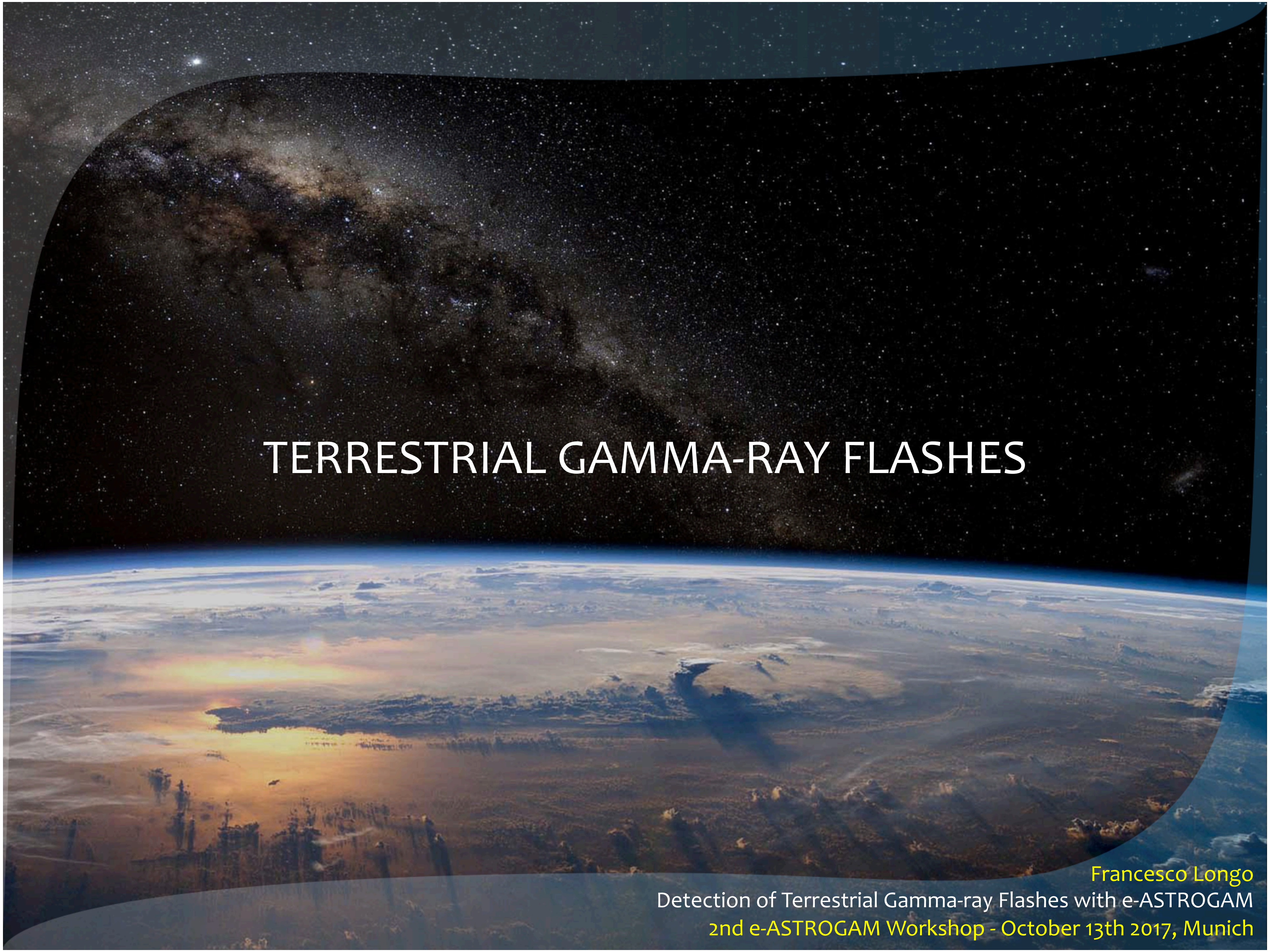
DETECTION OF TERRESTRIAL GAMMA-RAY FLASHES WITH e-ASTROGAM

Francesco Longo (Università di Trieste, INFN)

