第二届GECAM 研讨会

2020年10月30日-11月1日@北京

基于射频闪电信号测量的地球伽玛射线闪研究

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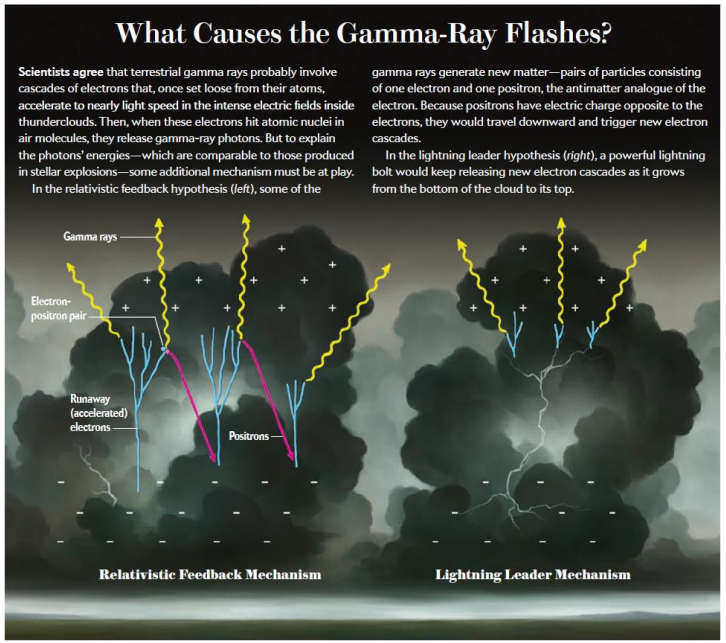
Mohd Riduan Ahmad (马来西亚技术大学)



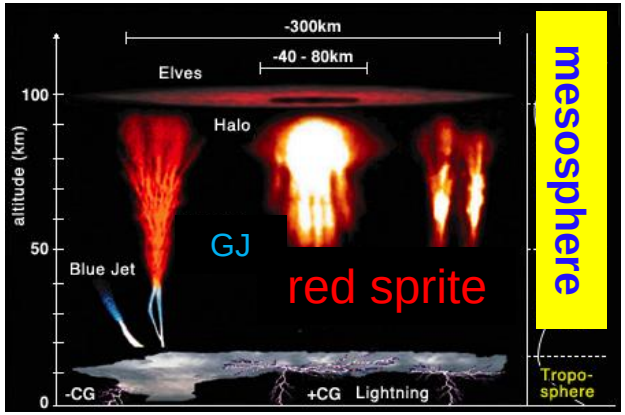
闪电是否影响雷暴上面的空间?

View from International Space Station

- 对流层的闪电是否影响雷暴上面的空间?

闪电及其近地空间电磁效应

对流层闪电

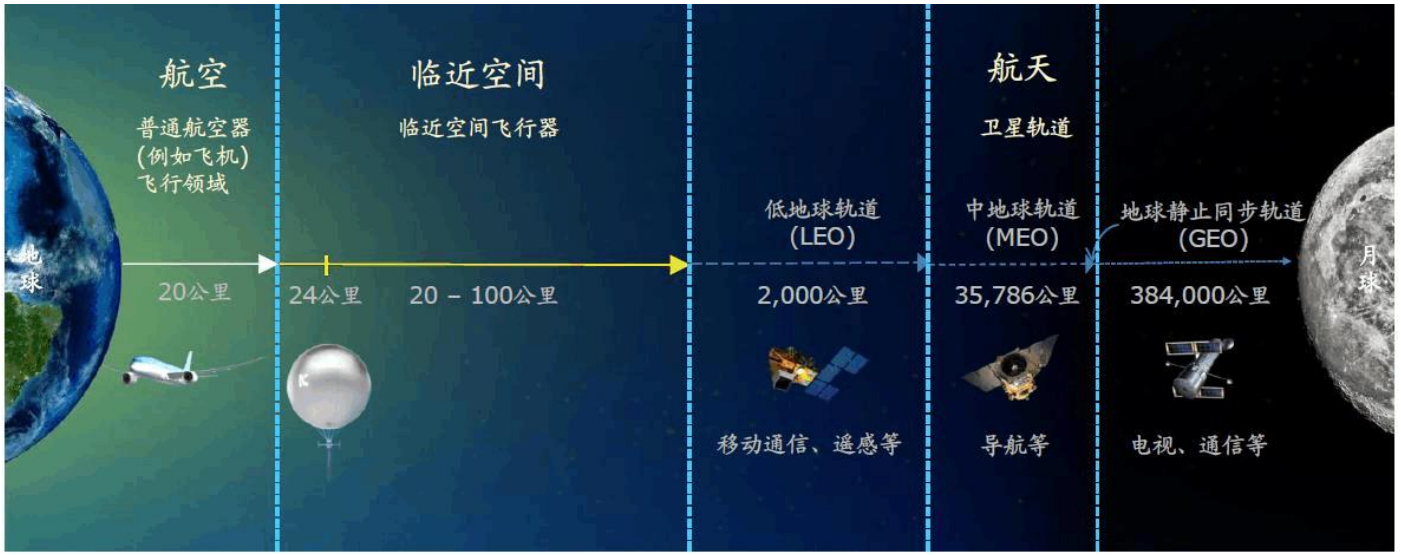


中高层瞬态发光现象

Franz et al. (1990)-Science; Pasko et al. (2002)-Nature

地球伽玛射线闪

Fishman et al. (1994)-Science



报告内容

(1) 地源伽玛射线闪研究进展

(2) 科大-大气所团队相关工作

(3) 利用HXMT数据获得的初步结果

(4) HXMT和GECAM卫星带来的机遇

地球伽玛射线闪 (Terrestrial Gamma-ray Flashes)

CGRO/BATSE
(Fishman et al. [1994])

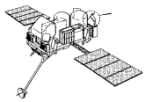
RHESSI
(Smith et al. [2005])

Fermi/GBM
(Briggs et al. [2010])

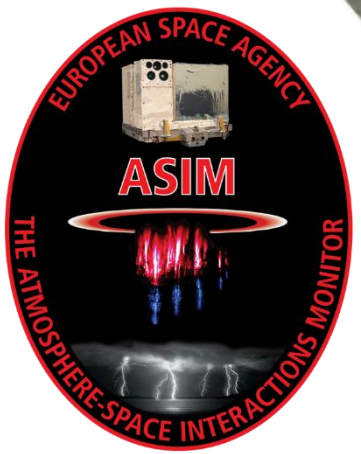
AGILE
(Marisaldi et al. [2010])

Insight-HXMT
(Zhang et al. [2020])

GECAM
(to be launched)



