IASF Bologna

AGILE and TGFs

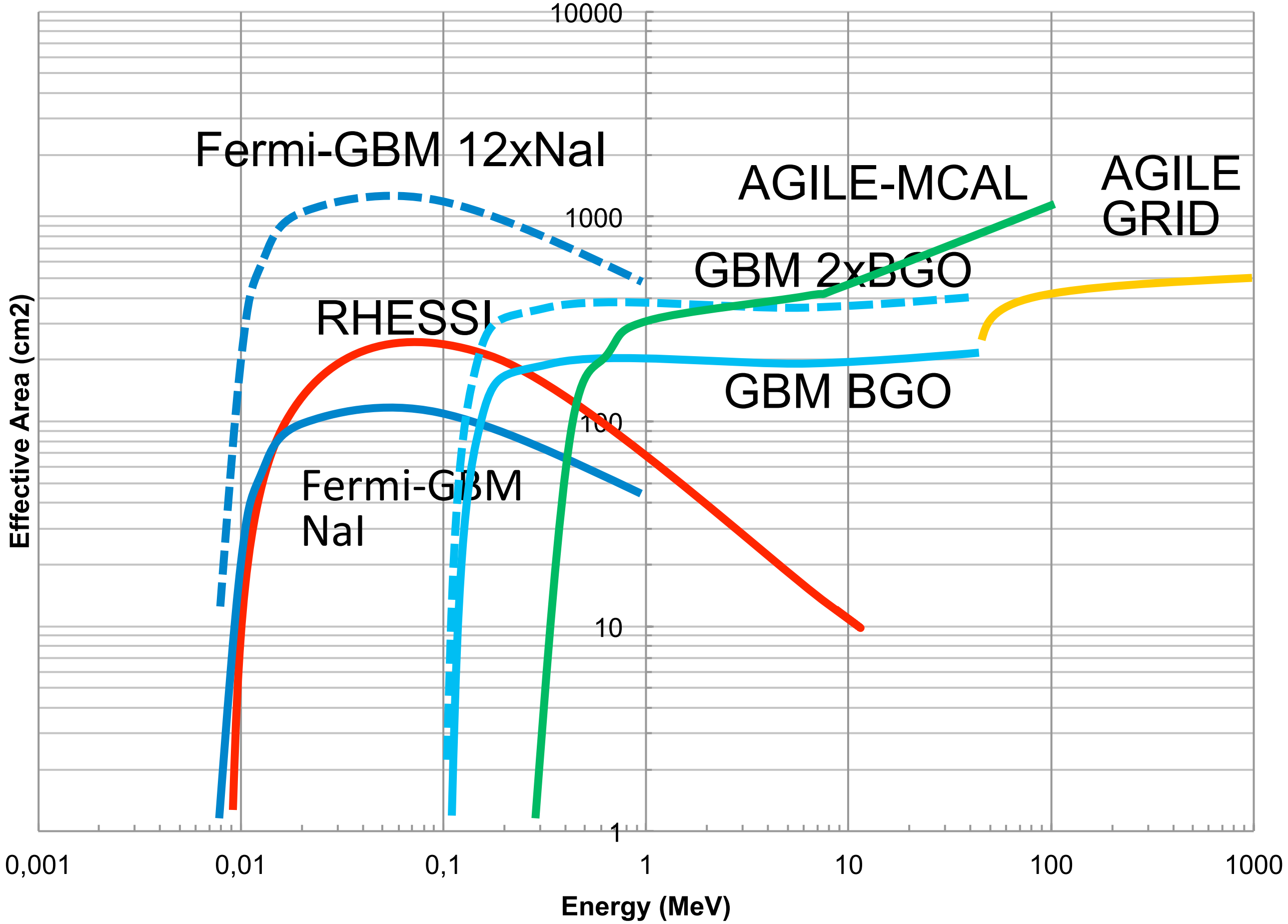
Latest results & activities

F. Fuschino and M. Marisaldi
on behalf of the
AGILE TGF&GRB Working Group

11th AGILE Science Workshop
"Gamma-rays and Galactic Cosmic Rays"
May 16-17, 2013
ASI Headquarters, Via del Politecnico, Rome

Operating TGF detectors

Effective Area vs. Energy



Data from: Smith et al. (2002), Meegan et al. (2009), Labanti et al. (2009), Tavani et al. (2009)

Operating TGF detectors

RHESSI Peculiarities

- 0.02 – 20 MeV Energy range
- Photon-by-photon (no on board trigger)
- 400 usec time resolution
- 38° orbit inclination

FERMI Peculiarities

- 0.008 – 40 MeV Energy range
- on board trigger down to 16 msec
- 2 usec time resolution
- 27° orbit inclination

AGILE Peculiarities

- MCAL energy range is extended up to **100 MeV**: probing the high energy tail of the TGF spectrum
- Efficient trigger at **ms** and **sub-ms** time scale (the TGF time scale): not biased toward brightest events
- **segmented independent detectors**: low dead time and pile-up
- **photon-by-photon** data download for triggered events with **2μs** time resolution
- **<100μs absolute timing accuracy**: mandatory for sferics correlation
- **AGILE orbit at 2.5° inclination** is optimal for mapping the equatorial region, where most of the events take place, with unprecedented exposure

Detection rate

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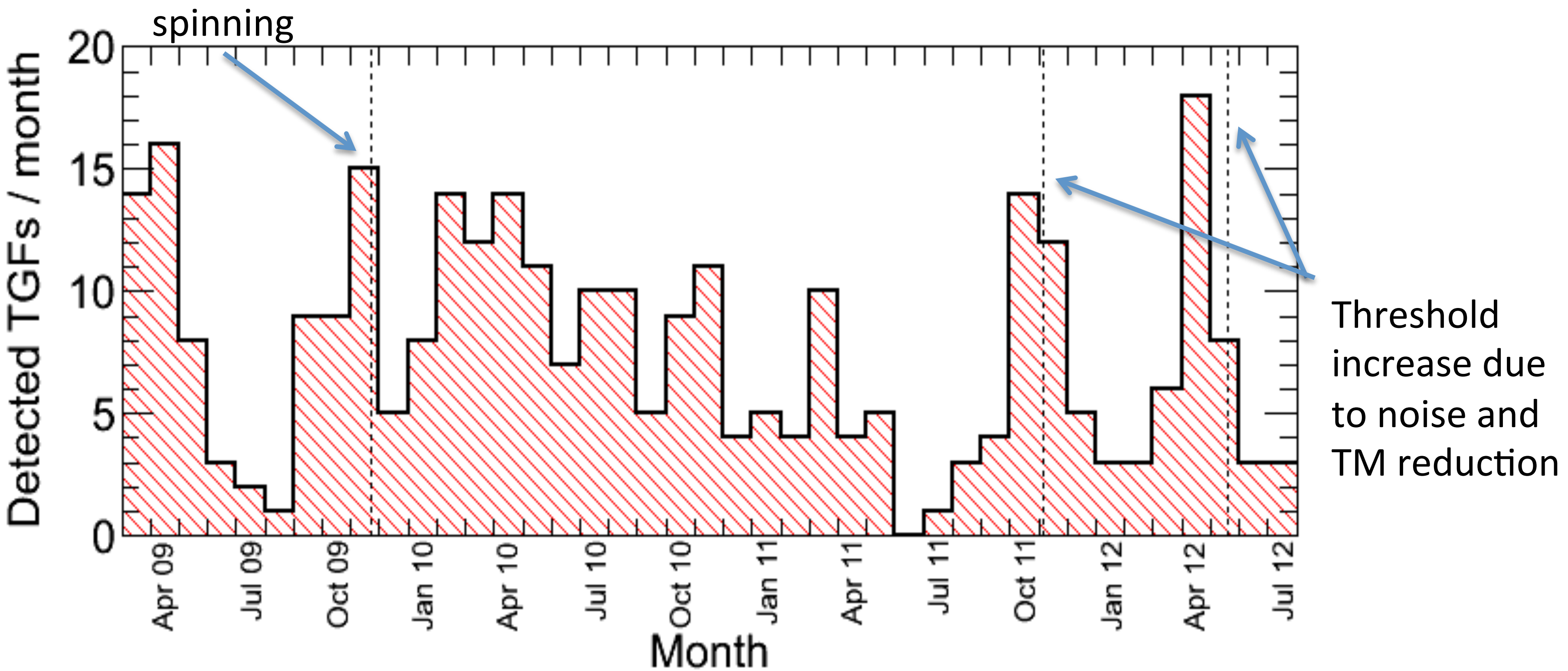

