UNIVERSITY OF BERGEN

Terrestrial Gamma ray Flashes observed over low cloud tops

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Motivation

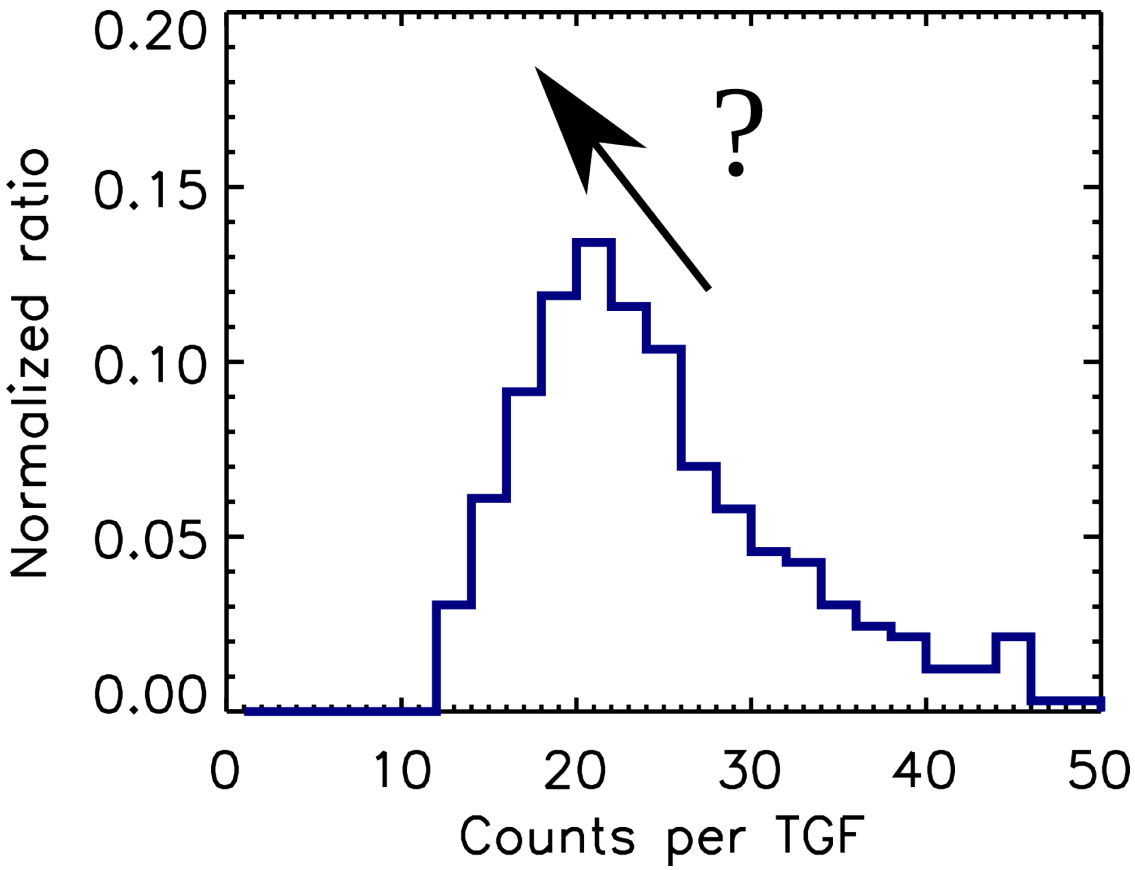
- Do TGFs have an impact on our atmosphere?

  Questions to be answered:

  1) How common are they?

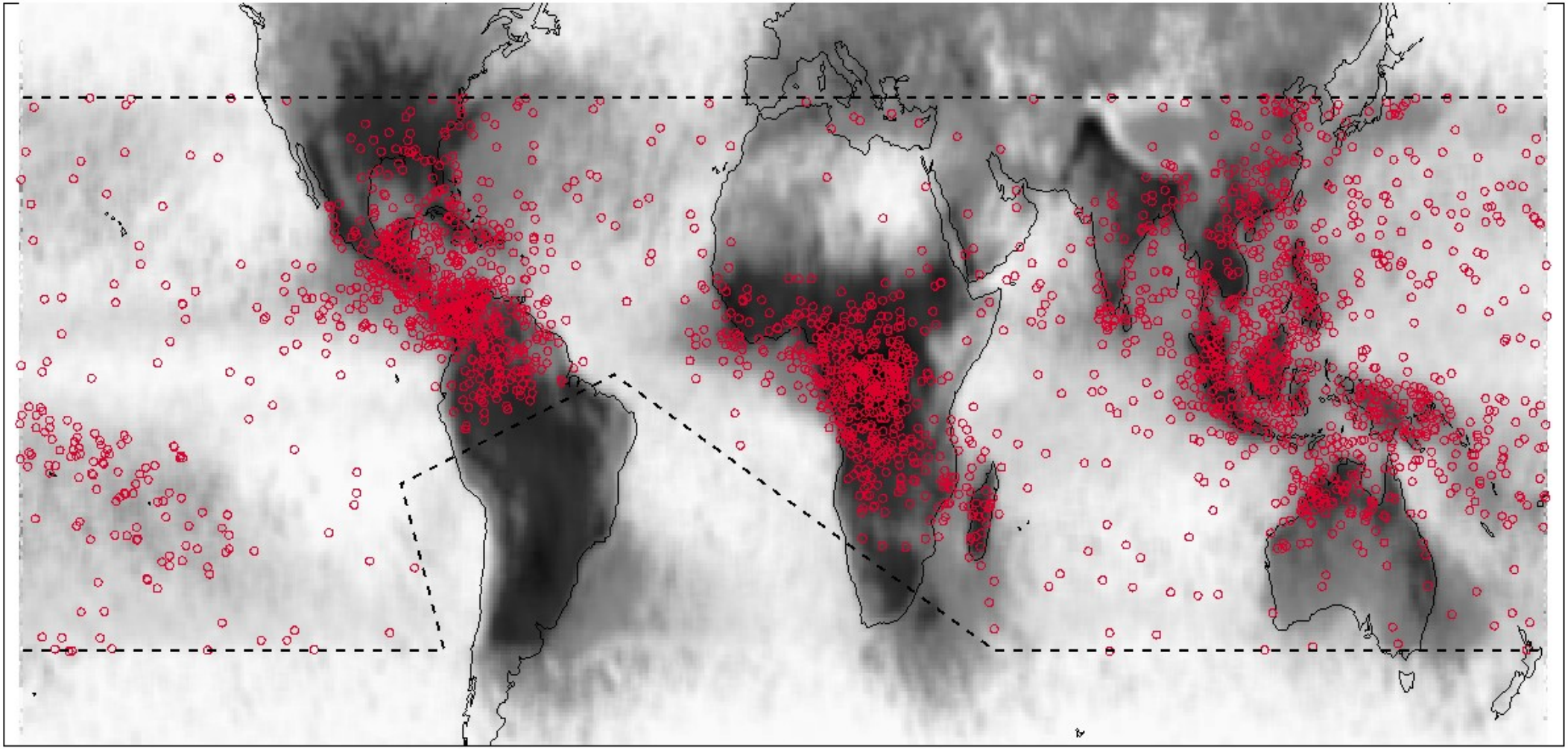
  2) How bright are they?

How common are TGFs?