on behalf of Alessandro Ursi (INAF-IAPS, Rome)
and the AGILE team



TERRESTRIAL GAMMA-RAY FLASHES

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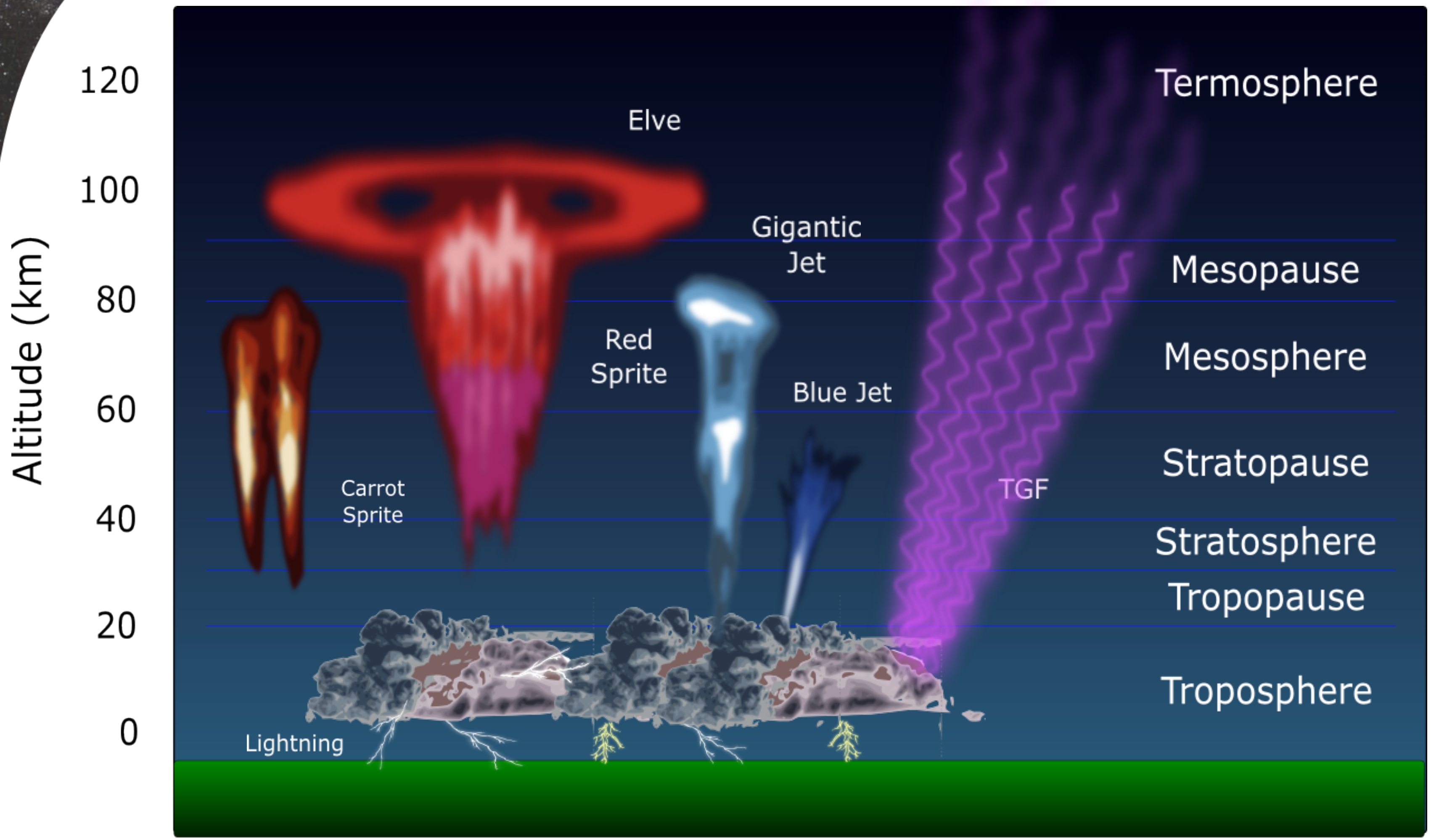
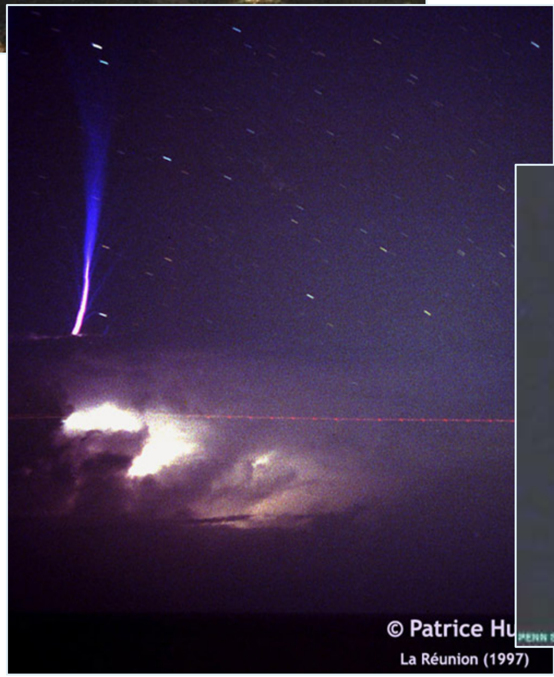
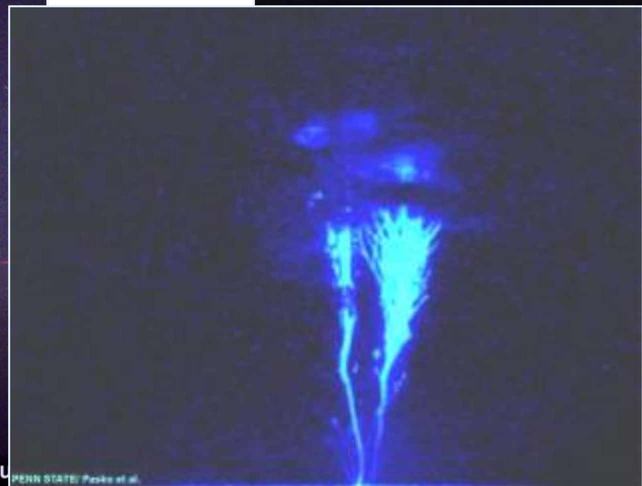
2nd e-ASTROGAM Workshop - October 13th 2017, Munich

Terrestrial events – Terrestrial Gamma-ray Flashes (TGFs)

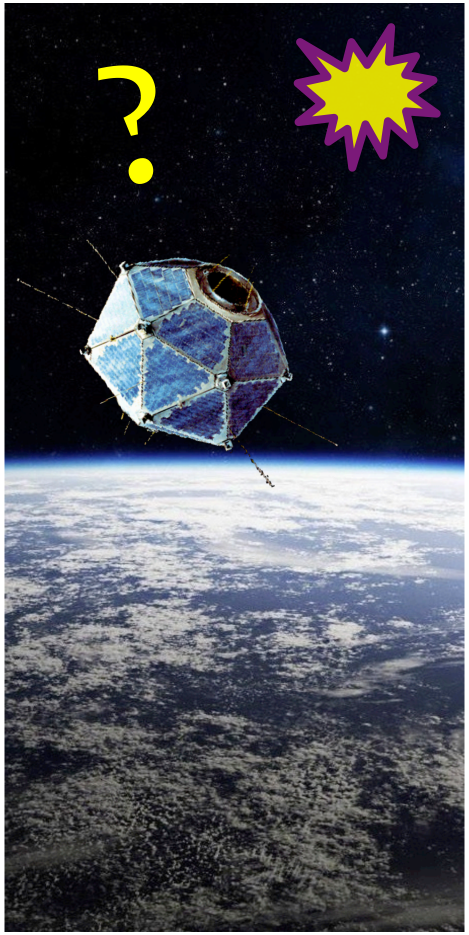


Terrestrial events – Terrestrial Gamma-ray Flashes (TGFs)