REQUIREMENTS ::: onboard trigger + ≥ 10 counts + hardness ratio ≥ 0.5 + E_{MAX} ≤ 30 MeV

361 TGFs between March 2009 and July 2012. 0.3 TGF/day

Low energy TGFs: paper almost ready for submission

Longitude distribution $E_{MAX} < 30$ MeV

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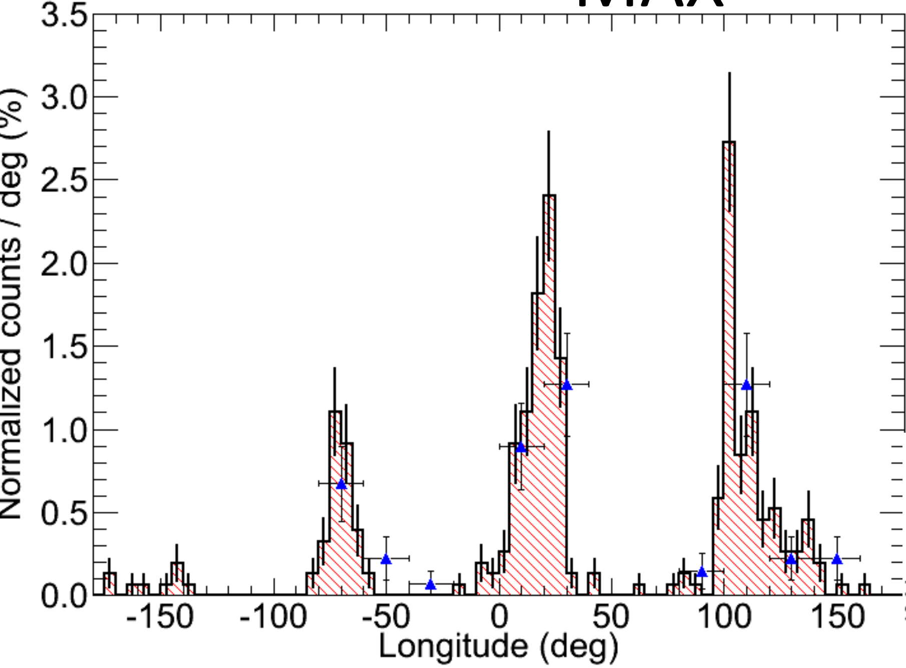

Longitude distribution peaks on continental masses, compliant with RHESSI.

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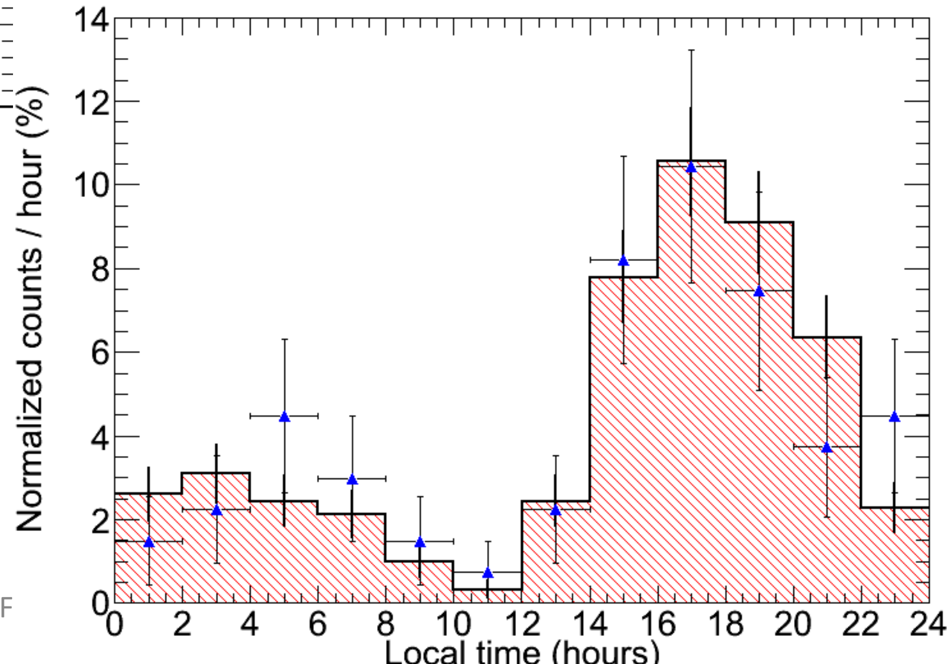
RHESSI