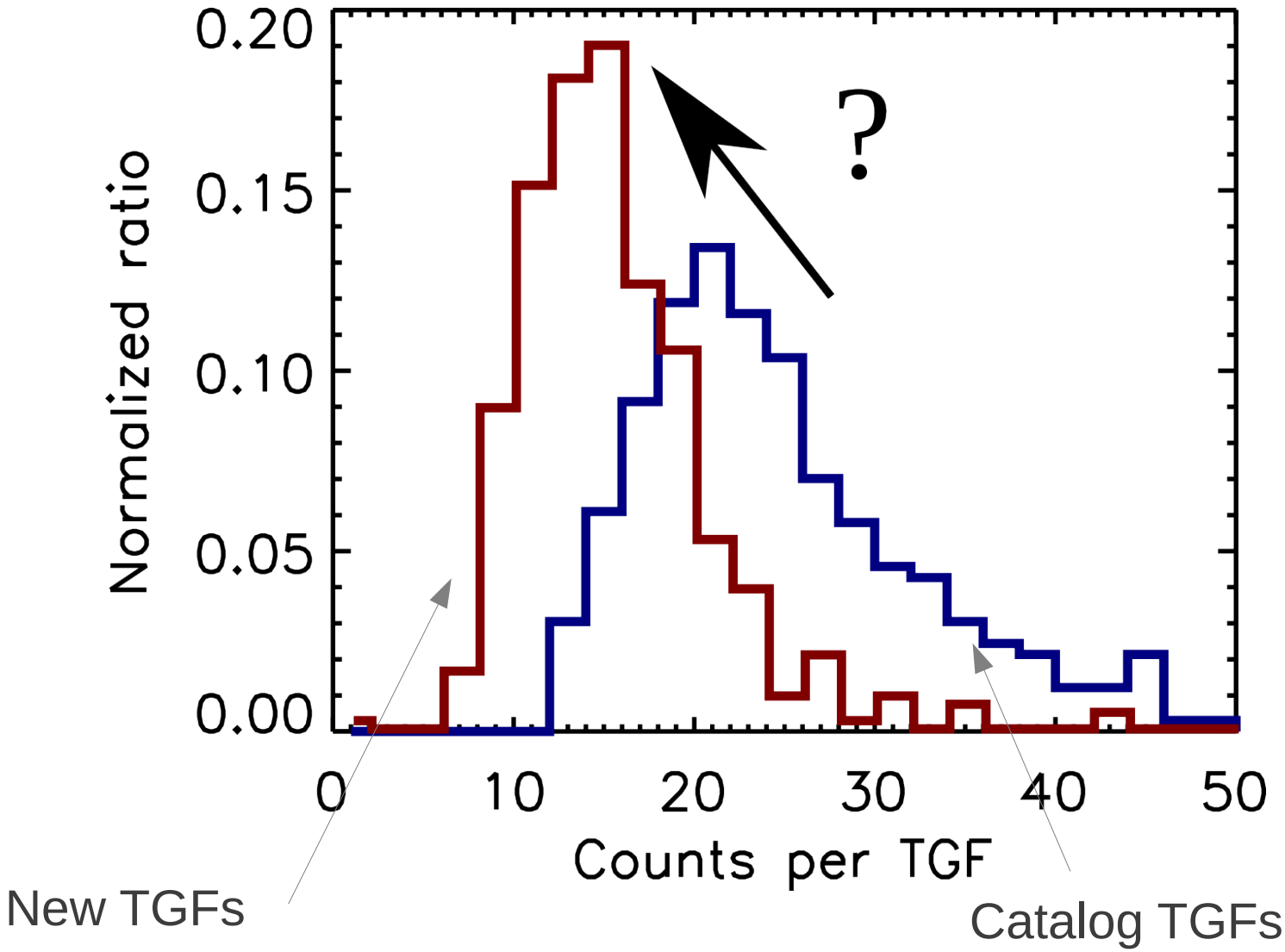


RHESSI Catalog fluence distribution
2004-2006 [Grefenstette et al., 2009]

2361 RHESSI TGFs (2002-2011)



Results from new search algorithm for RHESSI Gjesteland et al, 2012



"we can not rule out that all discharges produce TGFs" [Østgaard et al., 2012]

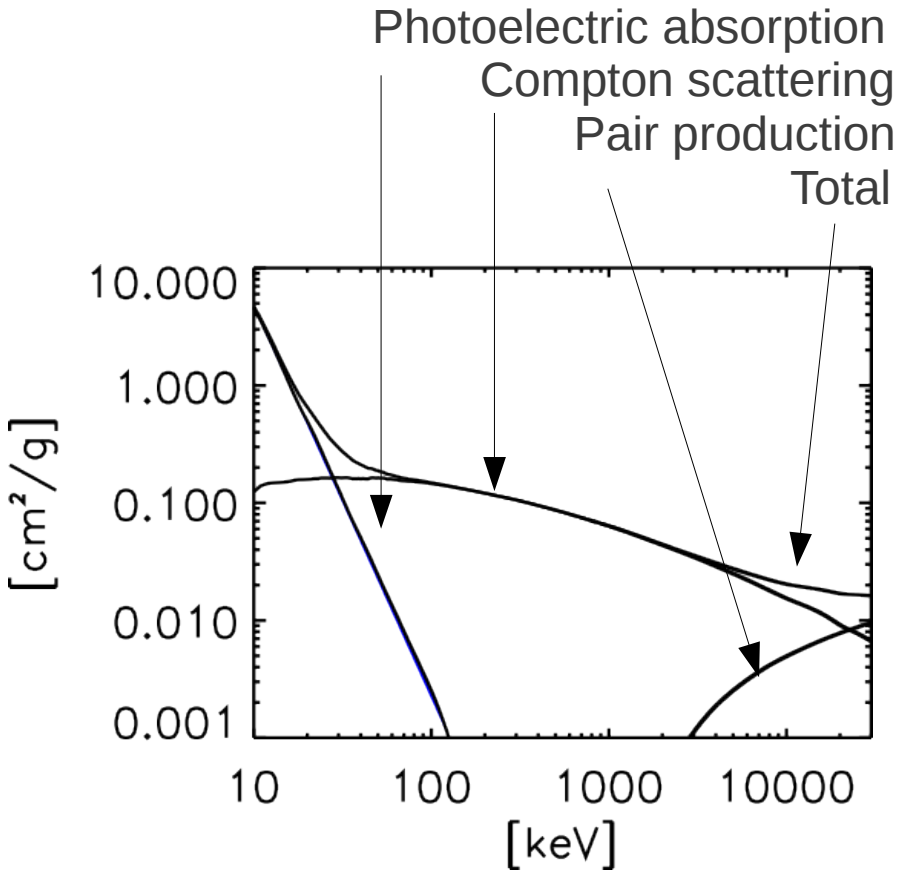
How bright can TGFs be?

Discovery of Intense Gamma-Ray Flashes of Atmospheric Origin

G. J. Fishman, P. N. Bhat,* R. Mallozzi, J. M. Horack, T. Koshut, C. Kouveliotou, G. N. Pendleton, C. A. Meegan, R. B. Wilson, W. S. Paciesas, S. J. Goodman, H. J. Christian

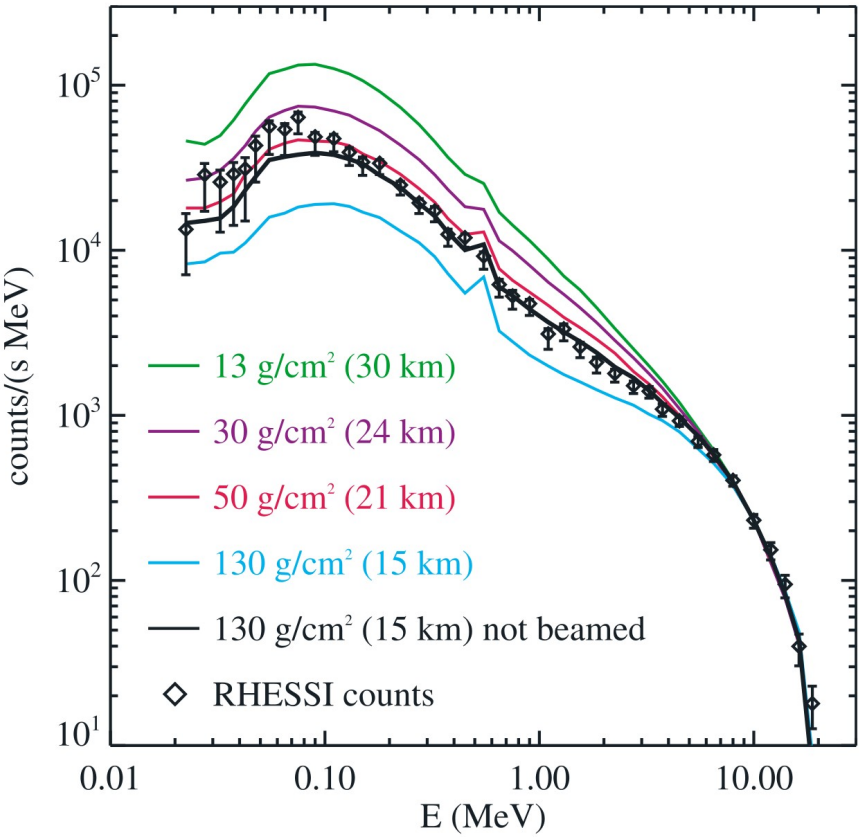
Detectors aboard the Compton Gamma Ray Observatory have observed an unexplained terrestrial phenomenon: brief, intense flashes of gamma rays. These flashes must originate in the atmosphere at altitudes above at least 30 kilometers in order to escape atmospheric absorption and reach the orbiting detectors. At least a dozen such events have been detected over the past 2 years. The photon spectra from the events are very hard (peaking in the high-energy portion of the spectrum) and are consistent with bremsstrahlung emission from energetic (million–electron volt) electrons. The most likely origin of these high-energy electrons, although speculative at this time, is a rare type of high-altitude electrical discharge above thunderstorm regions.

