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Instrumental development and preparation to future missions for **Terrestrial Gamma ray Flash** (TGF) detections

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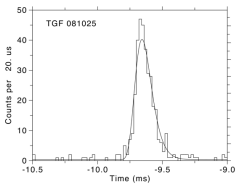
1 – Overview

What are Terrestrial Gamma ray Flashes?

Bursts of gamma rays produced in thunderstorms
- ~400,000 TGFs/year detectable by satellites
- Duration: <100 μs
- Photon energies: tens of keV to >40 MeV
- Very bright:
  10^{18} photons produced
  ~1 ph/cm^2 observed by satellite



Light curve of a TGF detected by Fermi-GBM [Briggs et al., 2010].

TGF current detections

- Mostly by satellites:
  - Mostly astrophysics instruments (e.g., *Fermi, Agile, RHESSI*)
  - Some TGF design instruments (*ASIM on the ISS*)
- Some ground-based detections (with the *Telescope Array)*
- 2 aircraft detections

APC and CNES context

- Taranis was the 1st satellite designed for TGF study
- XGRE: X and gamma scintillator
- Launch failure in 2020

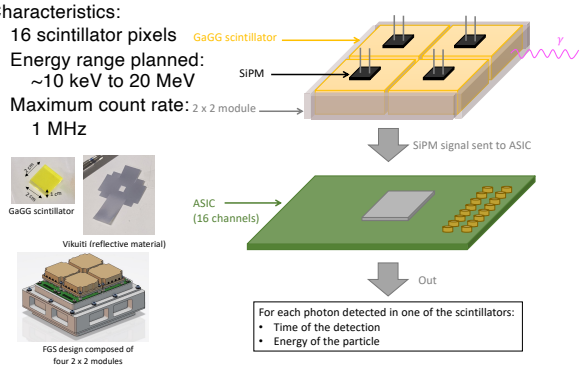
Objective: Develop an innovative gamma ray spectrometer multi-mission and for TGF detection → Space instrument adaptable to detect different gamma ray events: e.g., **TGFs, GRBs, solar bursts**

2 – FGS: new gamma ray spectrometer multi-mission

Fast Gamma ray Spectrometer (FGS) design

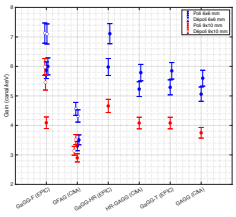
In collaboration with LESIA

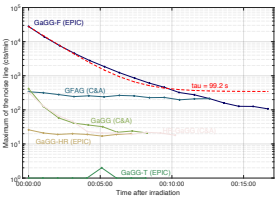
Characteristics:
- 16 scintillator pixels
- Energy range planned: ~10 keV to 20 MeV
- Maximum count rate: 1 MHz



GaGG type comparison

- 3 types:
  - GaGG "normal"
  - Fast GaGG
  - High-resolution GaGG
- 2 suppliers
- Gain
- Energy resolution





Proton irradiation

- Luminescence

3 – Future missions

Short term: Balloon flight

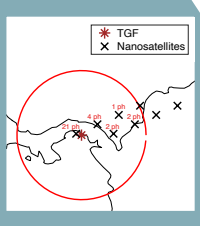
- Planned in June 2024 in Kiruna, Sweden with CNES
- Stratospheric balloon staying at ~30 km for ~10 hrs
- To validate FGS working in conditions close to space: detection of Crab pulsar

Long term example: Bursty Energetic Events in Space (BEES)

Nanosatellite constellation to study TGFs and GRBs
- Payload: FGS and a radio antenna from Czech Rep. team
- Aim: multiple TGF detection to study their characteristics, not assessable with only one measurement

Parallel study: Simulation of nanosatellite constellation for TGF detection

- Input:
  - TGF density map
  - Nanosatellite trajectories
  - Results of Monte-Carlo simulation of photon propagation in the atmosphere
- Objectives:
  - Determination of best nanosatellite configuration for TGF study
  - Find a method to determine tilt angle, opening angle, and other TGF characteristics



Preliminary results of a TGF detection with nanosatellite constellation