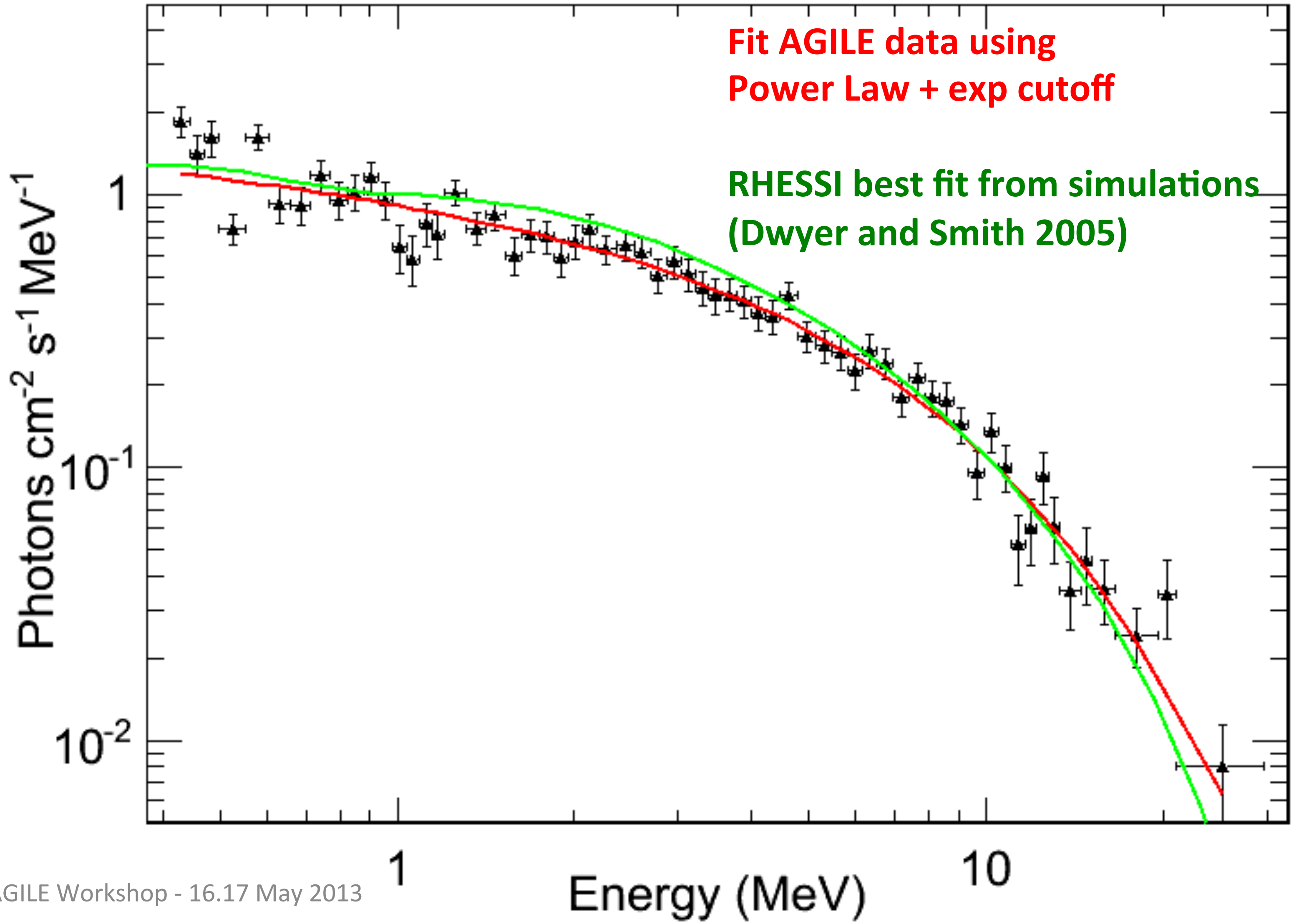
Local time distribution



Local time distribution peaks on late afternoon, compliant with RHESSI.

Cumulative spectrum

Selected only TGFs with no photons with E > 30 MeV



Energy spectra

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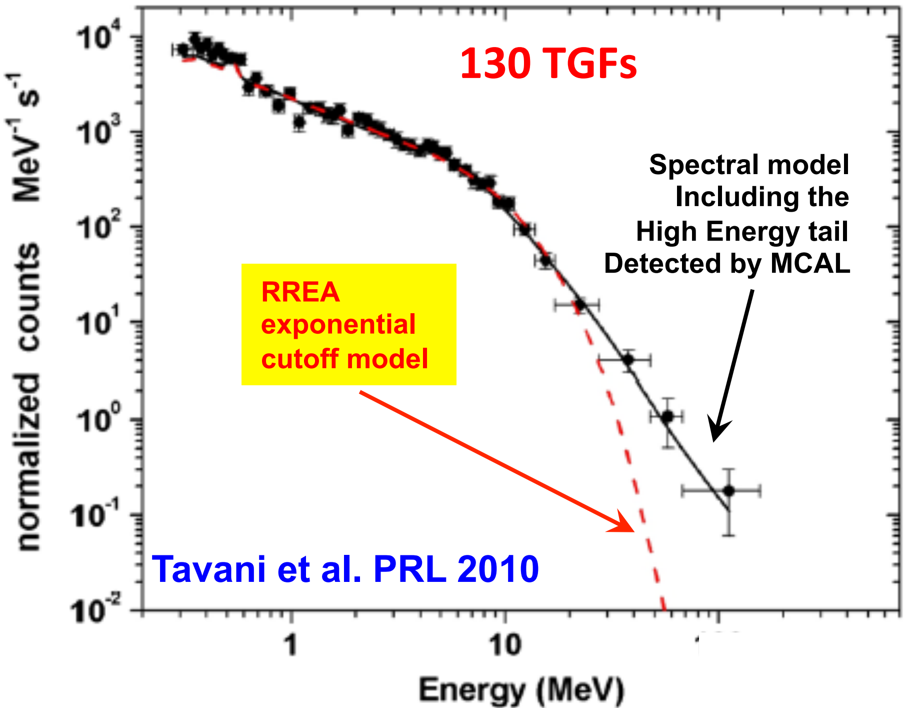
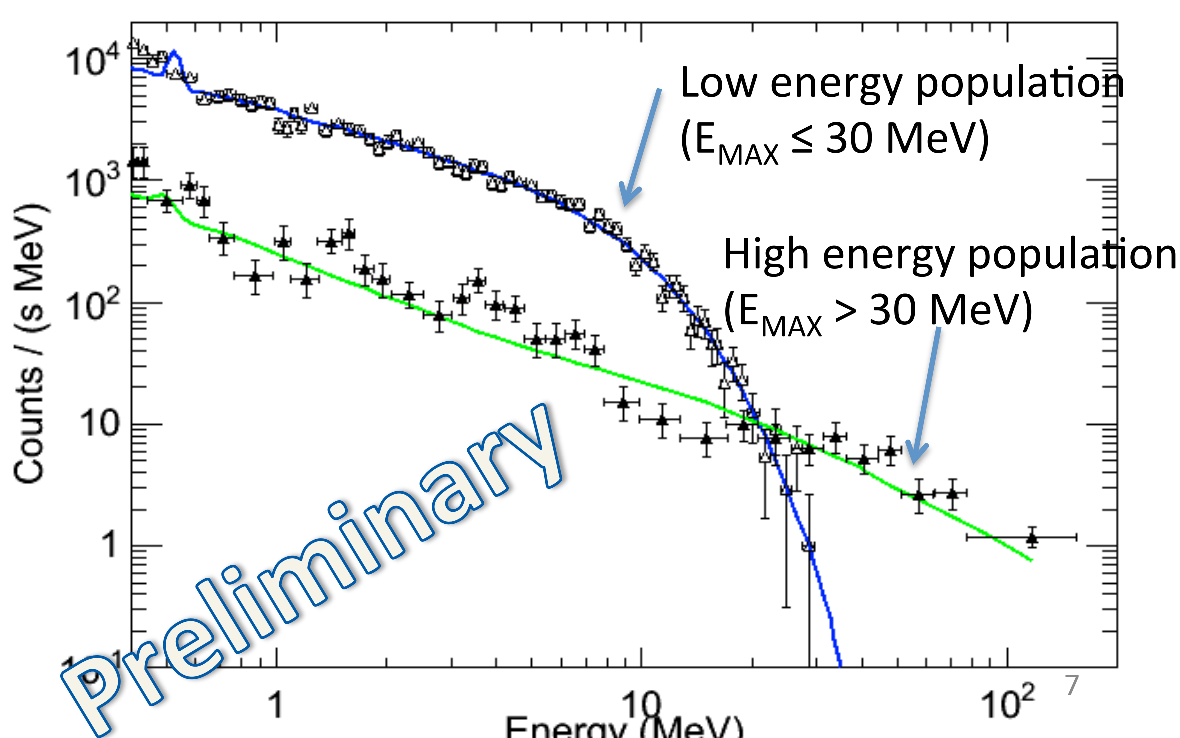