550 km



γ

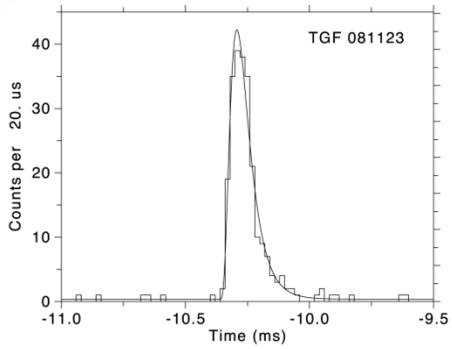
Ionosphere

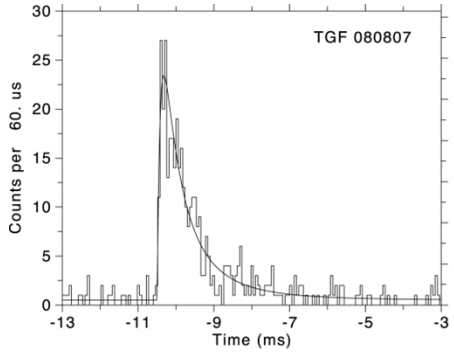
70-85 km

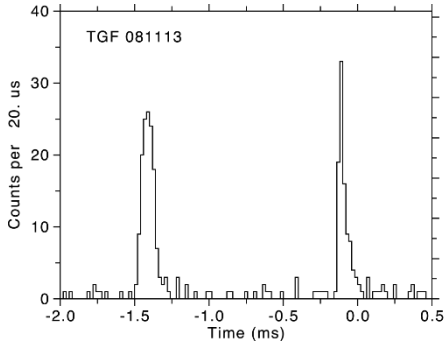
15 km

Sferic *B*-sensor

Earth



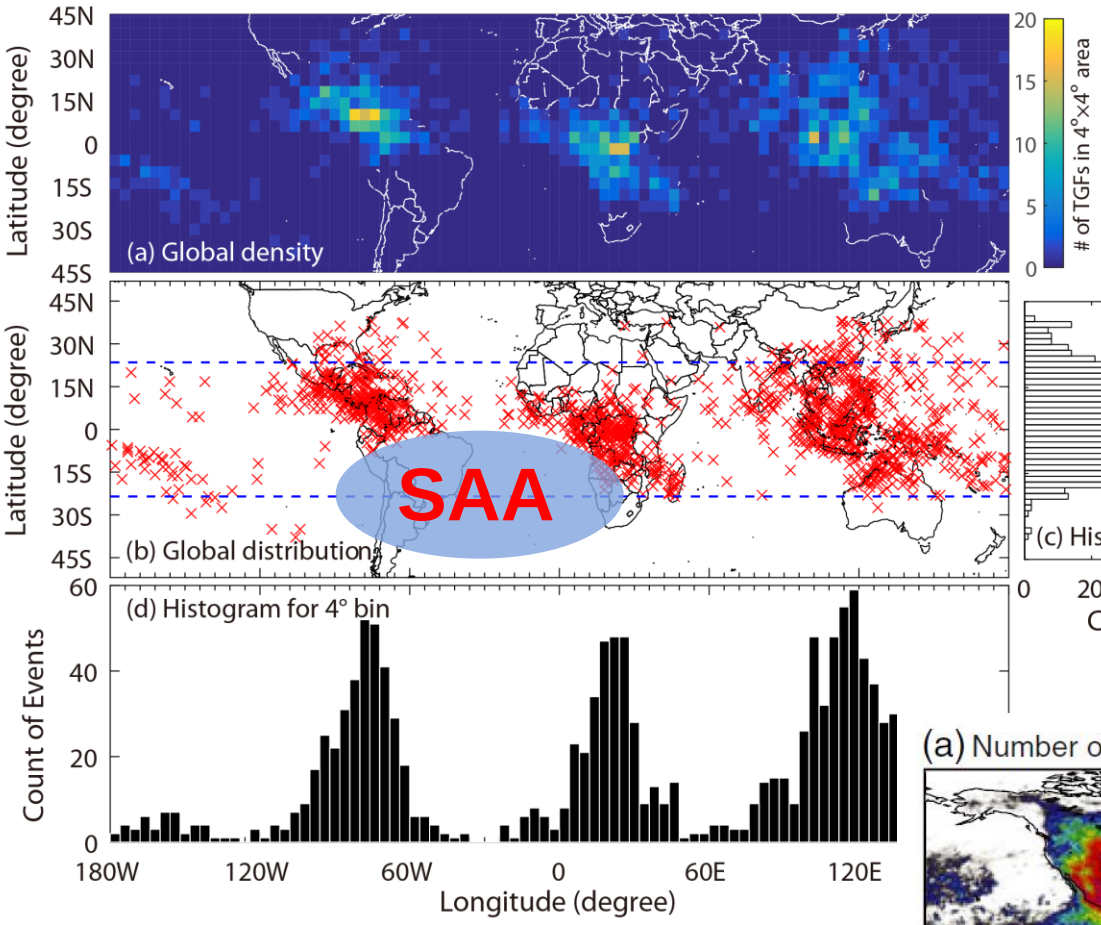




Briggs et al. [2010]
Fishman et al. [2011]

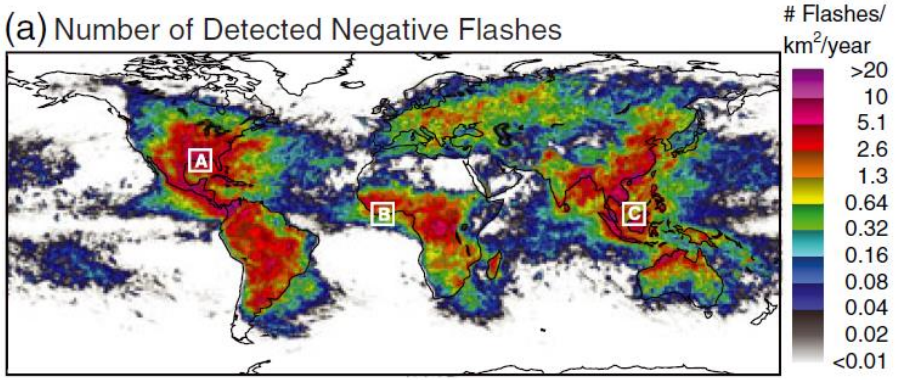
- **持续时间: 0.1 ms to a few ms**
- **单脉冲或者多脉冲**

TGF事件的全球分布（2002-2015年RHESSI数据）



卫星名字	国家	轨道高度	轨道倾角	观测能段	运行年限
CGRO-BATSE	美国	450 km	28.5°	20keV 到 2MeV, 8MeV	1991/4/5-2000/6/4
RHESSI	美国	490-505 km	38°	3keV 到 20MeV	2002/2/5-2018/8/16
FERMI-GBM	美国	550 km	25°	150keV 到 30MeV	2008/6/11 至今
AGILE	意大利	509-533 km	2.5°		2007/4/23 至今
ISS-ASIM	欧洲	403-408 km	51.64°	15keV-400keV, 200keV-40MeV	2018/4/22 至今
HXMT	中国	550 km	43°	8keV-5MeV	2017/6/15 至今
GECAM（双星）	中国	600 km	29°	8keV-2MeV	预定 2020 年发射

Said et al. (2013)



http://xatal.com/tgf/

Are TGFs produced by strong CG strokes?

PERSPECTIVES

ATMOSPHERIC SCIENCE

Inan [2005]-*Science*

Gamma Rays Made on Earth

Umran Inan

In 1994, Fishman *et al.* observed brief (>1 ms) bursts of intense gamma rays, called terrestrial gamma-ray flashes, with the Compton Gamma-Ray Observatory (CGRO) (*1*). Prior to this observation, intense transient bursts of gamma rays were only known to occur in an astrophysical context. Th
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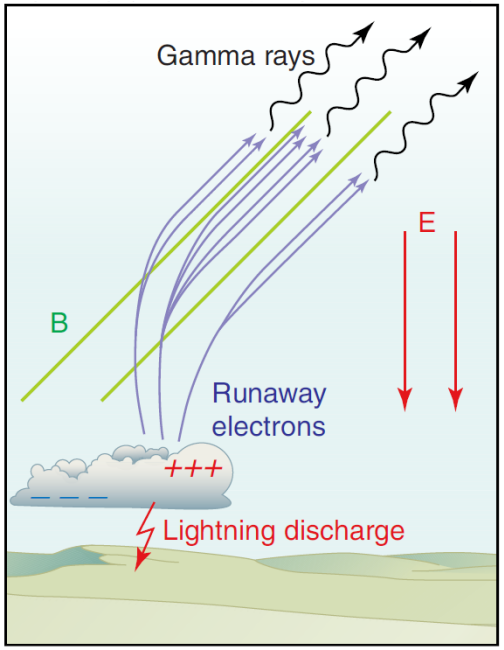
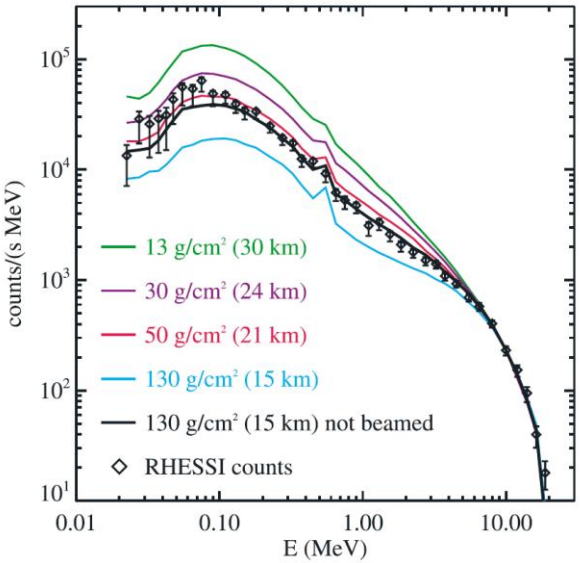
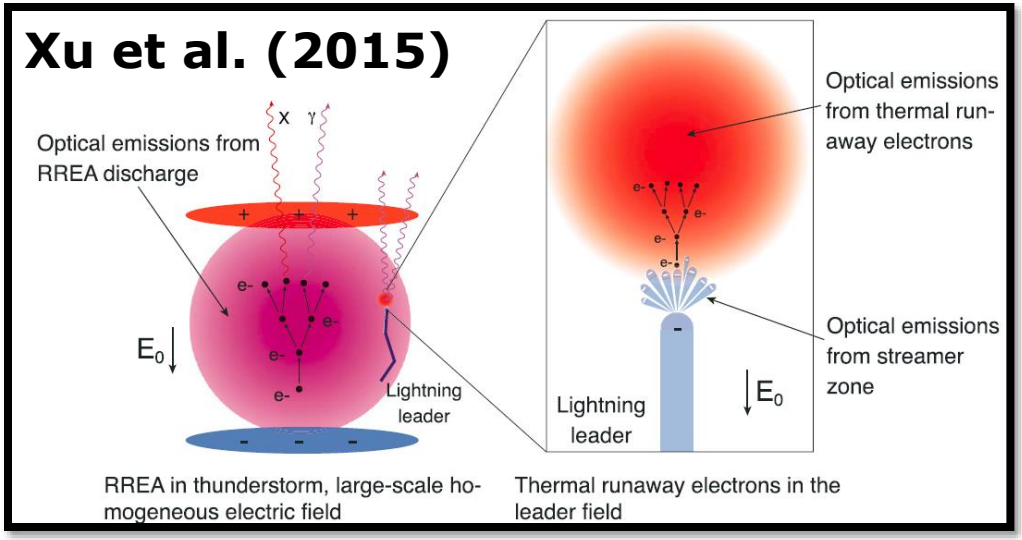
magnetic field). Here, some electrons may become trapped. A fraction of them may then precipitate in regions that are geomagnetically conjugate to intense lightning discharges (for example at the Southern Hemisphere termination of the magnetic field line that originates from a Northern Hemisphere thunderstorm).
interact with molecules in the
ly dense atmosphere to produce
issions and x-rays, which are ulti-
ised by the release of energy in a
ischarge in the parent hemisphere.
of ~76 terrestrial gamma-ray



