BEES : une constellation de nanosatellites pour l'étude des phénomènes haute énergie durant les orages

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- Introduction
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- Research questions
- Space mission project BEES
- Conclusions

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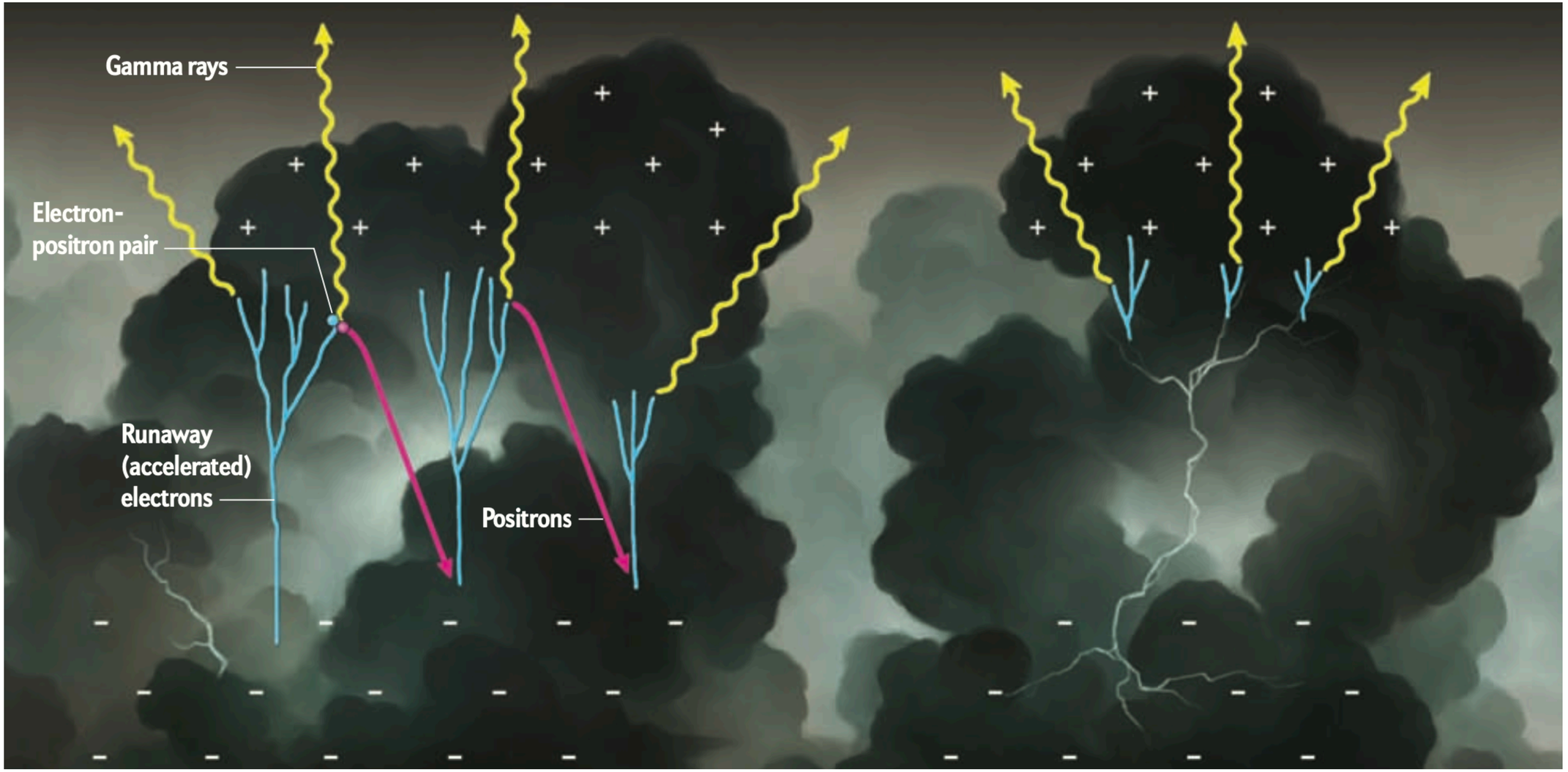
Gamma ray glows and Terrestrial Gamma ray Flashes (TGFs)