308 LE TGFs + 50 HE TGFs



High energy component: paper in preparation

Dead time induced by AC shield

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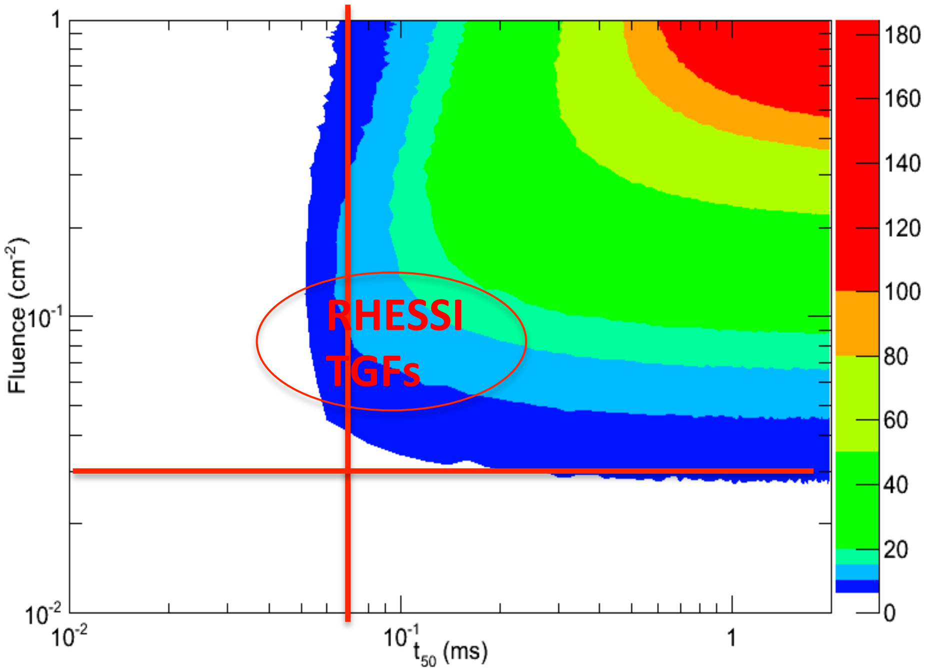
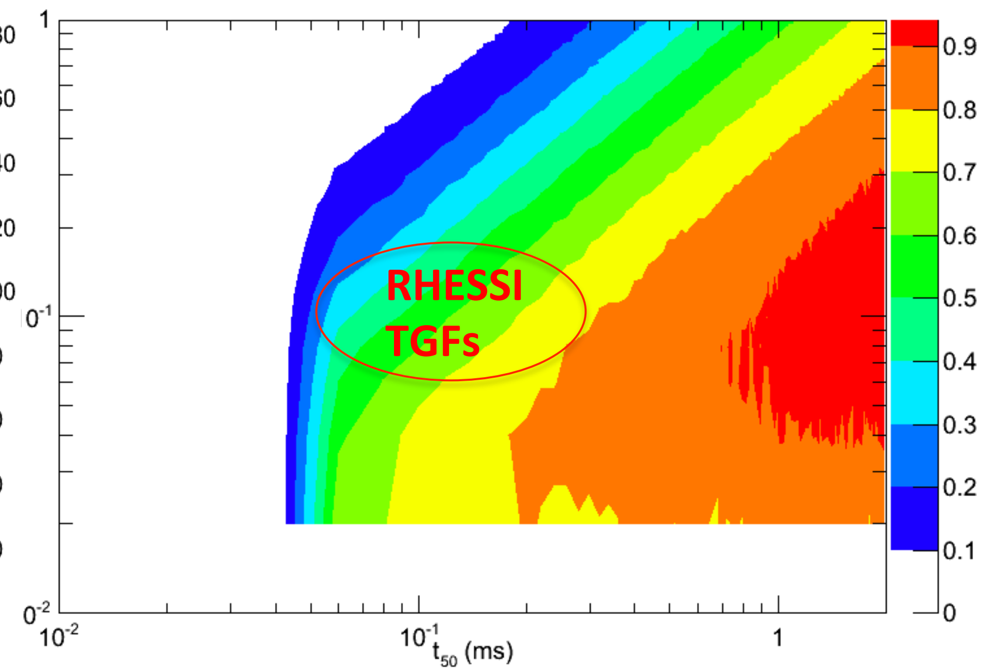
Detected counts



Live Time FRACTION



10 counts minimum: cannot detect 100μs TGFs, i.e. most of the events with a close lightning stroke association