Fishmann et al., 1994

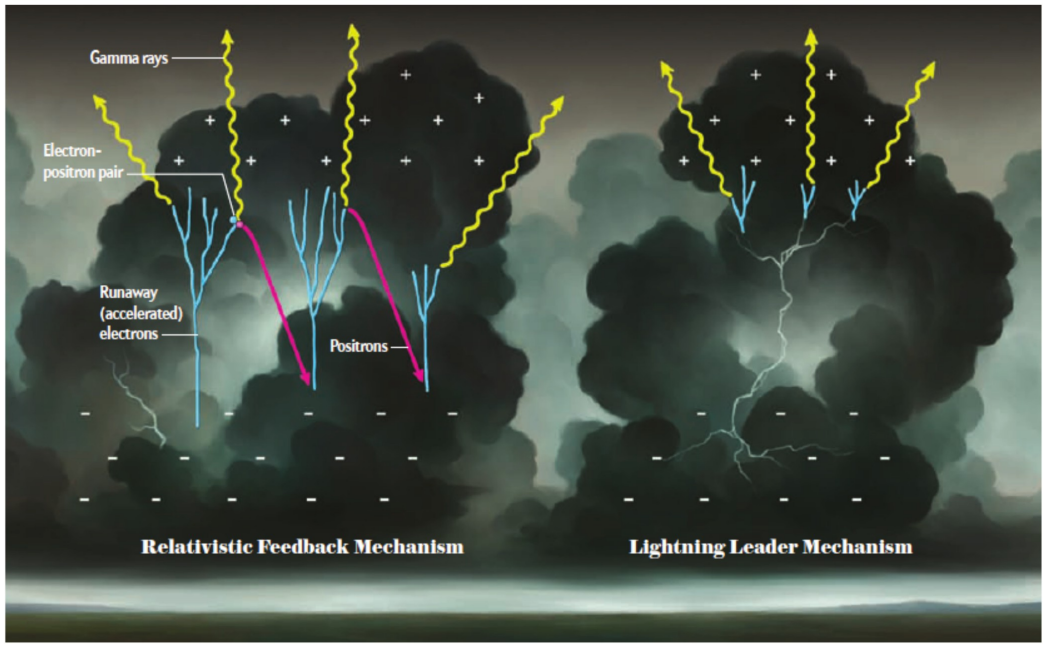


Gamma ray attenuation

TGFs are produced inside thunder clouds

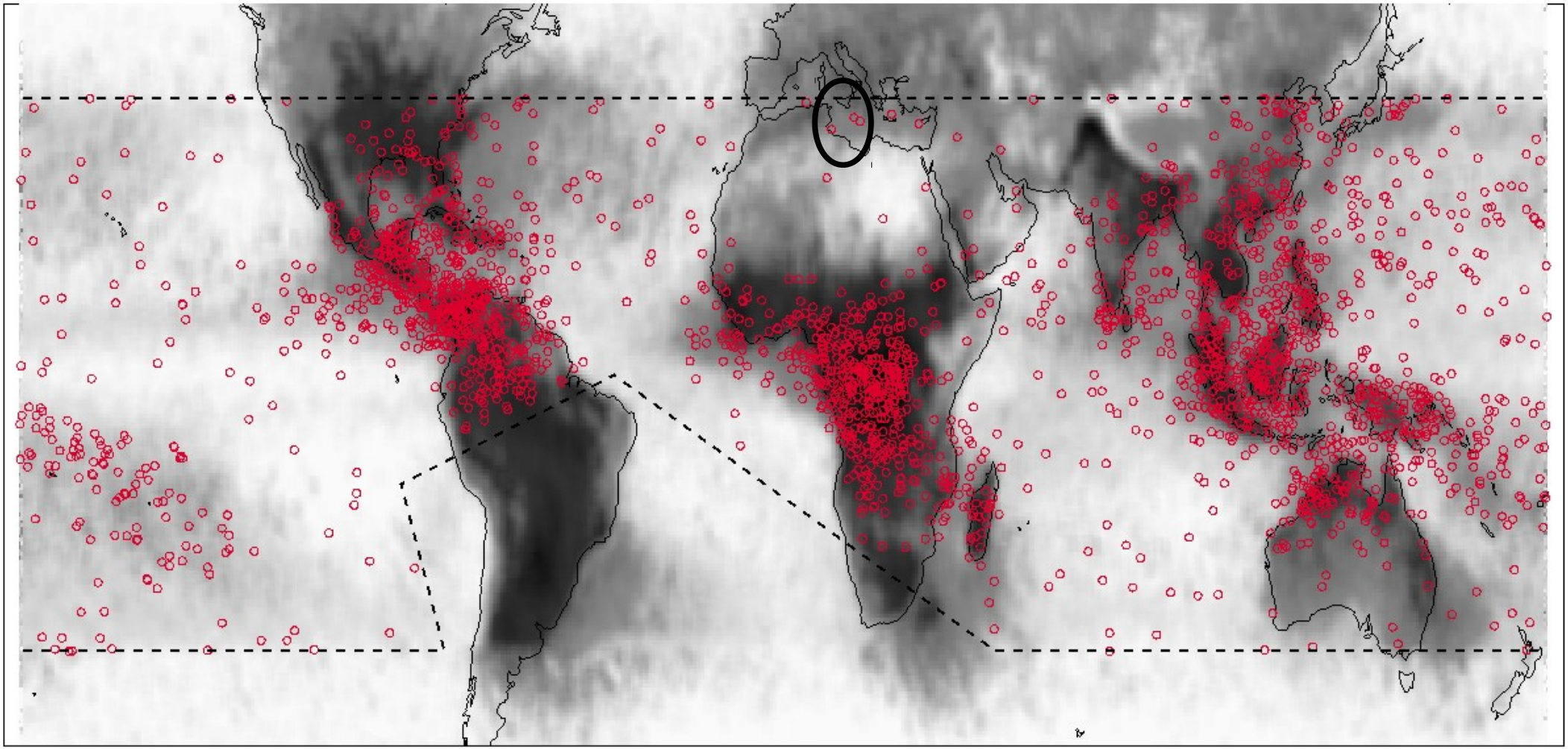


Dwyer and Smith, 2005

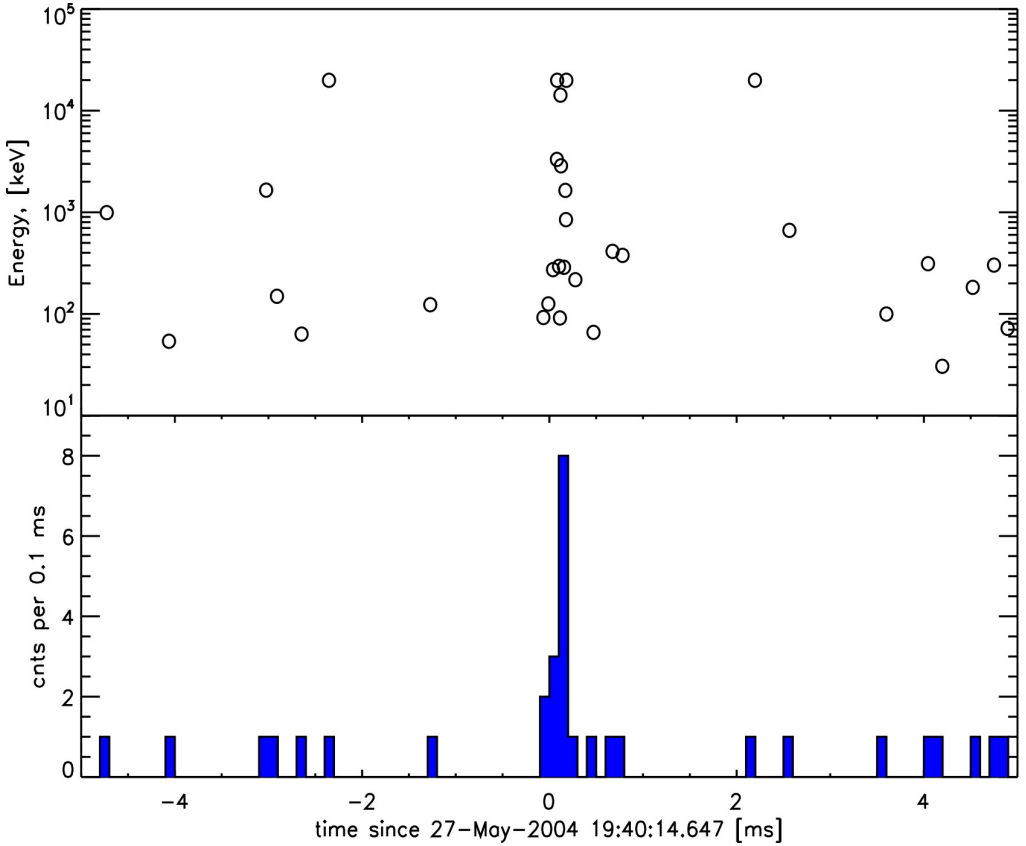


