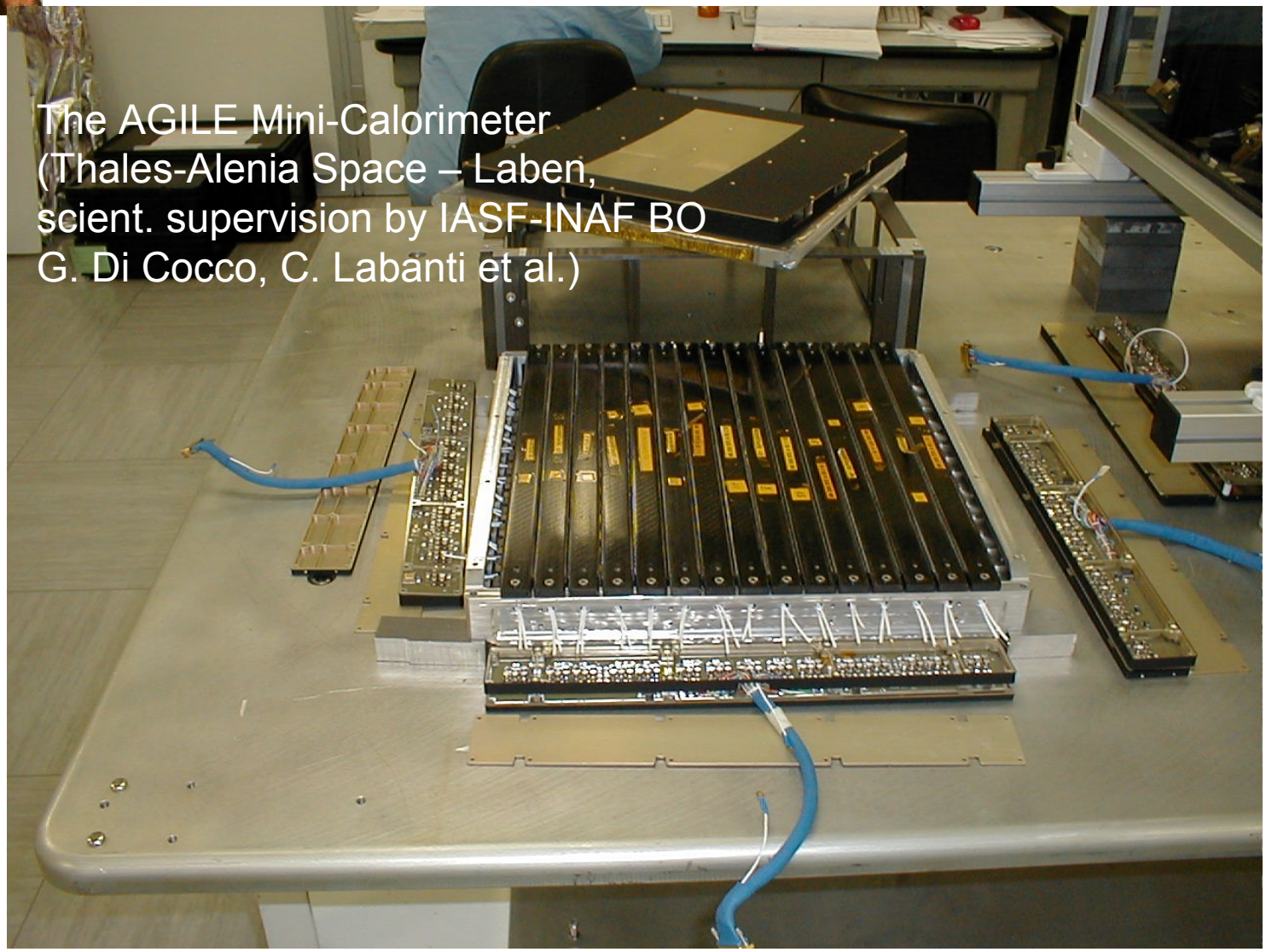
The AGILE instrument

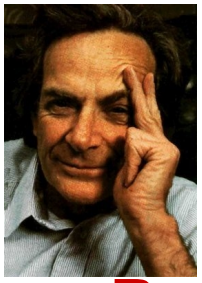


GRID detection of natural bkg gamma-rays



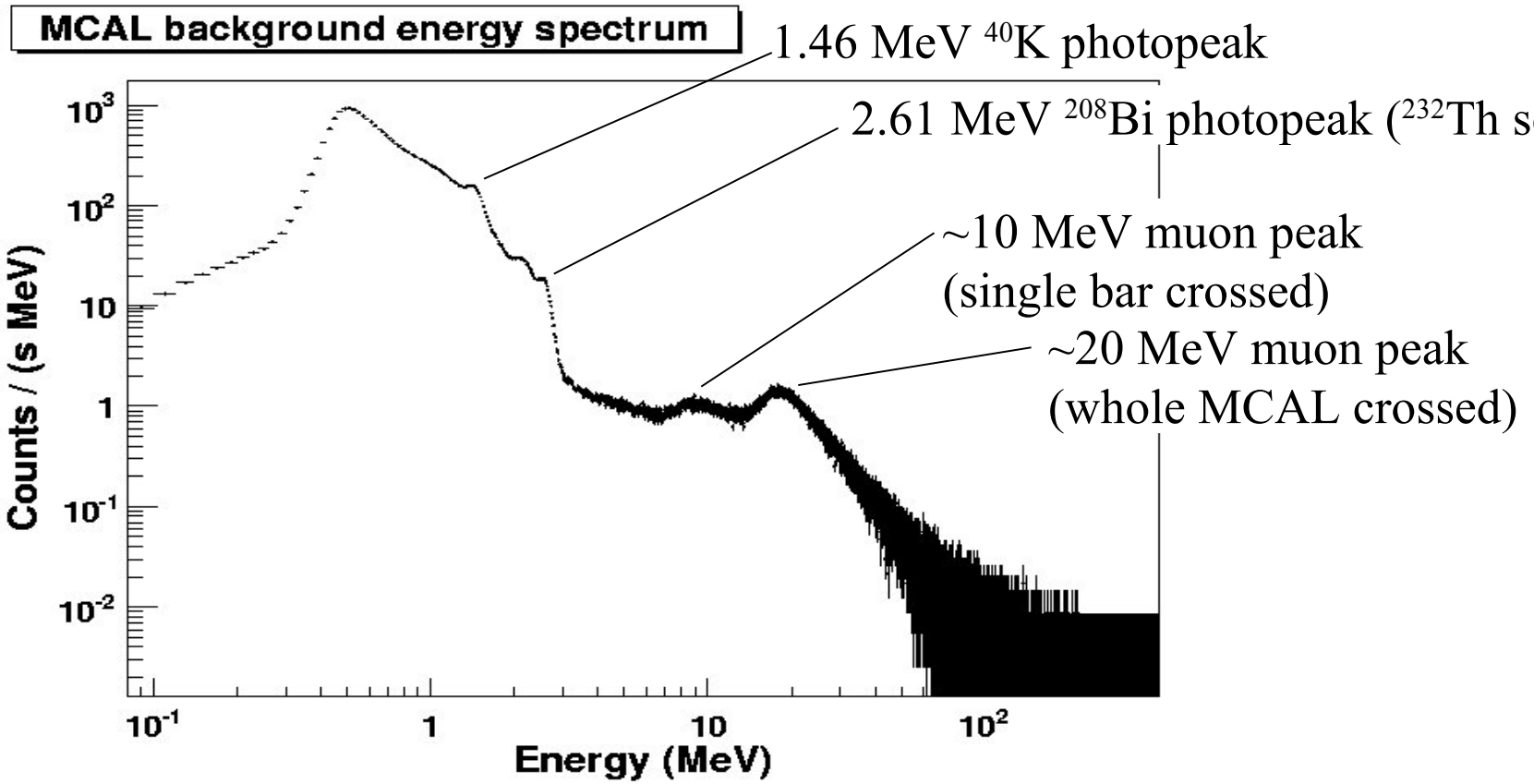
The AGILE instrument



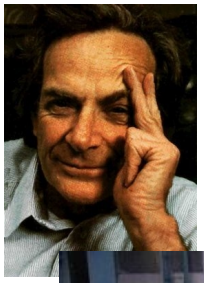


The AGILE instrument

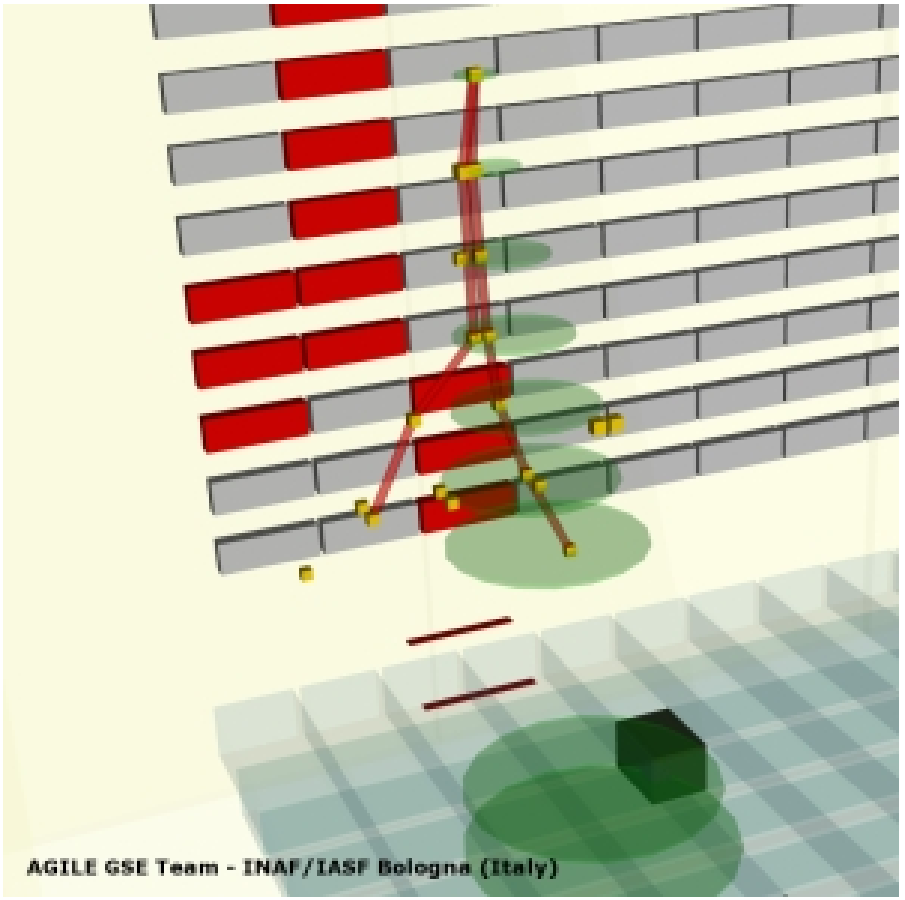
Room Radioactivity (measured in the lab by MCAL)

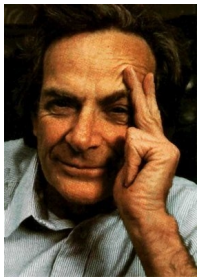


Broad band background energy spectrum measured by a CsI detector (MCAL of AGILE) sensitive in the 400 keV – 100 MeV energy range.Several features due to radioisotopes in the environment and atmospheric muons can be identified.