Dead time fraction of ~50% for the average RHESSI TGF population

Simulations by M. Galli, assuming 120° off-axis beam

Duration distribution

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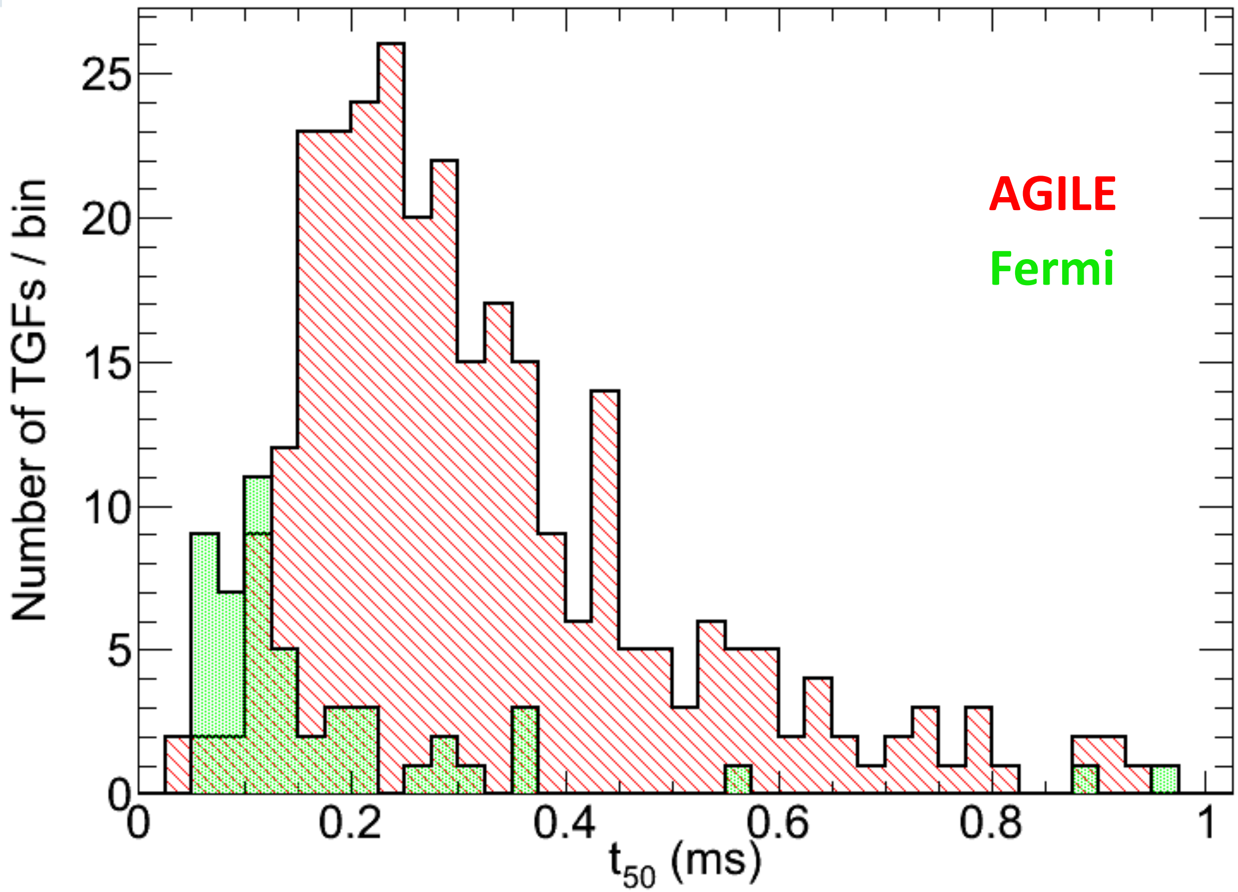

Switch-off of the AC for MCAL would enable detection of short TGFs, which are the vast majority according to RHESSI and Fermi results

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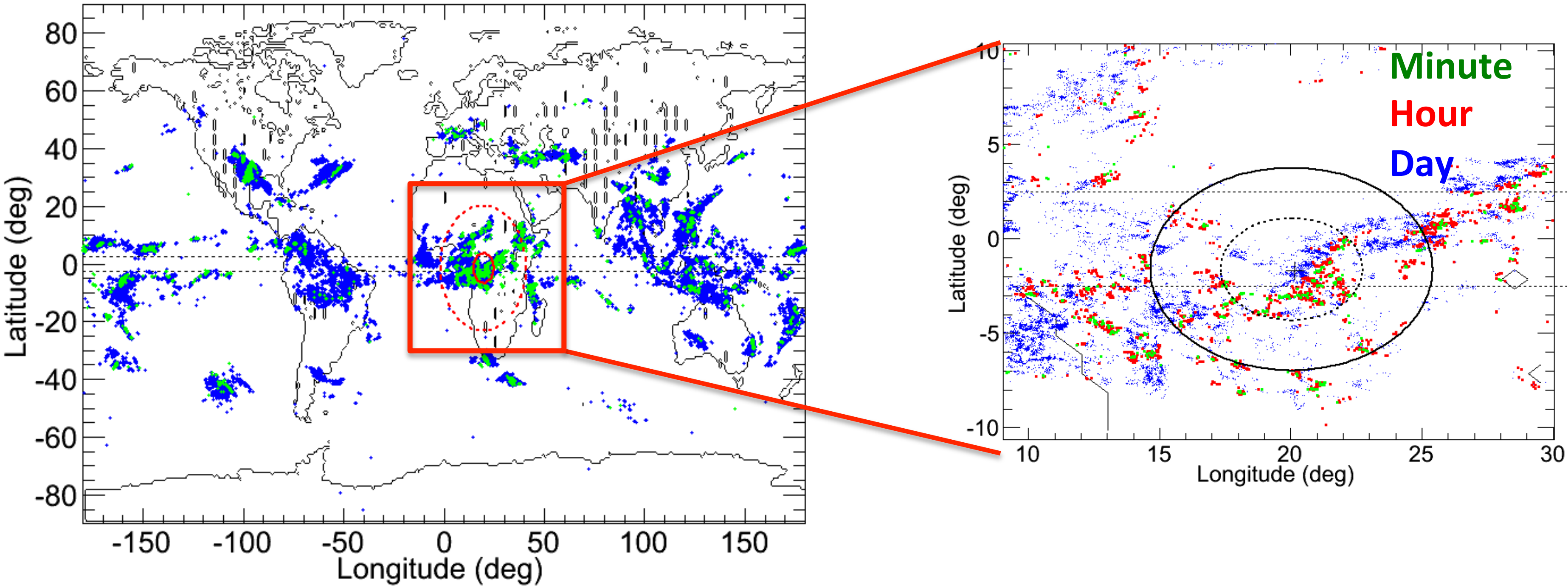
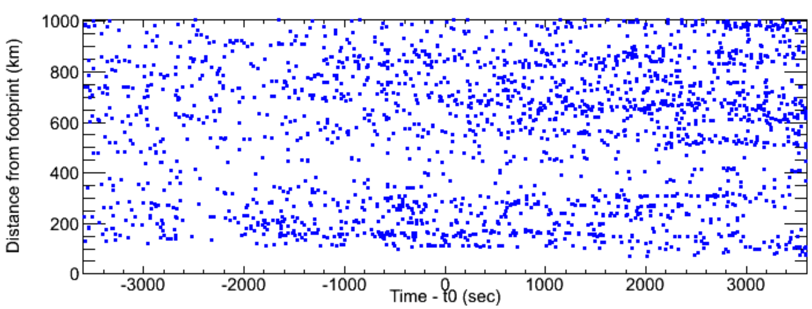
TGFs and WWLLN

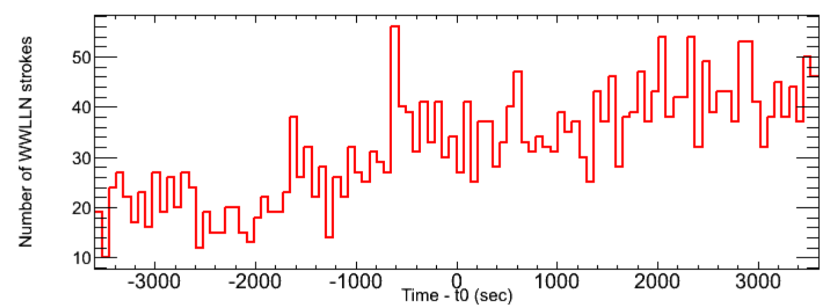


No simultaneous (within 200 μs) sferics were found. This is compatible with the larger average duration of the AGILE TGFs (Connaughton et al., JGR 2013 in press; Dwyer & Cummer JGR 2013 in press).