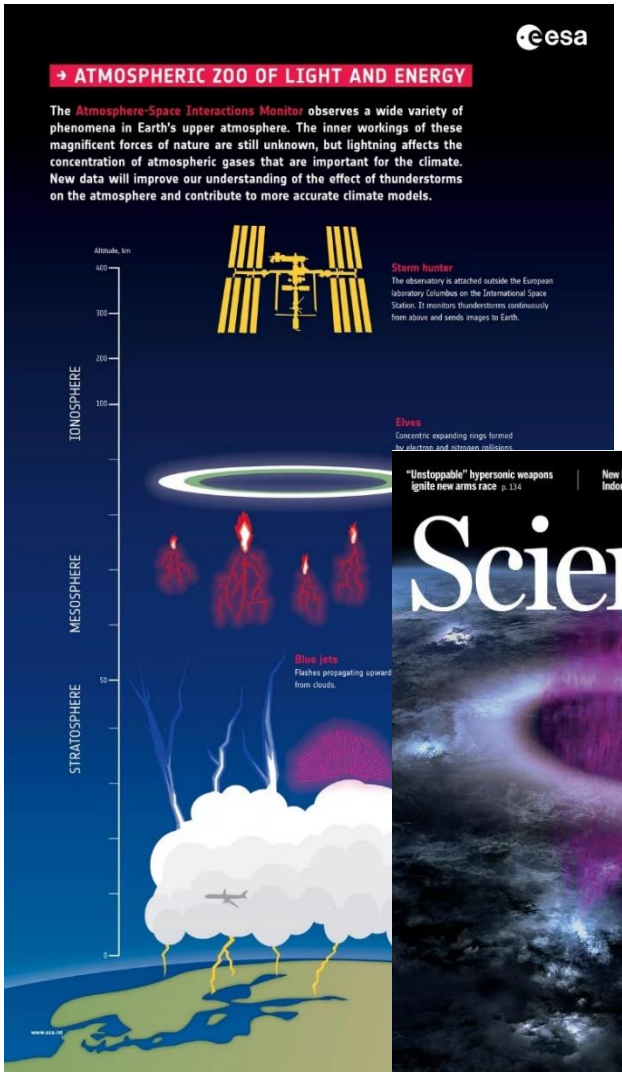
Dwyer et al. (2005)



云闪初始放电产生的伽马射线脉冲



ASIM项目最新成果



Science REPORTS

Cite as: T. Neubert *et al.*, *Science* 10.1126/science.aax3872 (2019).

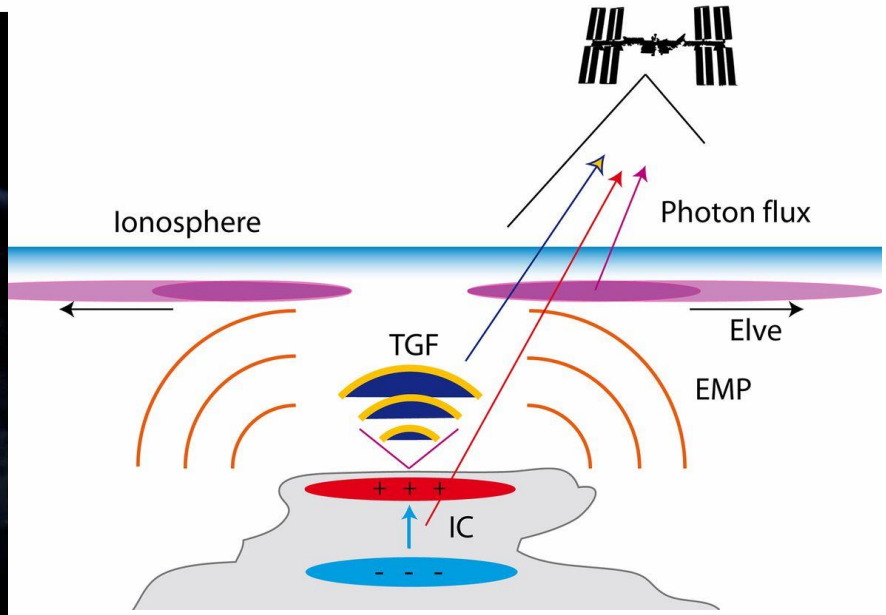
A terrestrial gamma-ray flash and ionospheric ultraviolet emissions powered by lightning

Torsten Neubert[1]*, Nikolai Østgaard[2], Victor Reglero[3], Olivier Chanrion[1], Matthias Heumesser[1], Krystallia Dimitriadou[1], Freddy Christiansen[1], Carl Budtz-Jørgensen[1], Irfan Kuvvetli[1], Ib Lundgaard Rasmussen[1], Andrey Mezentsev[2], Martino Marisaldi[2,4], Kjetil Ullaland[2], Georgi Genov[2], Shiming Yang[2], Pavlo Kochkin[2], Javier Navarro-Gonzalez[3], Paul H. Connell[3], Chris J. Eyles[3]

[1]National Space Institute, Technical University of Denmark (DTU Space), Kongens Lyngby, Denmark. [2]Birkeland Centre for Space Science, Department of Physics and Technology, University of Bergen, Bergen, Norway. [3]Image Processing Laboratory, University of Valencia, Valencia, Spain. [4]Astrophysics and Space Science Observatory, National Institute for Astrophysics, Bologna, Italy.

*Corresponding author. Email: neubert@space.dtu.dk

Neubert et al. (2019) - *Science*



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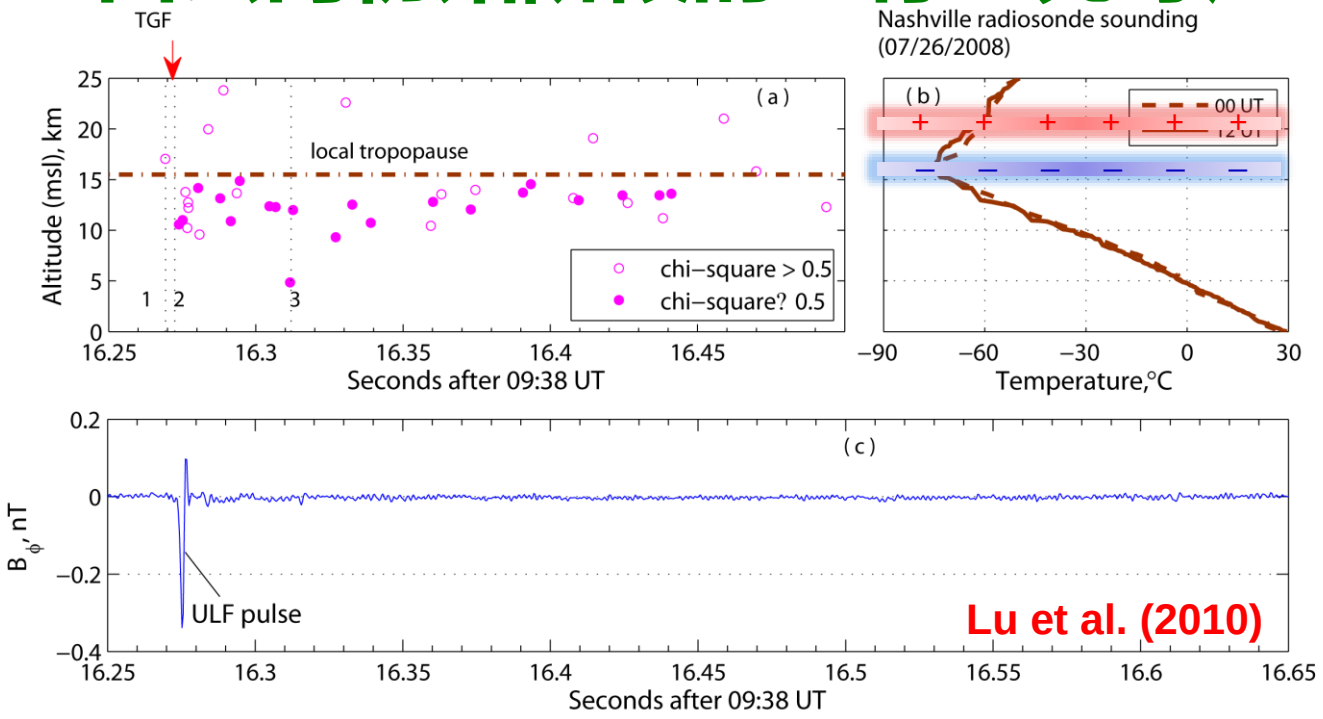
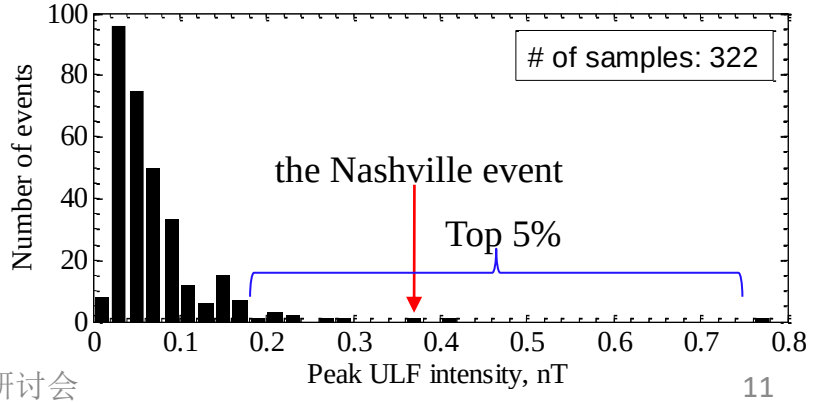
首次实现TGF母体闪电的三维成像观测

TGF由云闪初始阶段的上行正先导产生



- Distinct slow pulse (ΔM_q ~ +90 C·km) early in a normal intracloud (IC) flash.