The Last Gamma on Earth

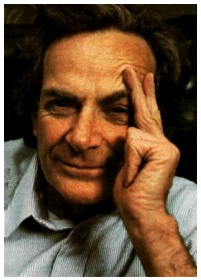




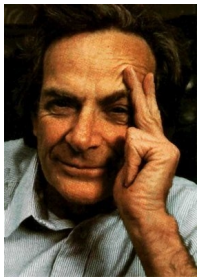
AGILE launch

Sriharikota launch base (India)

PSLV-C8 launch, April 23, 2007



AGILE in orbit



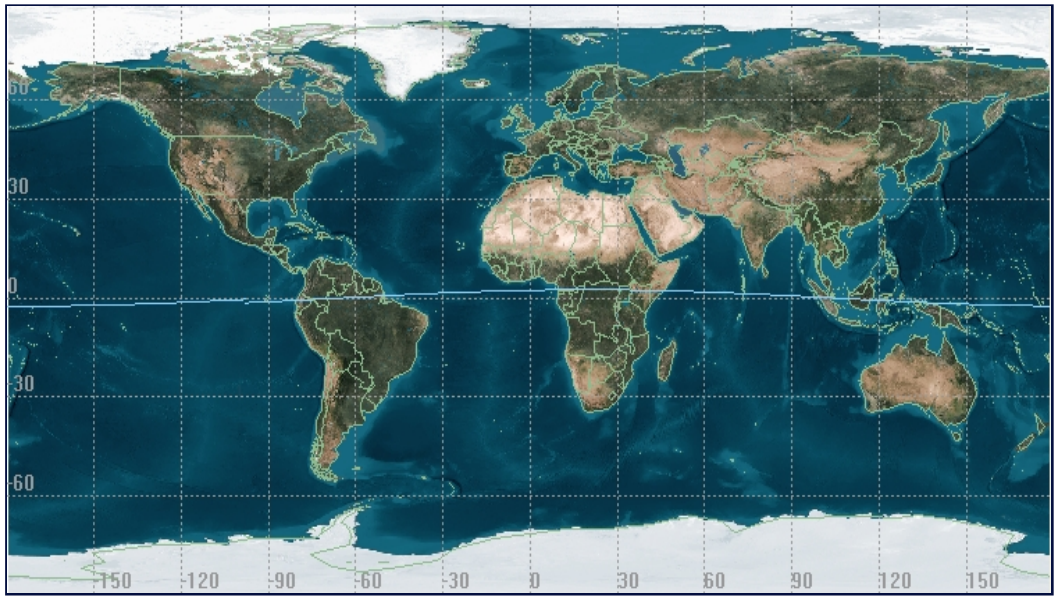
AGILE in orbit

AGILE orbital parameters

Semi-major axis: 6922.5 km (± 0.1 km)
Requirement: 6928.0 ± 10 km

Inclination angle: 2.48° (±0.04°)
Requirement: < 3°

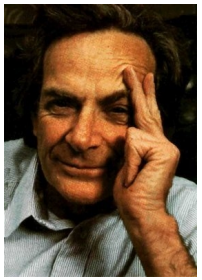
Eccentricity: 0.002 (±0.0015)
Requirement: < 0.1°



The AGILE orbit is the best for gamma-ray astrophysics

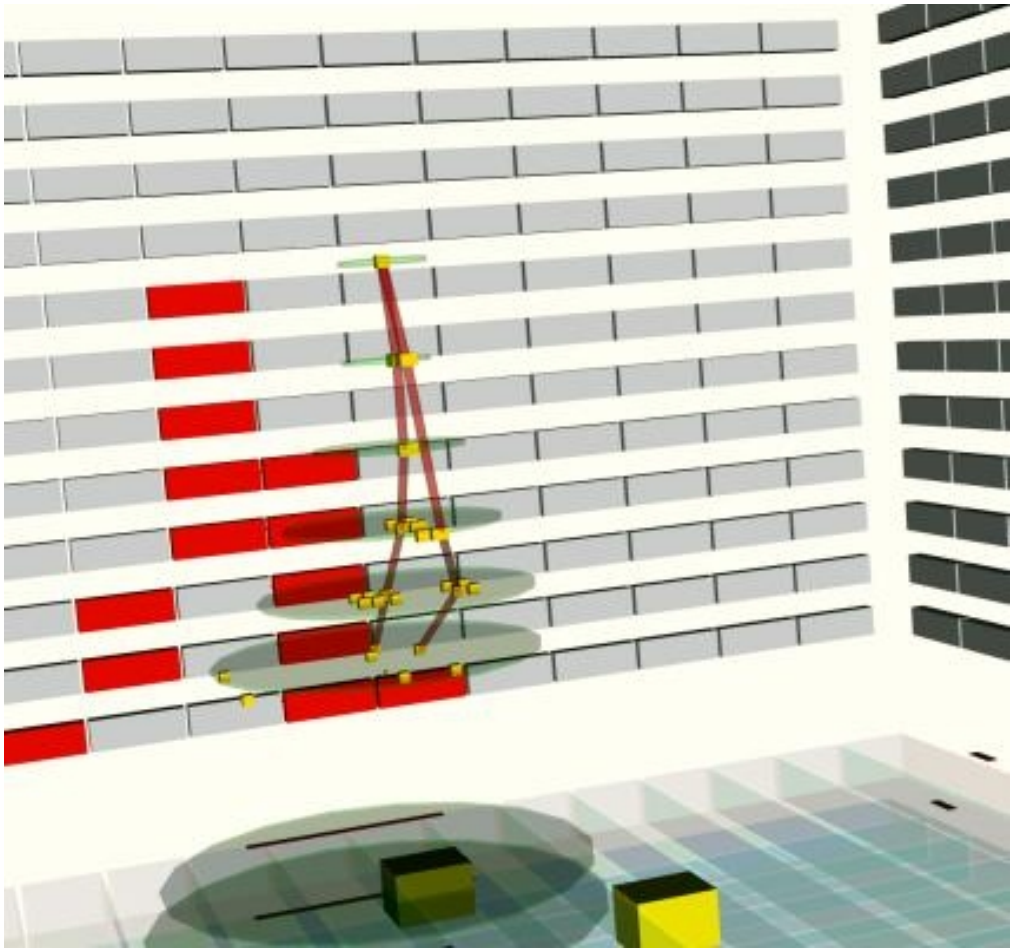
Low particle background !

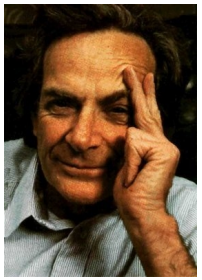
Average height: 540 km
Inclination angle: 2.48 degrees



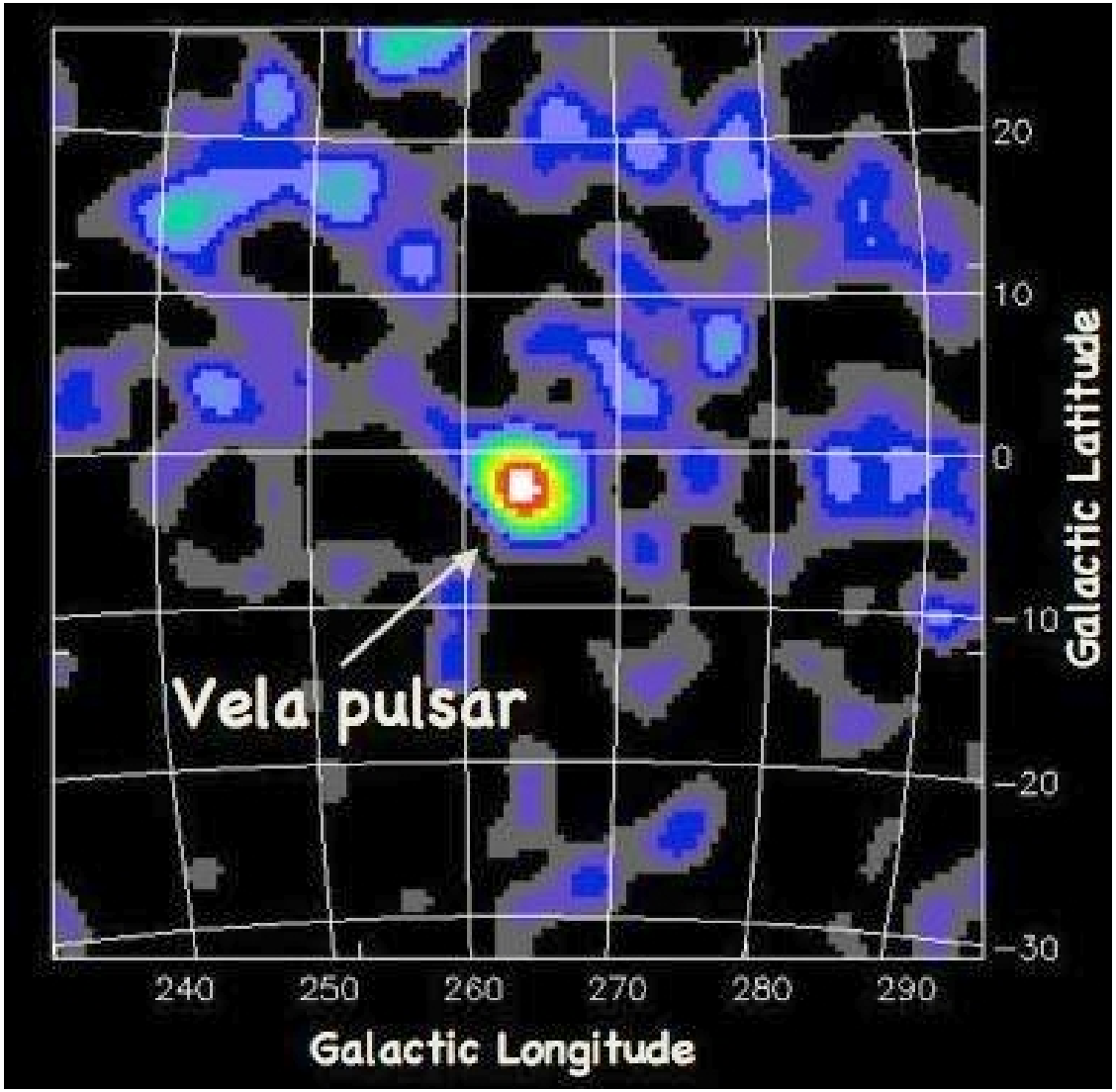
The First Gamma in Orbit

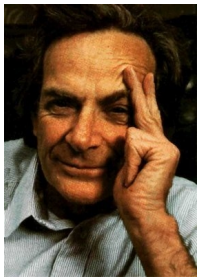
First gamma-ray detected in orbit with the nominal GRID trigger configuration (May 10, 2007)



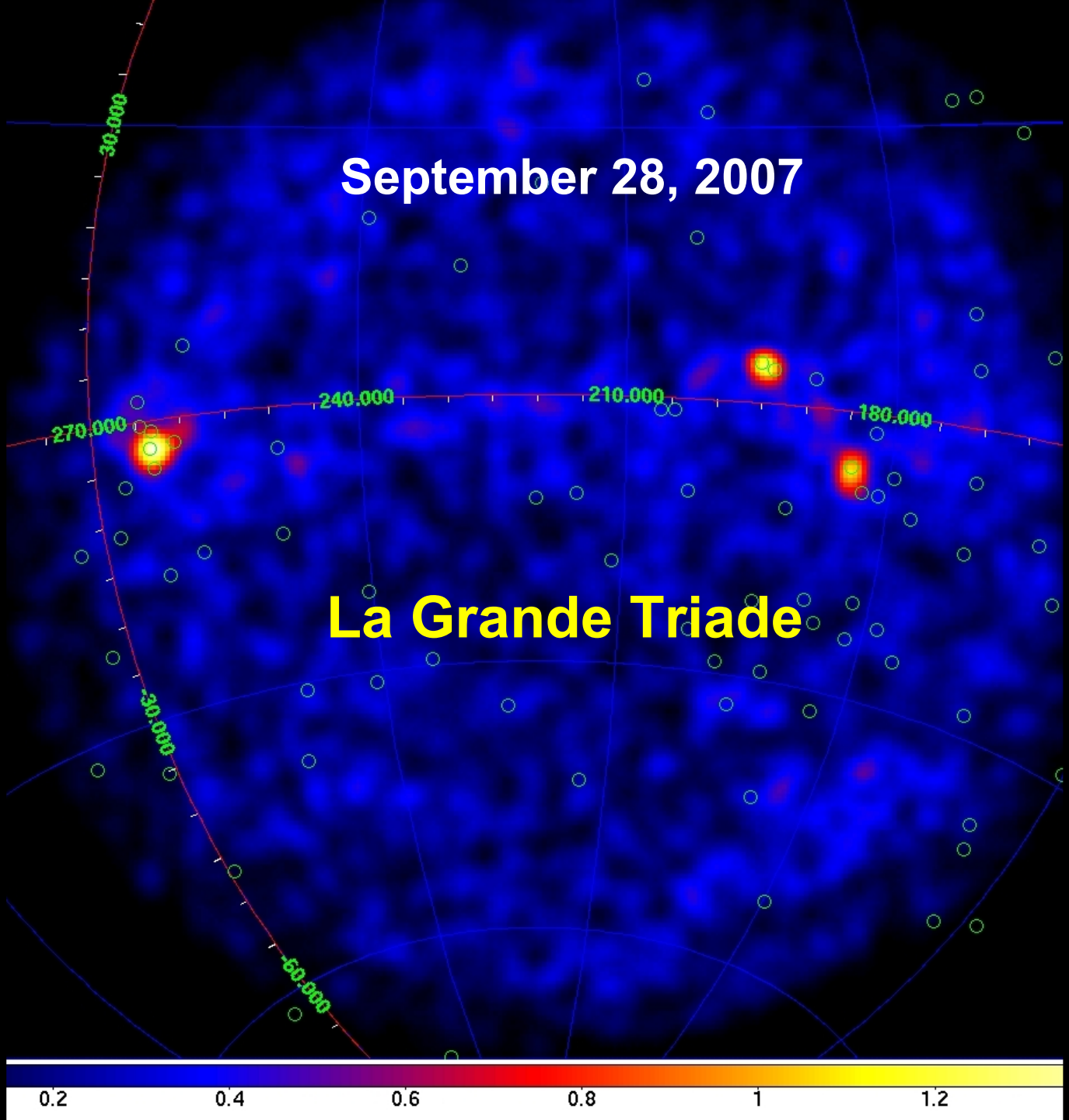


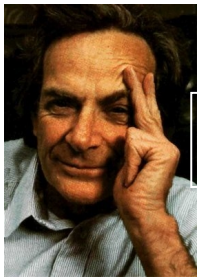
First Light


Vela pulsar
20
10
0
−10
−20
−30
Galactic Latitude
240
250
260
270
280
290
Galactic Longitude