Reproduced from [Dwyer & Smith, Sci. Am., p. 55, August 2012]

Terrestrial Gamma ray Flashes (TGFs)

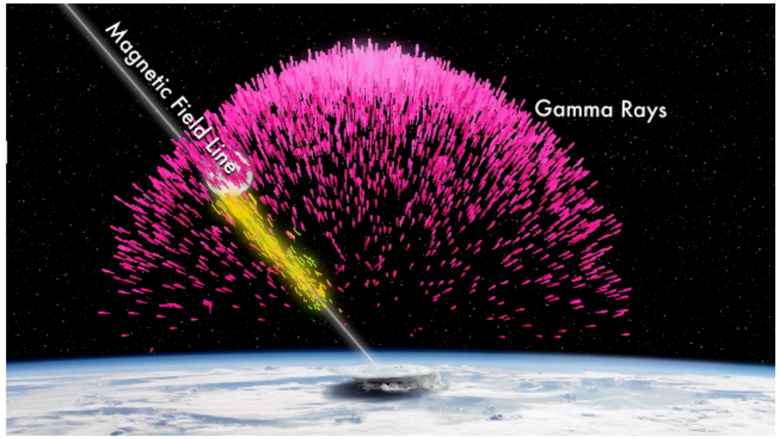
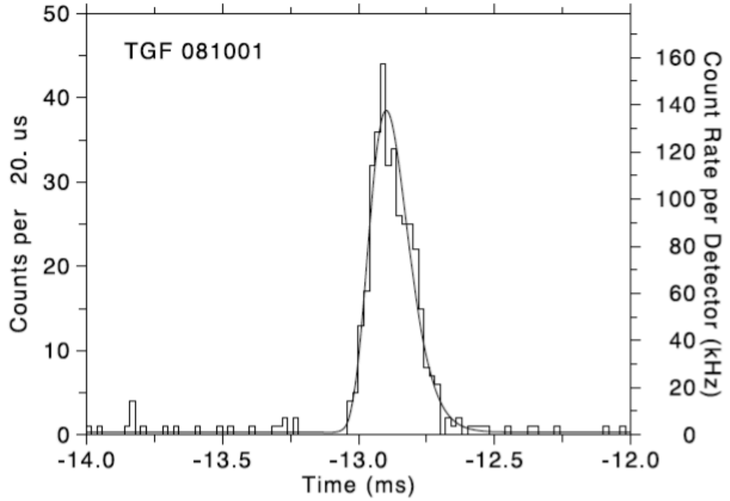


Illustration of a TGF. Credit: NASA/Goddard Space Flight Center.



Example of a TGF detected by Fermi-GBM [*Briggs et al.*, JGR, 115, A07323, 2010].

- Typical max. energy: $\sim$30 MeV.
  - Max. energy reported (AGILE): 100 MeV ! [*Tavani et al.*, PRL, 106, 018501, 2011].
- Typical duration: fraction of ms.
  - t_{50}-duration distribution peak reported $\sim$100 μs [e.g., *Fishman et al.*, J. Geophys. Res., 116, A07304, 2011; *Marisaldi et al.*, Geophys. Res. Lett., 42, 9481, 2015].
- Typical fluence: $\gtrsim$0.5 photon/cm^2 when observed from low-orbit.
  - The maximum TGF fluence is yet to be established (due to deadtime, pile-up, etc.).