Distance from TGF position vs time



Total lightning within the area vs time



TGFs and WWLLN

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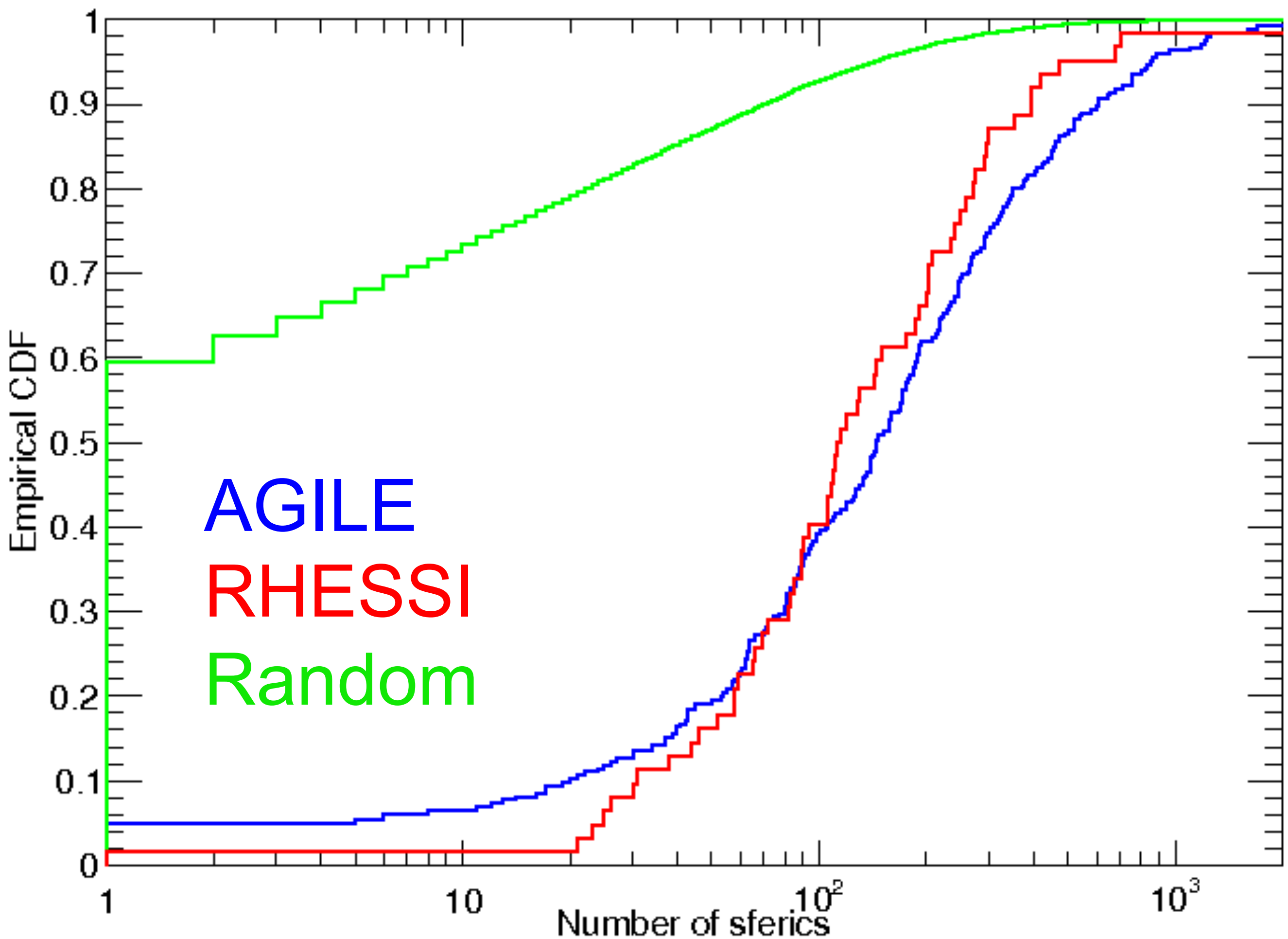

AGILE and new RHESSI TGFs are compatible with the same parent distribution (Kolmogorov Smirnov test)

AGILE is not compatible with a random dataset.

Lightning correlation with AGILE TGFs

Mar09-Feb10 data published by
Fuschino et al., GRL 38 047817, 2011

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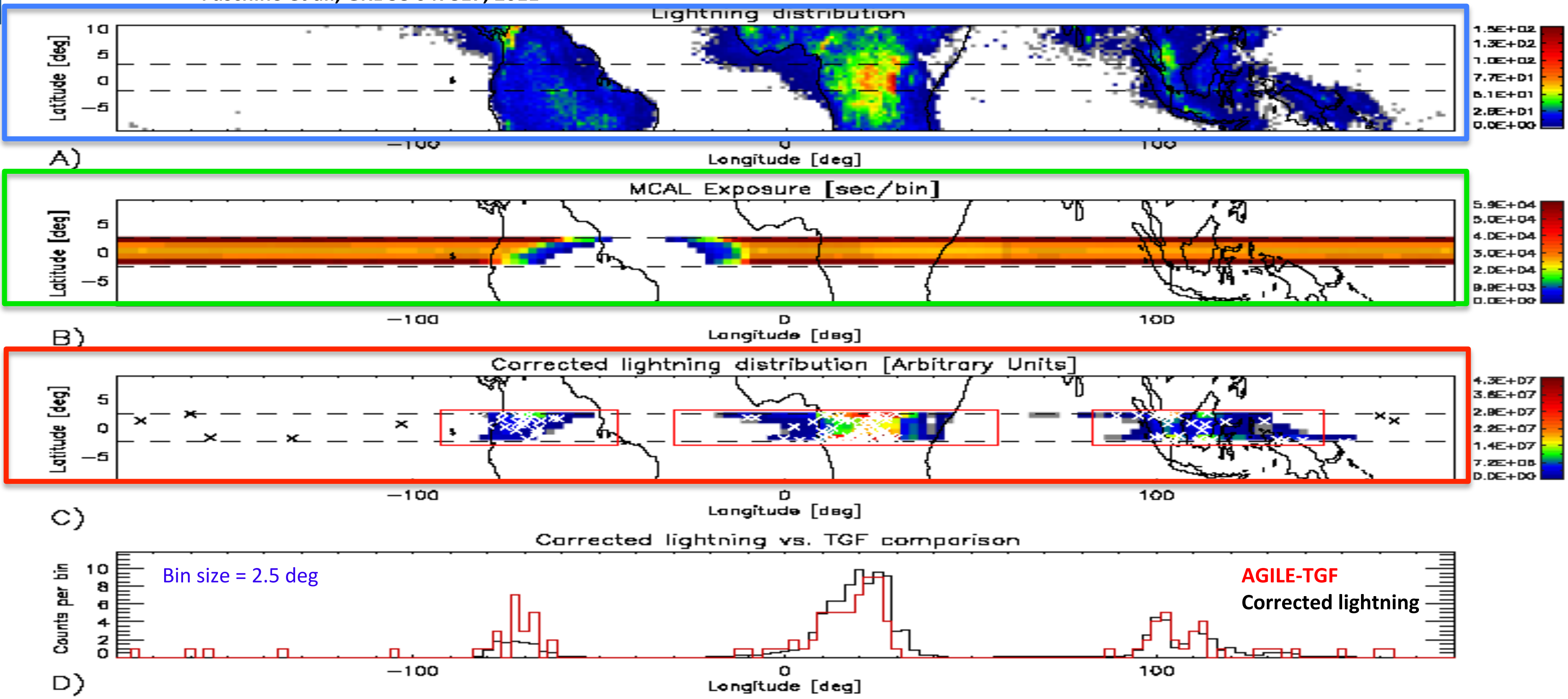