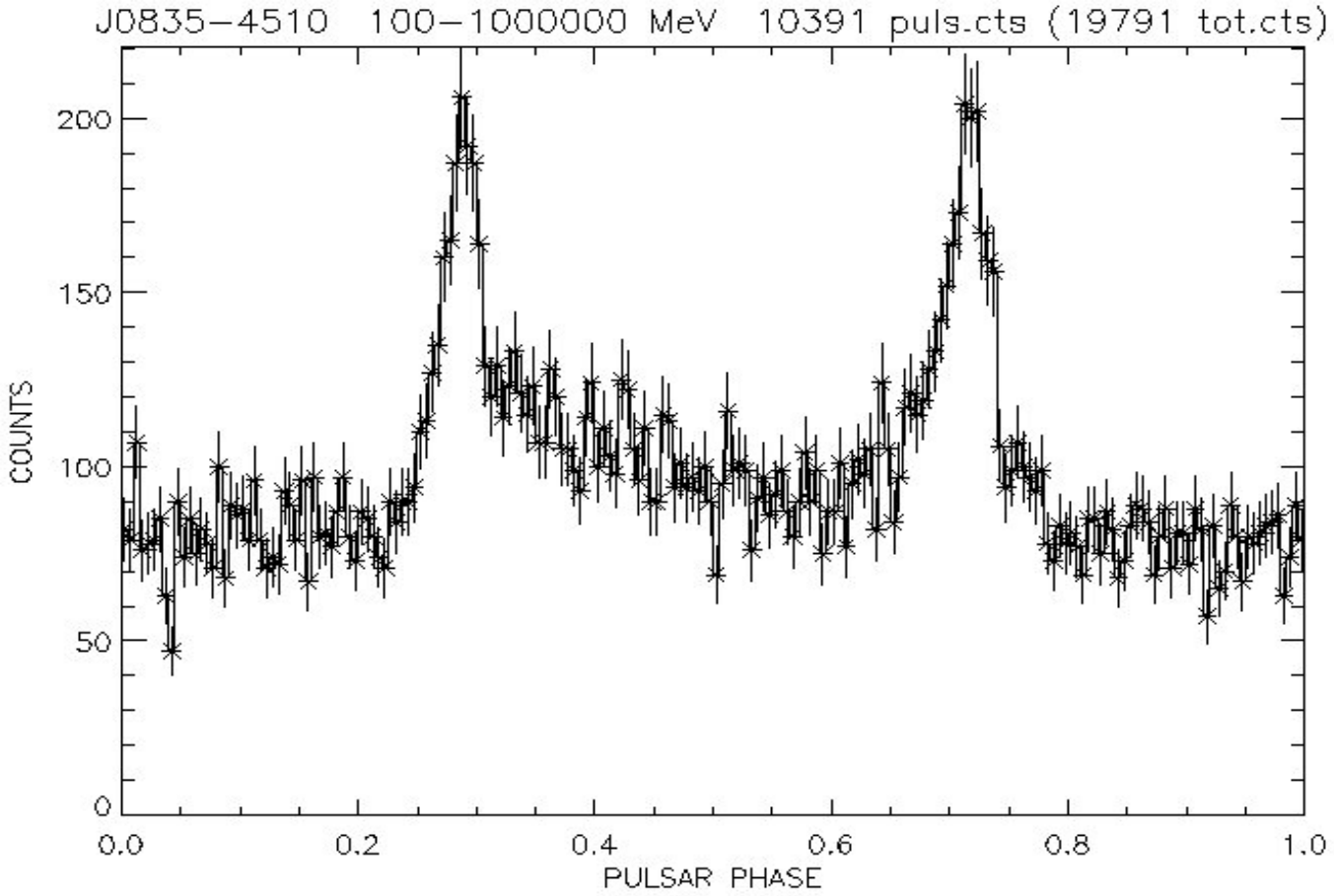


AGILE results

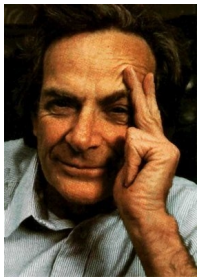

September 28, 2007
La Grande Triade
30.000
240.000
210.000
180.000
270.000
-30.000
-60.000
0.2
0.4
0.6
0.8
1
1.2



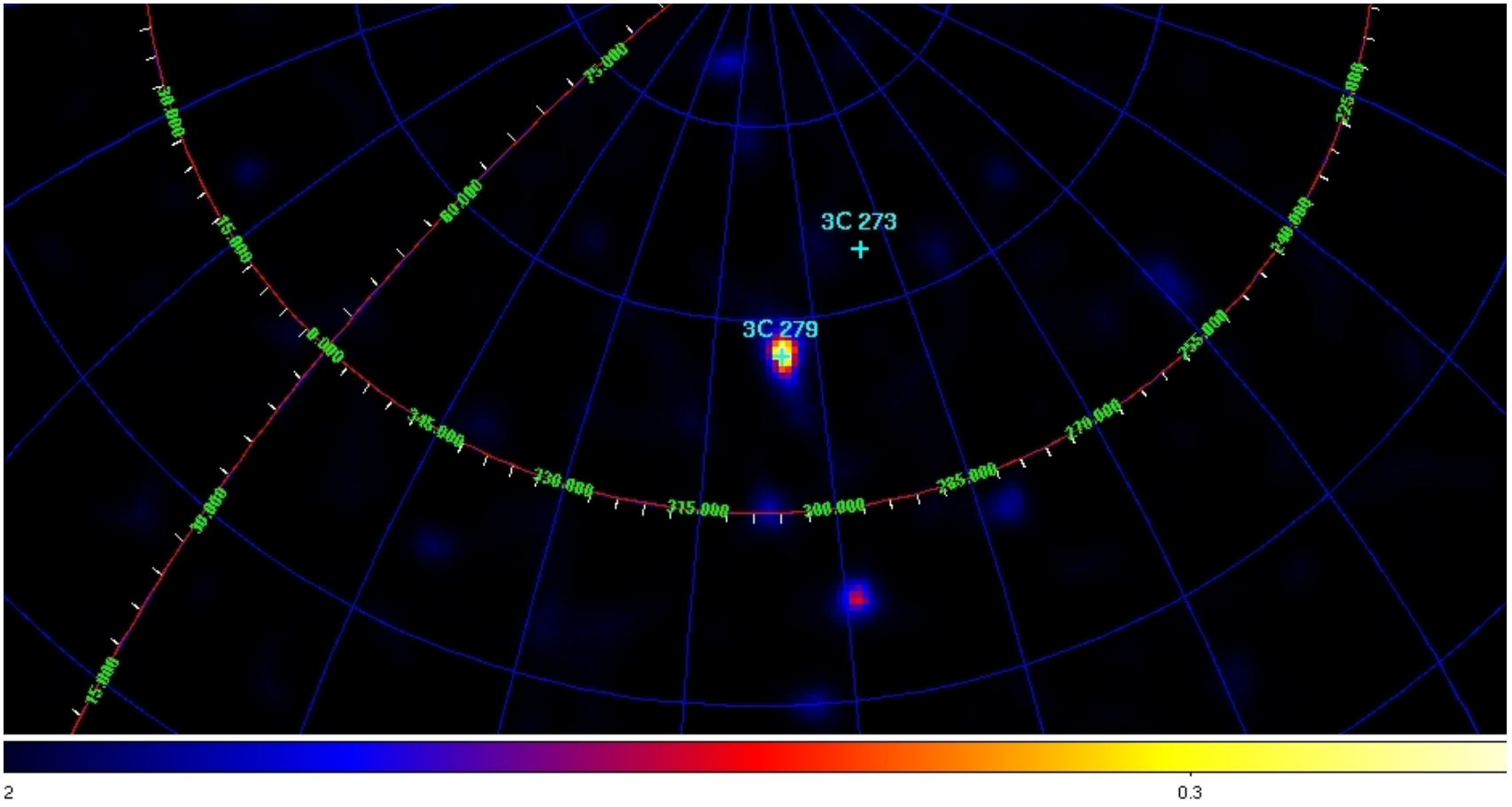
Vela Pulsar

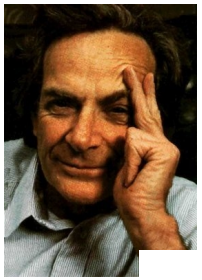


Vela PSR light curve (E>100 MeV), ~20 day integration, (calibration observation blocks, July-August, 2007). 0.5 ms time bins.