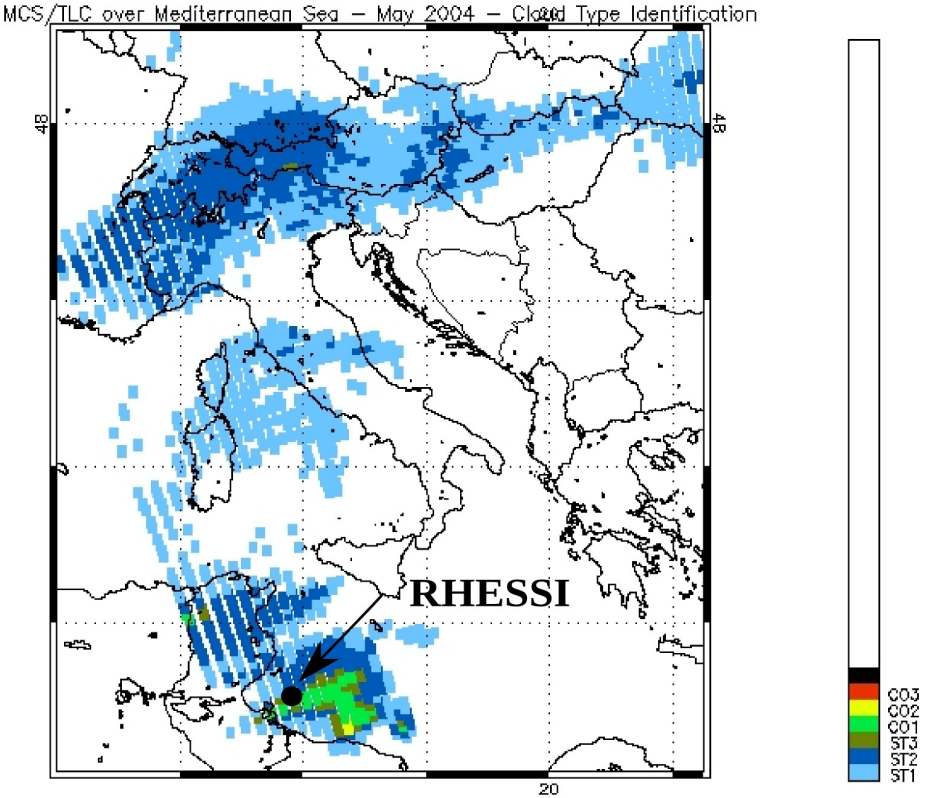
Dwyer and Smith, 2012

3 TGF over the Mediterranean basin



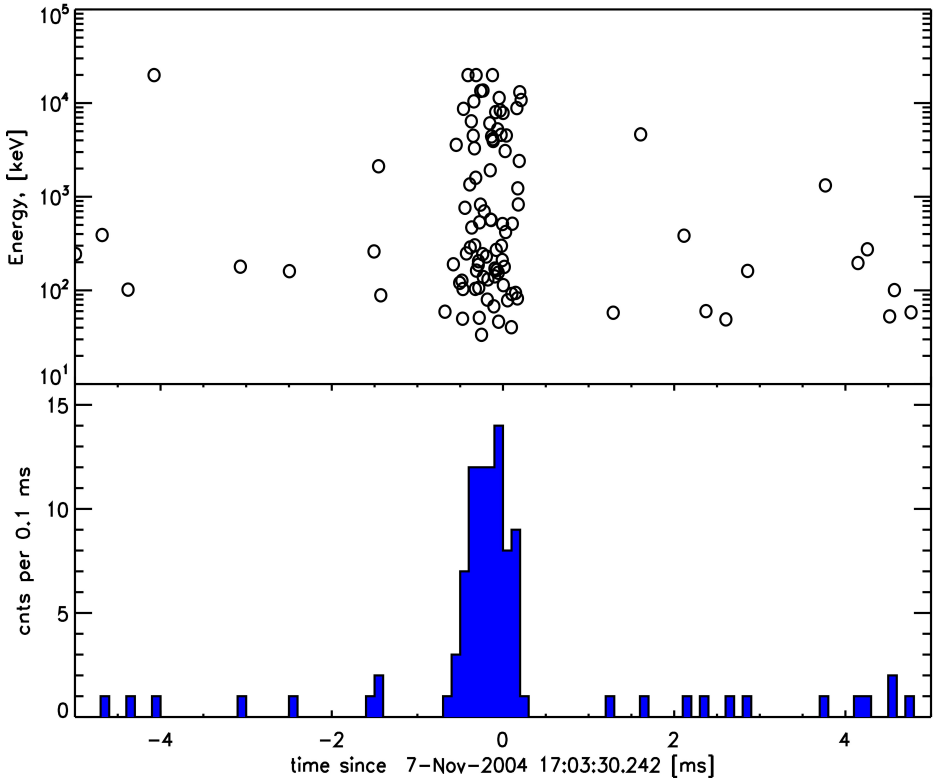
May 27, 2004

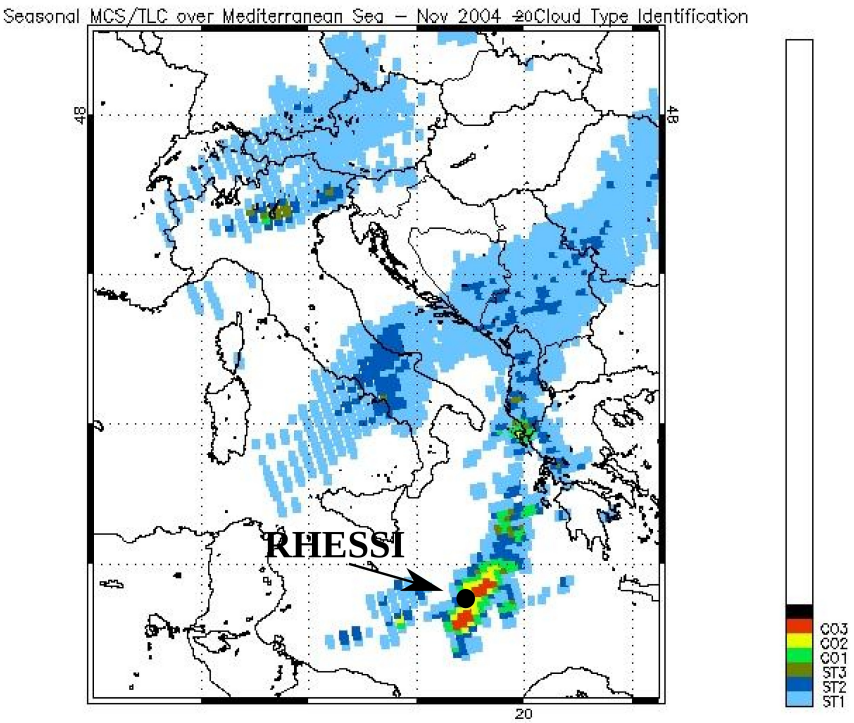




Cloud top 6-8 km

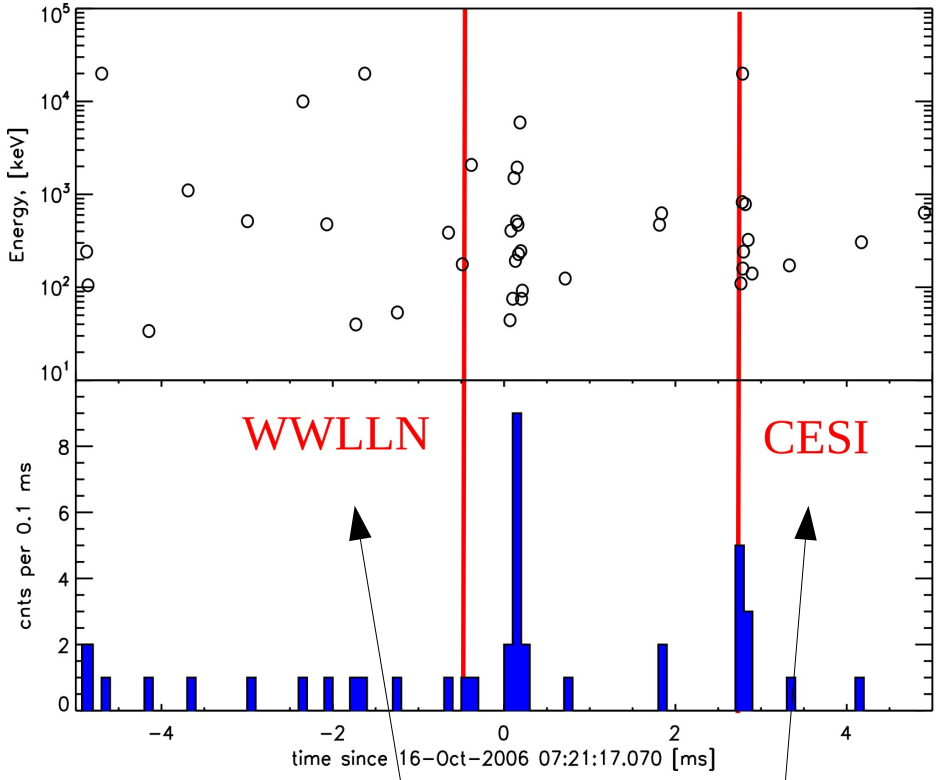