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Brand-spanking new results

Illustration of an aircraft flying above thunderclouds to monitor gamma-ray glows, colored in purple. Credit: The ALOFT team/Mount Visual (CC BY 4.0)

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Highly dynamic gamma-ray emissions are common in tropical thunderclouds

M. Marisaldi, N. Østgaard, A. Mezentsev, T. Lang, J. E. Grove, D. Shy, G. M. Heymsfield, P. Krehbiel, R. J. Thomas, M. Stanley, D. Sarria, C. Schultz, R. Blakeslee, M. G. Quick, H. Christian, I. Adams, R. Kroodsma, N. Lehtinen, K. Ullaland, S. Yang, B. Hasan Qureshi, J. Søndergaard, B. Husa, D. Walker, M. Bateman, D. Mach, S. Cummer, M. Pazos, Y. Pu, P. Bitzer, M. Fullekrug, M. Cohen, J. Montanya, C. Younes, O. van der Velde, J. A. Roncancio, J. A. Lopez, M. Urbani & A. Santos

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Flickering gamma-ray flashes, the missing link between gamma glows and TGFs

N. Østgaard, A. Mezentsev, M. Marisaldi, J. E. Grove, M. Quick, H. Christian, S. Cummer, M. Pazos, Y. Pu, M. Stanley, D. Sarria, T. Lang, C. Schultz, R. Blakeslee, I. Adams, R. Kroodsma, G. Heymsfield, N. Lehtinen, K. Ullaland, S. Yang, B. Hasan Qureshi, J. Søndergaard, B. Husa, D. Walker, D. Shy, M. Bateman, P. Bitzer, M. Fullekrug, M. Cohen, J. Montanya, C. Younes, O. van der Velde, P. Krehbiel, J. A. Roncancio, J. A. Lopez, M. Urbani, A. Santos & D. Mach — Show fewer authors

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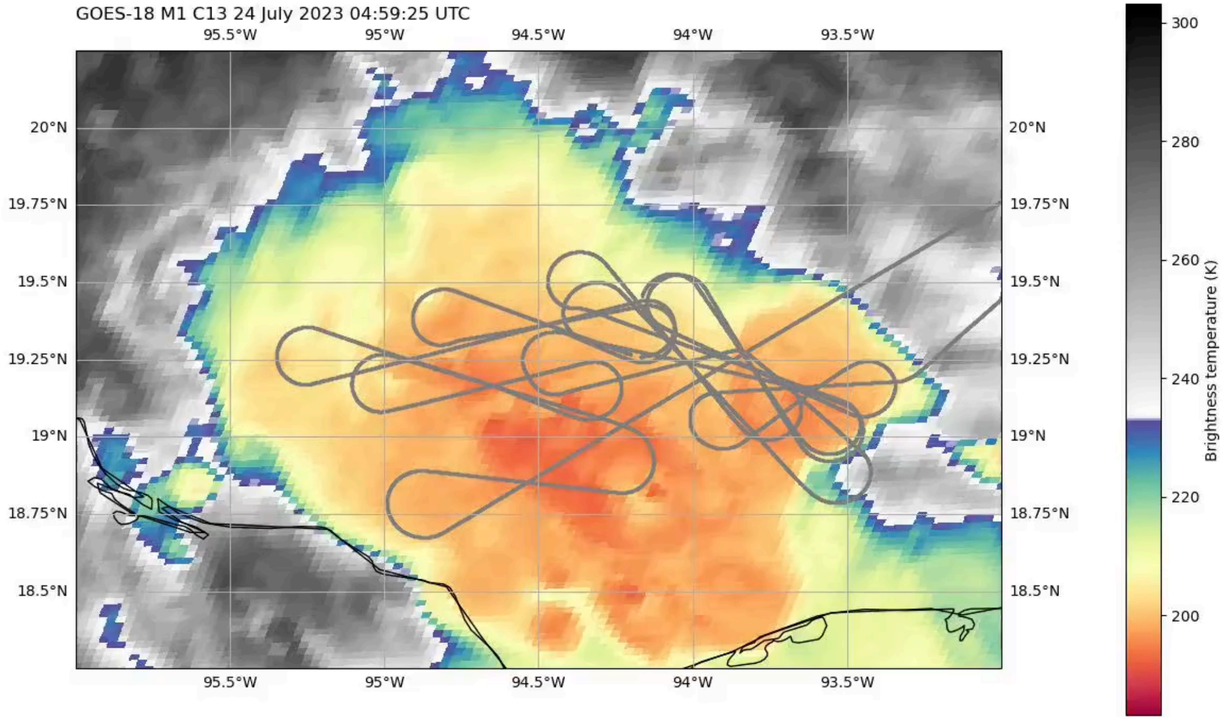
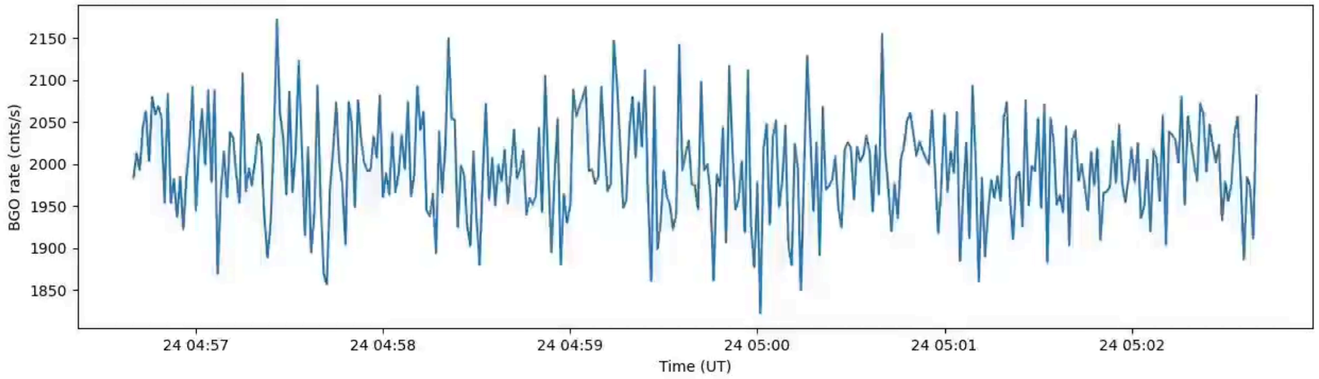
ALOFT (July, 2023)





