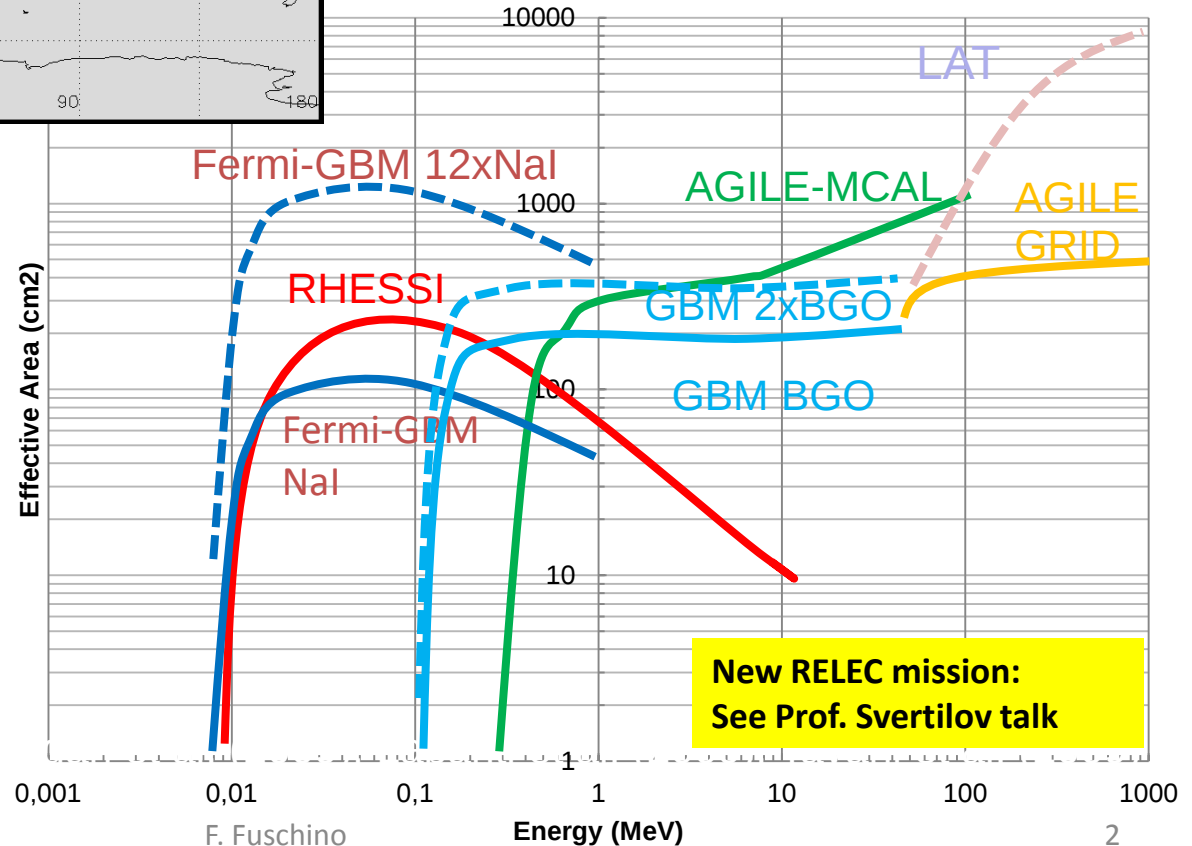
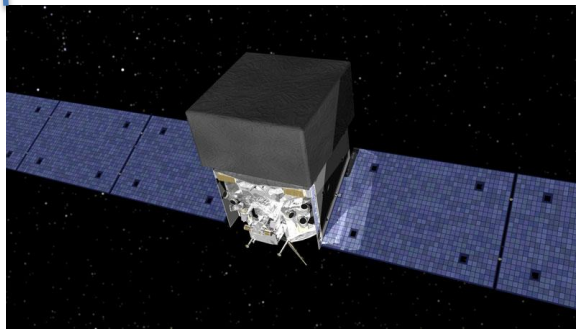
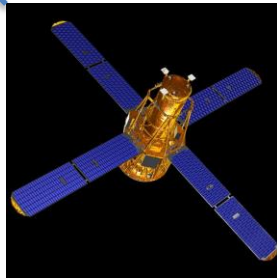
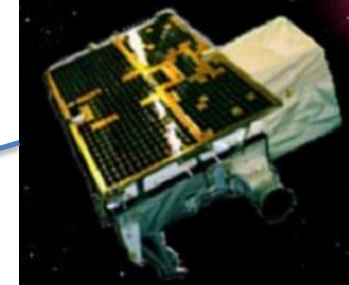
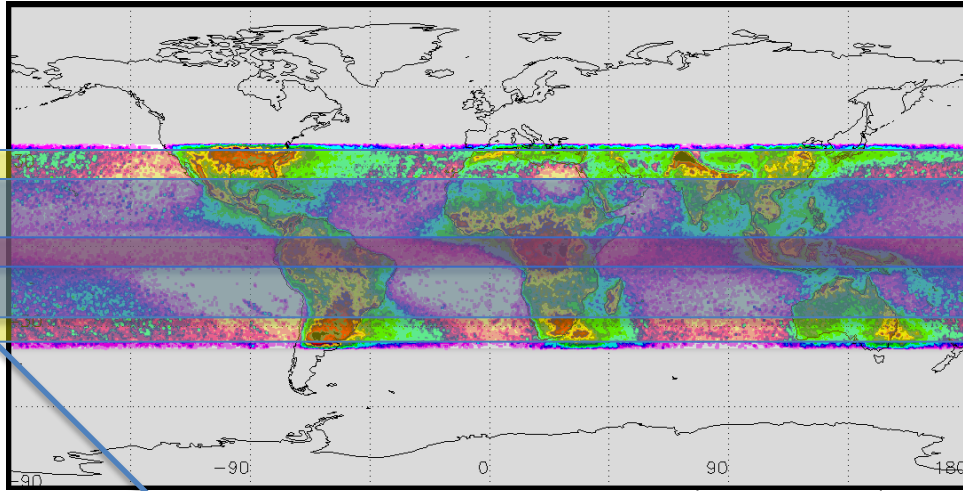


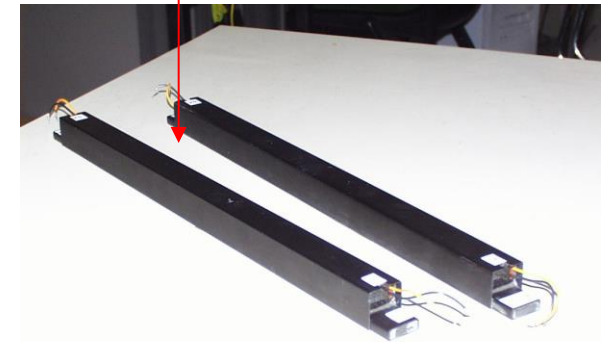
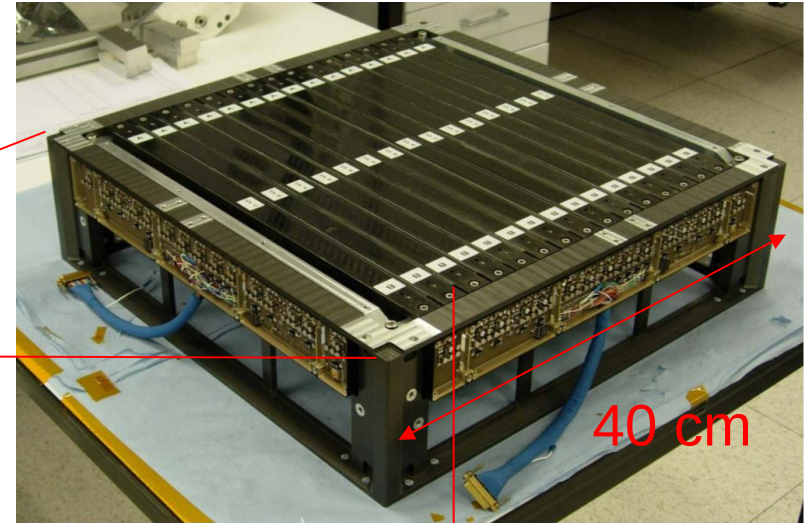
TGF Studies with AGILE: a Forthcoming Revolution

F. Fuschino on behalf the AGILE
TGF working group

Operating TGF detectors



The Mini-Calorimeter (MCAL): do it as clever as possible!