November 7, 2004



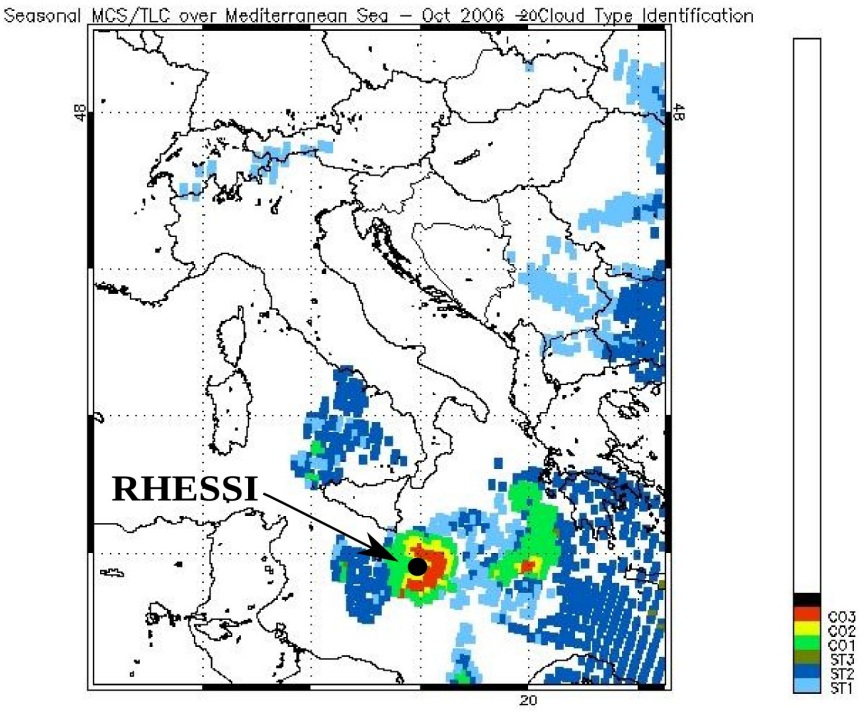


Cloud top 8-10 km

October 16, 2006

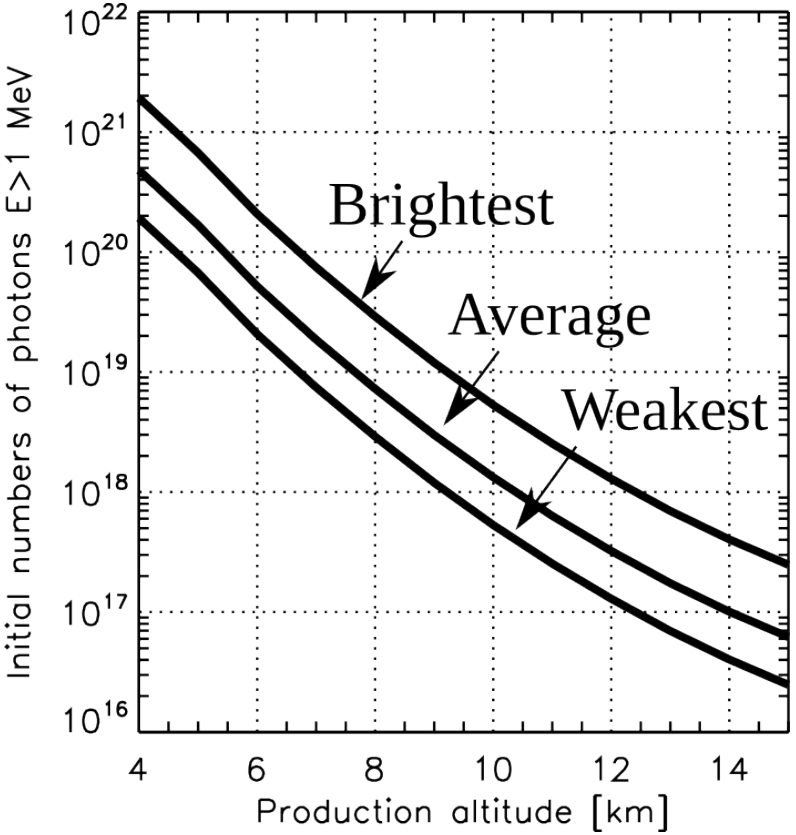


Lightning location network



Cloud top 8-10 km

How bright are these TGFs?