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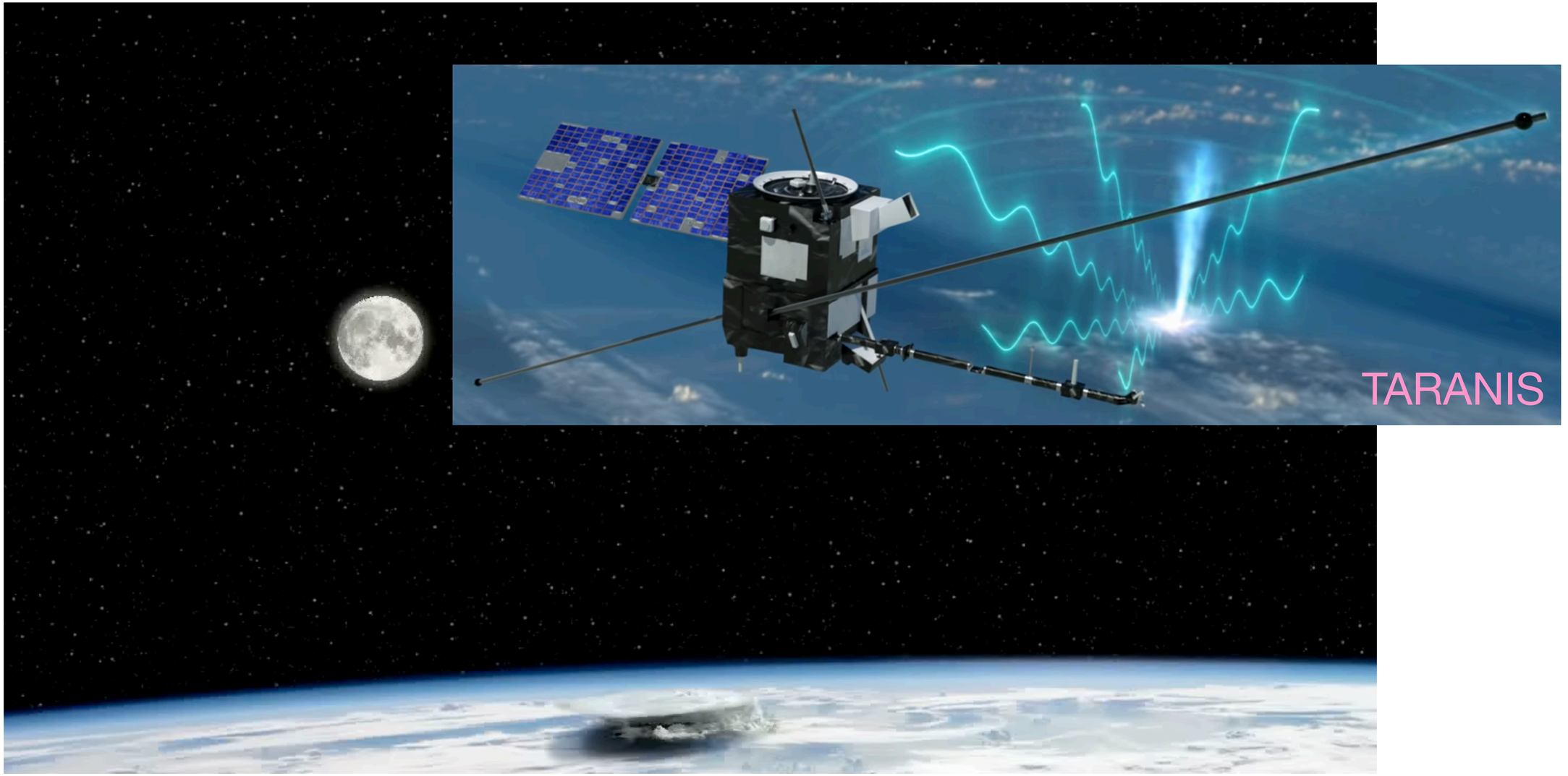
Research questions