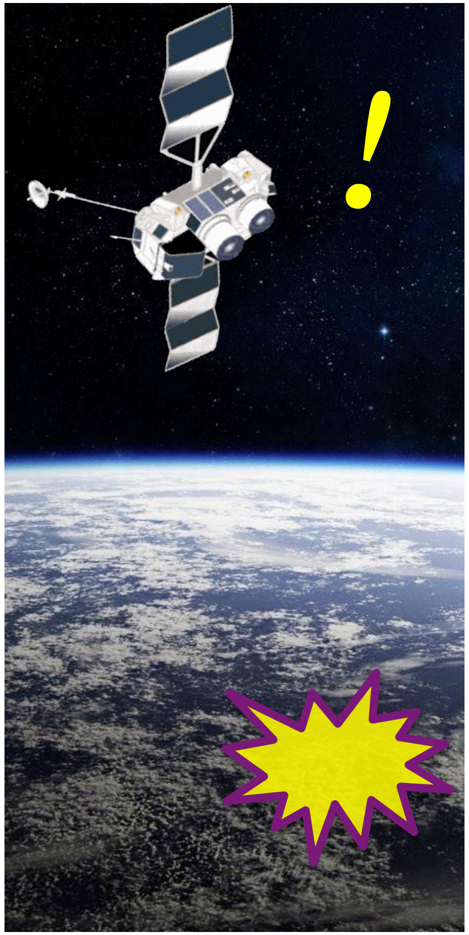


Terrestrial Gamma-ray Flashes



1967 VELA

GRB [*Klebesadel et al.*, 1973]



1991 CGRO

TGF [*Fishman et al.*, 1973]

- discovered in 1994
- brief bursts of γ-rays
- produced ~20 km a.s.l.
- associated to lightning
- bremsstrahlung photons
- observed by few satellites

serendipitous
discovery

Terrestrial Gamma-ray Flashes

time duration = tens μs ÷ few ms

energy = few keV ÷ tens of MeV

production height ~ 15÷20 km a.s.l.

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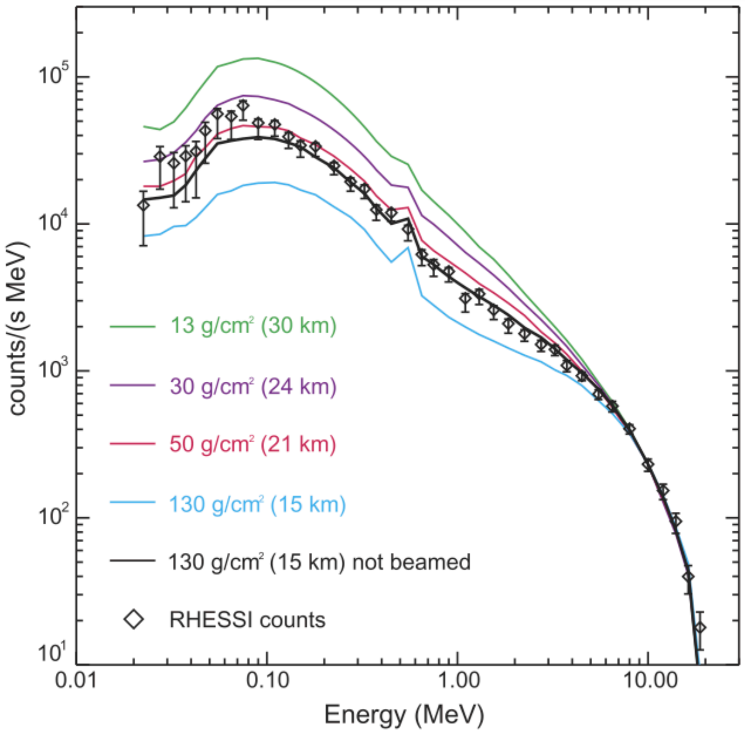
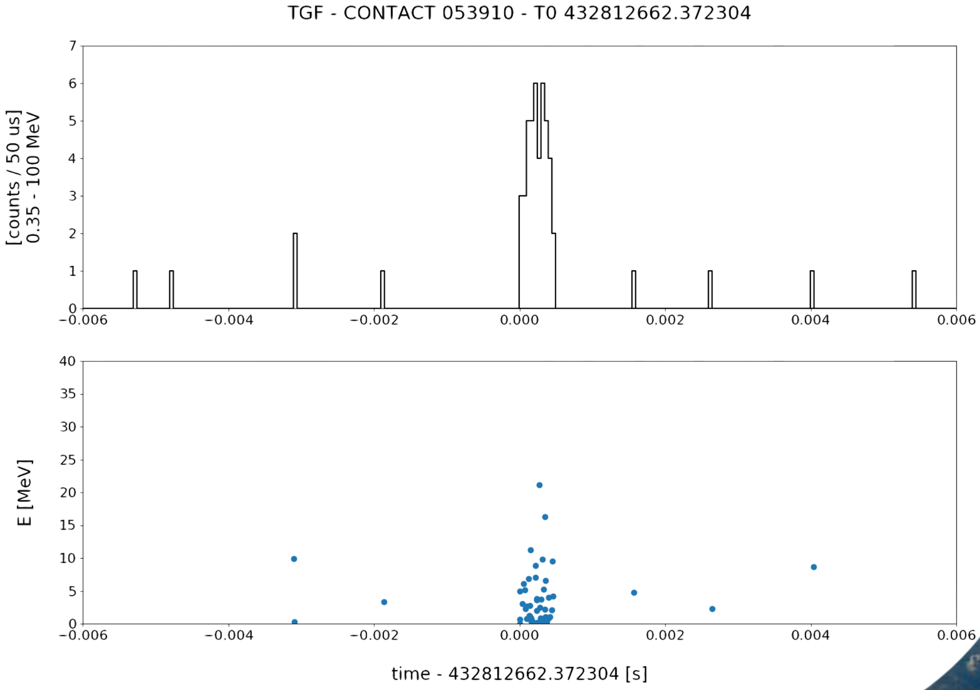


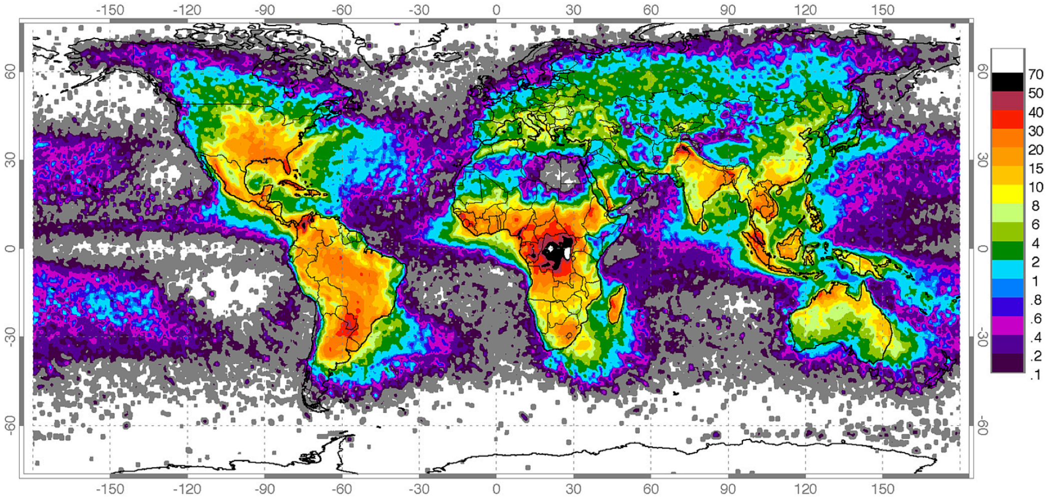
TGF energy spectrum

[*Dwyer and Smith*, 2005]