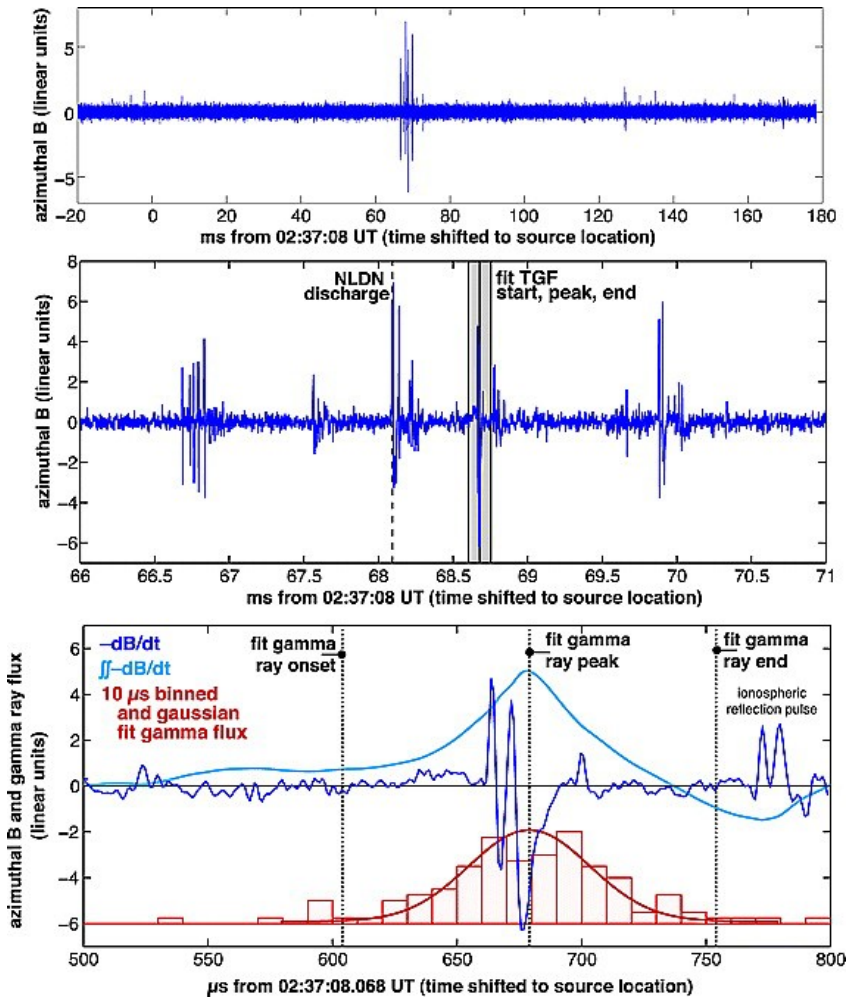


Electrons to photons

Average ratio: 5

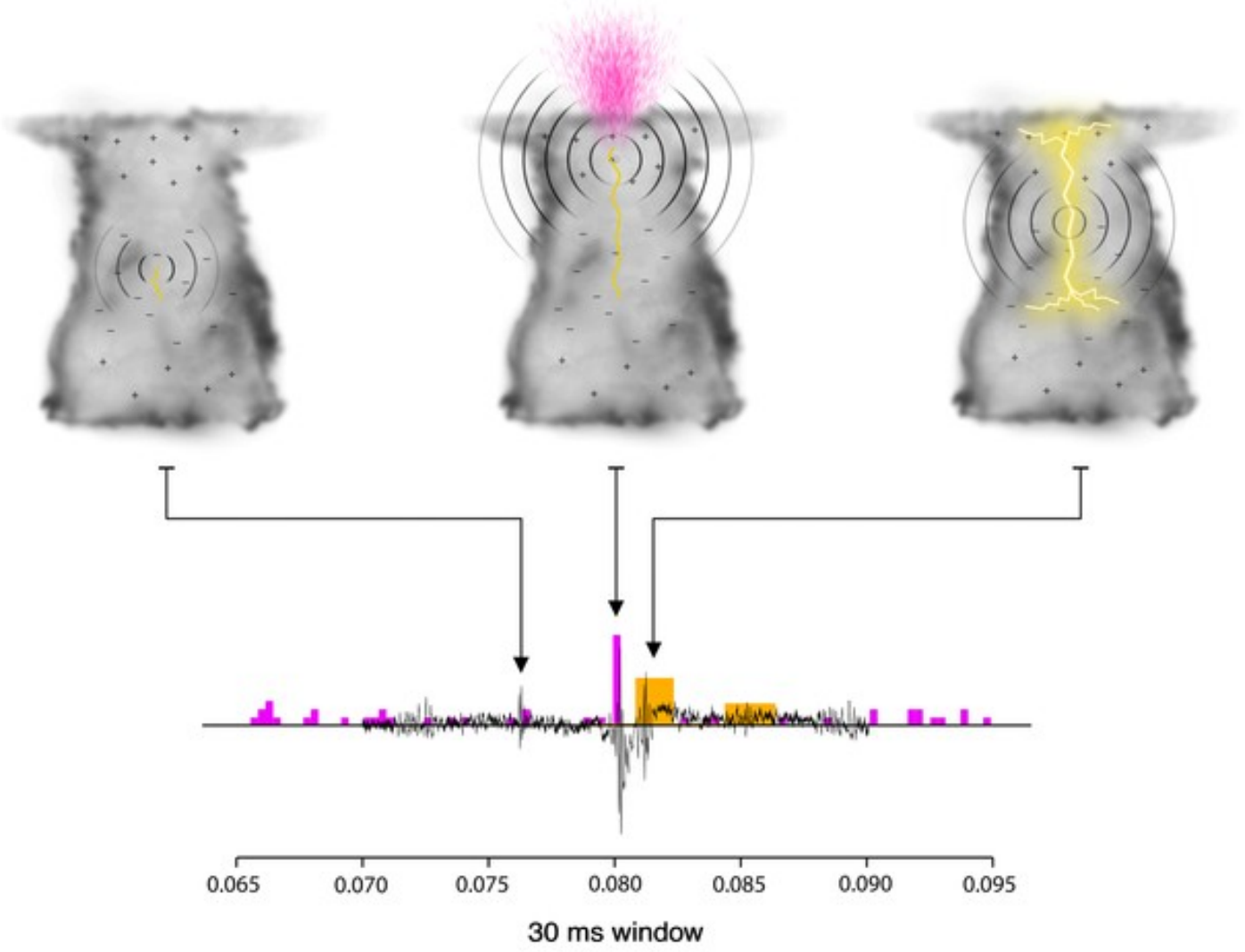
Estimation of initial number of photons in a TGF based on RHESSI brightest, average and weakest event