Constraints:

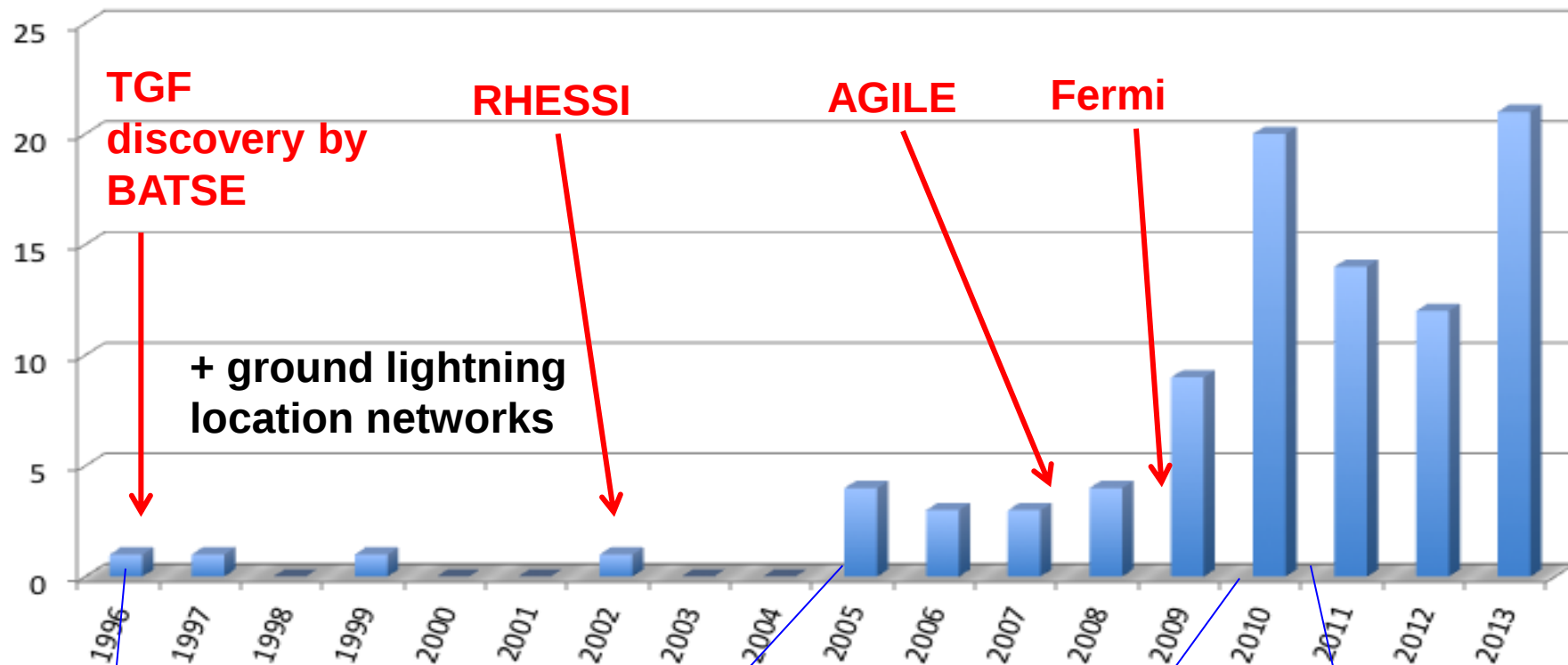
- Low weight
- Low power $\rightarrow$ few channels / solid state readout
- Low telemetry budget $\rightarrow$ on-board trigger logic

Design choices:

- Hodoscopic architecture $\rightarrow$ position reconstruction with few channels (30)
- PD readout: 350 keV threshold $\rightarrow$ energy range extended up to 100 MeV
- Trigger logic $\rightarrow$ very short time scales (300 μ s, 1ms) + photon-by-photon data + GPS

Observational breakthrough

TGF related publications (from ADS)



Association to lightning

- Cumulative spectrum
- Energy up to 20 MeV
- production altitude < 20km

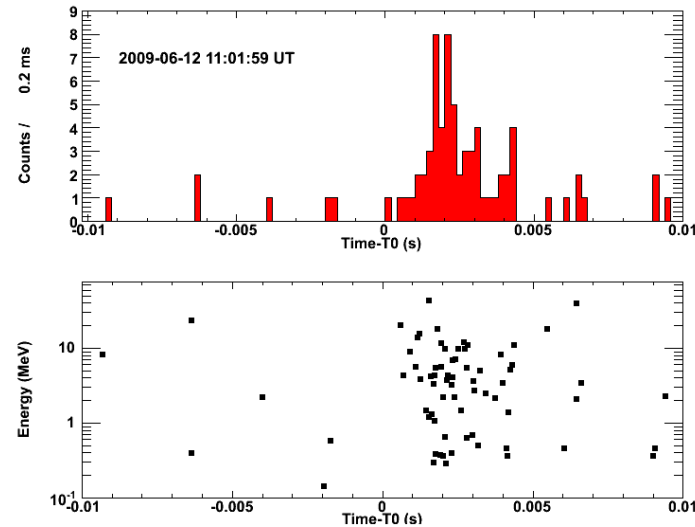
- Energy > 40 MeV up to ~ 100 MeV
- First localization in γ -rays from space
- TGF & global lightning activity
- 1st AGILE catalog

- Discovery of e^+/e^- flashes
- Radio emission from TGFs
- Improved selection

AGILE contributions to TGF science

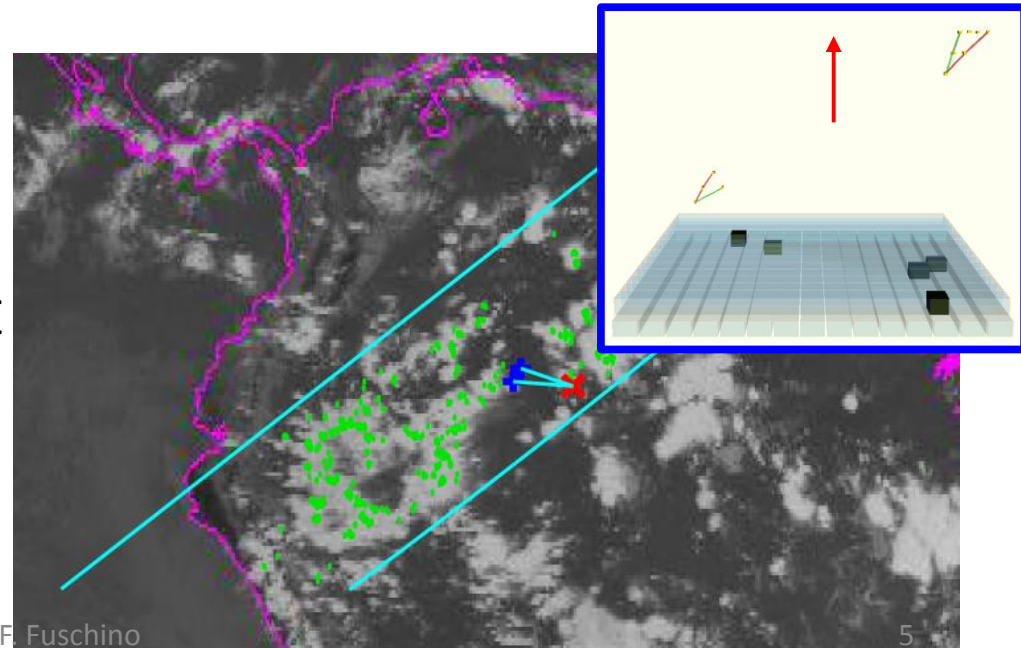
- ❑ TGF energy range extends at least to 40 MeV, doubling the previous range set by RHESSI:

Marisaldi et al., *J. Geophys. Res.* 115 (2010)



- ❑ TGFs can be localized from space directly in gamma-rays by the AGILE silicon tracker:

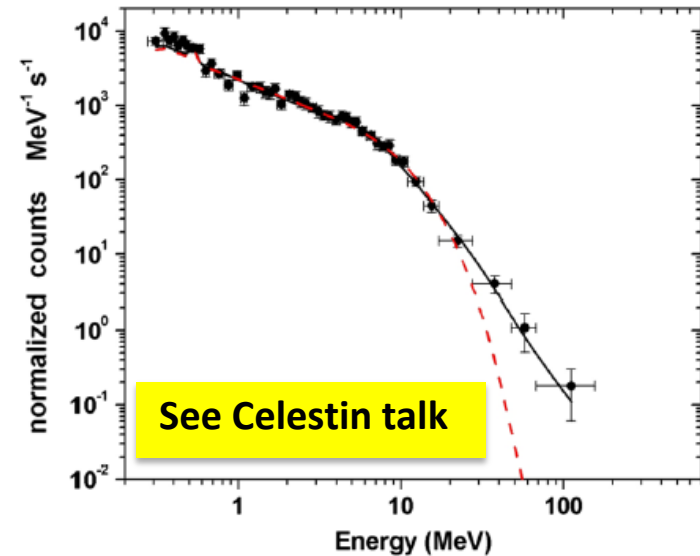
Marisaldi et al., *Phys. Rev. Lett.* 105 (2010)



AGILE contributions to TGF science

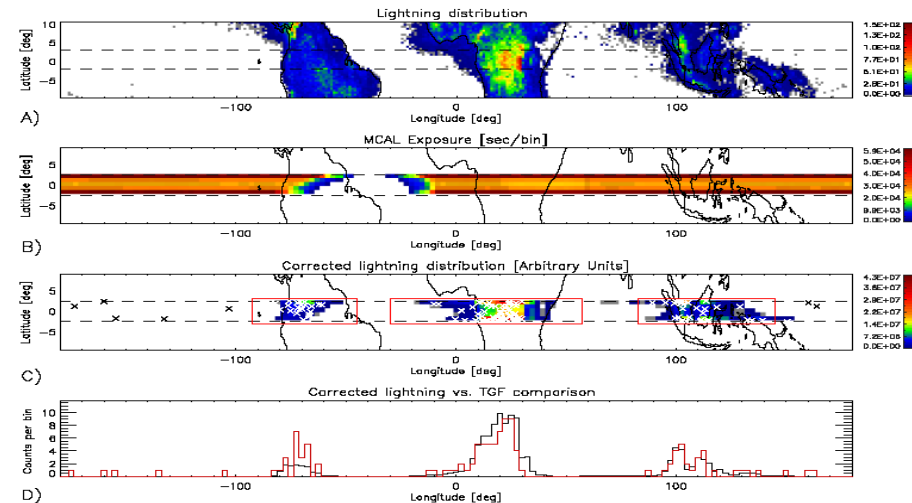
- TGFs high-energy spectrum extends up to ~ 100 MeV and challenges current models:

Tavani et al., Phys. Rev. Lett. 106 (2011)



- The TGF / lightning flash ratio is not constant over different geographical regions:

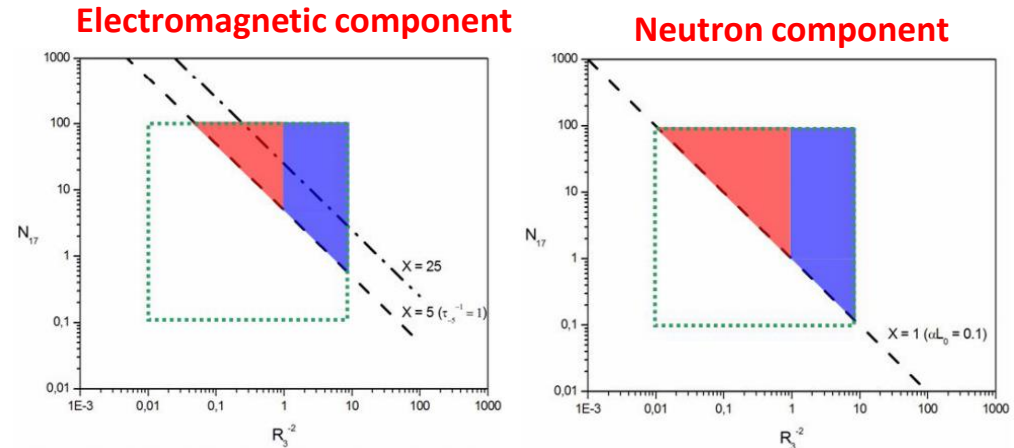
Fuschino et al., Geophys. Res. Lett. 38 (2011)



AGILE contributions to TGF science

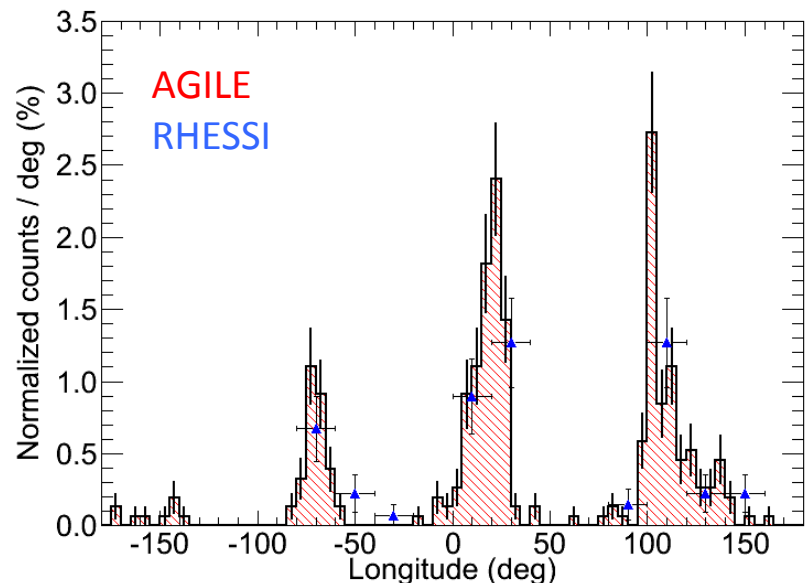
- ❑ TGFs can potentially affect aircraft avionics:

Tavani et al., NHESS 13 (2013)



- ❑ AGILE TGFs in the frame of current observational framework; delivery of the 1st AGILE TGF catalog:

Marisaldi et al., J. Geophys. Res. 119 (2014)



Interactive public TGF catalog

Available on the web through ASI science data center (ASDC) website
www.asdc.asi.it/mcaltgfcatalog

Properties of Terrestrial Gamma-Ray Flashes detected by AGILE MCAL below 30 MeV

TGF ($E < 30$ MeV) observed from March 2009 to July 2012

Help

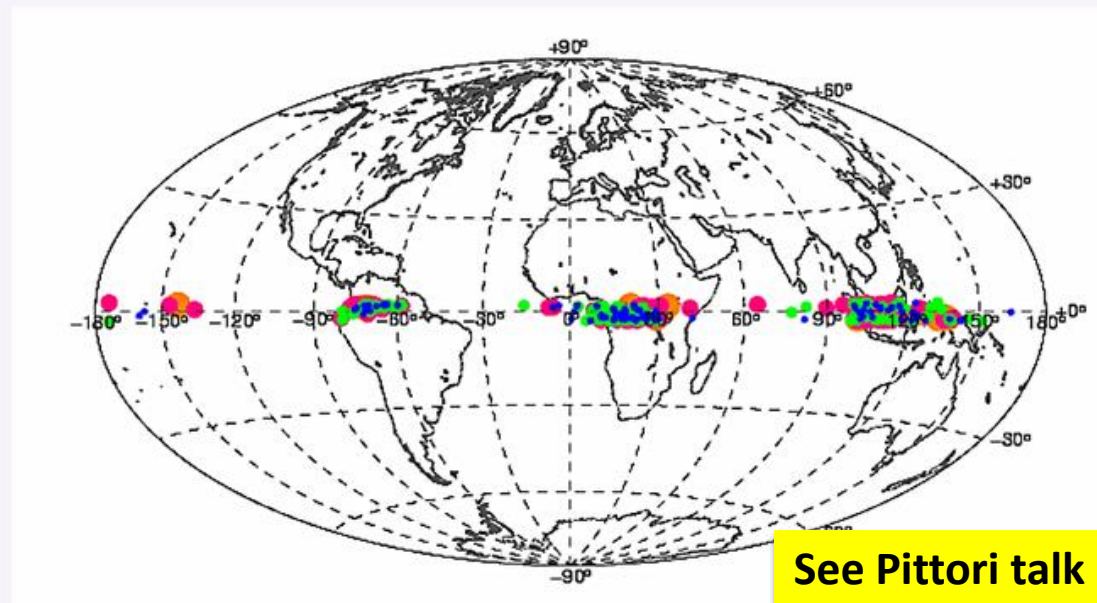
Show/hide columns

Advanced filtering

Print current view of table

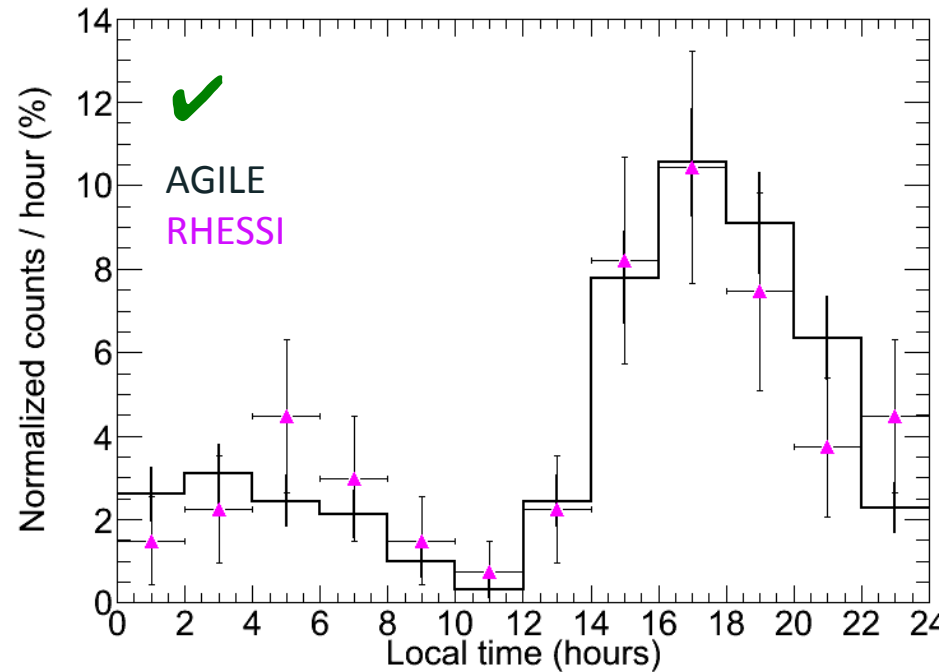
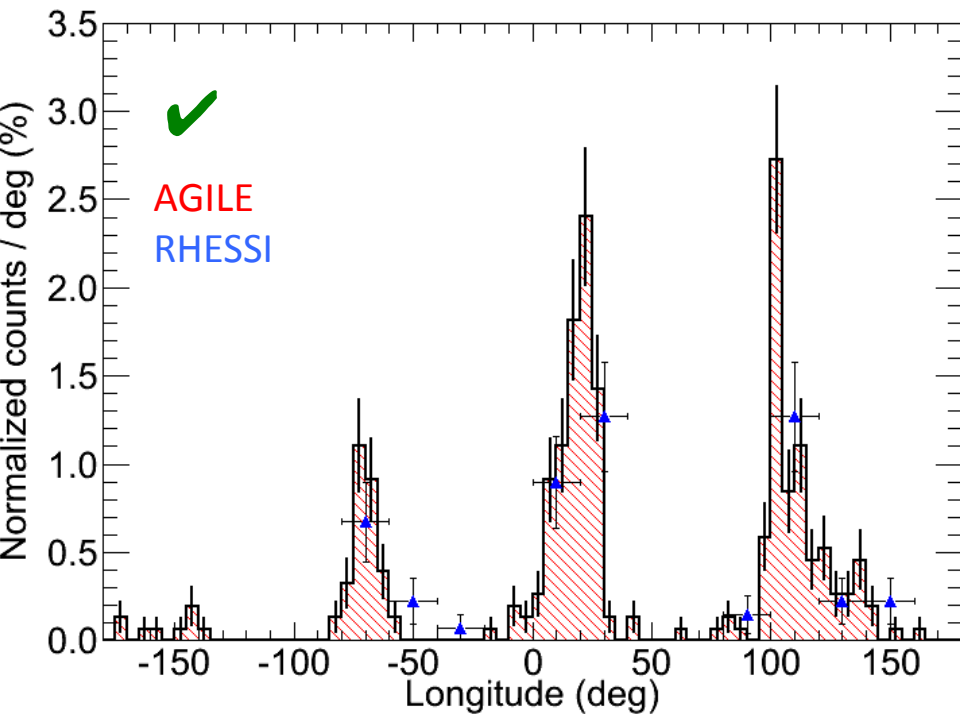
Print complete table