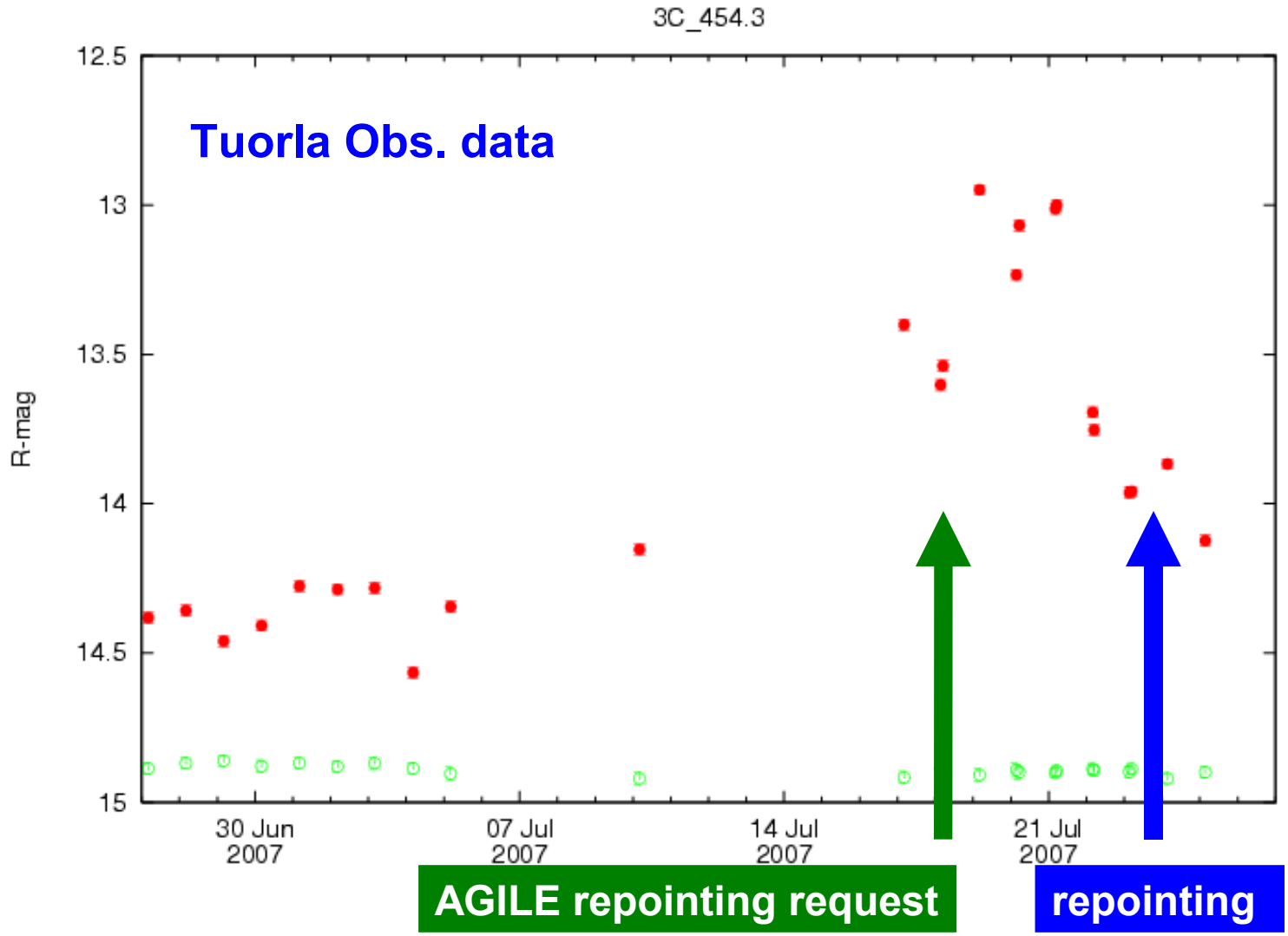


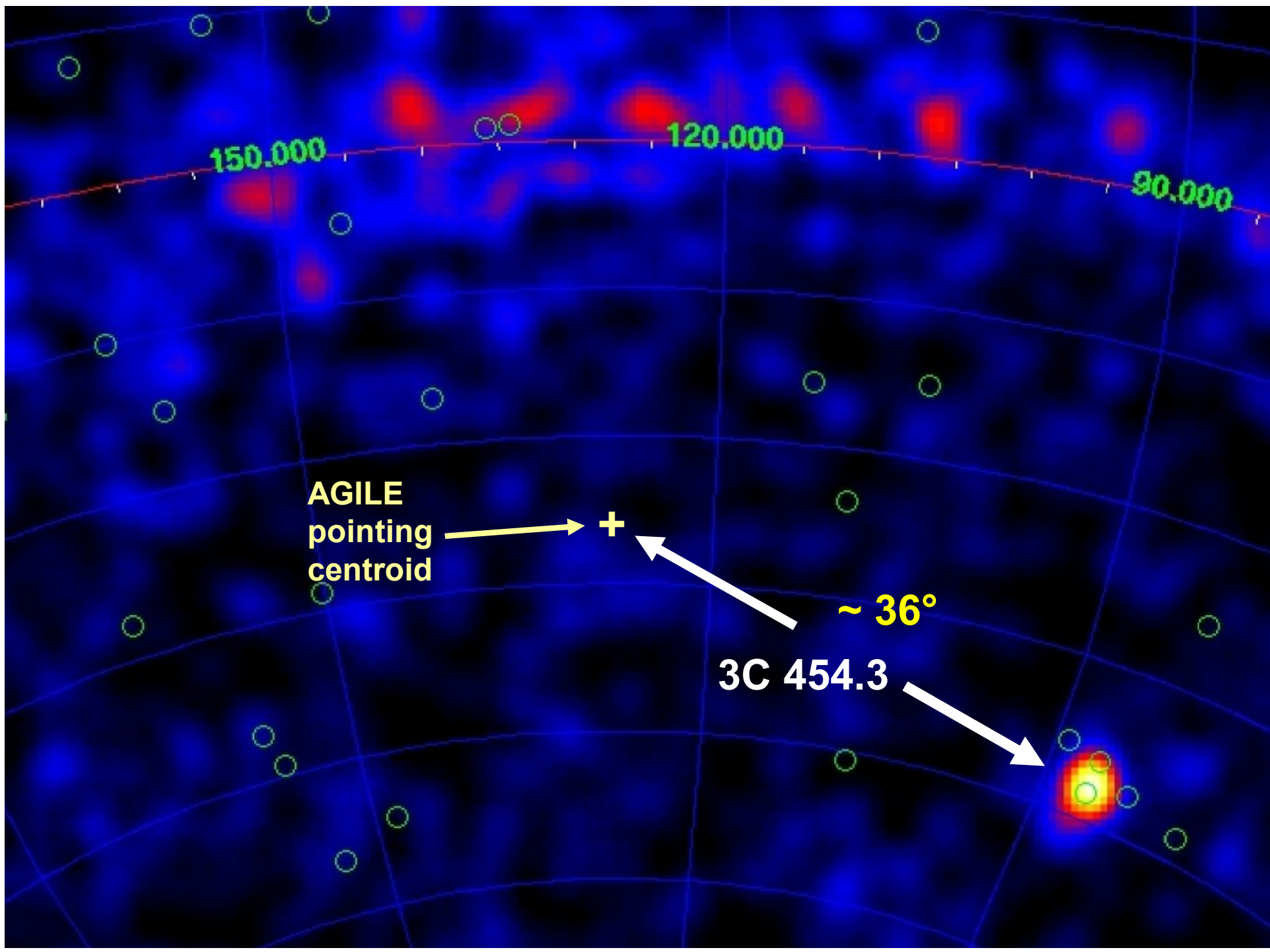
AGILE detection of 3C 279 !

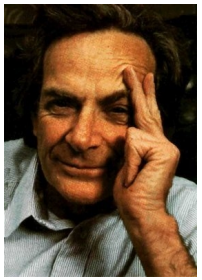




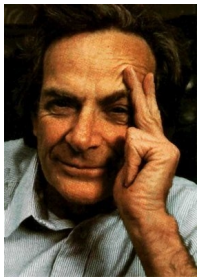
3c454


3C_454.3
Tuorla Obs. data
R-mag
12.5
13
13.5
14
14.5
15
30 Jun 2007
07 Jul 2007
14 Jul 2007
21 Jul 2007
AGILE repointing request
repointing


150.000
120.000
90.000
AGILE
pointing
centroid
~ 36°
3C 454.3

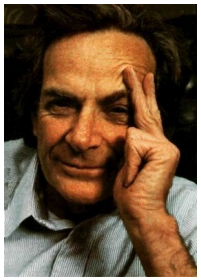


Terrestrial Gamma-ray Flashes

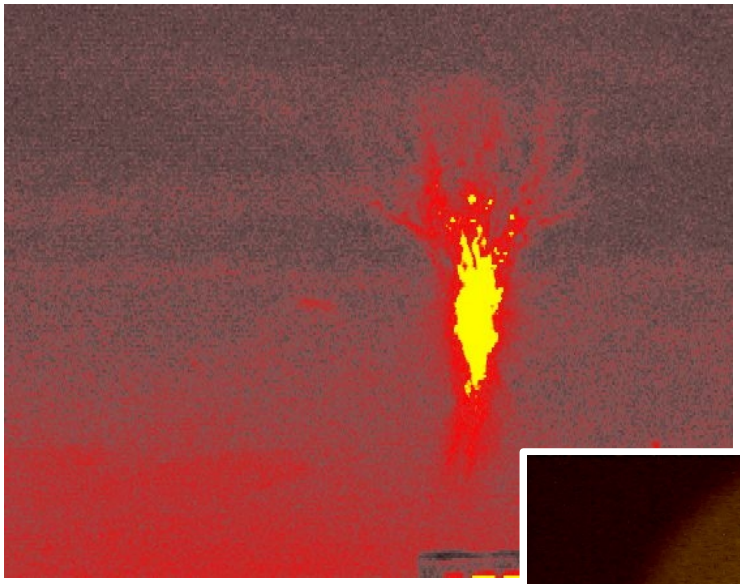


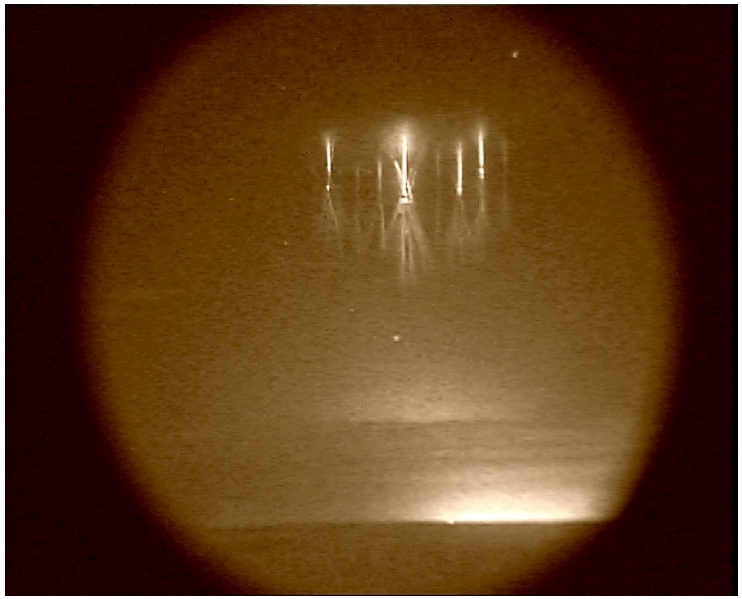
Terrestrial Gamma-ray Flashes

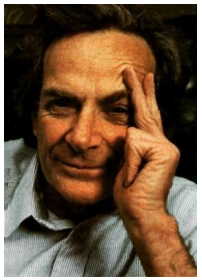
- AGILE detected gamma-ray emission coming from the Earth, very short (1 ms) and of high intensity
- Terrestrial gamma-ray flashes were first discovered in 1994 by BATSE
- TGFs were linked to an individual lightning strike occurring within a few ms of the TGF
- BATSE detected only a small number of TGF events in nine years
- The newer RHESSI satellite has observed TGFs with much higher energies
- approximately fifty TGFs occur each day, larger than previously thought but still only representing a very small fraction of the total lightning on Earth (3-4 million lightning events per day on average)



Sprites







Sprites

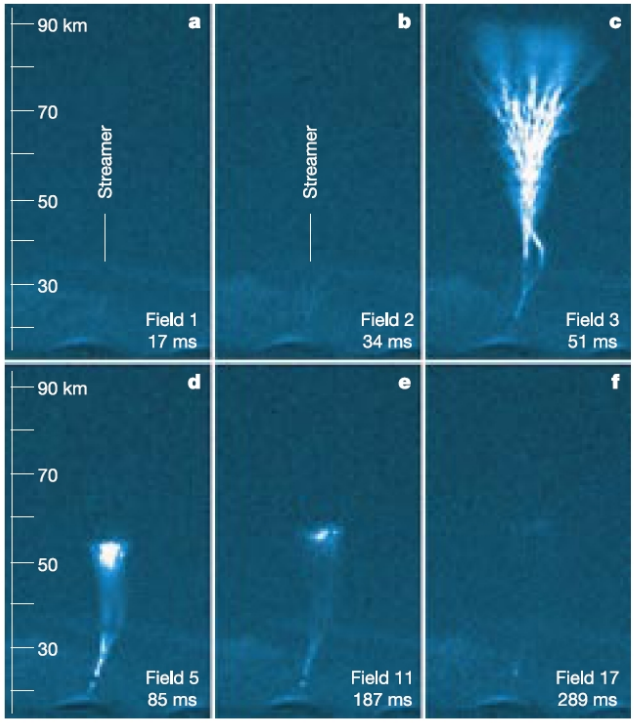


Figure 2 Selected and cropped image fields of event 1. The monochrome images were tinted to various shades of blue to bring out the salient structural features. The imaging system consists of a Watec N-100 CCD, a 20 mm/*f*1.8 lens, and a digital video recorder. Frame rate of the imaging system is 30 frames per second. Each frame was further separated into even and odd image fields of ~17-ms resolution. The spectral sensitivity of the CCD is from 400 to 1,000 nm, with 50% detection efficiency at 400 nm and at 780 nm. The persistent time of the Watec CCD's phosphor is less than 0.01 ms. (The cameras we used are intensified low light level cameras, which used a phosphor coating as image intensifier.)