- Similar slow pulse is common to the IC flashes produced in the same storm.

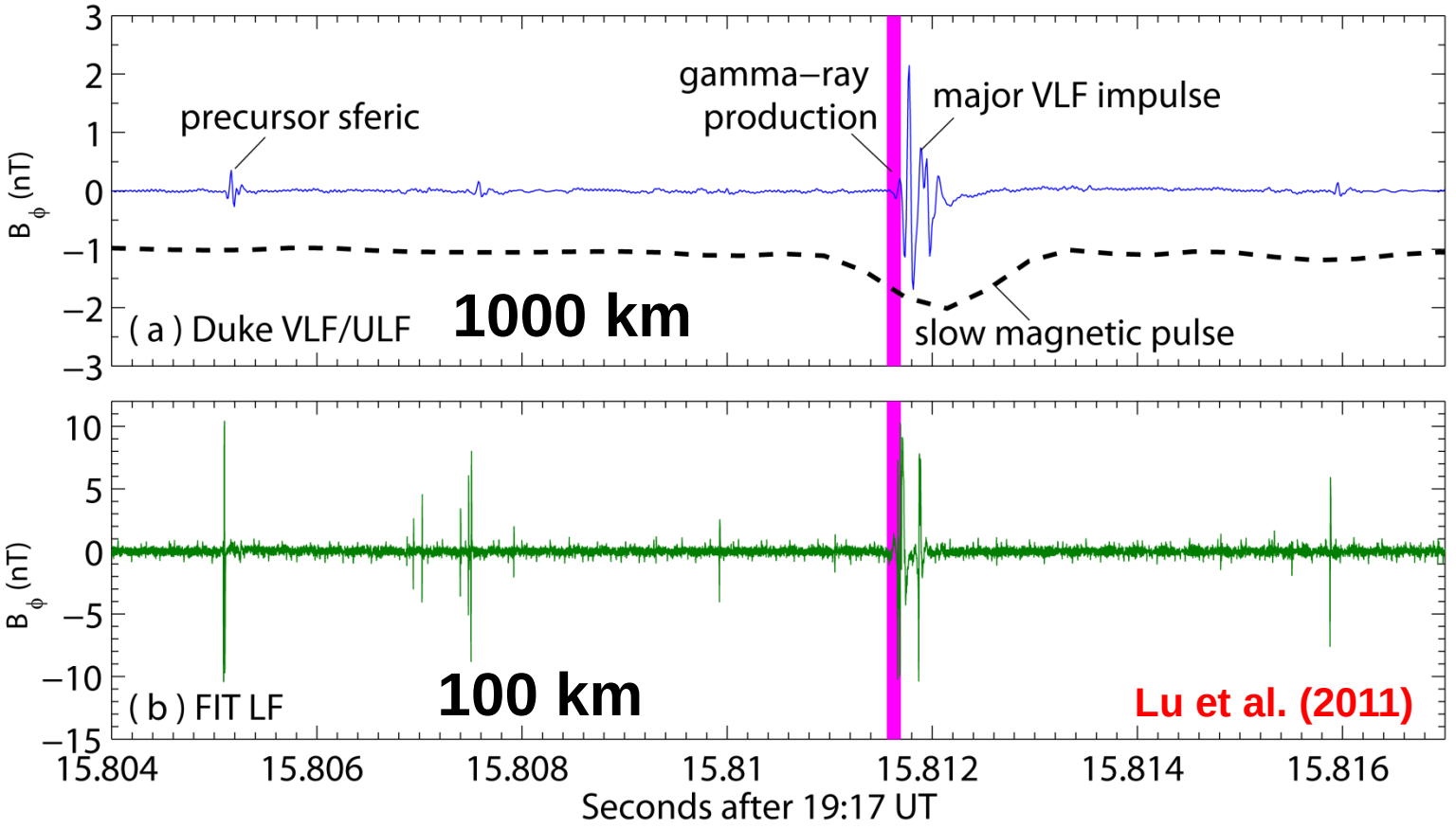


TGF闪电射频信号的典型特征

- precursor sferic
- slow magnetic pulse
- fast impulse

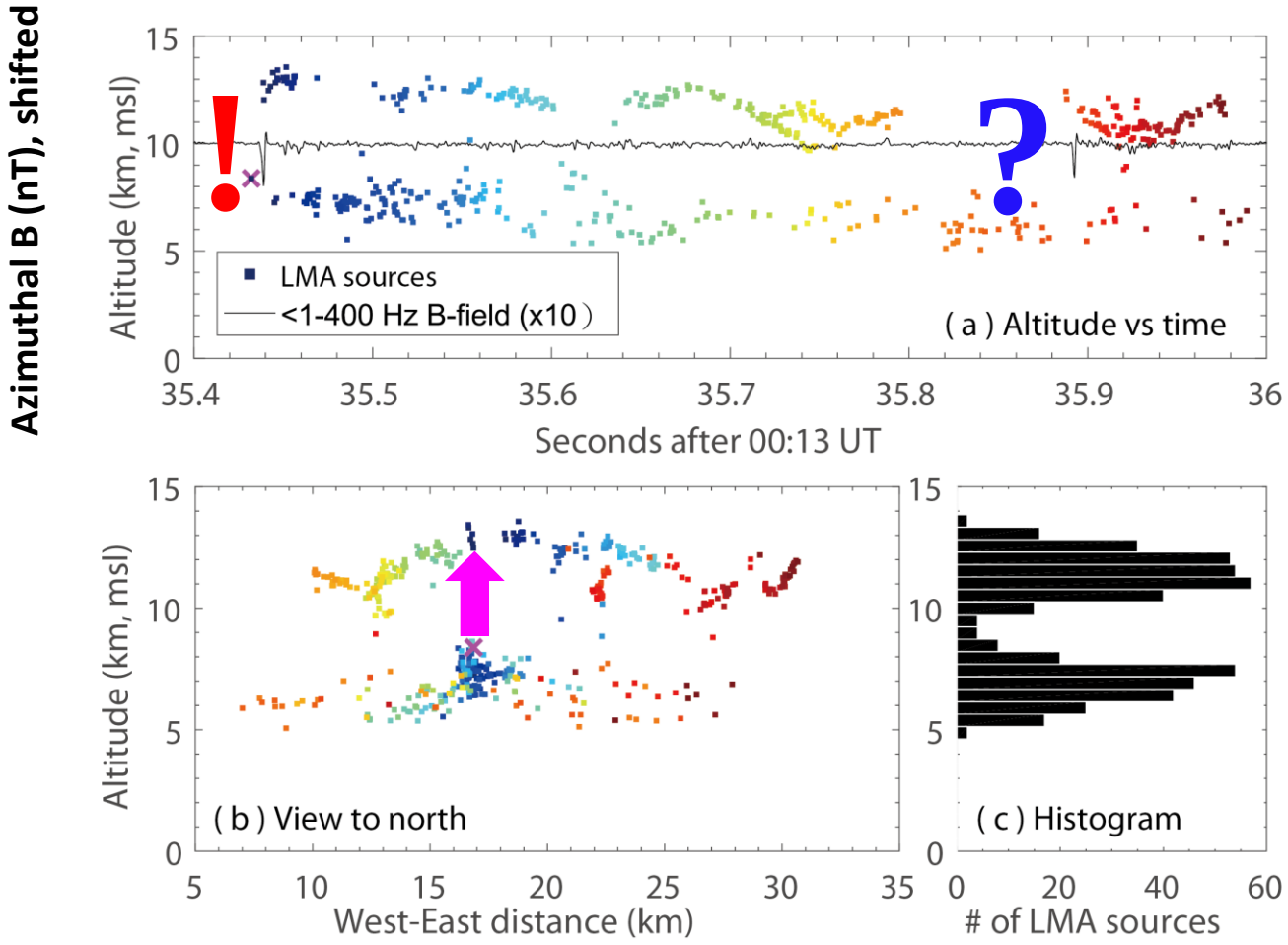
⟺

- flash initiation
- leader progression
- gamma-ray production

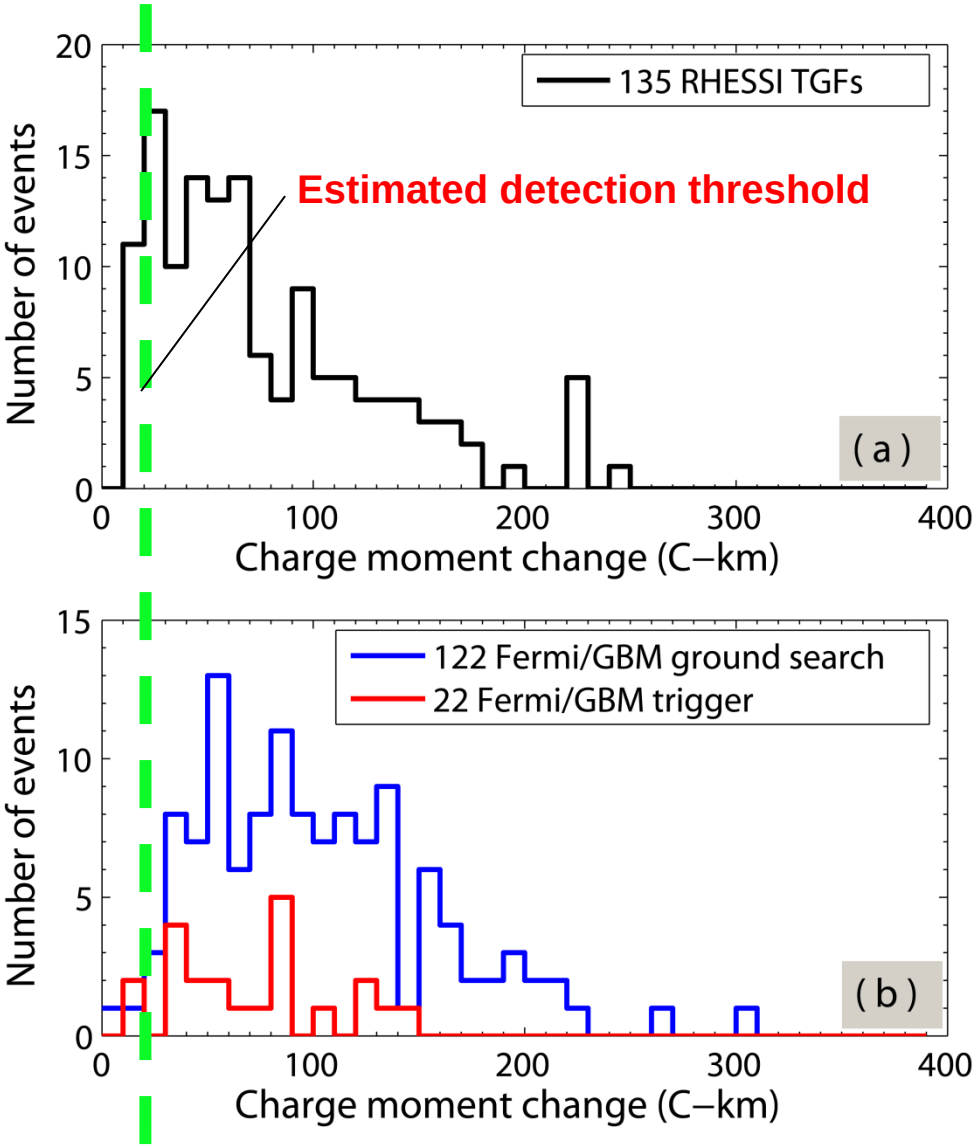


TGF同云闪初始阶段大脉冲事件的相关性