Terrestrial Gamma-ray Flashes

Lightning distribution by LIS



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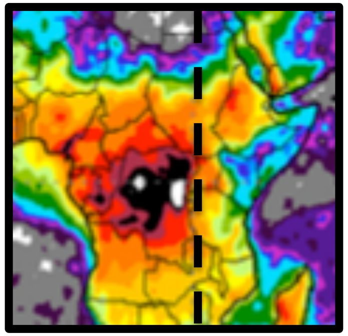

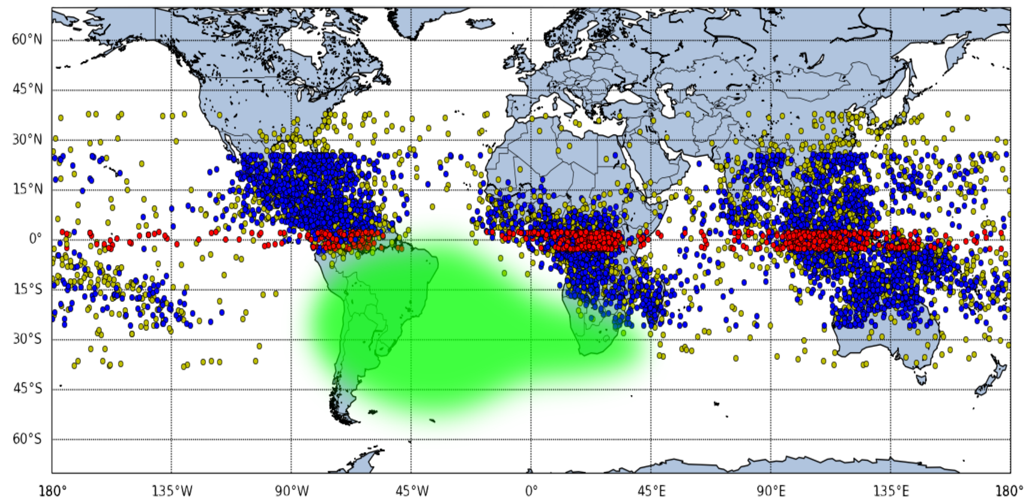

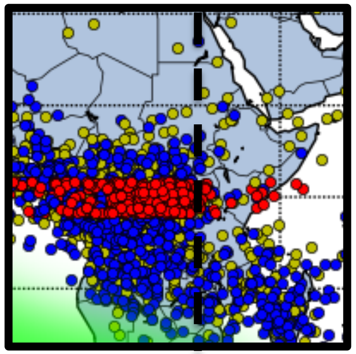

All RHESSI and AGILE TGFs

Terrestrial Gamma-ray Flashes

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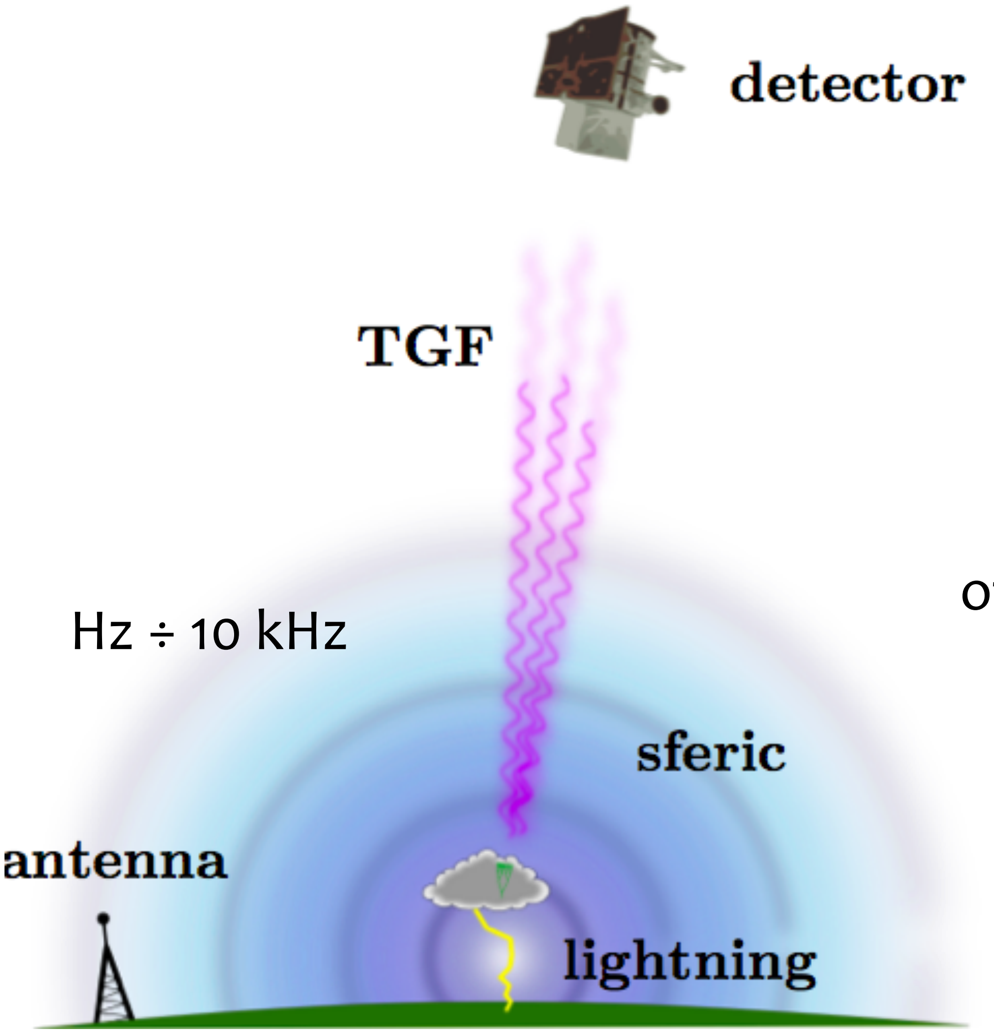
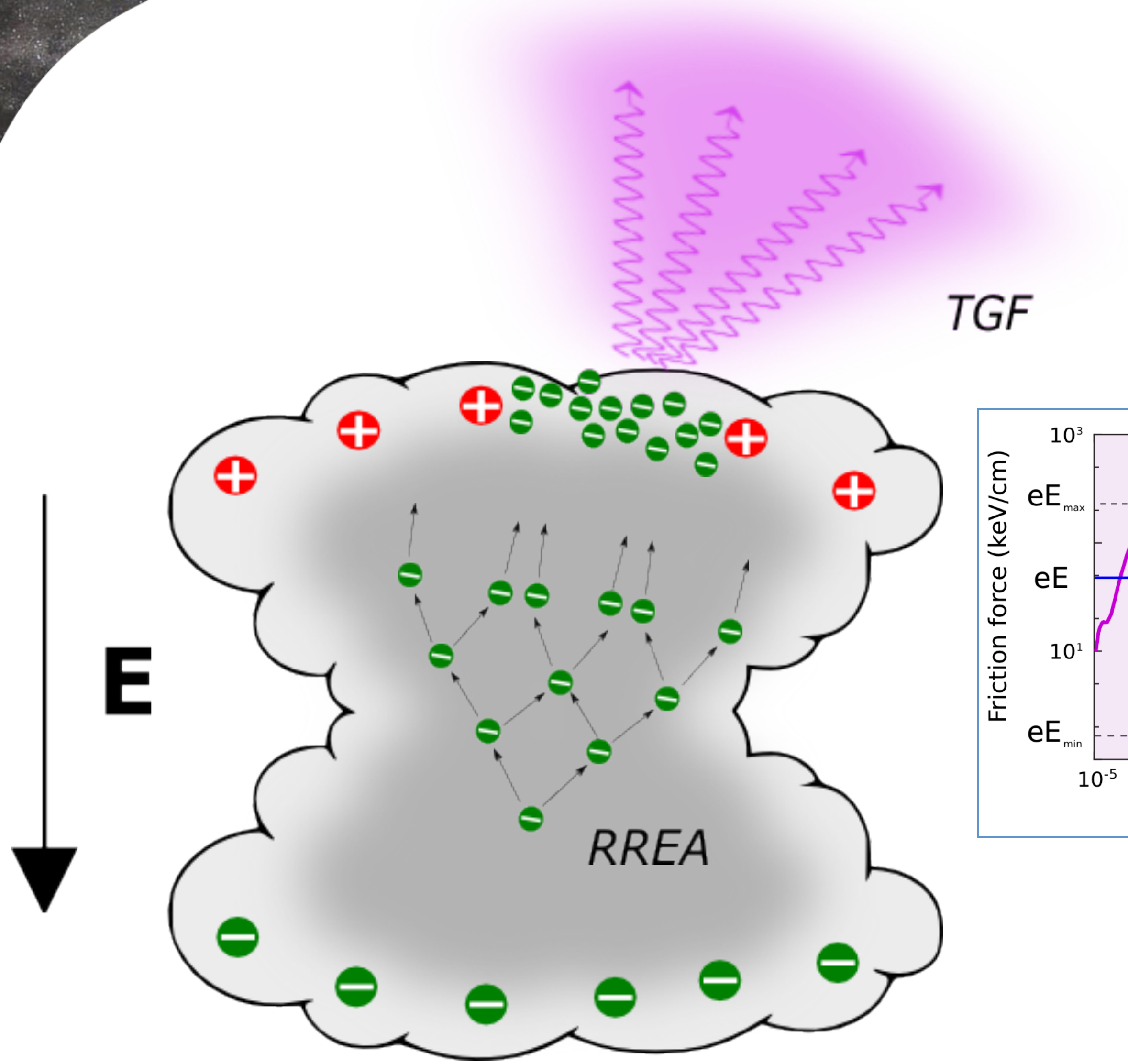


time coincidences
(within 200 μs)
of lightning sferics and TGFs