LIS Annual Flash rate [fl/km 2/year]
0.5 x 0.5 deg per bin

Lightning maps was built starting from seasonal (3 months) maps concurrent with TGF data (collaboration with Lightning Imagins Sensor – LIS – PI H. Christian)

MCAL Exposure [Seconds per bin]
2.5 x 1.0 deg [lon x lat]

Exposure maps was built on seasonal basis identifying anomalous blocks to include only really active Trigger Logic periods

Convolved Lightning distribution multiplied by the MCAL exposure

Lightning distribution was convolved with a **2D-Gaussian function** and multiplied by the MCAL exposure

Longitude distributions, summed over all latitudes, of the AGILE-TGF and corrected lightning normalized to the total number of TGFs (i.e 101 events).

Lightning correlation with AGILE TGFs

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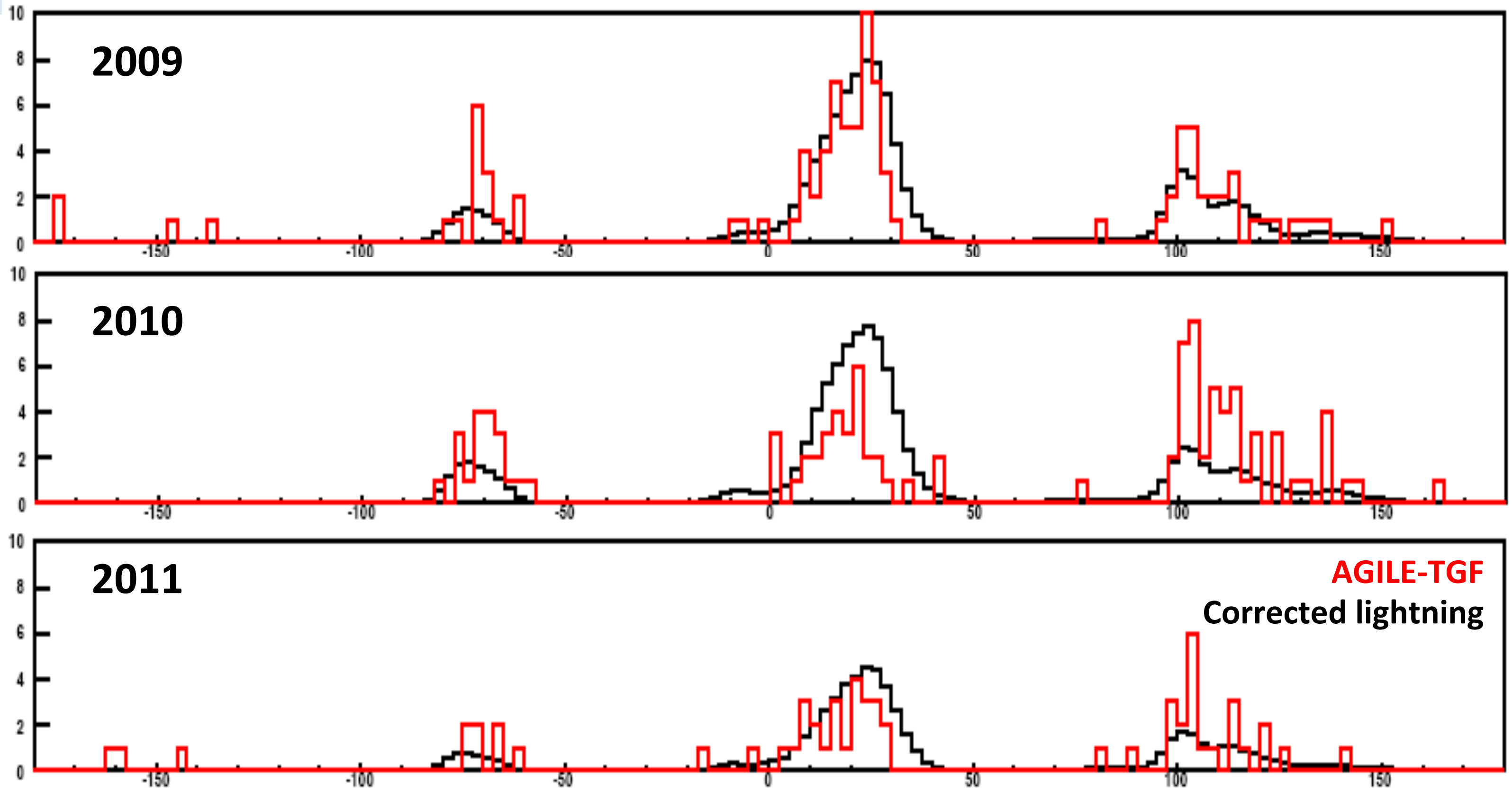
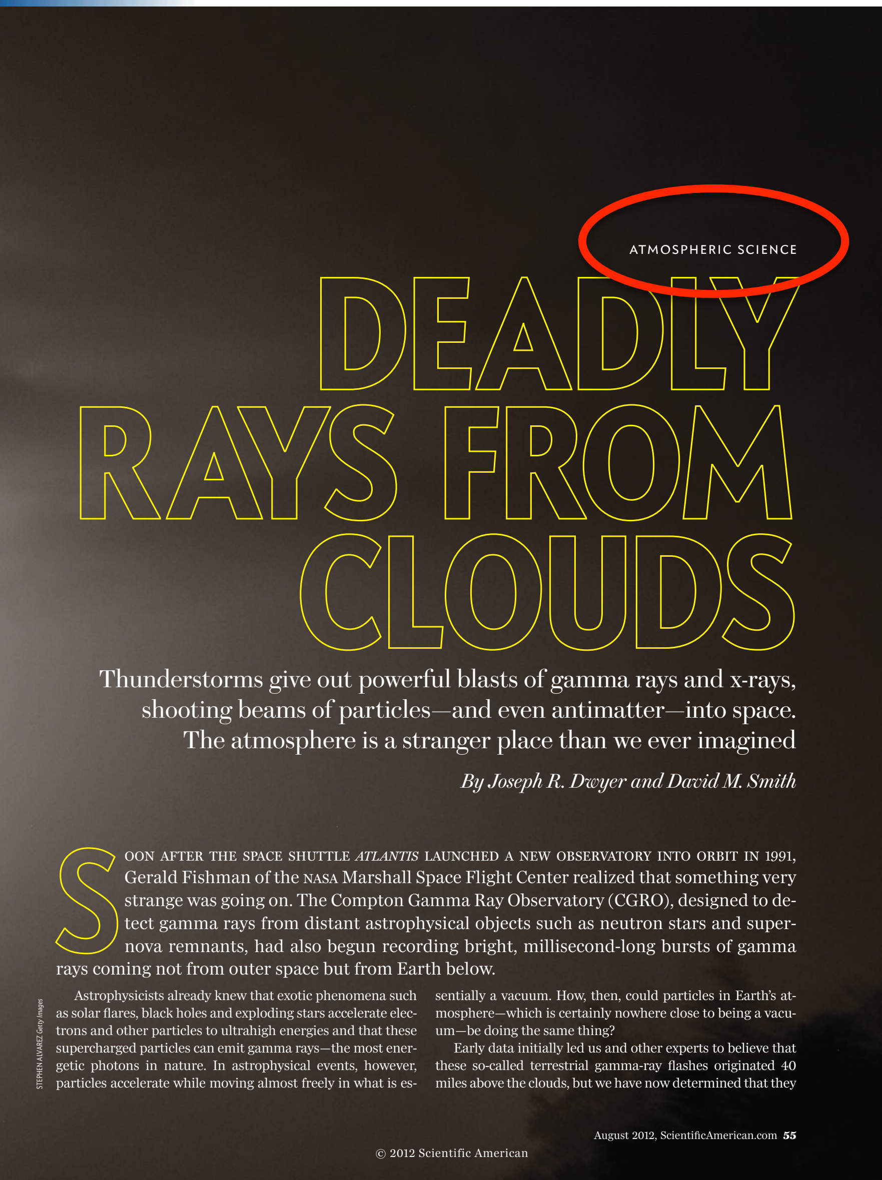