Reset all filters



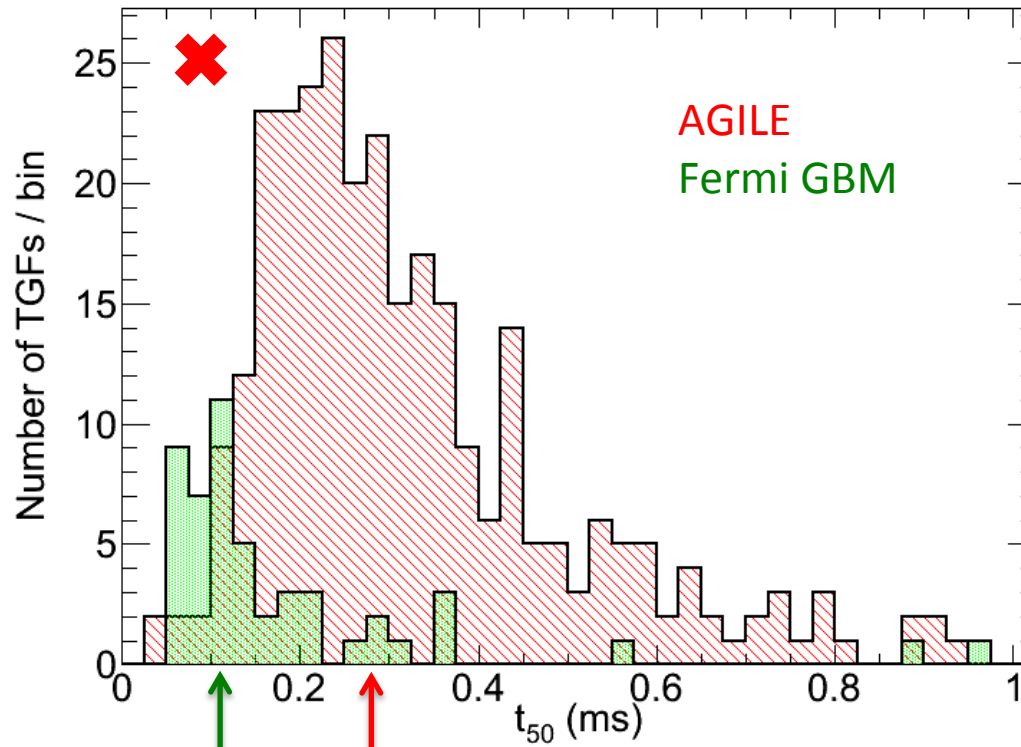
See Pittori talk

AGILE vs. RHESSI: longitude and local time



- Comparison with sample of 67 TGFs detected in the $\pm 2.5^\circ$ latitude band (1st RHESSI catalog)
- Good agreement found

AGILE vs. Fermi: duration distribution



Fermi Median = 0.11 ms

AGILE Median = 0.29 ms

- Used 50 triggered TGF duration in Fishman et al. (2011) because untriggered TGFs in Briggs et al. (2013) have incompatible duration distribution
- Trigger on the BGO ($E > 200$ keV) is more similar to the MCAL case
- **Why AGILE TGFs are significantly longer?**

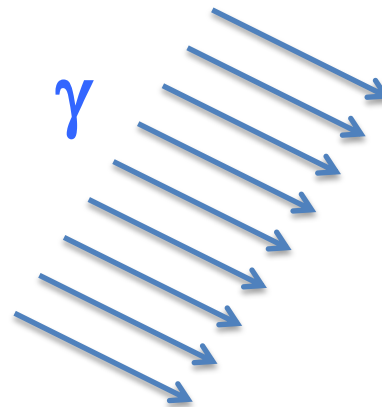
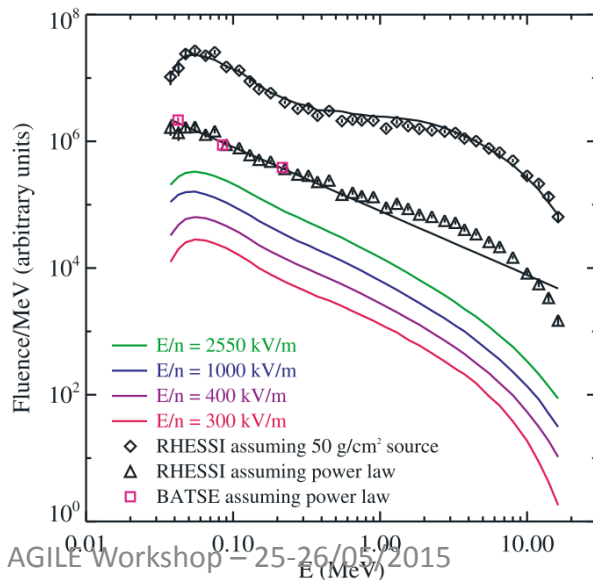
Is dead time important?

Dead time affects all known TGF detectors up to now

MCAL is highly segmented with 30 independent detectors

The AC induced dead time

We simulated the AC-induced dead time using the GEANT3 AGILE mass model and the TGF empirical spectrum of Dwyer and Smith (2005)

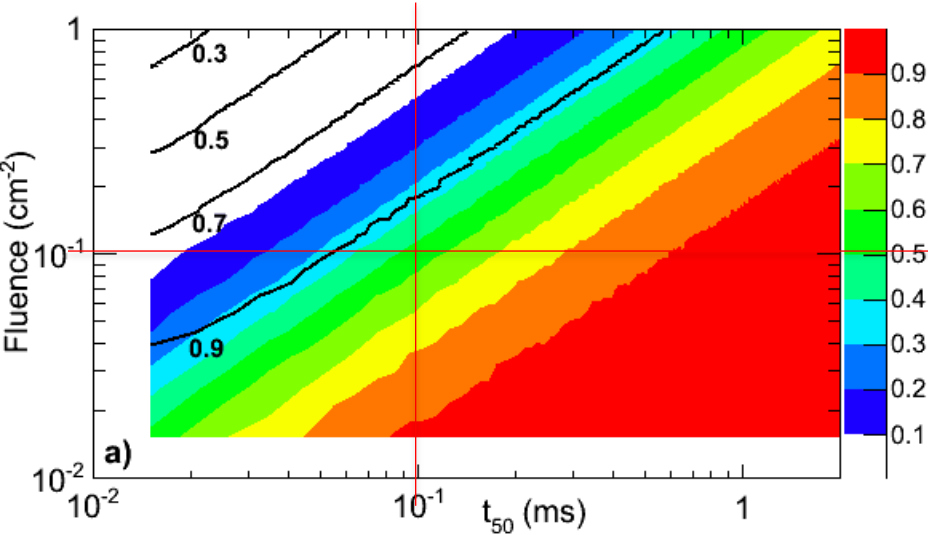


F. Fuschino

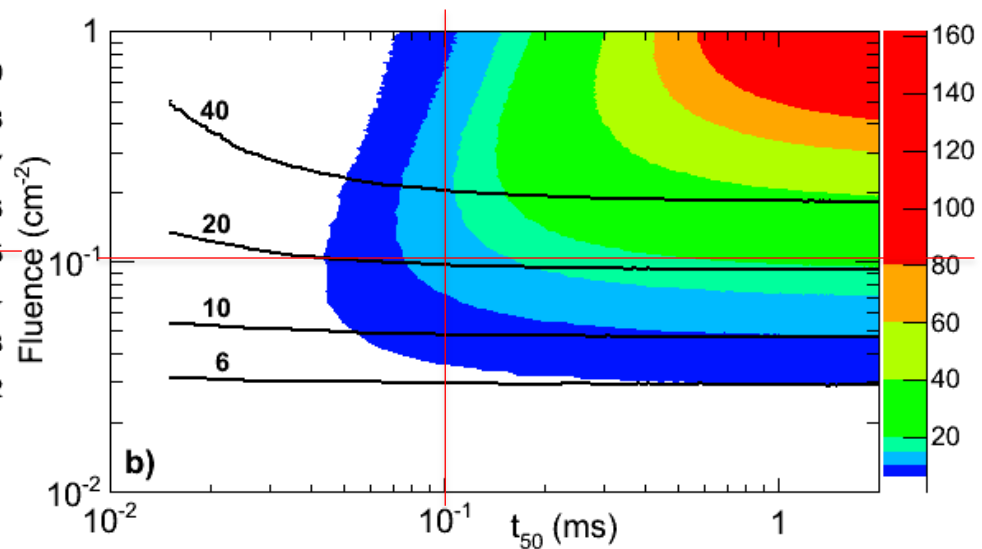


Yes, it is!

Live time fraction



Detected number of counts



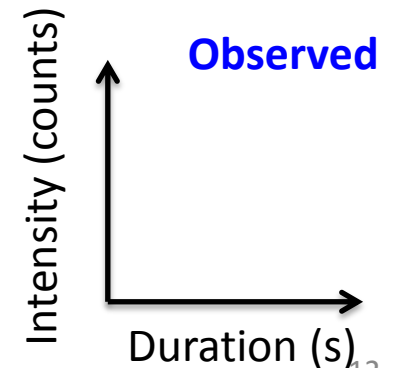
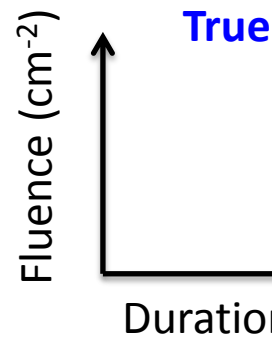
No TGF with $T_{50} < \sim 100 \mu\text{s}$

No TGF with fluence $< \sim 0.05 \text{ ph/cm}^2$

AC veto dominates
the MCAL dead-time



Bias on the
duration distribution



Switching a detector off should be an easy task... or not?