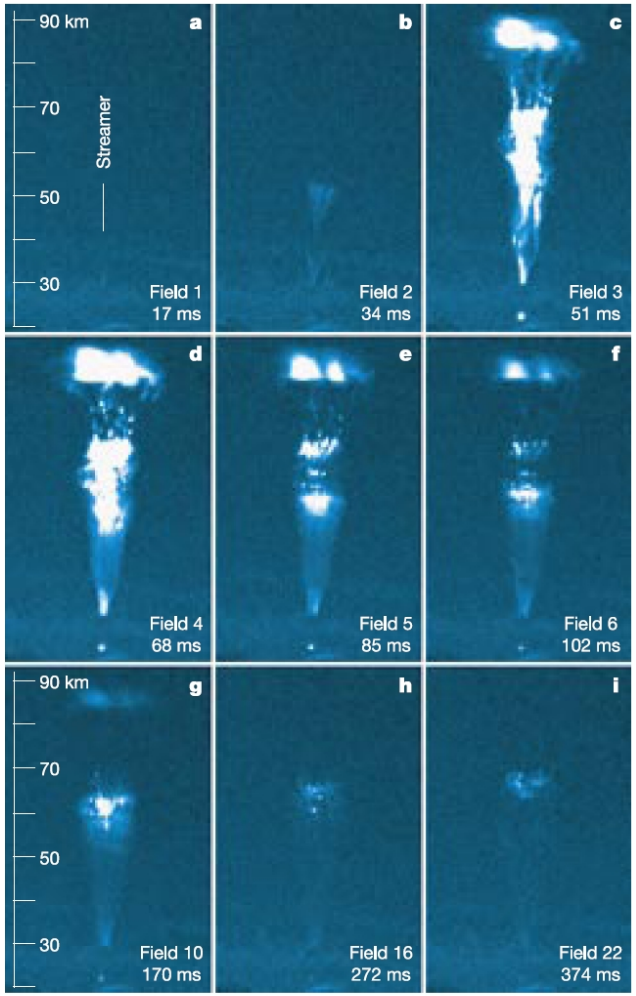
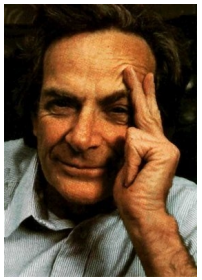
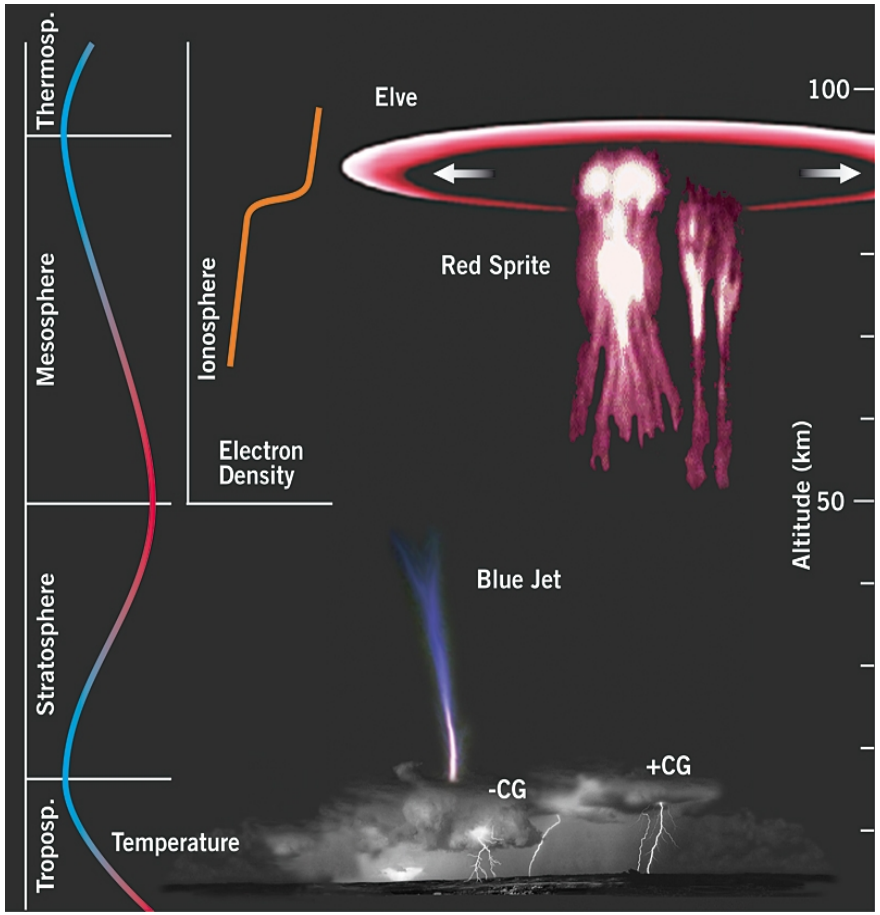
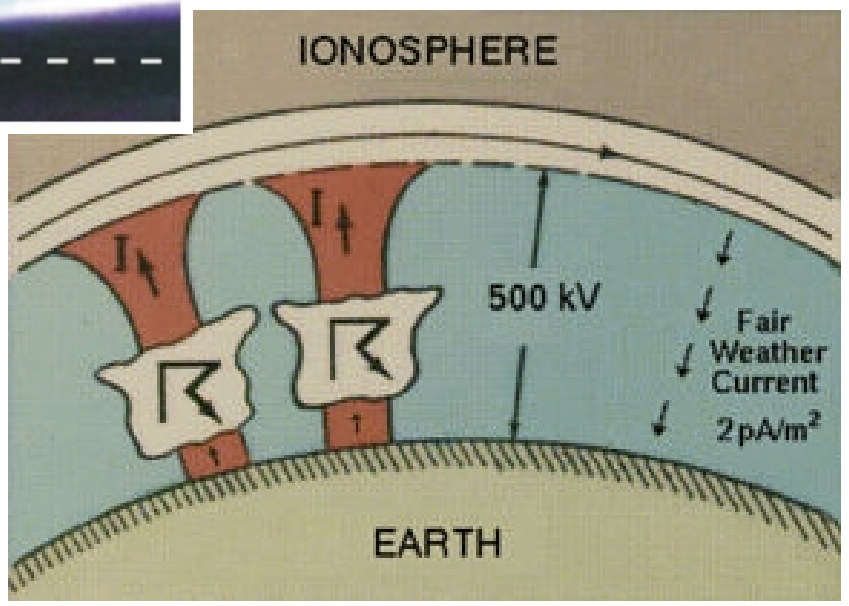


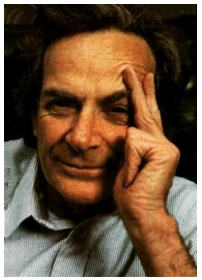
Figure 3 Selected and cropped image fields of event 4. The gigantic jet evolves in three stages: the leading jet (**a**, **b**), the fully developed jet (**c**–**g**) and the trailing jet (**e**–**i**).