Variation of TGF/lightning above the different continental area is confirmed also by Fermi (Briggs et al. JGR 2013)

AGILE is the only satellite able to estimate the TGF/lighting ratio variation on annual basis (Fuschino et al. in prep)

Deadly rays from thunderclouds



DEADLY RAYS FROM CLOUDS

Thunderstorms give out powerful blasts of gamma rays and x-rays, shooting beams of particles—and even antimatter—into space. The atmosphere is a stranger place than we ever imagined

By Joseph R. Dwyer and David M. Smith

SOON AFTER THE SPACE SHUTTLE *ATLANTIS* LAUNCHED A NEW OBSERVATORY INTO ORBIT IN 1991, Gerald Fishman of the NASA Marshall Space Flight Center realized that something very strange was going on. The Compton Gamma Ray Observatory (CGRO), designed to detect gamma rays from distant astrophysical objects such as neutron stars and supernova remnants, had also begun recording bright, millisecond-long bursts of gamma rays coming not from outer space but from Earth below.

Astrophysicists already knew that exotic phenomena such as solar flares, black holes and exploding stars accelerate electrons and other particles to ultrahigh energies and that these supercharged particles can emit gamma rays—the most energetic photons in nature. In astrophysical events, however, particles accelerate while moving almost freely in what is essentially a vacuum. How, then, could particles in Earth's atmosphere—which is certainly nowhere close to being a vacuum—be doing the same thing?

Early data initially led us and other experts to believe that these so-called terrestrial gamma-ray flashes originated 40 miles above the clouds, but we have now determined that they

STEPHEN ALVAREZ Getty Images

August 2012, ScientificAmerican.com 55

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NEW OUTLIERS

THE APPEARANCE OF POSITRONS was not to be our last shock. Later in 2011 the Italian Space Agency's AGILE observatory found that the energy spectrum of terrestrial gamma-ray flashes extends up to 100 mega-electron-volts, a value that would be amazing even if it came from a solar flare. If correct, these observations cast doubt on our models because it seems highly unlikely that the runaway mechanism could generate such energies by itself. In fact, it is not clear what could possibly accelerate electrons to such energies inside thunderstorms. At this point, we need more observations to help guide the theory. Fortunately, teams from the U.S., Europe and Russia are now beginning to launch the first space missions dedicated to detecting terrestrial gamma rays.

Meanwhile, to get closer to the action, we and our collaborators have built an aircraft instrument designed to measure gamma rays from thunderstorms. Worry about the dangers of gamma-ray exposure prevents us from flying straight into a storm.

EGU TGF session & press conference

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Oscar Van der Velde
Technical University
of Catalogna

Joseph Dwyer
Florida Institute
of Technology

Marco Tavani
INAF &
University of Tor Vergata

First official TGF session within the EGU conference
M. Marisaldi was convener of the session

Possible effects on avionics induced by terrestrial gamma-ray flashes
Tavani et al. 2013
Nat. Hazards Earth Syst. Sci., 13, 1127

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Current Collaborations

WWLLN (World Wide Lightning Location Network) – Prof. Colin Price, Department of Geophysical, Atmospheric and Planetary Sciences, Tel Aviv University

LIS (Lightning Imaging Sensor) - Dr. Hugh J. Christian, NASA / Marshall Space Flight Center

Mediterranean sea studies and more extended activities - T. Gjesteland, N.Ostgaard et al. of University of Bergen and BCSS (Birkeland Center for Space Science)

Members of the European network TEA-IS

Atmospheric and lightning physics – S. Dietrich CNR-ISAC (Atmospheric and Climate Science Institute of Consiglio Nazionale delle Ricerche)

LINET (LIghtining NETwork) data correlation above Colombia – F. Fabrò, J. Montanya, UPC, Spain

TGF effects on avionics (next talk) – A. Paccagnella, Department of Information Engineering at Padova University

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Next Steps

Papers in preparation:

- **Low Energy population properties (ready for submission)**
- **High Energy population properties**
- **Annual basis TGF/Lightning correlations**

To understand the open issues on the TGF science we are working to better study TGF-like events using:

a. On ground detectors
b. On-board airplane detectors
c. On-board satellite detectors
d. AGILE could provide rapid alert for violent thunderstorms

Improve the AGILE TGF detection strategy (AC veto switch-off)

→ **Proposal submitted to ASI**