A possible TGF-producer over the North Alabama LMA on 06/10/2010



TGF闪电强度 (脉冲电荷矩) 的统计特征

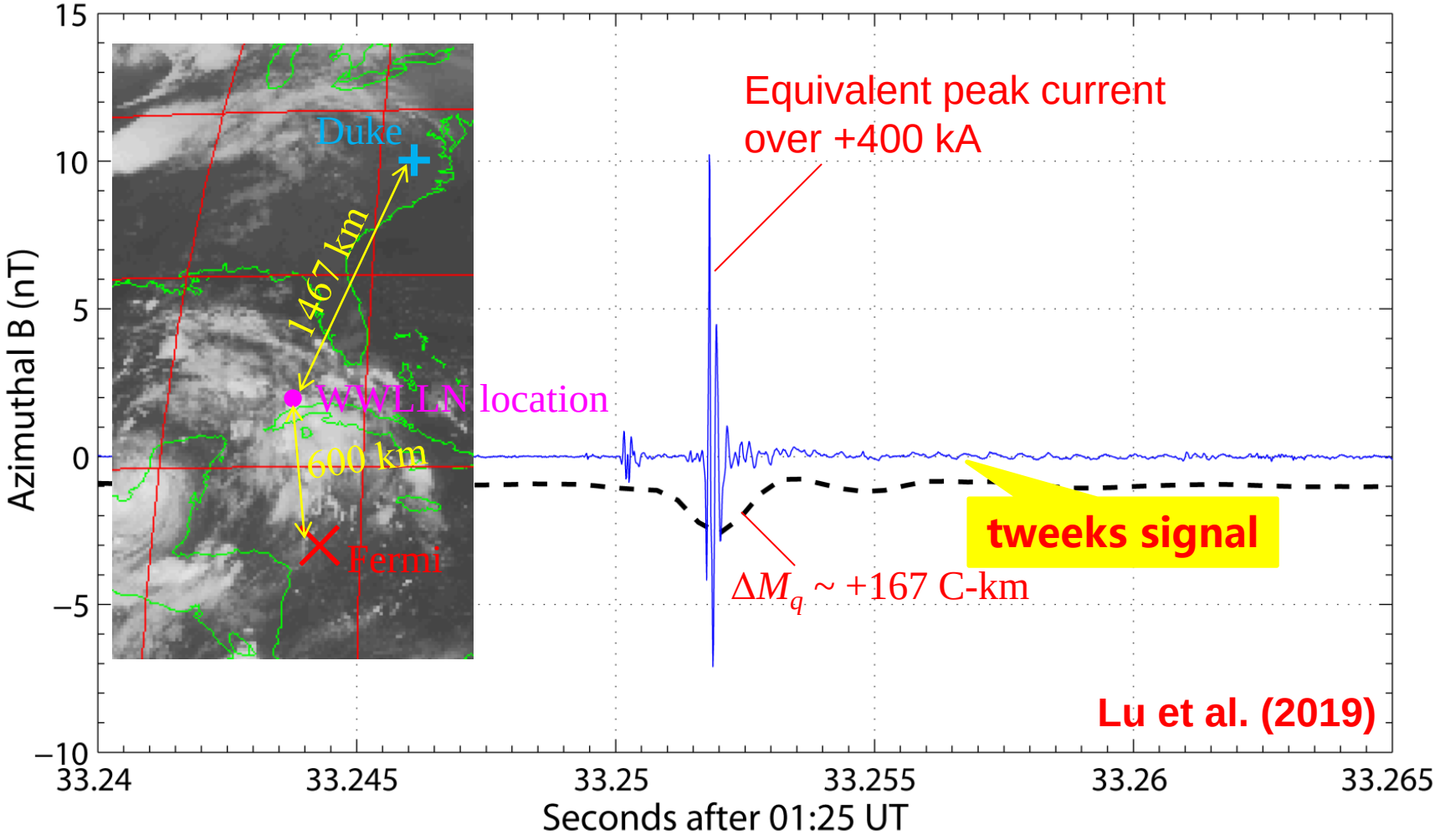


Mean ΔM_q: +78 C-km
Median ΔM_q : +62 C-km
(135 RHESSI TGFs from 2004 to 2011)

Mean ΔM_q: +98 C-km
Median ΔM_q : +87 C-km
(144 Fermi/GBM TGFs from 2009 to 2011)

一次强度极高的TGF闪电个例

Associated with a Fermi/GBM ground-search TGF on September 16, 2010.