Terrestrial Gamma-ray Flashes



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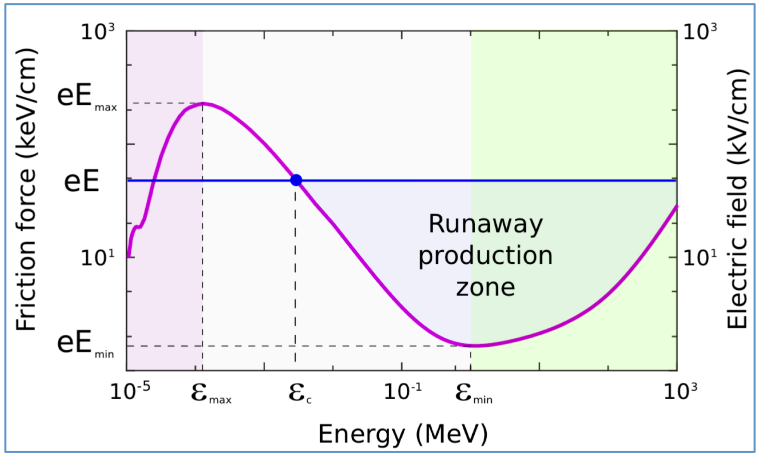

Terrestrial Gamma-ray Flashes

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Aircraft hazards?

gamma-rays/induced particles

+

airlines

TGF rate = 100 mSv ~ 10^{12} environmental rate

commercial airplanes struck by lightning once per year [*Uman and Rakov*, 2003]

possible effects of fast neutrons on the electronics [*Tavani et al.*, 2011]

neutrons from a TGF [*Bowers et al.*, 2017]