Carlo Gavazzi Space (Milano)

Prime contractor
Spacecraft responsibility

Thales Alenia Space Italia (Milano)

P/L data handling unit
onboard software

INAF IASF (Bologna)

Proposal for configuration change, scientific assessment

Italian Space Agency (ASI) (Roma)

Mission ownership
Data center

Telespazio (Roma, Fucino AQ,)
TM/TC P/L control
Data acquisition

INAF IAPS (Rome)

Proposal for configuration change, scientific assessment

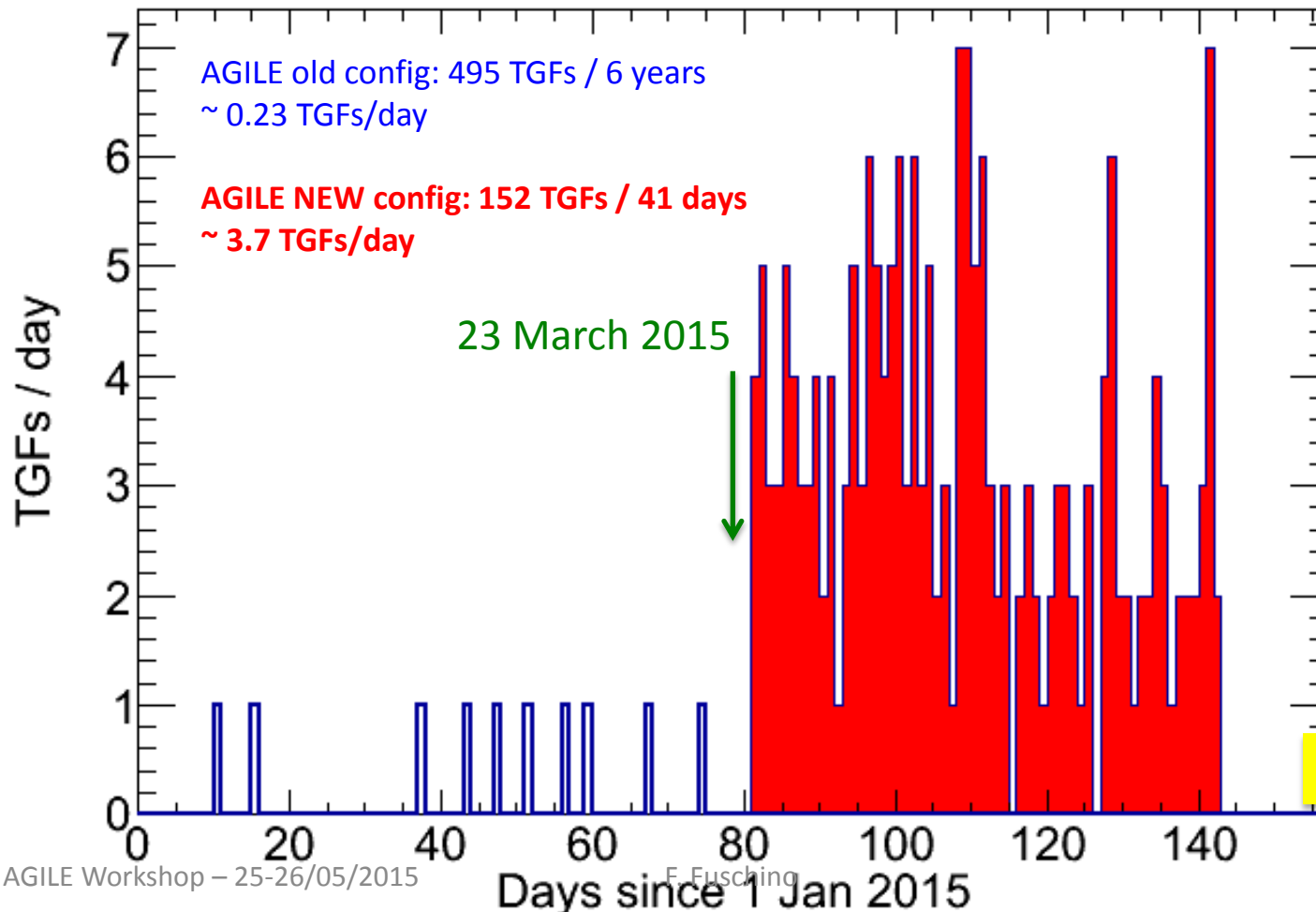
AGILE



AGILE new life

A factor ~16 TGF detection rate improvement

TGF daily detection rate

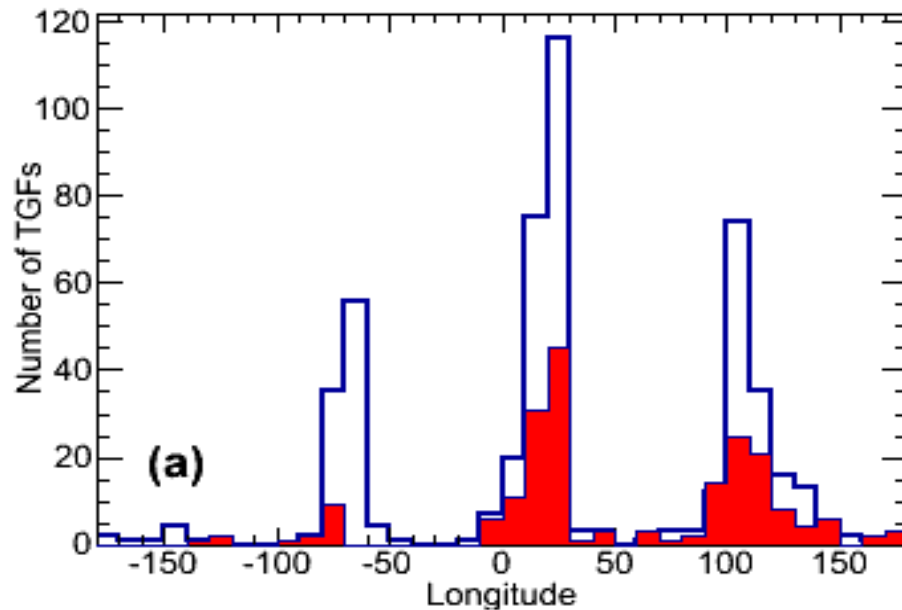


The new sample:

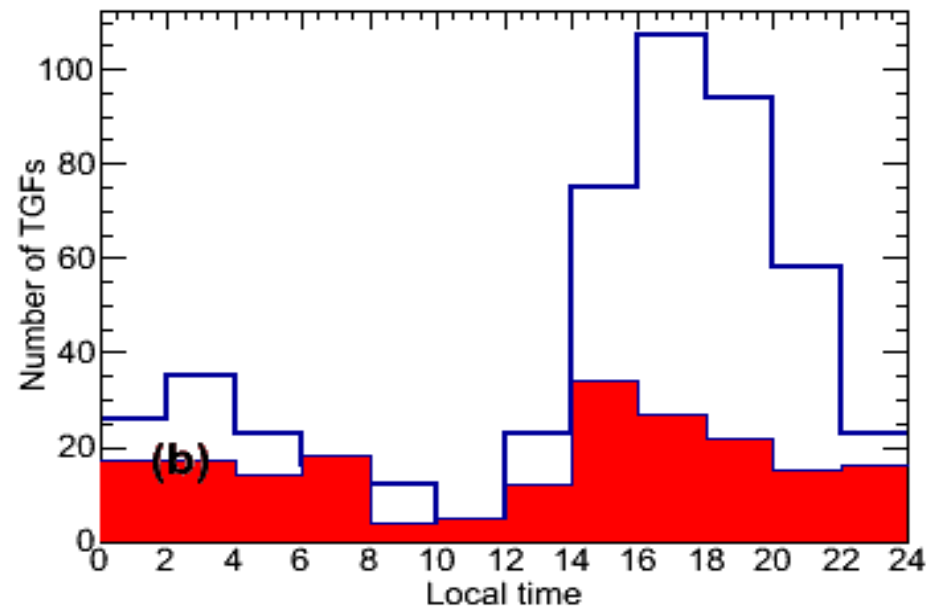
AGILE old config: 495 TGFs / 6 years
~ 0.23 TGFs/day