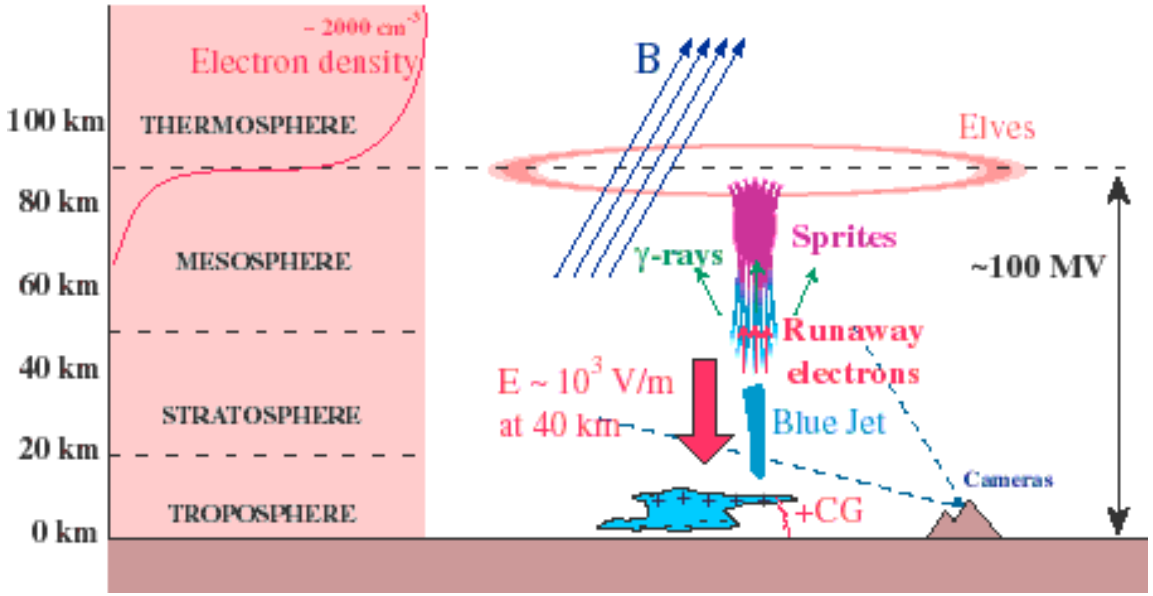
The global and local electric circuit

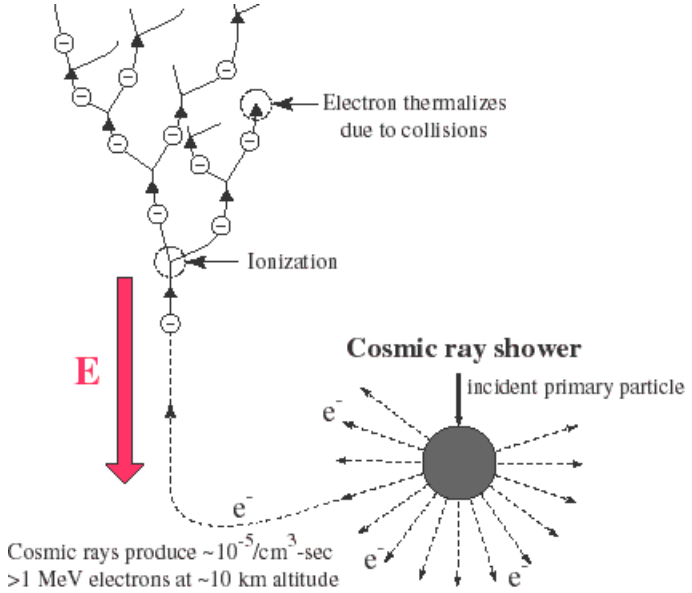


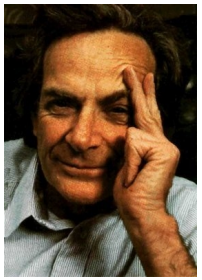




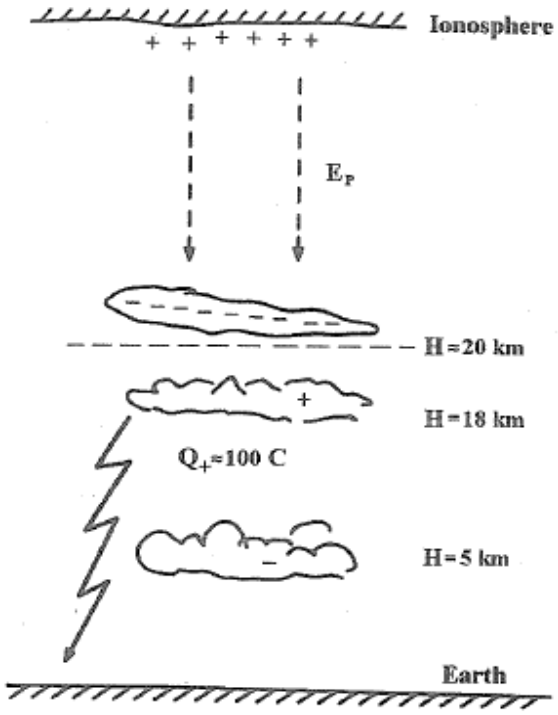
The global and local electric circuit

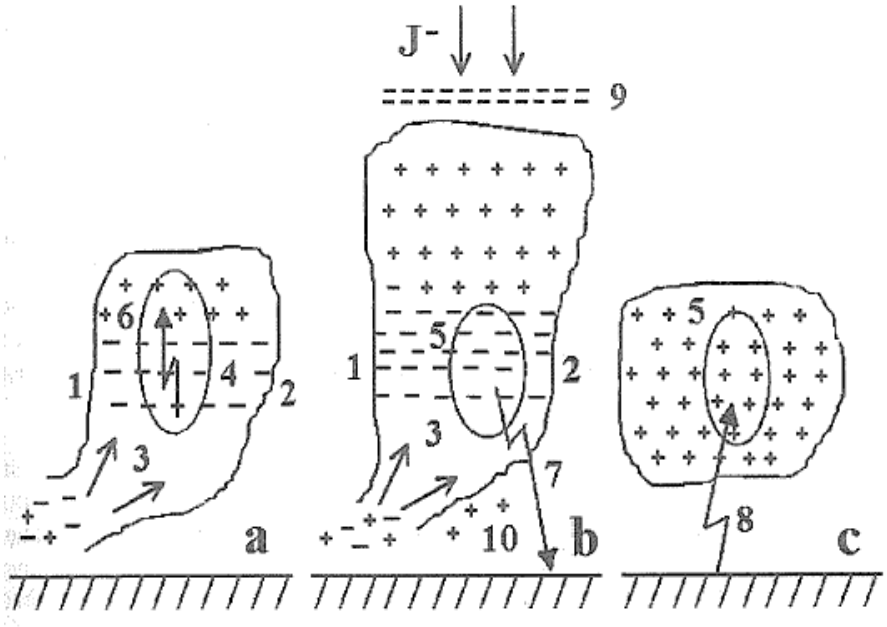


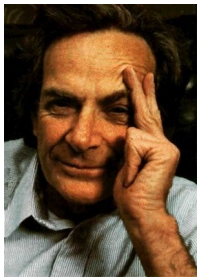




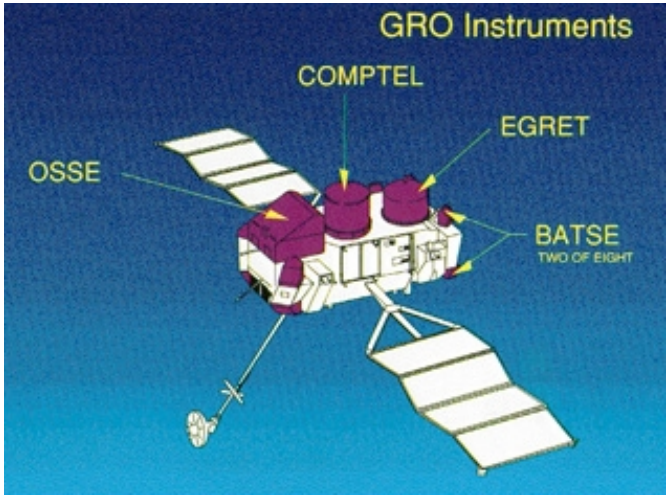
Model for sprite discharge





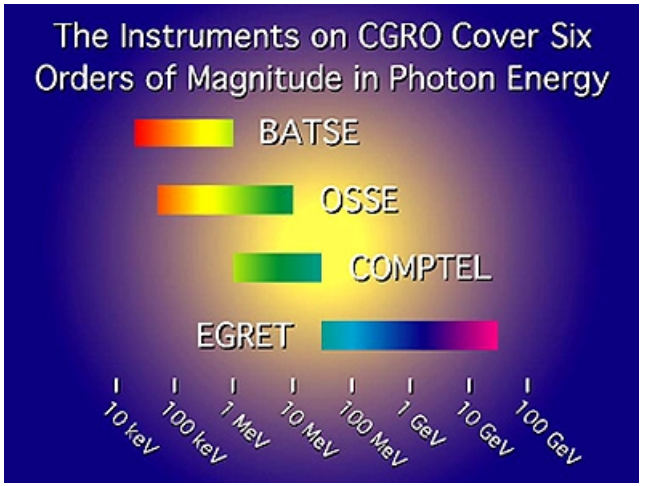


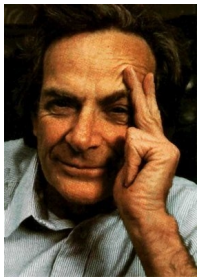
BATSE - CGRO



- Space mission planned to study gamma emission from celestial sources
- In orbit from 1991 to 2000
- Energy range: 30 keV - 30 GeV

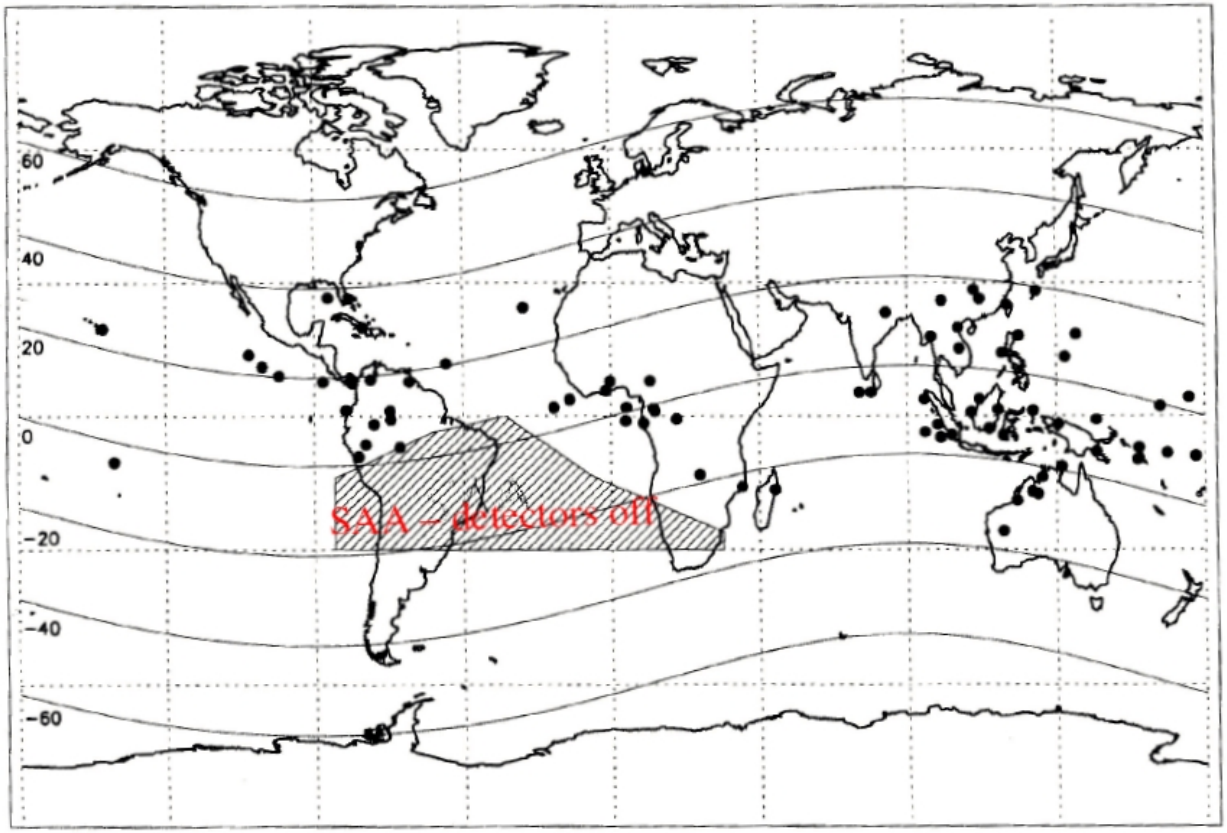
- Only very high energy satellite (up to 30 GeV) before GLAST