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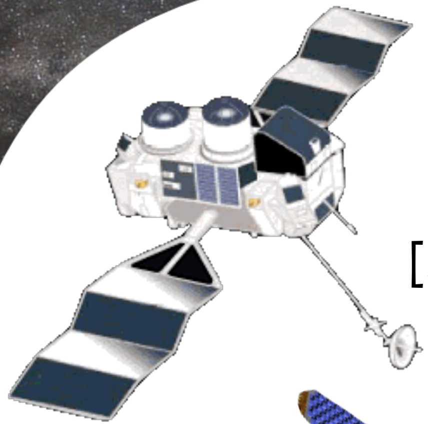
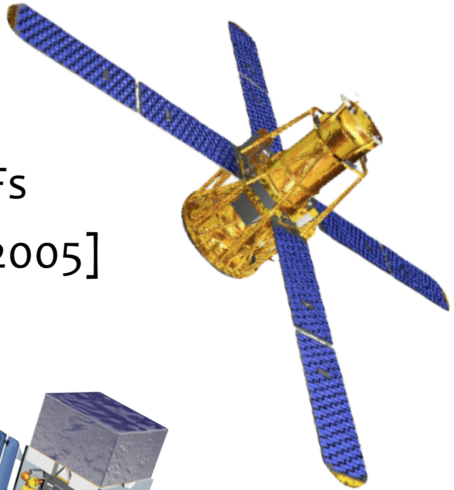
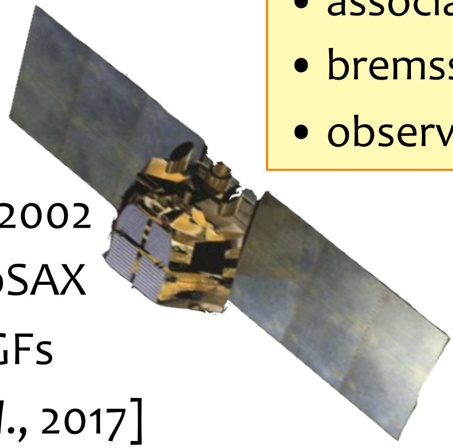


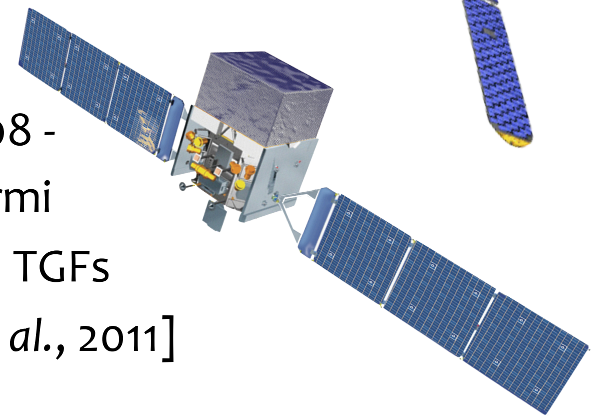
1991 - 2000
BATSE/CGRO
76 TGFs
[*Fishman et al.*, 1994]



2002 -
RHESSI
>3000 TGFs
[*Smith et al.*, 2005]



1996 - 2002
BeppoSAX
12 TGFs
[*Ursi et al.*, 2017]



2008 -
Fermi
>3000 TGFs
[*Briggs et al.*, 2011]

2007 -
AGILE
>3000 TGFs
[*Marisaldi et al.*, 2014]

e-ASTROGAM AS A TGF DETECTOR

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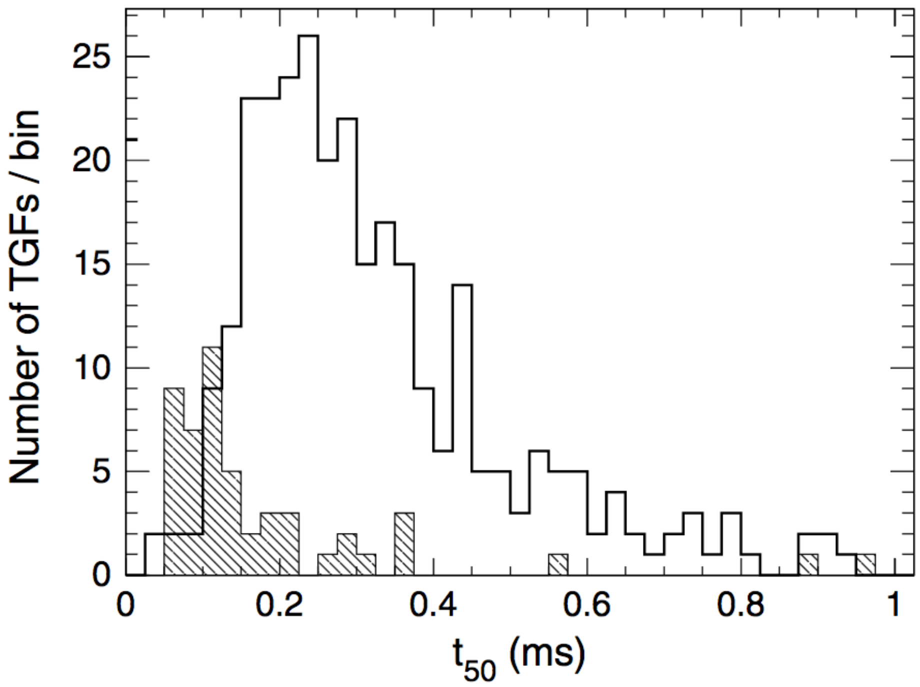
e-ASTROGAM calorimeter trigger logic

<u>e-ASTROGAM CAL sub-millisecond trigger logic:</u>

- TGFs are sub-millisecond phenomena (Δt ~ 100 μs)
- fundamental to trigger on TGFs



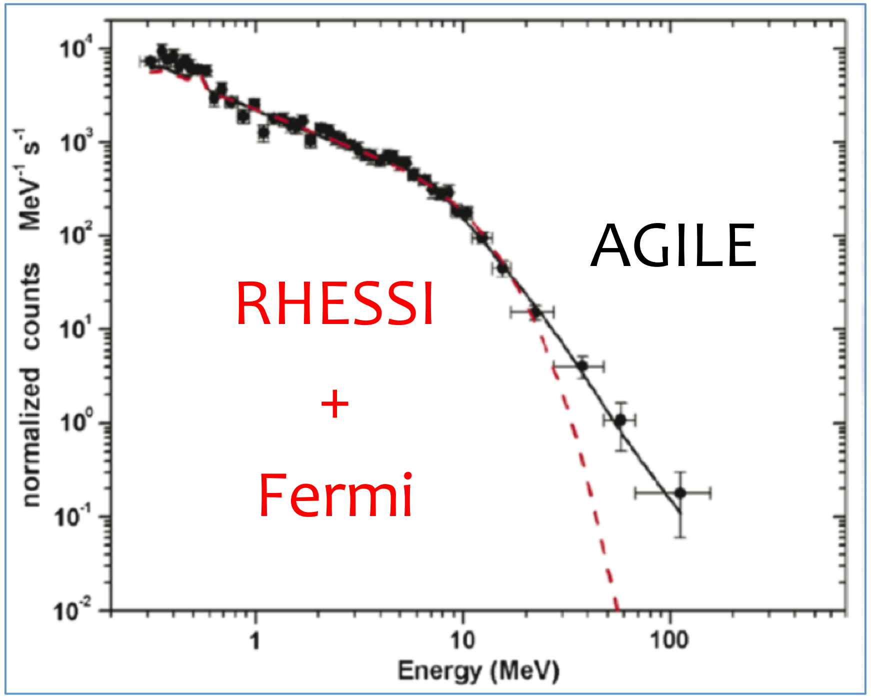
strongest point of the AGILE MCAL [Marisaldi et al., 2015]

time resolution 2 μs

e-ASTROGAM calorimeter energy range

e-ASTROGAM CAL energy range up to 200 MeV allows:

- detection of TGFs at the highest energies (≥ 40 MeV)
- assess the presence of high-energy photons
- challenge for theoretical models



already detected by the AGILE satellite [Tavani et al., 2011]

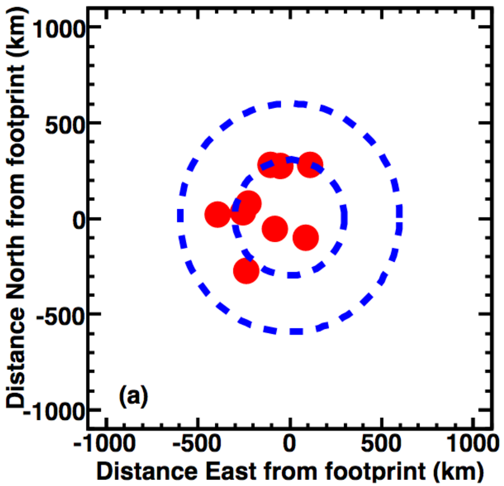
Compton range [0.3 – 15 MeV] of atmospheric processes linked to TGFs

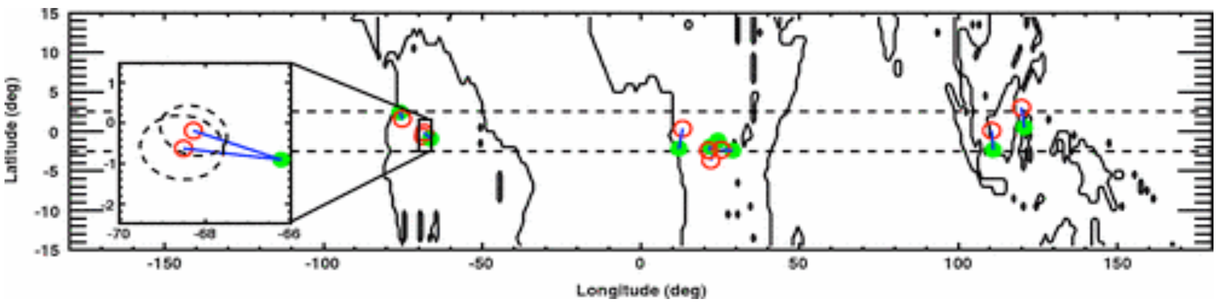
e-ASTROGAM silicon tracker

e-ASTROGAM CAL + tracker allows:

- imaging of TGFs from Earth
- reconstruct TGF position with better accuracy (5°)
- helpful to constrain the TGF emission beaming angle

already performed by the
AGILE satellite [Marisaldi et al., 2010b]





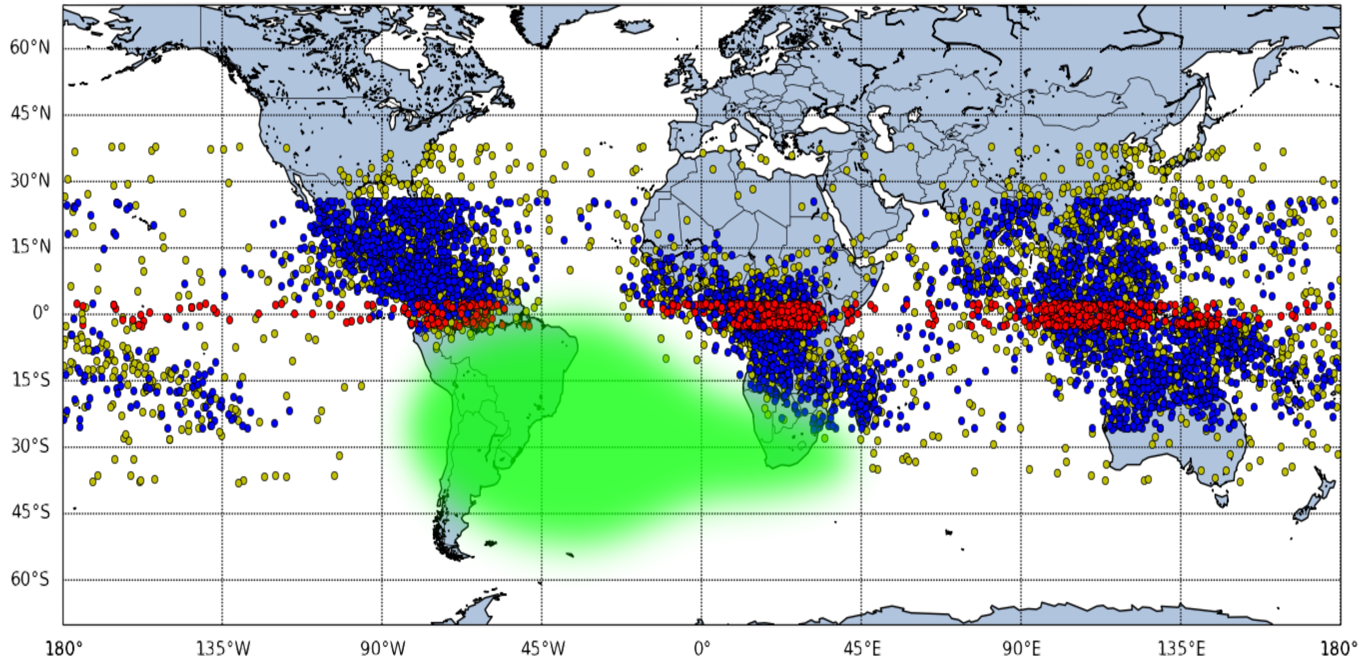
first TGF imaging (accuracy ~ 5°-10°)
with the ST from *Marisaldi et al., 2010b*