AGILE NEW config: 152 TGFs / 41 days
~ 3.7 TGFs/day

Longitude distribution

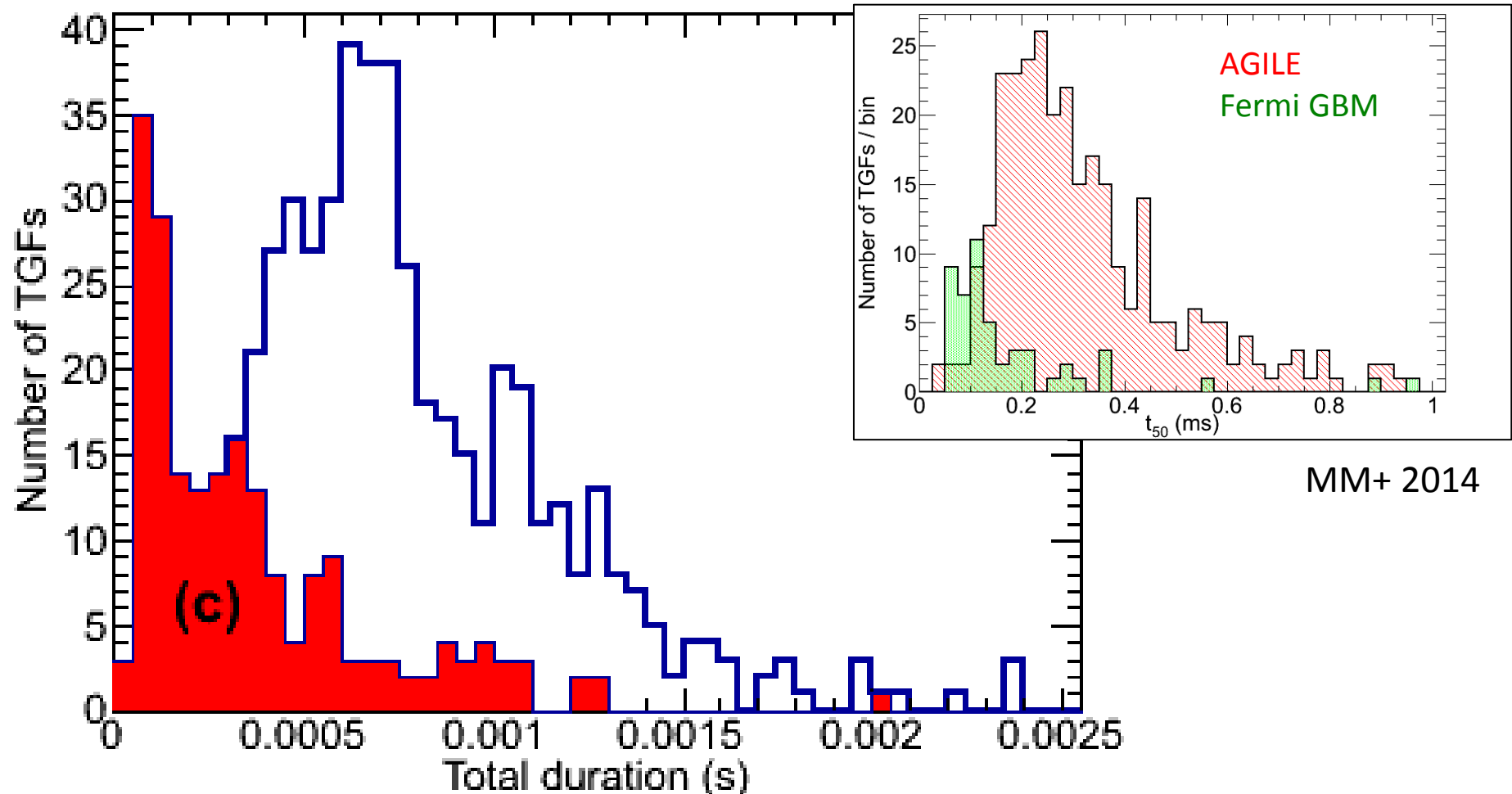


Local time distribution



The new sample:

Duration distribution

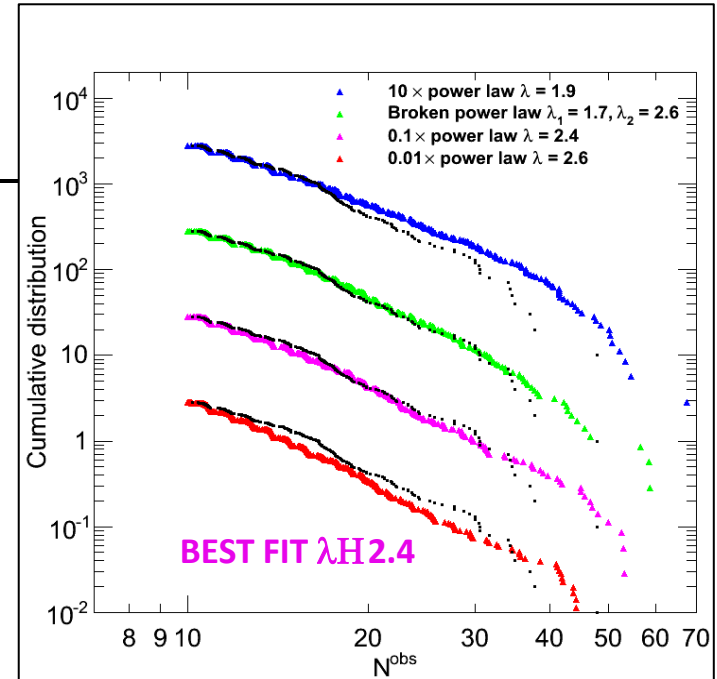
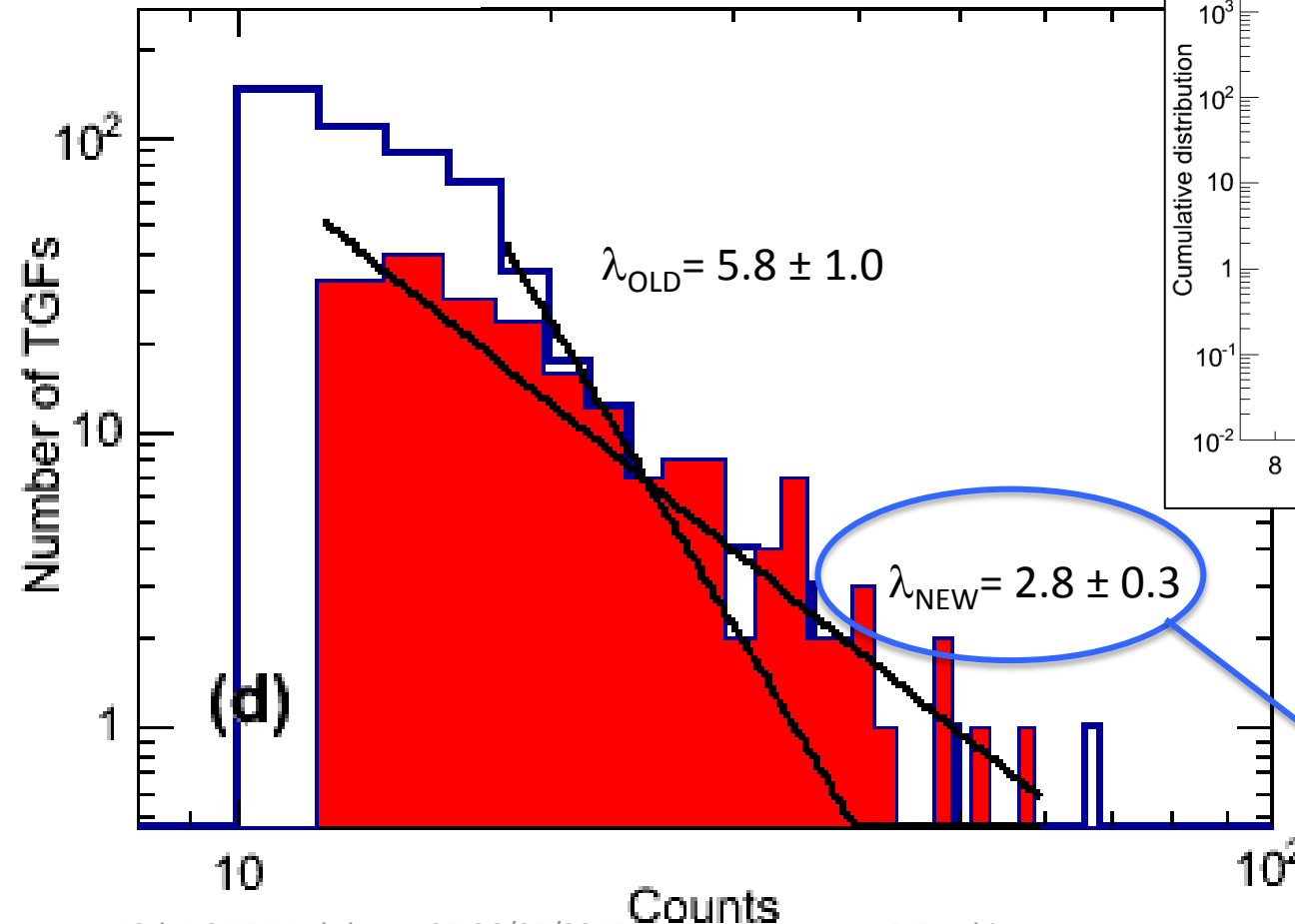


The new sample:

Complex dead time model

$$\frac{dN}{dn} = A_0 n^{-\lambda}$$

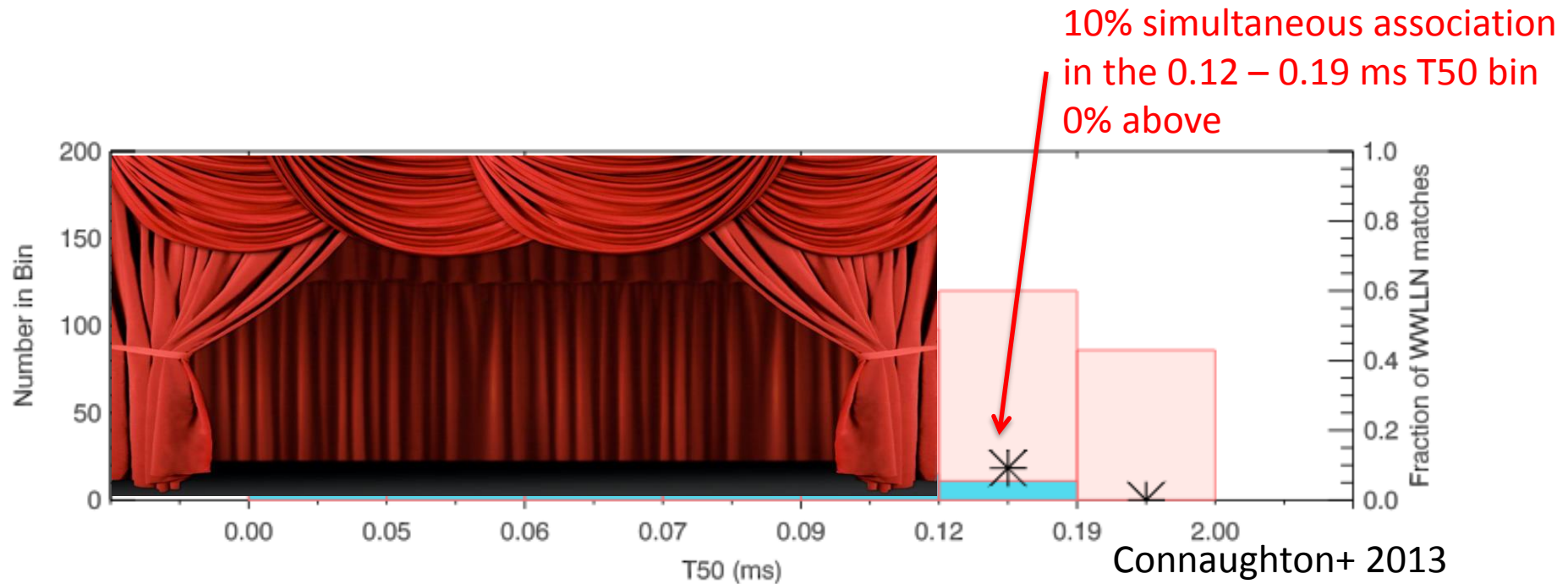
Intensity distribution



MM+ 2014

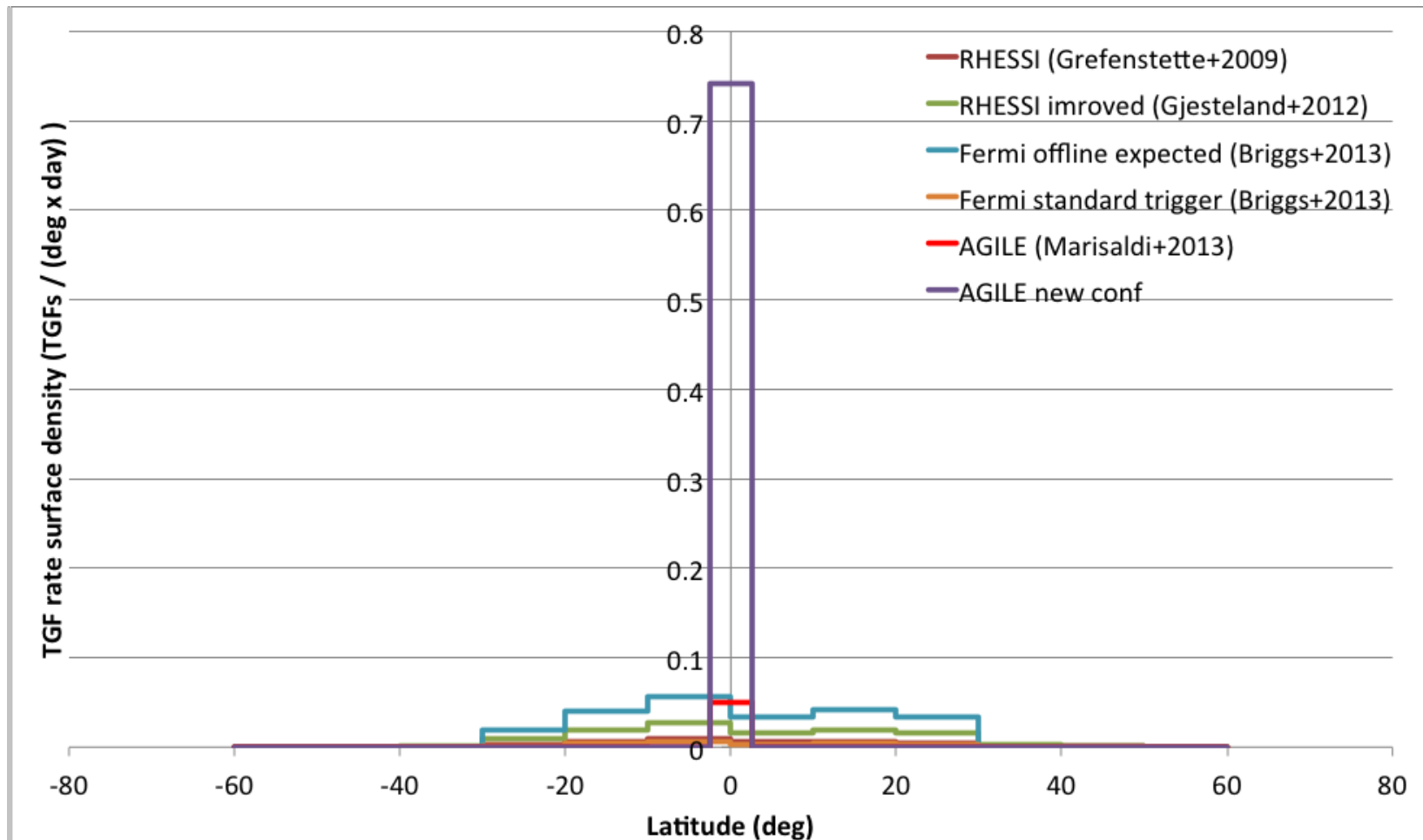
No dead time modeling

Association with WWLLN sferics

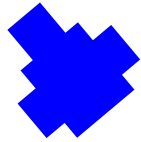


What is it for?

Detection rate surface density



What is going on in the world?



Space



Balloon

COBRAT (CNES+)
USA

ADELE (USA)
ILDAS (NL)
Air France + IRSN

Kochkin talk

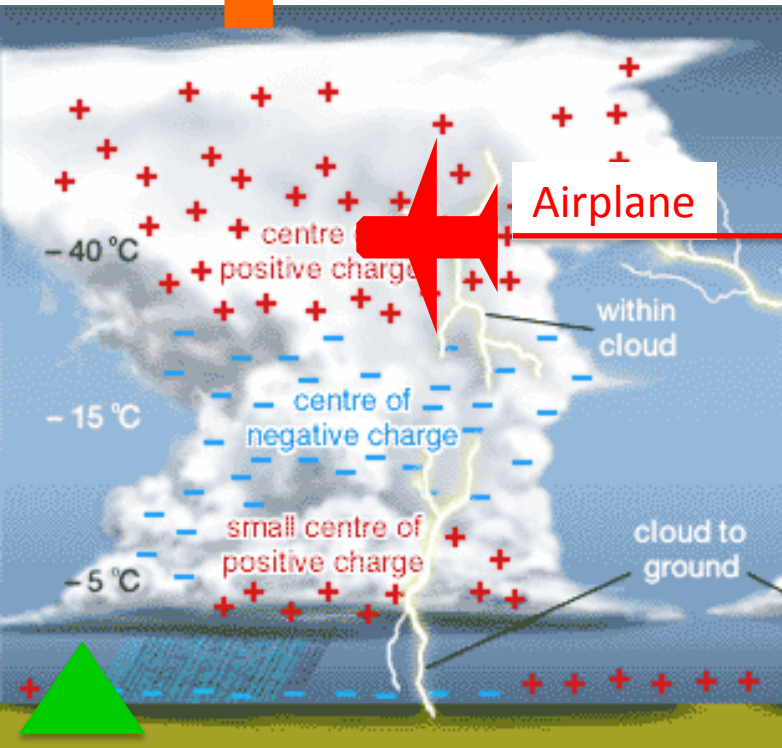
AGILE, RHESSI, Fermi

+

ASIM (ESA) - ISS
TARANIS (CNES)
Firefly (USA)
Firestation (USA) – ISS
GLIMS (JP) – ISS
RELEC – RKA –
Svertilov talk