- Acceleration and amplification processes (RREA, thermal runaway, relativistic feedback, etc.)
- Source geometries (altitude, size, geometry, etc.)
- Gamma ray spectrum variability and associated radio emissions
- Impact of/on the T-storm electrodynamic system
- Radionuclide and neutron production
- Overall radiation risk assessment (collaborations IRSN & Air France)

- Need for a new kind of space mission

Terrestrial Gamma ray Flash / Terrestrial Electron beam



Credit: NASA/Goddard Space Flight Center/J. Dwyer/Florida Inst. of Technology.

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Bursty Energetic Events in Space (BEES)

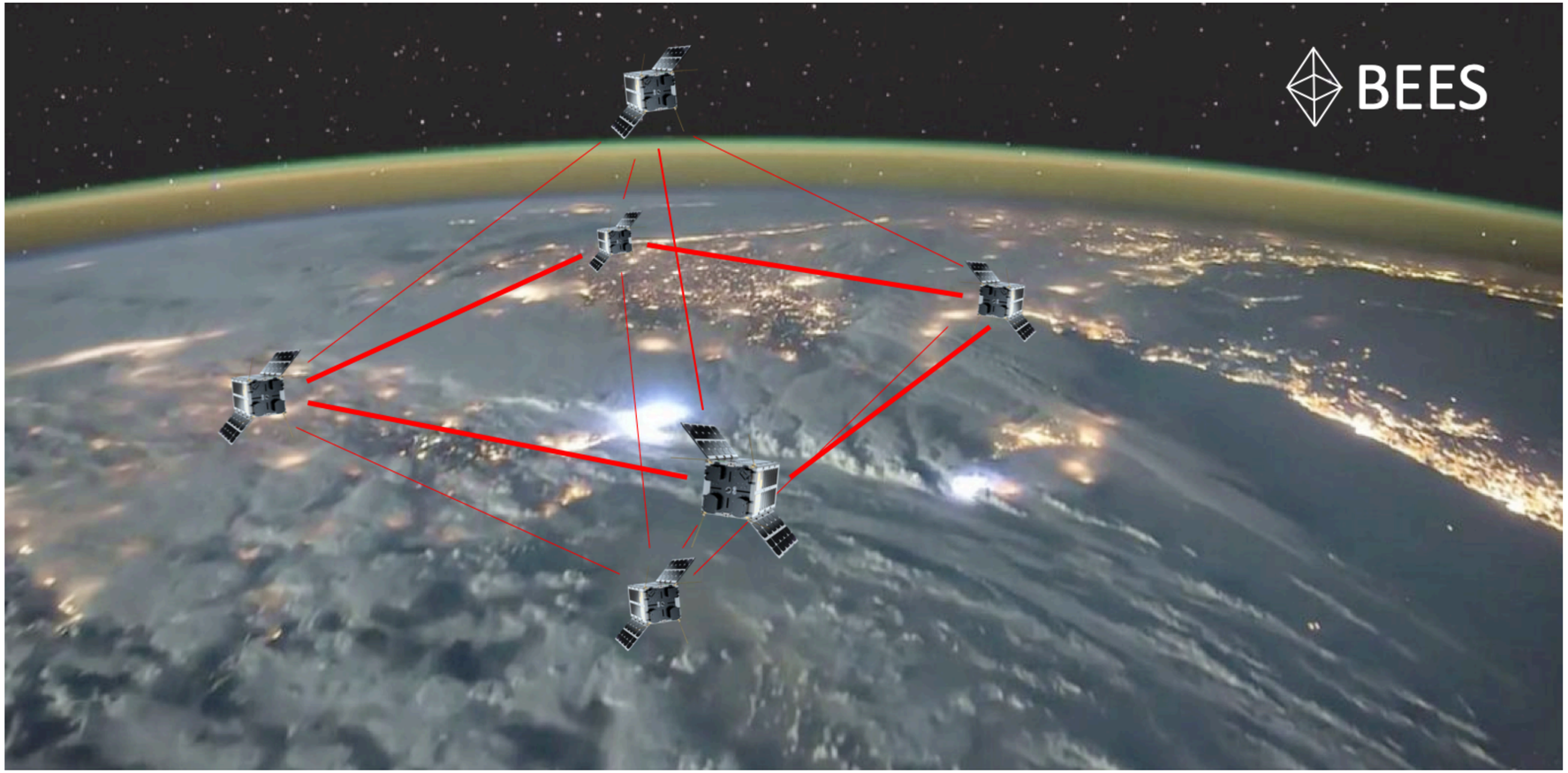
A buzzing mission concept to perform multipoint observations of short GRBs and TGFs

Science case

- Critically missing observables in TGFs: beaming geometry and electromagnetic emissions in the HF range
    - Beaming geometry => spectrum at the source
    - EM emissions => physical processes at the source

- Short GRBs: identification of GW’s EM counterparts
- Space weather/plasmas: processes associated with solar flares (X-ray emissions and radio bursts)