闪电临近空间效应研究平台

Since 2014

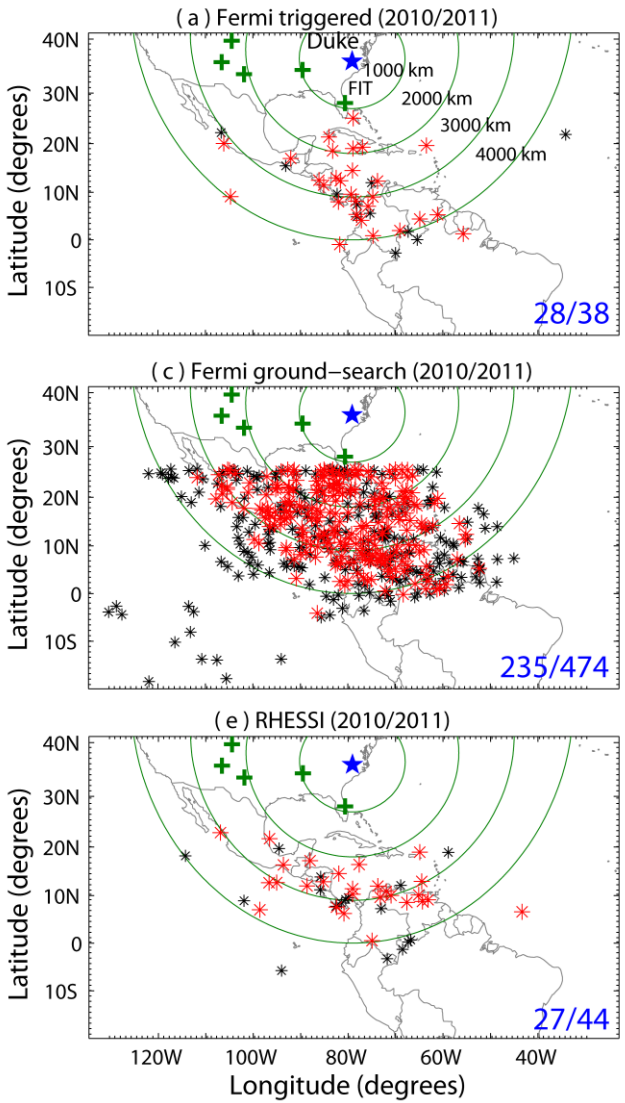
- 长基线混频闪电定位网
- 中层瞬态发光现象观测

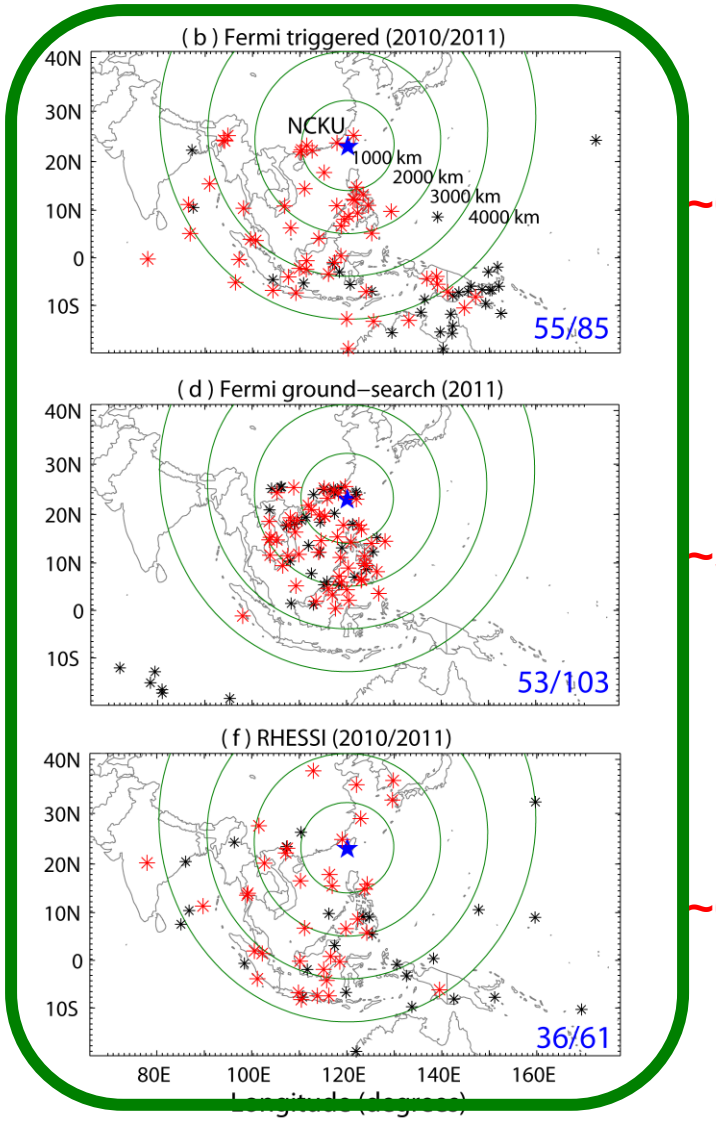
东亚地区更适合开展TGF的协同地基观测

~74%

~50%

~60%





~65%

~51%

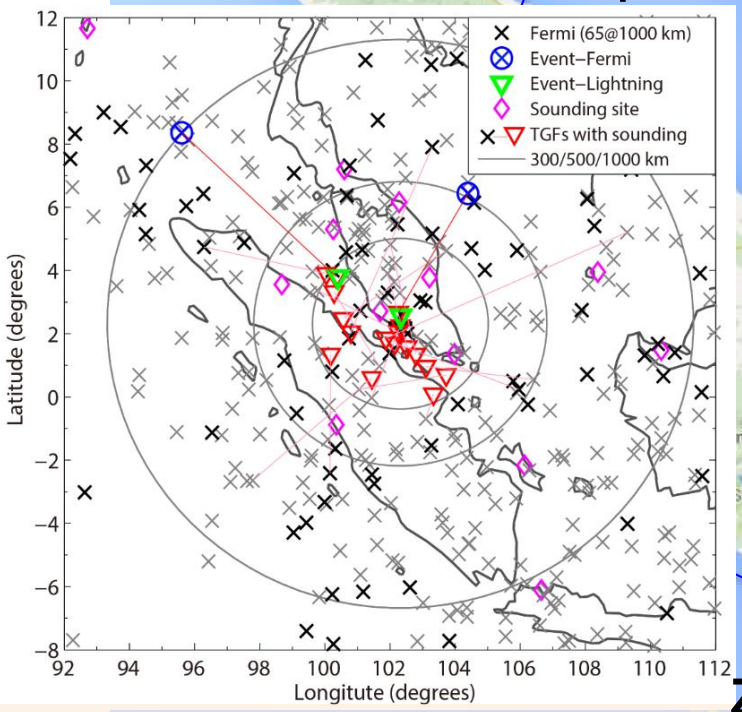
~60%

Lu et al. (2019JASTP)

赤道附近的LERP-Melaka站点

FERMI

Fermi footprint

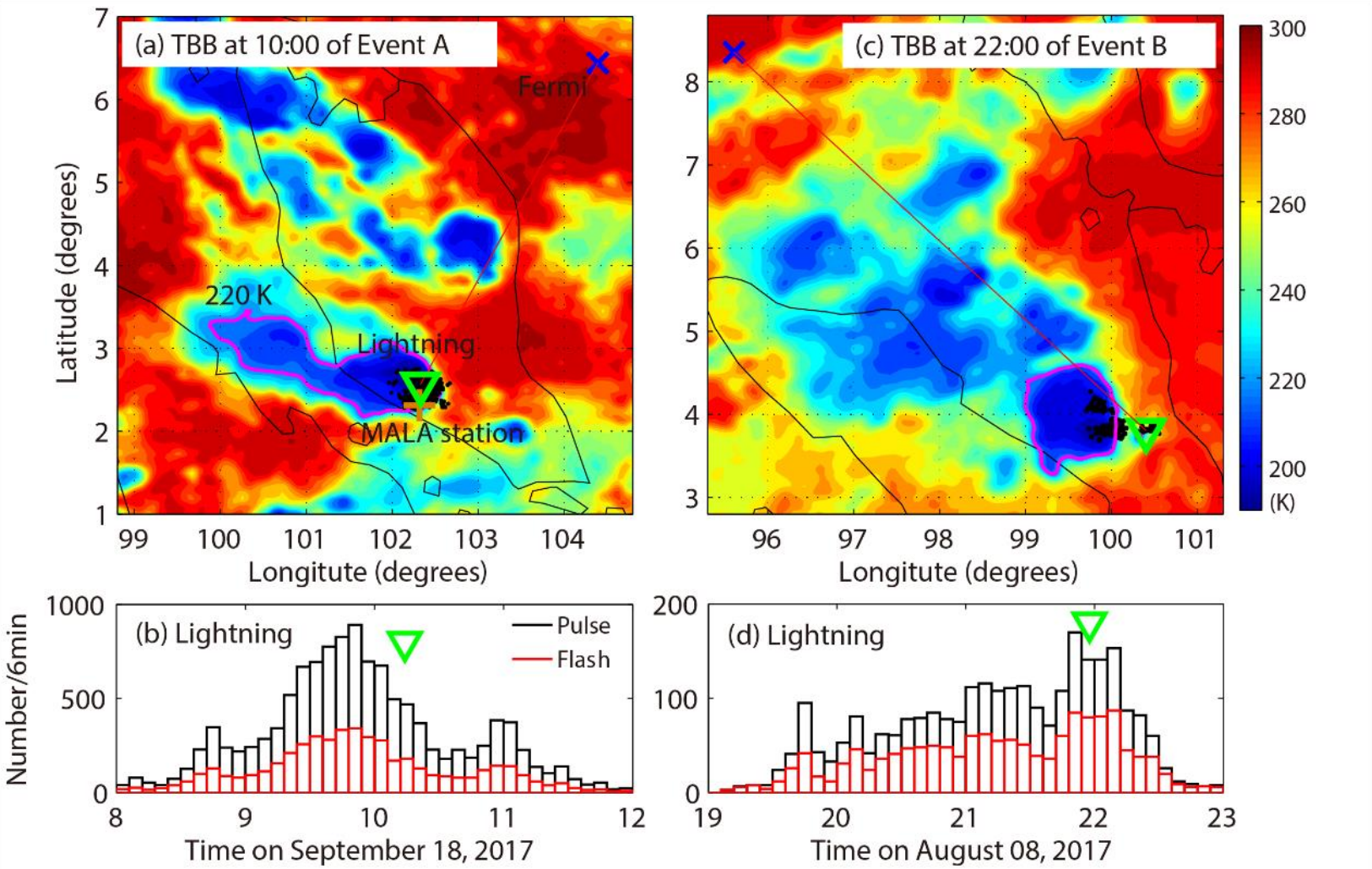


Zhang, Lu et al. (2020)