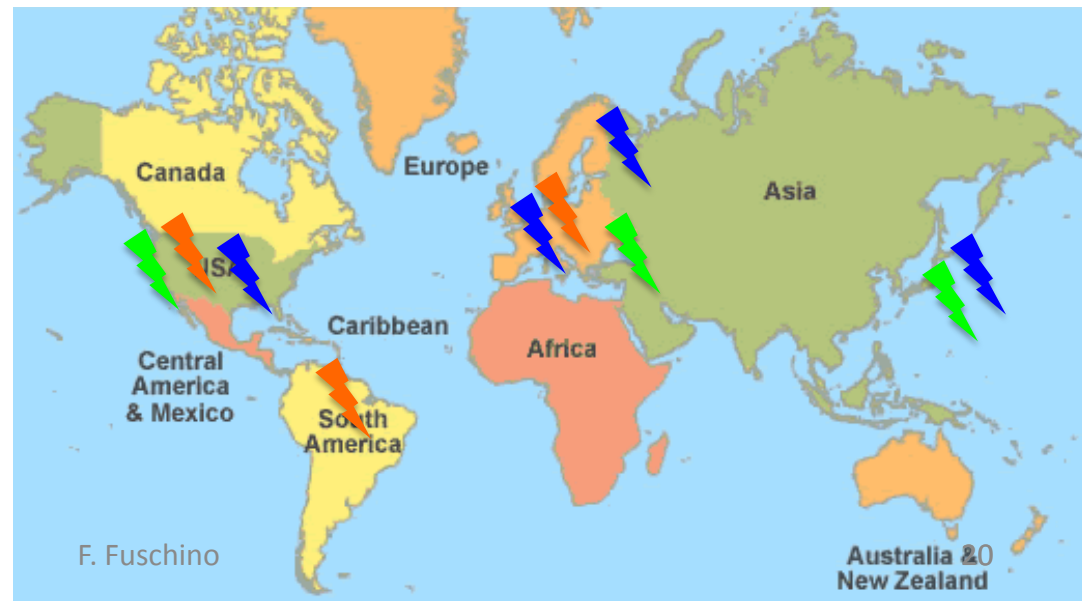


Airplane

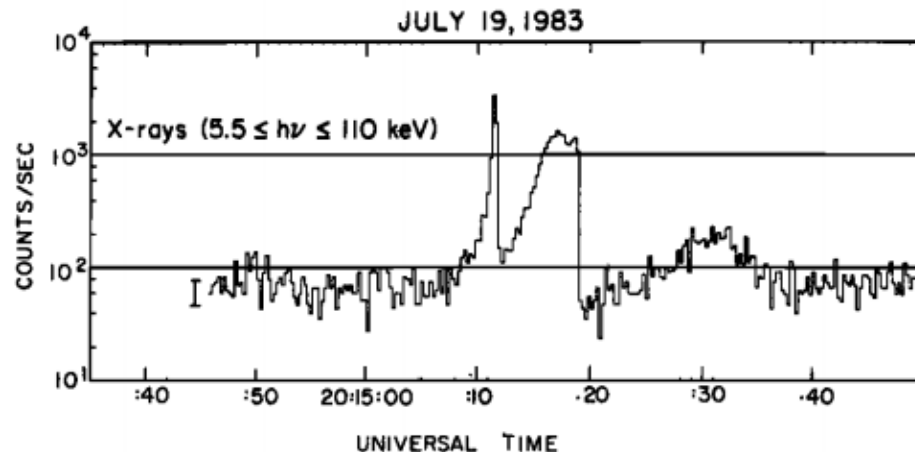


Ground

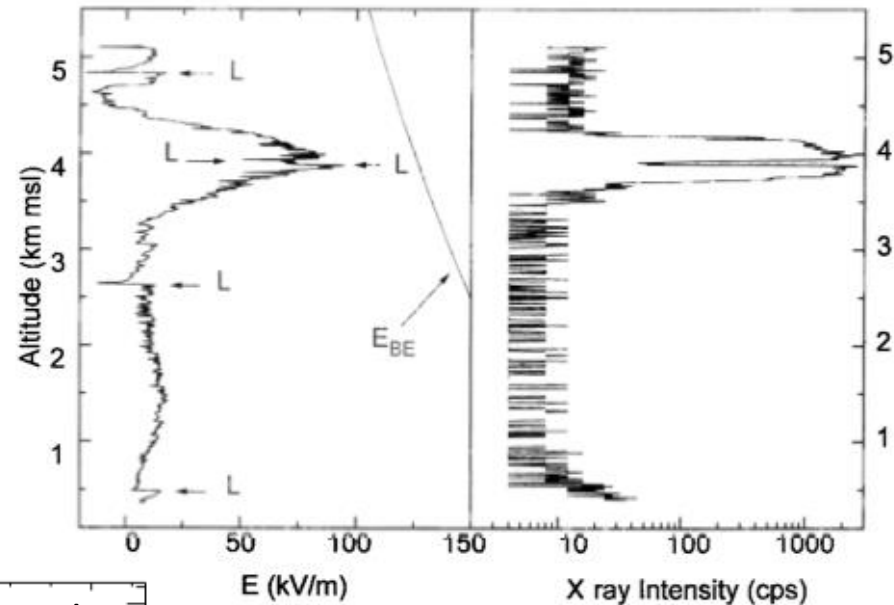
USA
Japan
Armenia



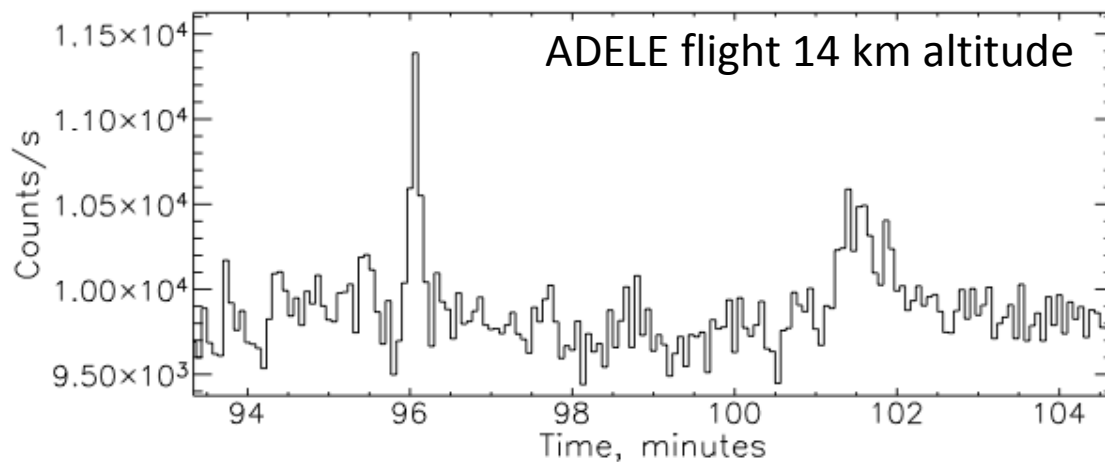
Airplane and balloon observations



McCarty & Parks, GRL (1985)



Eack et al., JGR (1996)

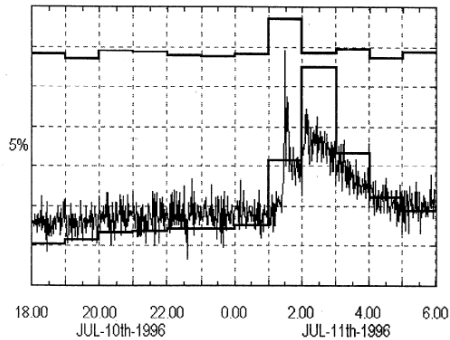


Dwyer Smith & Cummer, Sp. Sci. Rev. (2012)

Ground observations

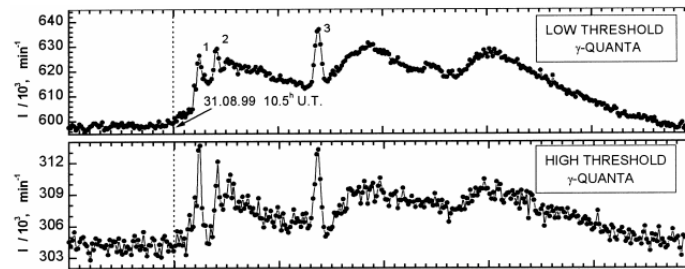
**Italy, Gran sasso,
2005 m a.s.l.**

(Brunetti+2000)

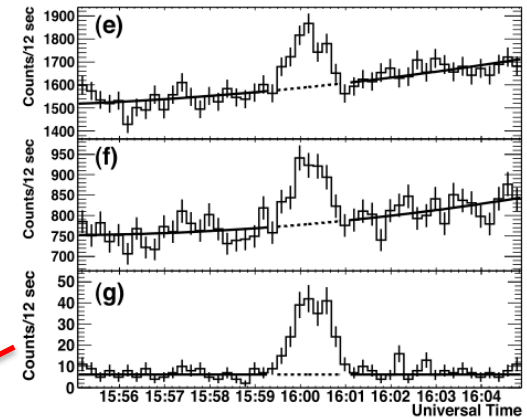


**Russia / Kazakhstan,
Tien-Shan, 3340 m a.s.l.**

(Chubenko+2000)

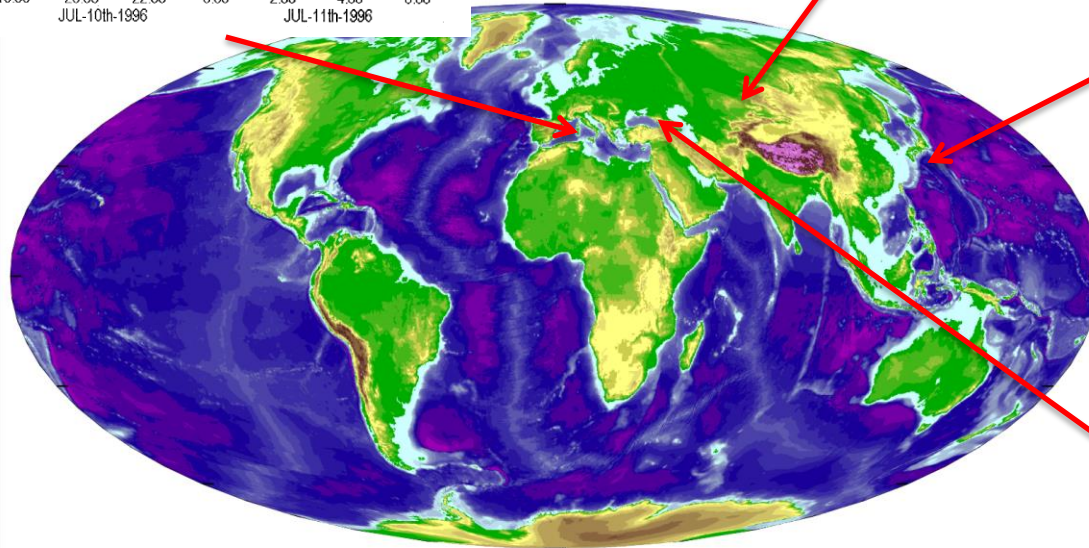
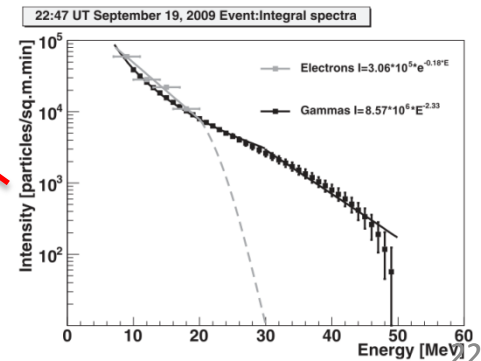


**Japan winter thunderstorms
Sea level (Tsuchiya+2009, 2011)**

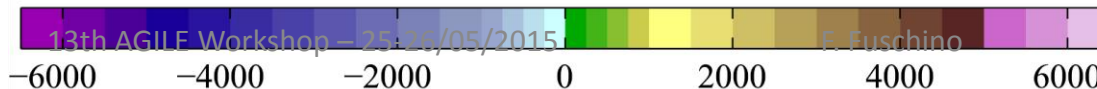


**Armenia, Aragats
3250 m a.s.l.**

(Chilingarian+
2010,2011,2013)



Present day Earth topography [m]



AGILE Team activities



8 MCAL spare bars
Available in our laboratories