e-ASTROGAM orbit

<u>e-ASTROGAM quasi-equatorial (2.5°) orbit allows:</u>

- detection of TGFs at the highest rate

TGFs cluster within the tropical belt

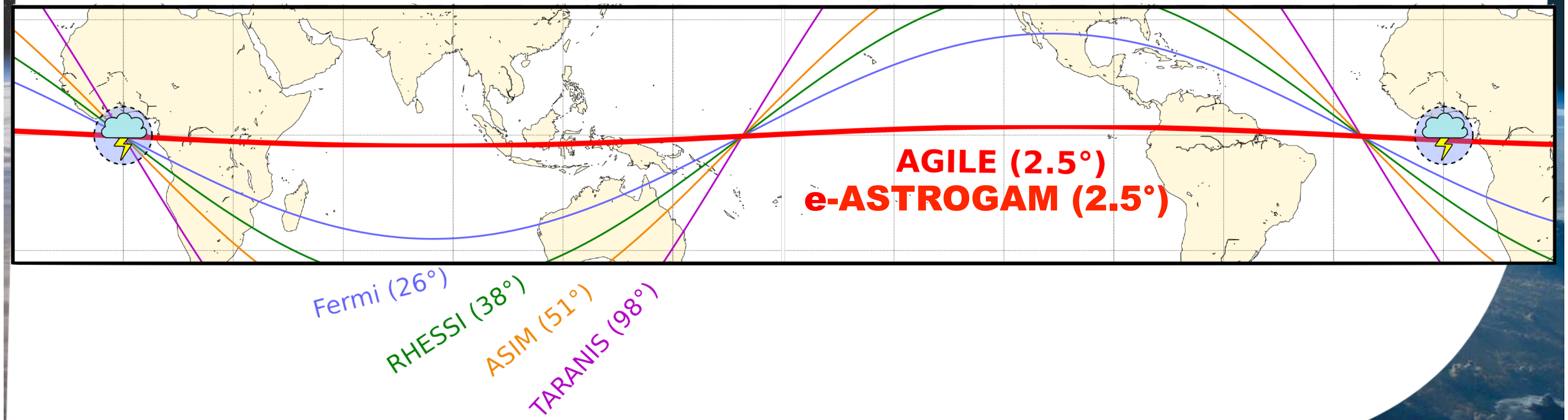


e-ASTROGAM orbit

<u>e-ASTROGAM quasi-equatorial (2.5°) orbit allows:</u>

- detection of multiple TGFs at successive overpasses
- produced from the same thunderstorms

already observed by the
AGILE satellite [Ursi et al., 2016]

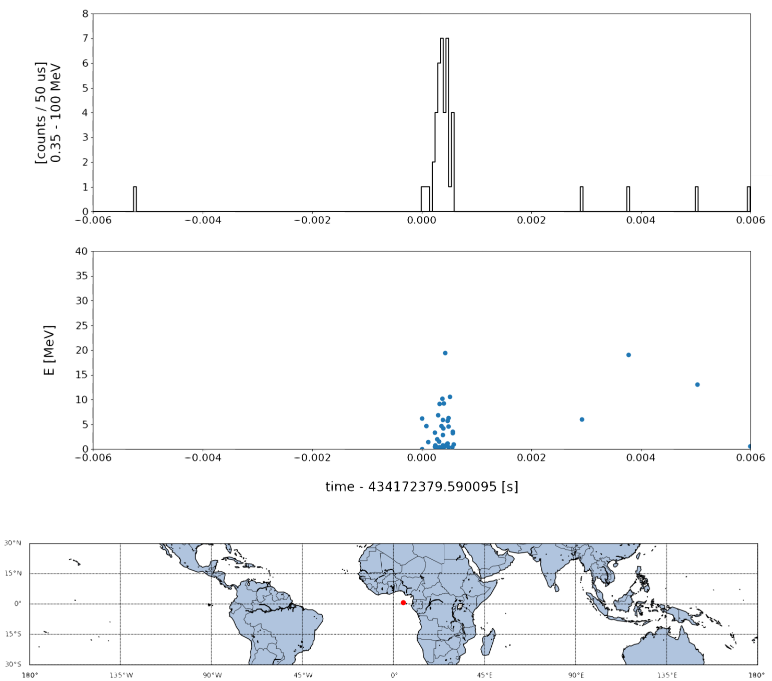


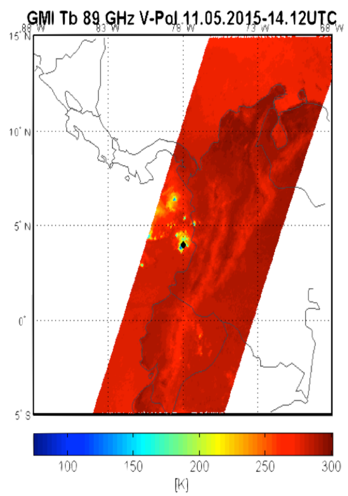
e-ASTROGAM link with meteo

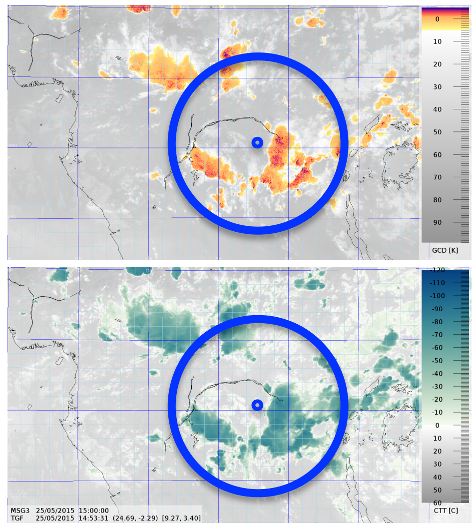
e-ASTROGAM TGF meteo analysis:

- link with GEO/LEO meteorological satellites
- fulfill a database for scientific purposes

already performed with the AGILE satellite [Ursi et al., 2017a]







Conclusions

TGFs with e-ASTROGAM

• <u>sub-millisecond trigger logic</u> •
high sensitivity to TGFs

• <u>CAL 30 keV ÷ 200 MeV energy range</u> •
investigation of he-TGFs

• <u>silicon tracker</u> •
imaging of TGFs

• <u>quasi-equatorial orbit</u> •
monitoring and follow-up of thunderstorms

THANK YOU!