TGFs produce VLF sferics



Cummer et al., 2011

Simultainous observation of TGF, VLF and lightning



Østgaard et al., 2013

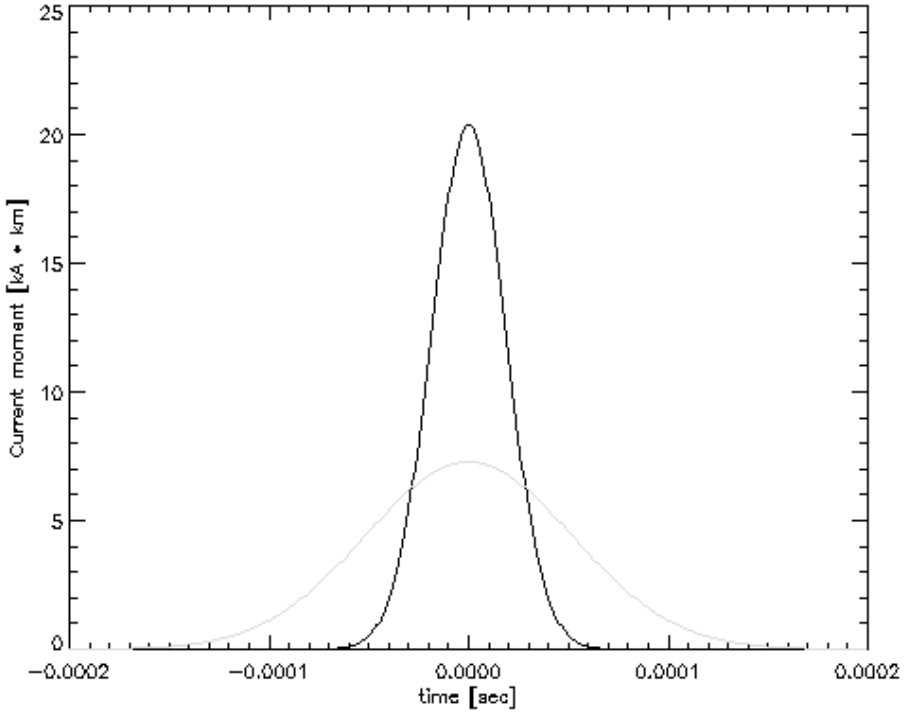
Current Moment from TGFs

$$I_{\mathrm{mom}} = \frac{e\alpha\tau_a\mu_e EN_{\mathrm{re}}\Delta z}{\sqrt{2\pi}0.74T_{50}}\exp\left(\frac{-t^2}{2(0.74T_{50})^2}\right)$$

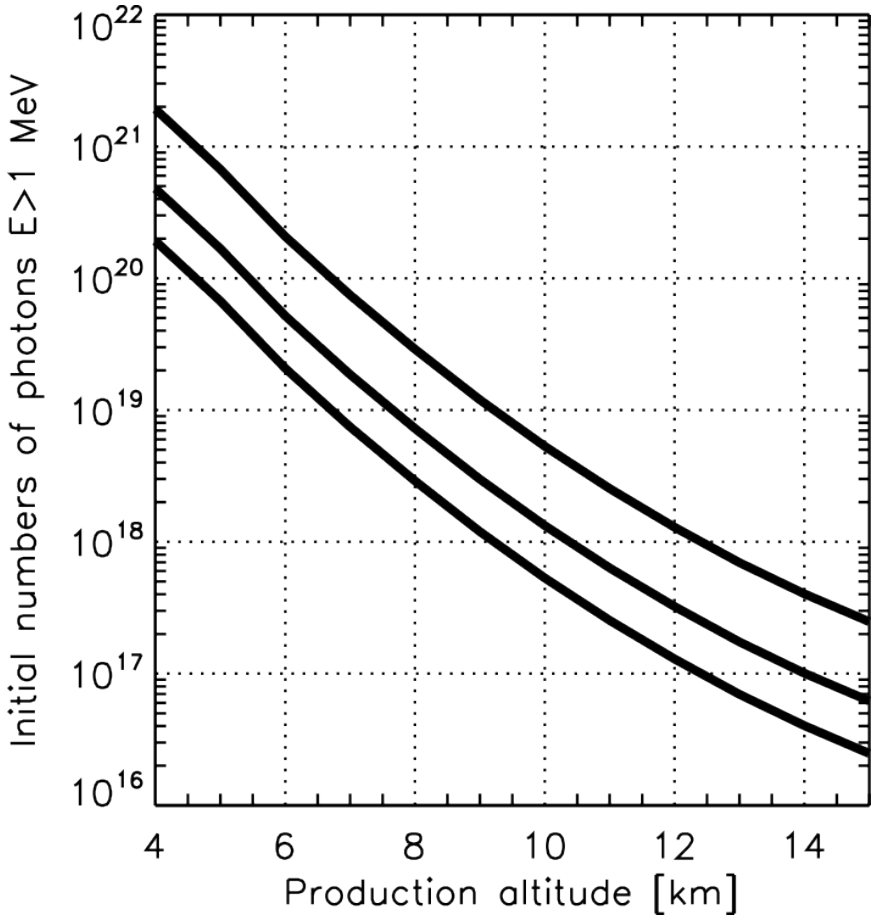
From Connaughton et al, 2013 , Dwyer 2012

- e charge of the electron;
- α is the ionization per unit length per runaway electron
- μ_e mobility of the low-energy electrons,
- τ_a the air attachment time
- E electric field strength
- T50 -duration of the TGF

- **N_{re} number of runaway electrons**
- **Δz is the vertical distance over which the runaway electrons travel**



Estimated Current Moment from a TGF



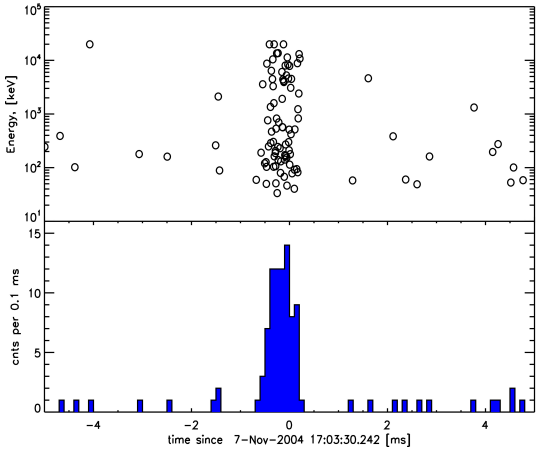
Assume TGF at 8 km altitude

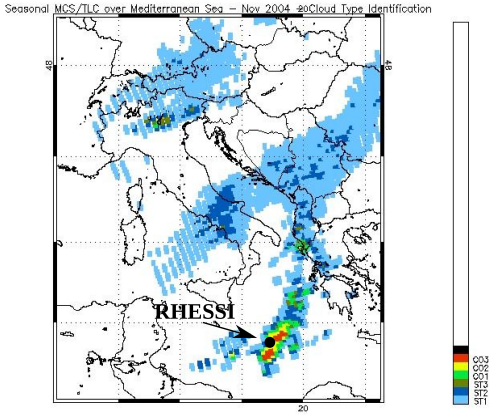
- E =3.54 e4 x m/n [V/m]
- T50= 110e-6 [s]

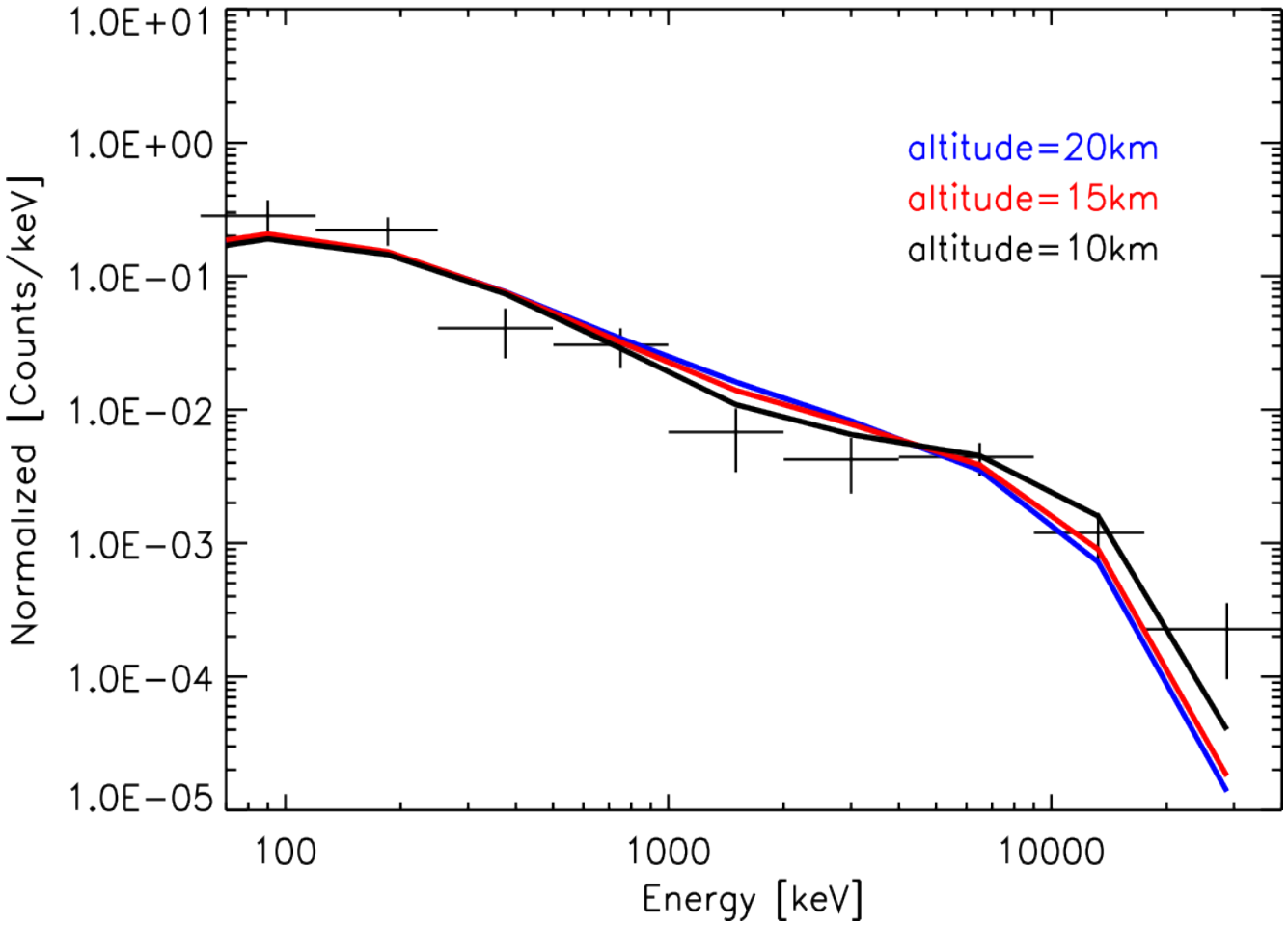
- **N_{re} = 10^{19} number of electrons**
- **Δz =90 x n/m [m]**