理想的观测和研究平台

赤道地区TGF母体雷暴特征分析

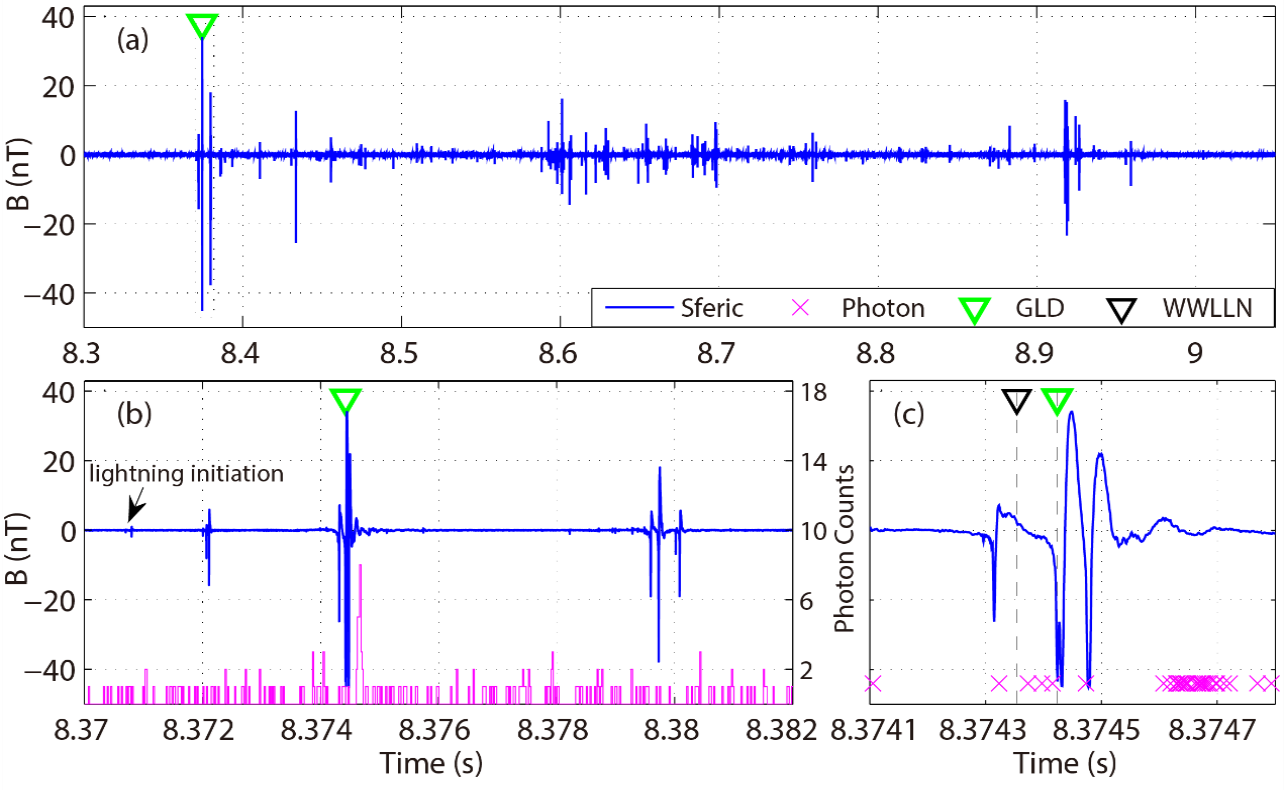
Zhang, Lu et al. (2020)



成熟阶段、TBB强中心

成熟阶段、TBB强中心边缘

个例1-迄今为止最近距离地基观测 (28公里)



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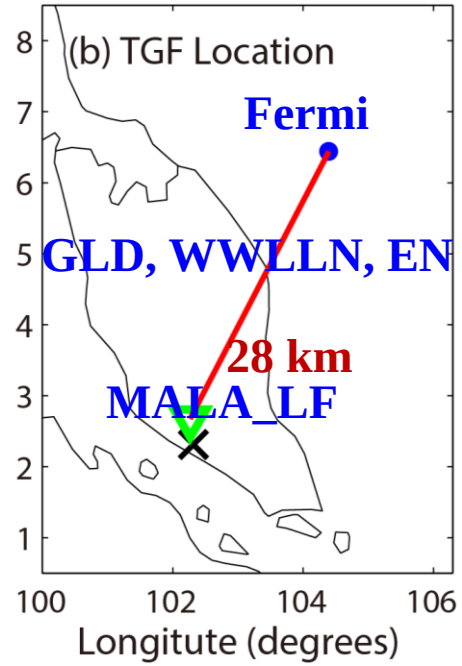
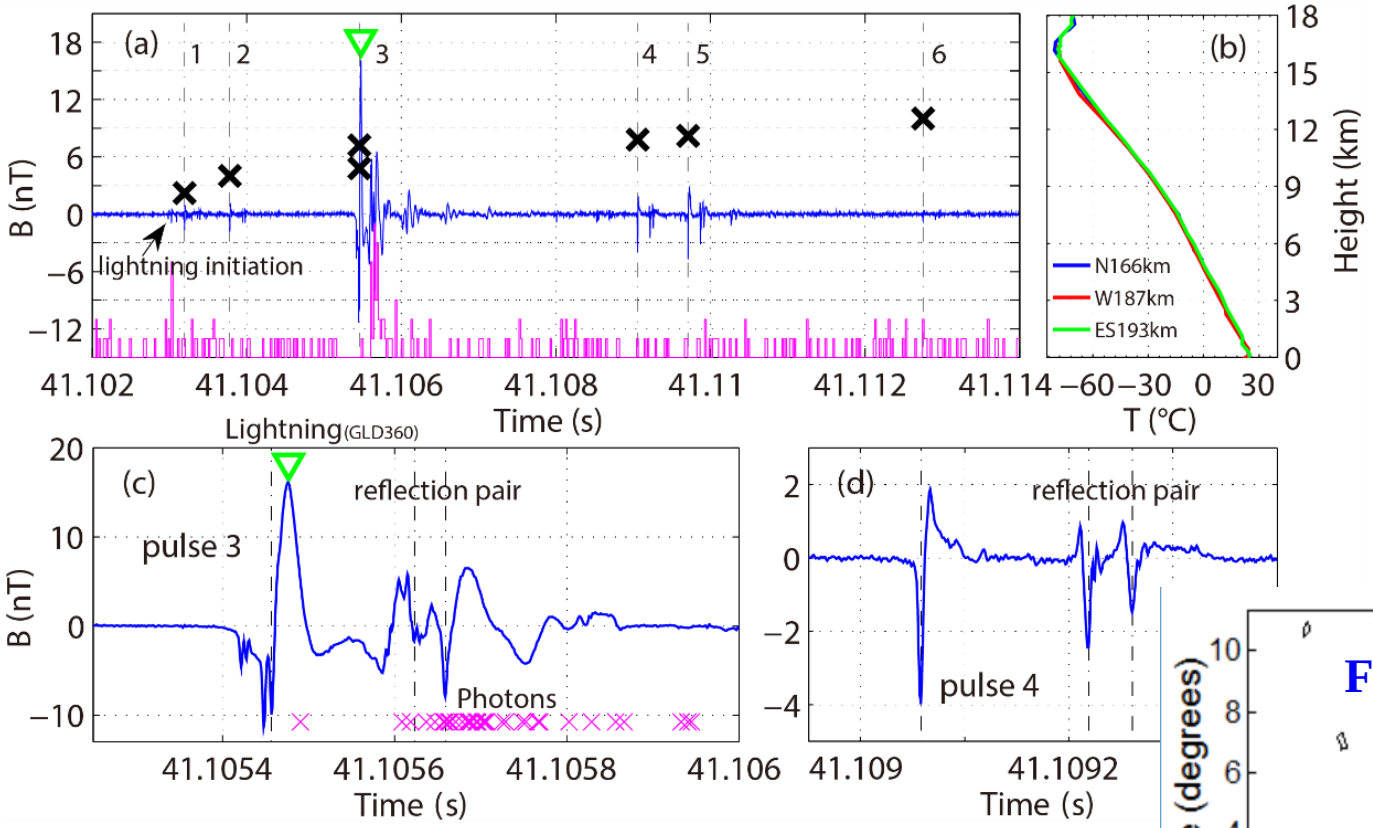
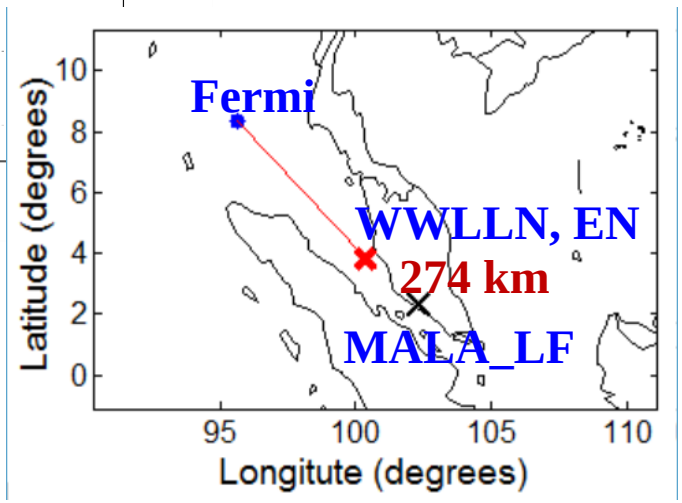