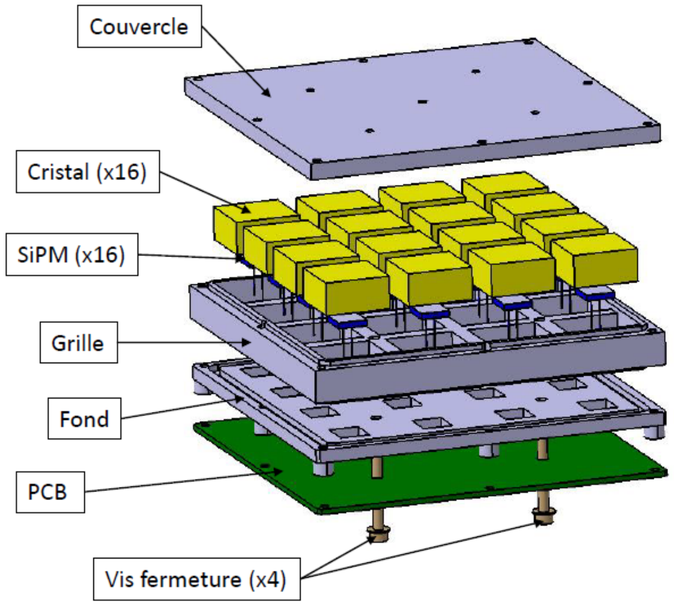
Mission concept

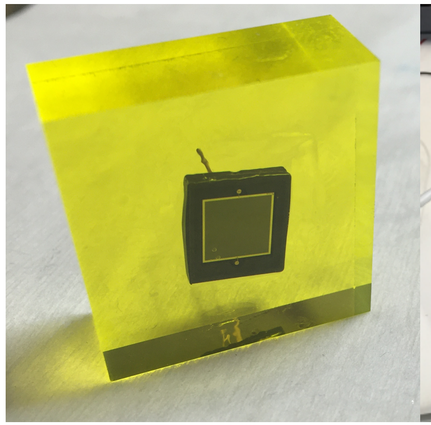


- **Initial study phase by the French space agency (CNES)**
- Two instruments on board each nanosat: one gamma ray detector and one HF receiver
- Source localization using high timing accuracy

FGS: Flash Gamma ray Spectrometer

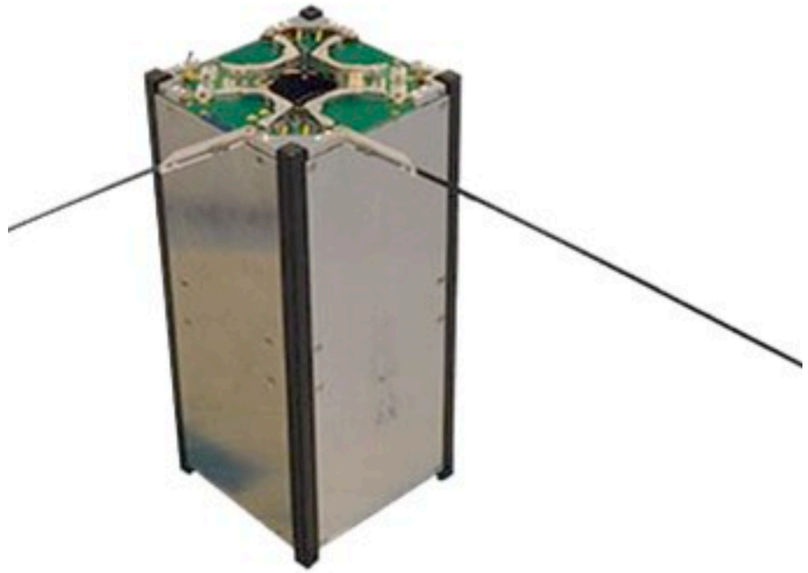
- Currently under development at the AstroParticle and Cosmology (APC) laboratory - joint institute between Paris Cité University, Paris Observatory, CNRS, and CEA (PI: Philippe Laurent)
- Segmented GaGG-F (energy range objective: 10 keV-20 MeV) & SiPMs
- Resolution: 10% @ 662 keV
- Front-end electronics (dev. w/ LESIA & IDEAS): 16-channel ASIC; max. 1 Mcps / channel; 12-bit ADC
- Geometric area 64 cm² (16 pixels)





RIP-2 (Radio Instrument Package for 2-component measurements)

- Developed by the Institute of Atmospheric Physics (IAP) of the Czech Academy of Sciences, Prague, Czech Republic (PIs: Ondrej Santolik and Ivana Kolmasova)
- Broadband digital FPGA-based radio receiver
- E-field deployable antennas
- ~5 kHz to 40 MHz



Expectations from the initial study phase

- Preliminary mission analysis: orbits, formation flying, power & mass budget, telemetry, and possibility for intra-cluster communication
- Nanosatellite platforms definition
- Payload performance analysis
- Observation plan and data processing strategy

Contents

Conclusions

- Need for a space mission to observe radio emissions associated with TGFs after the failure of TARANIS launch
- Multi-point measurements can give a strong push to current research questions (source geometries, association with specific discharge processes, etc.)
- Very fast instruments are needed to detect TGFs, and in turn can help detect and understand short GRB events (esp. in association with GWs) and high-energy events associated with solar flares

Thank you for your attention

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