I_{mom} = 49.9 kA km

Energy spectrum





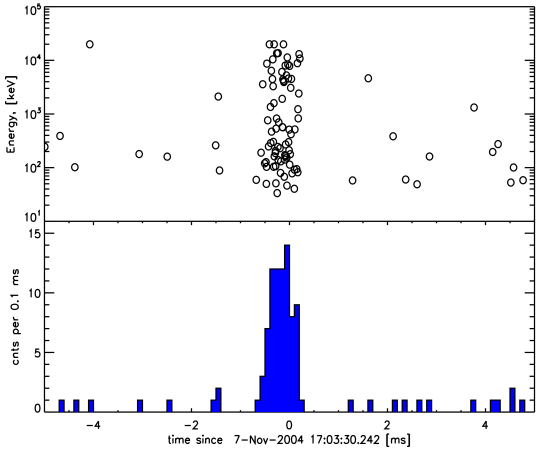


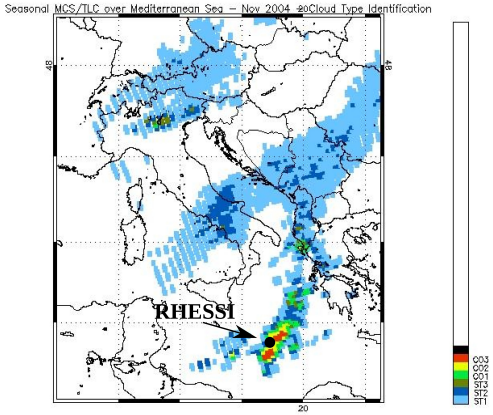
Assume TGF at 9 km altitude

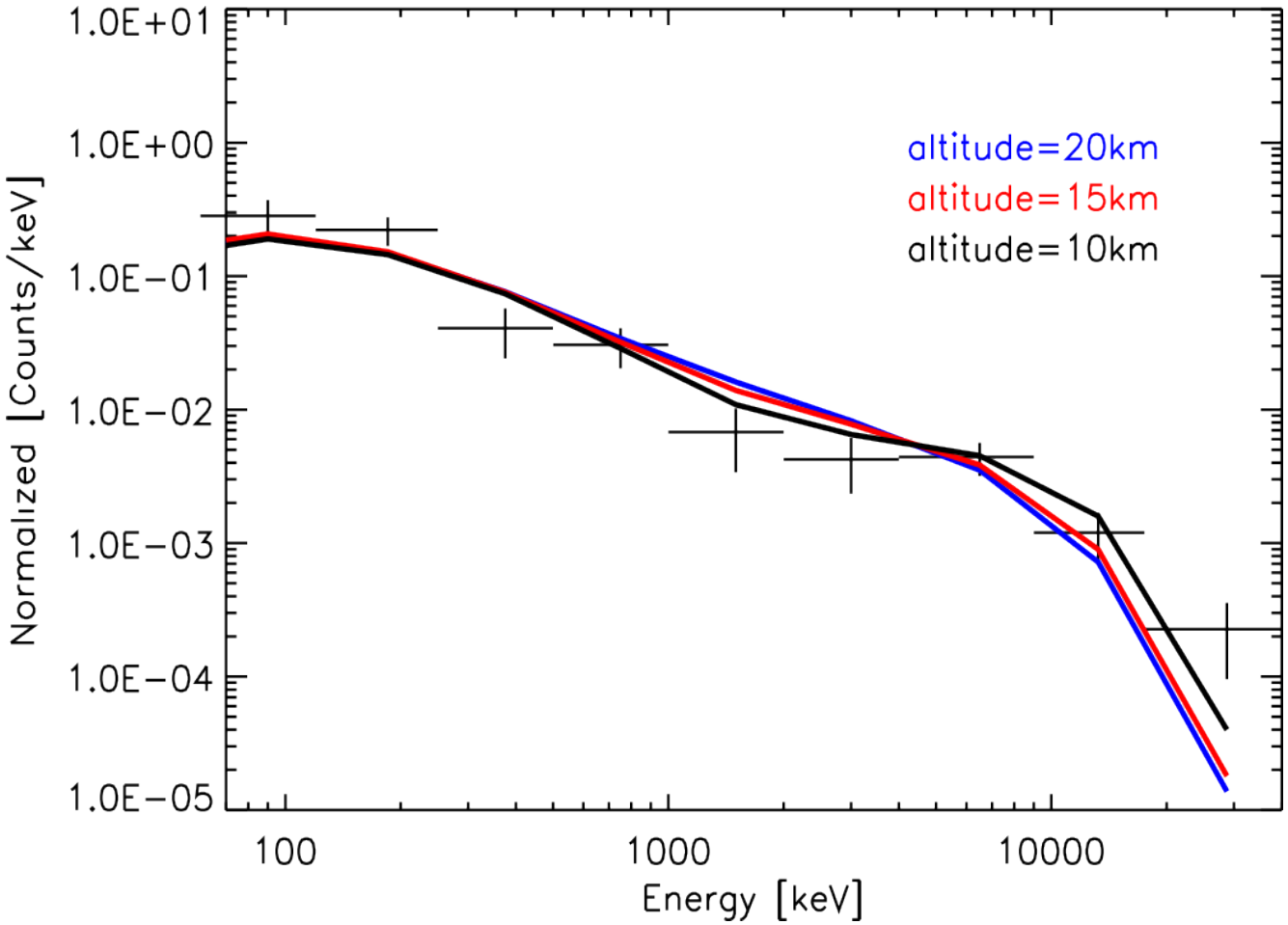
- T50=0.53 ms
- **N_{re} = 5 X 10^{19} electrons**

I_{mom}=69.7 kA km

Energy spectrum







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I_{mom}=69.7 kA km

Energy in a TGF

$E_{TGF}=10^{19}$ el * 7 MeV * 1.6 $*10^{-19}$ J/eV ~ 10 MJ

Conclusions

We have observed 3 TGFs from low clouds in the Mediterranean basin

- All TGFs are produced below 10 km altitude
- The TGFs contains 10^{19}-10^{20} electrons
- This is consistent with typical current moment measurements (preliminary result...)
- Low production altitude (10 km) is supported by spectral analysis