➢ **云闪发展期间(3.7 ms) 最强脉冲**

个例2-明显电离层反射信号用于定位辐射源高度



TGF170808915



- 云闪向上发展期间(2.3 ms)，高度范围10-11 km

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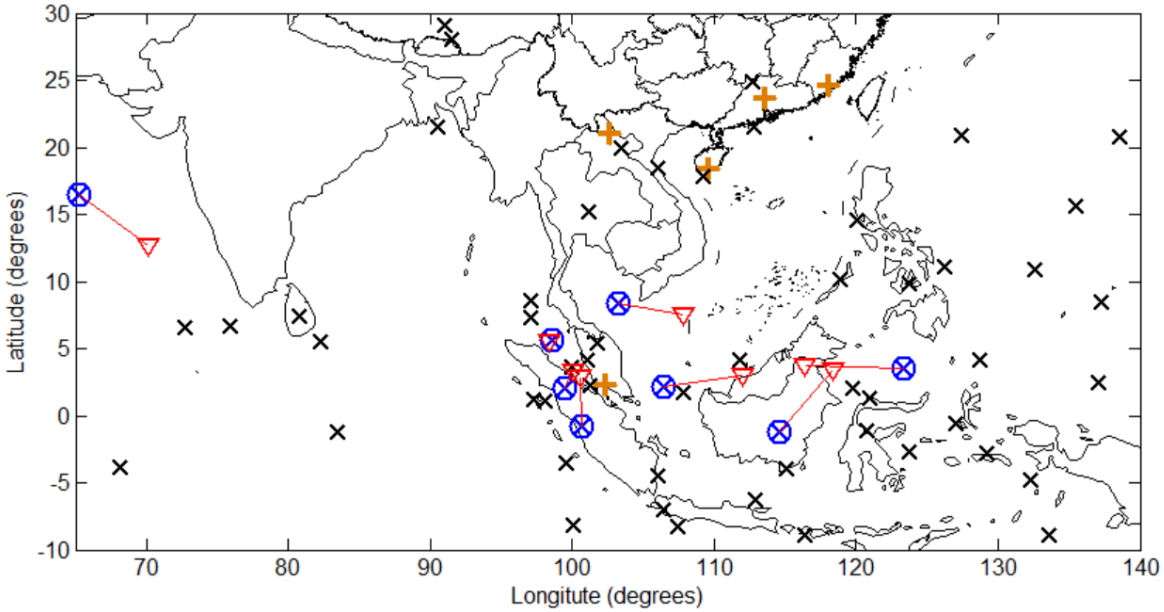
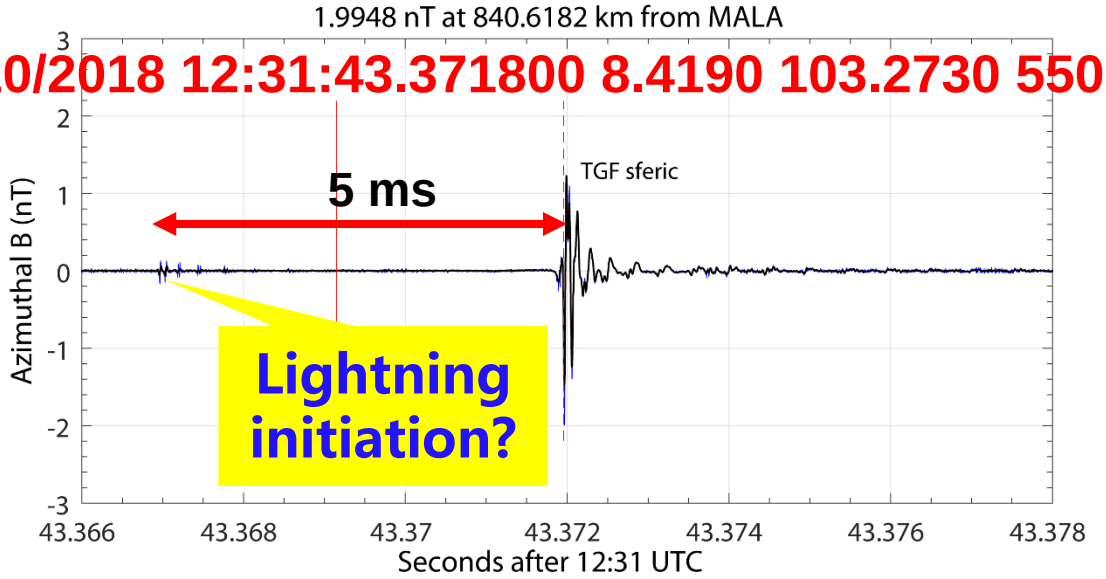
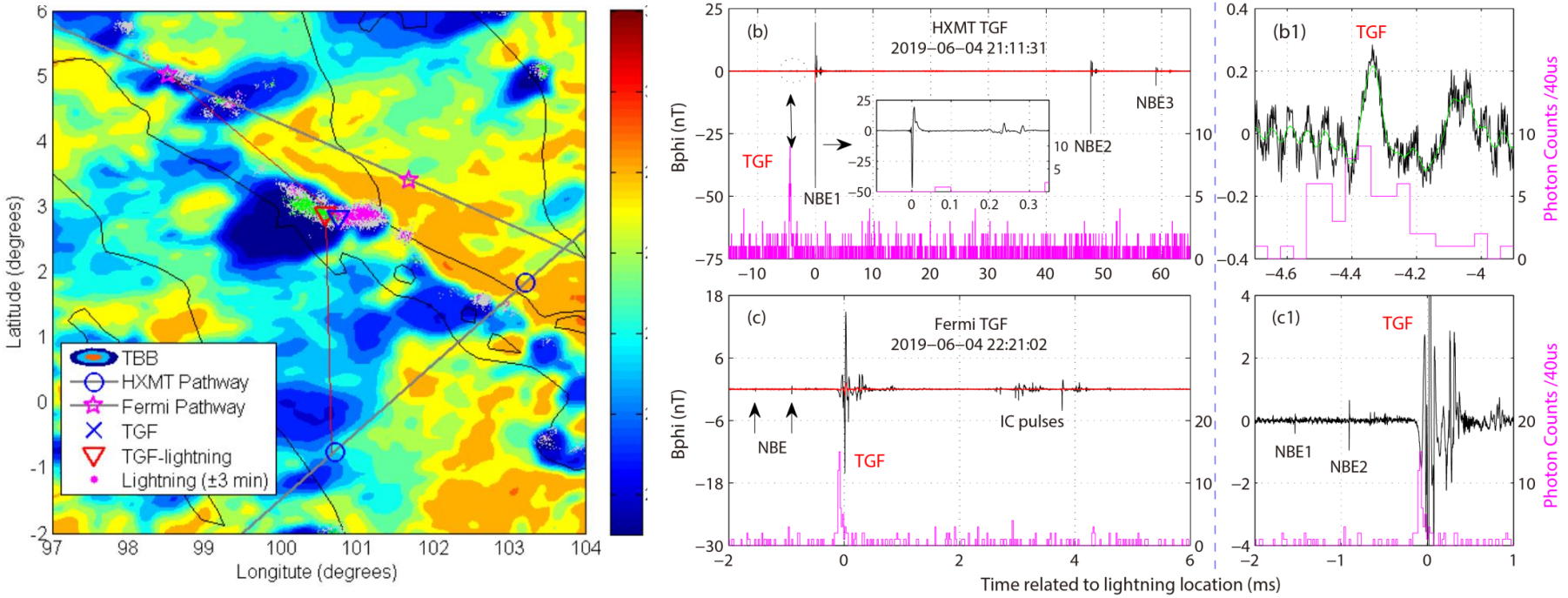
HXMT探测TGF事件的射频信号测量



慧眼Insight-HXMT卫星



HXMT和FERMI卫星对一次雷暴的TGF探测



- 赤道地区TGF-闪电相关性同其它地区基本一致
- 近距离对于一些TGF相关的弱放电过程非常重要

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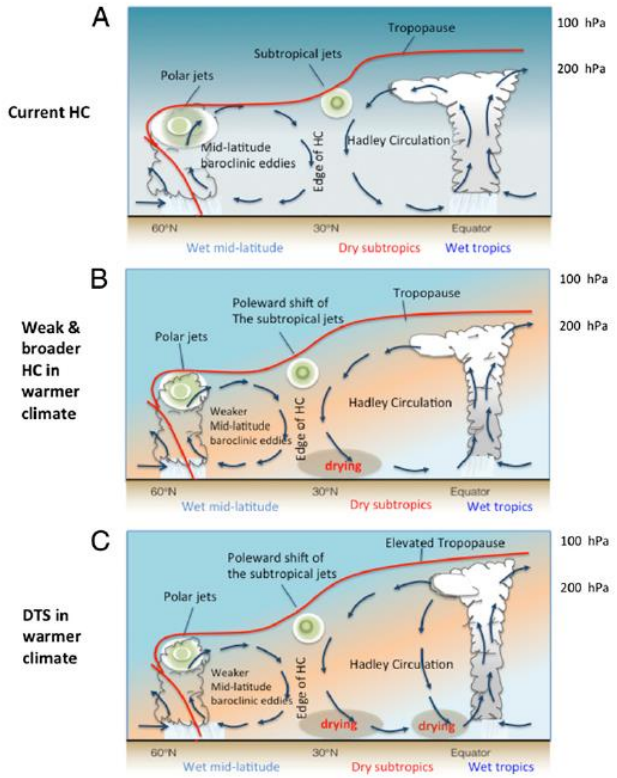
地球伽玛闪研究小结及展望

- TGF对应于**云闪先导向上发展阶段**，对应其**最强**的脉冲
- **不同类型**的雷暴均可以产生TGF，雷暴一般处于**成熟阶段**，TGF源位于母体雷暴**强对流中心或其边缘（边缘占比高）**



基于**LERP平台**优势和华南地区已有探测设备，**利用Fermi、慧眼HXMT、ASIM和GECAM等**卫星资料将获取更多**近距离**TGF源区探测和同步闪电三维定位**观测数据**。

HXMT和GECAM给雷电物理研究带来的机遇

- 完全利用自主探测数据的TGF-母体闪电相关性研究
- TGF母体闪电的高时空分辨率三维成像
- 云内大脉冲过程的精细物理过程及其远场辐射特征
- 闪电负先导产生高能伽玛射线的物理机制
- 地源伽玛闪事件的遥感探测研究

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

中国科学院大气物理研究所
IAP
CAS

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Thank You!

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