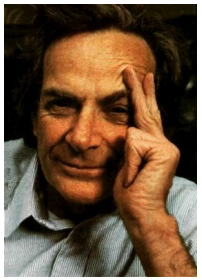




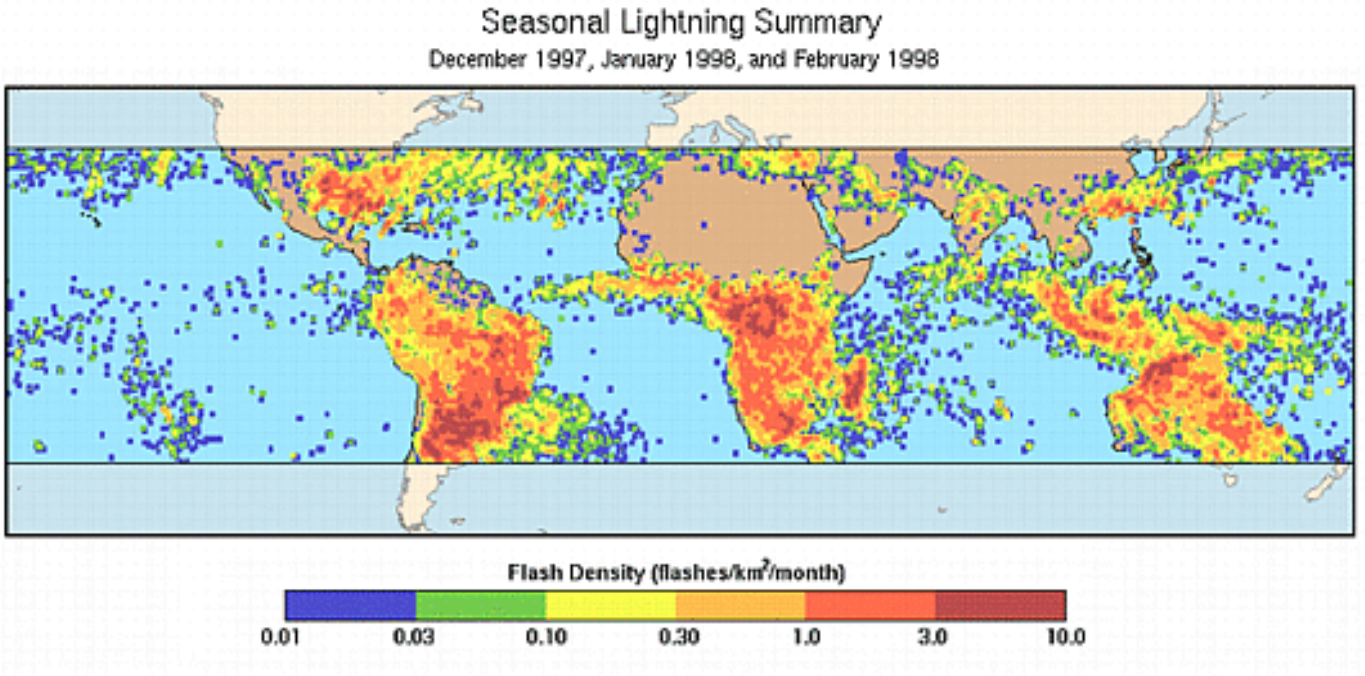
BATSE

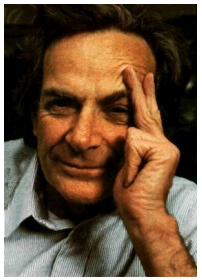
76 TGFs observed over 9 years



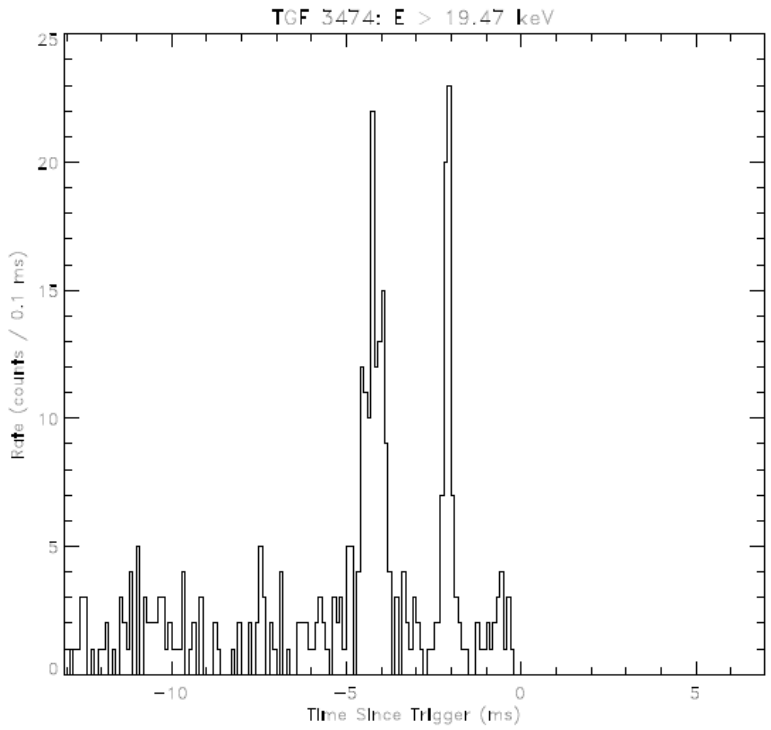


Correlation with thunderstorms

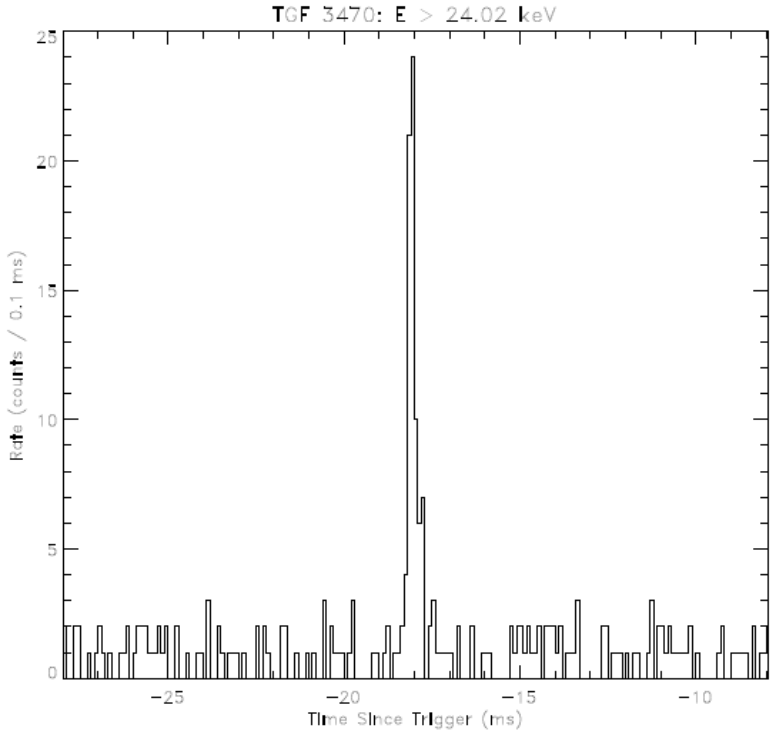




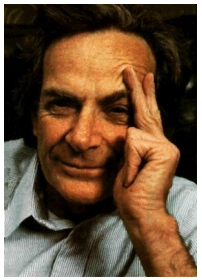
BATSE



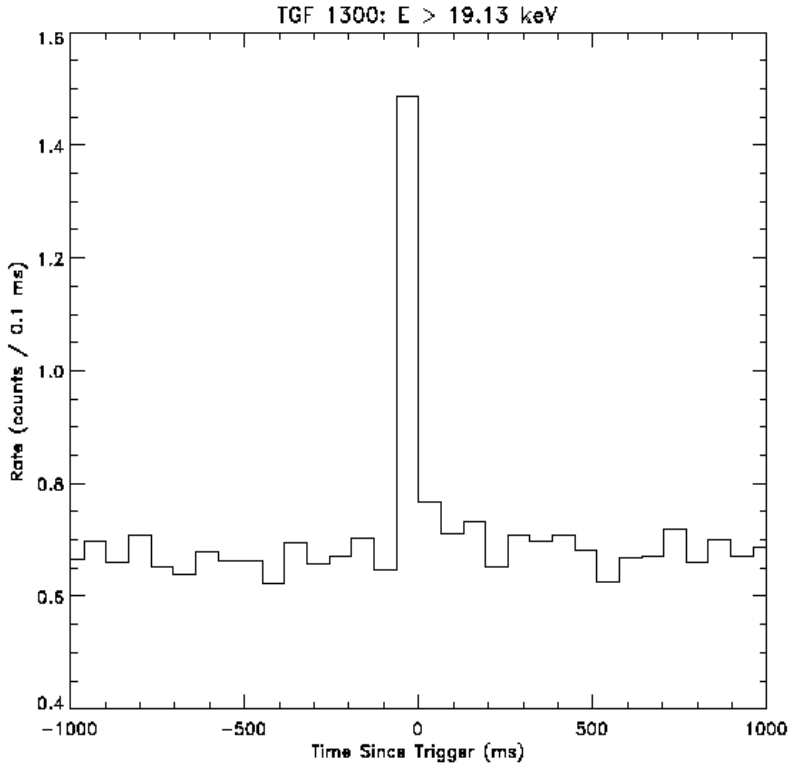
TGF950318
BATSE Trigger Number: 3474
Start Time (tjd, sod): 9794, 29434.3535
Start Time (yymmdd, hhmmss): 950318, 08:10:34.3535
Detector Type: LAD
Detectors [7−0]: 7−−4−−−0
Data Type(s): DISCLA
CGRO Lon, Lat: 357.04, 6.48



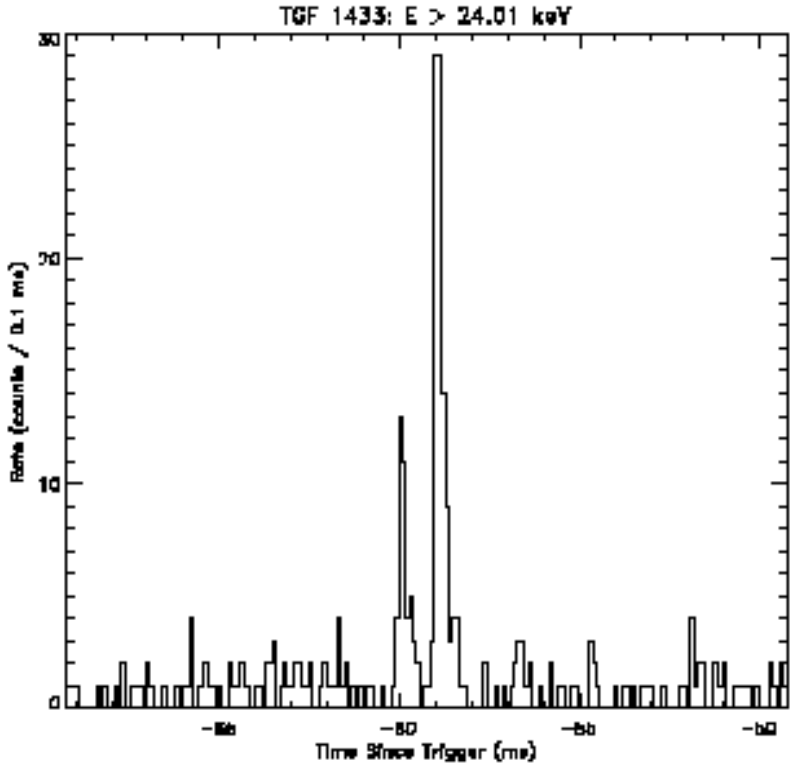
TGF950316
BATSE Trigger Number: 3470
Start Time (tjd, sod): 9792, 34736.8175
Start Time (yymmdd, hhmmss): 950316, 09:38:56.8175
Detector Type: LAD
Detectors [7−0]: −−−4−2−−
Data Type(s): DISCLA
CGRO Lon, Lat: 6.09, −1.96



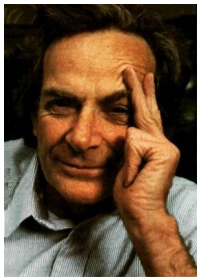
BATSE



TGF920115
BATSE Trigger Number: 1300
Start Time (tjd, sod): 8636, 47707.6672
Start Time (yymmdd, hhmmss): 920115, 13:06:47.6672
Detector Type: LAD
Detectors [7−0]: 7−−−3−−−
Data Type(s): DISCLA,DISCSC,PRFB
CGRO Lon, Lat: 140.52, 15.07

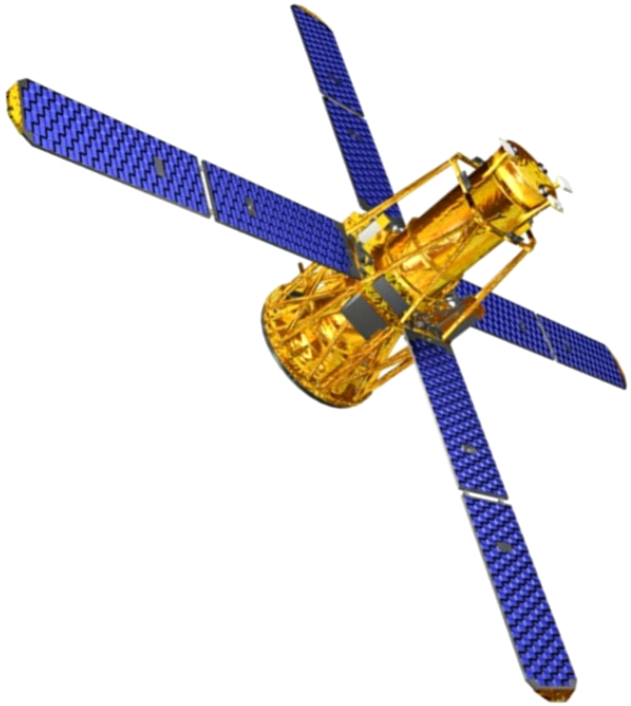


TGF930224
BATSE Trigger Number: 1433
Start Time (tjd, sod): 8878, 38547.3437
Start Time (yymmdd, hhmmss): 930224, 10:42:27.3437
Detector Type: LAD
Detectors [7−0]: −63−−−−−
Data Type(s): DISCLA,DISCSC,PRFB,TTF
CGRO Lon, Lat: 41.29, −16.62

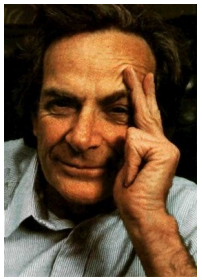


RHESSI

REUVEN RAMATY HIGH ENERGY SOLAR SPECTROSCOPIC IMAGER

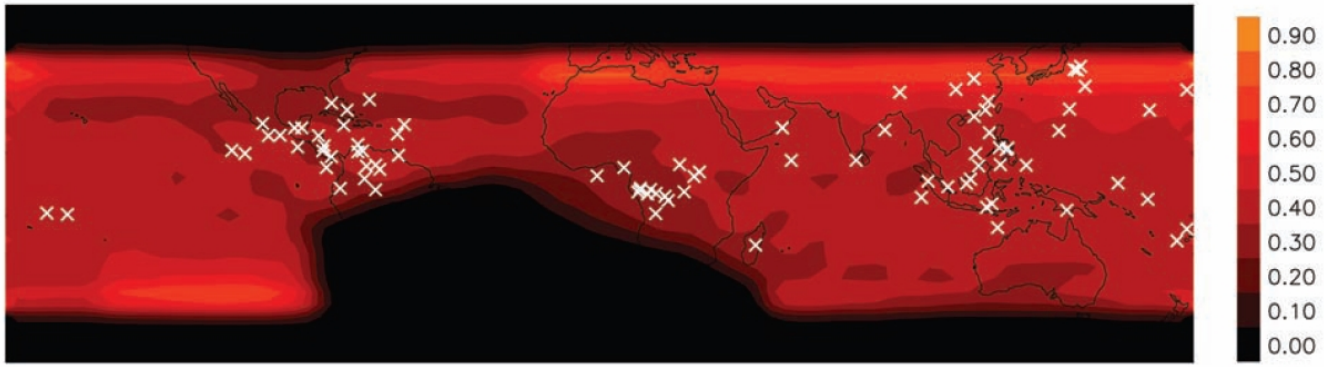


- Launched on Feb 5, 2002
- Low Earth Orbit:
  Altitude 600 km
  i = 38°
- Detectors smallers than BATSE but better high-energy response and resolution

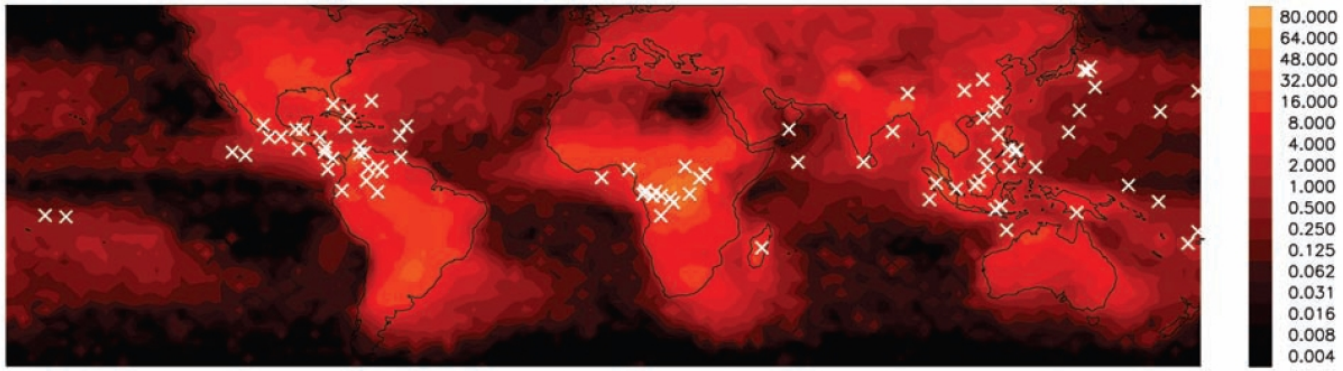


RHESSI

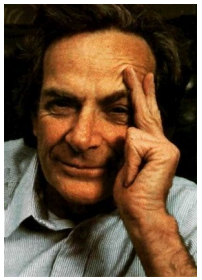
RHESSI position during each recorded TGFs



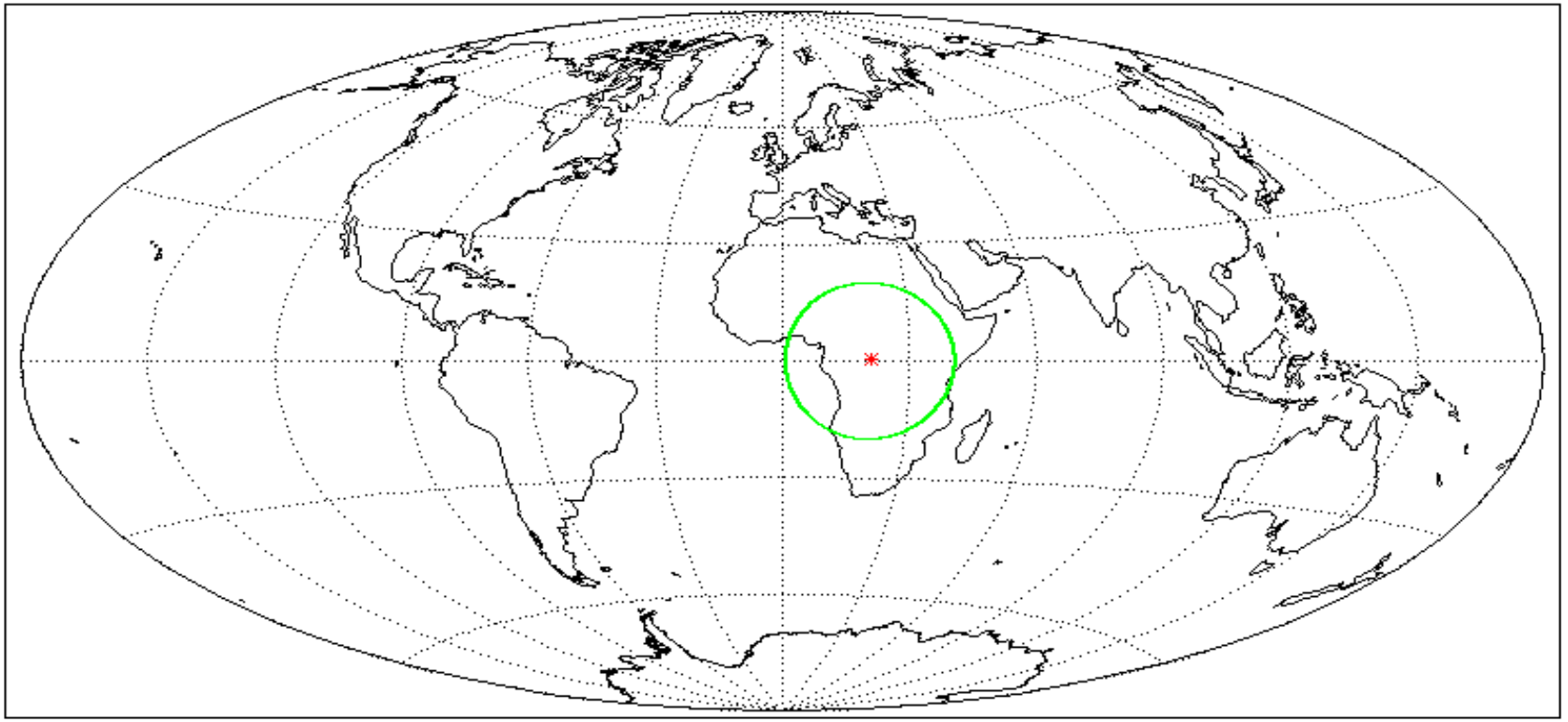
the expected distribution of observed TGFs if the population were evenly distributed over the globe (fraction of maximum exposure)

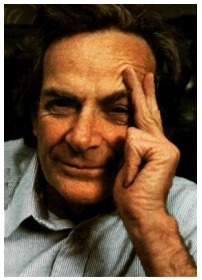


long-term lightning frequency data (flashes per square kilometer per year)

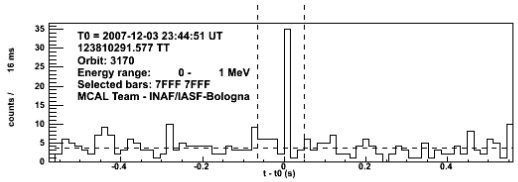


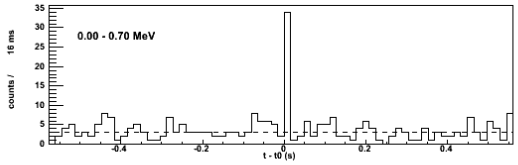
AGILE

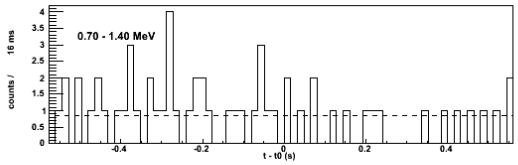


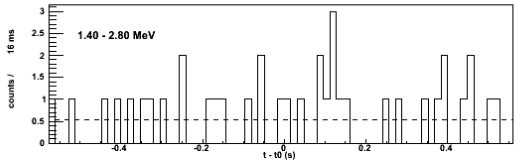


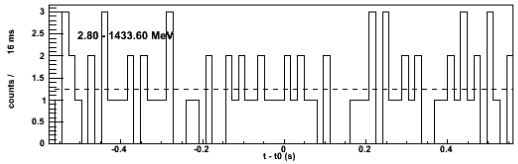
AGILE

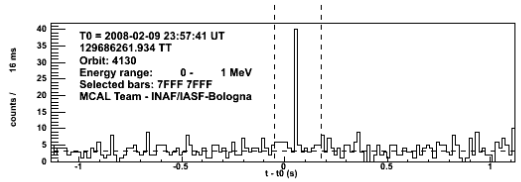

T0 = 2007-12-03 23:44:51 UT
123810291.577 TT
Orbit: 3170
Energy range: 0 - 1 MeV
Selected bars: 7FFF 7FFF
MCAL Team - INAF/IASF-Bologna
counts / 16 ms
t - t0 (s)

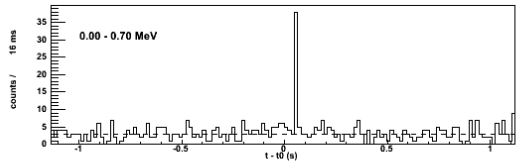

0.00 - 0.70 MeV
counts / 16 ms
t - t0 (s)

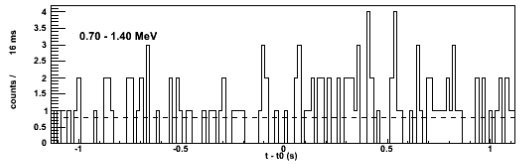

0.70 - 1.40 MeV
counts / 16 ms
t - t0 (s)

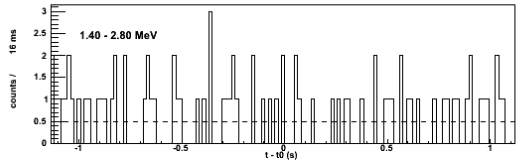

1.40 - 2.80 MeV
counts / 16 ms
t - t0 (s)

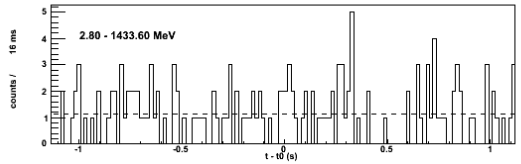

2.80 - 1433.60 MeV
counts / 16 ms
t - t0 (s)

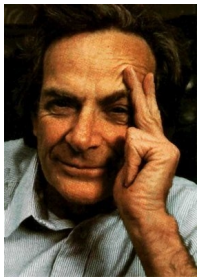

T0 = 2008-02-09 23:57:41 UT
129686261.934 TT
Orbit: 4130
Energy range: 0 - 1 MeV
Selected bars: 7FFF 7FFF
MCAL Team - INAF/IASF-Bologna
counts / 16 ms
t - t0 (s)


0.00 - 0.70 MeV
counts / 16 ms
t - t0 (s)

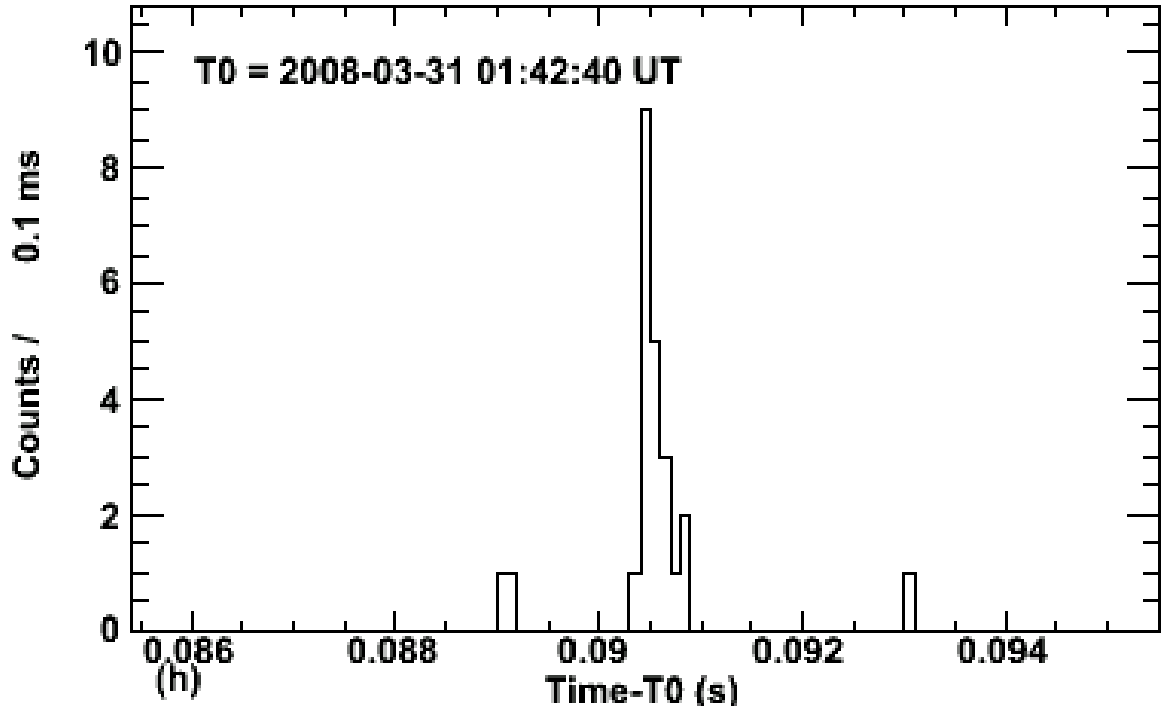

0.70 - 1.40 MeV
counts / 16 ms
t - t0 (s)

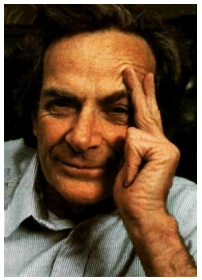

1.40 - 2.80 MeV
counts / 16 ms
t - t0 (s)


2.80 - 1433.60 MeV
counts / 16 ms
t - t0 (s)



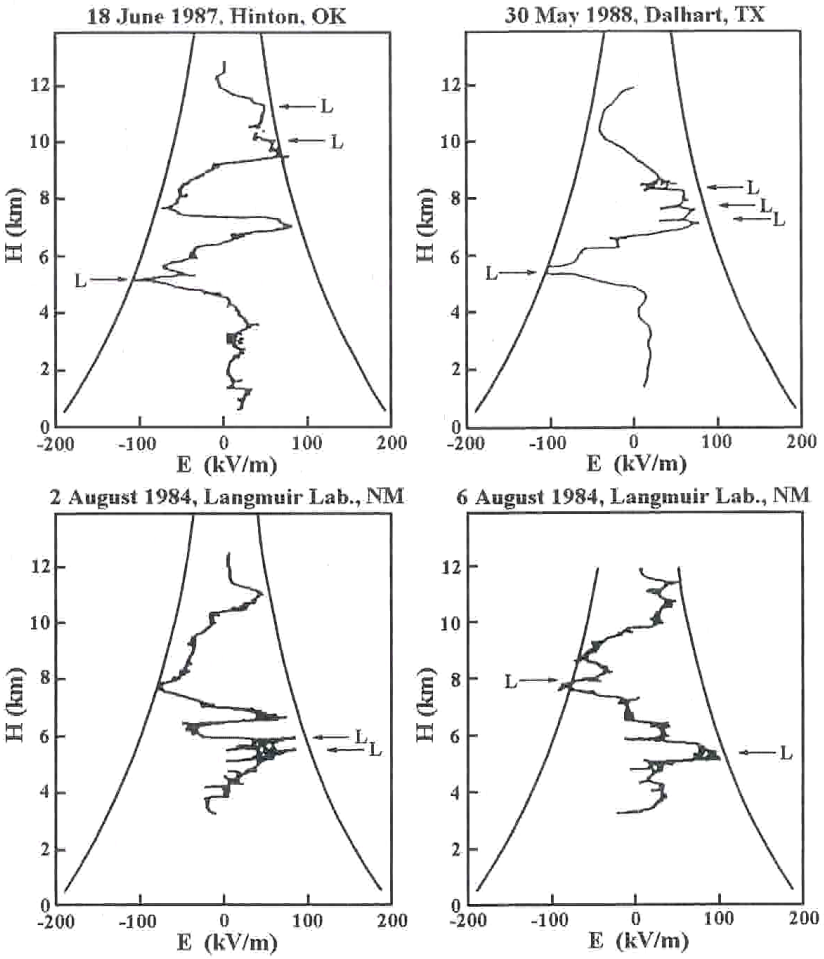
AGILE


T0 = 2008-03-31 01:42:40 UT
Counts / 0.1 ms
0
2
4
6
8
10
0.086
(h)
0.088
0.09
0.092
0.094
Time-T0 (s)



Cosmic Ray Influence

Atmospheric electric field in periods of thunderstorms




agile
Astro-rivelatore Gamma a Immagini LEggero