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Energy spectrum from single TGFs detected by ASIM

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Abstract

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Terrestrial Gamma-ray Flashes (TGFs) are sub milliseconds bursts of high energy photons associated with lightning flashes in thunderstorms. The Atmosphere-Space Interactions Monitor (ASIM), launched in April 2018, is the first space mission specifically designed to detect TGFs. We will mainly focus on data from the High Energy Detector (HED) which is sensitive to photons with energies from 300 keV to > 30 MeV, and include data from the Low Energy Detector (LED) sensitive in 50 keV to 370 keV energy range. Both HED and LED are part of the Modular X- and Gamma-ray Sensor (MXGS) of ASIM.

The energy spectrum of TGFs, together with Monte Carlo simulations, can provide information on the production altitude and beaming geometry of TGFs. Constraints have already been set on the production altitude and beaming geometry using other spacecraft and radio measurements. Some of these studies are based on cumulative spectra of a large number of TGFs (e.g. [1]), which smooth out individual variability. The spectral analysis of individual TGFs has been carried out up to now for Fermi TGFs only, showing spectral diversity [2]. Crucial key factors for individual TGF spectral analysis are a large number of counts, an energy range extended to several tens of MeV, a good energy calibration as well as knowledge and control of any instrumental effects affecting the measurements.

We strive to put stricter constraints on the production altitude and beaming geometry, by comparing Monte Carlo simulations to energy spectra from single ASIM TGFs. We will present the dataset and method, including the correction for instrumental effects, and preliminary results on individual TGFs.

Thanks to ASIM's large effective area and low orbital altitude, single TGFs detected by ASIM have much more count statistics than observations from other spacecrafts capable of detecting TGFs. ASIM has detected over 550 TGFs up to date (January 2020), and ~115 have more than 100 counts. This allows for a large sample for individual spectral analysis.

The ASIM mission

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- The Atmosphere-Space Interactions Monitor (ASIM) was launched in April 2018
- ASIM is mounted on the Columbus module on ISS
- The first space instrument specifically designed for TGF detection
- ASIM has detected over 650 TGFs up to date (April 2020)

- **Modular X- and Gamma-ray Sensor (MXGS)**
  - Imaging and spectral X- and Gamma-ray instrument
  - High Energy Detector (HED)
    - 12 Bismuth-Germanium-Oxide (BGO) detector bars, each coupled to a photomultiplier tube
    - Energy range: 300 keV to >30 MeV
  - Low Energy Detector (LED)
    - Energy range: 50 to 370 keV

- **Modular Multispectral Imaging Array (MMIA)**
  - Two cameras and three high-speed photometers for detection of lightning activity and Transient Luminous Events (TLE)

Motivation

- The motivation for this work is to compare measurements with modelling and set further constrains on production altitude and beaming geometries of TGFs

Method

- We will select a sample of TGFs suitable for spectral analysis by the following criteria:
    - Lightning match to find production location
    - Large count statistics (more than 100 counts)
    - Low flux

Method

Data

Correct for instrumental effects → Convert channel to keV

Compare

Forward modeling

- Source spectrum (keV)
- Propagated through atmosphere from location and altitude

→

- Apply ASIM mass model to spectra

Preliminary results on a single TGF

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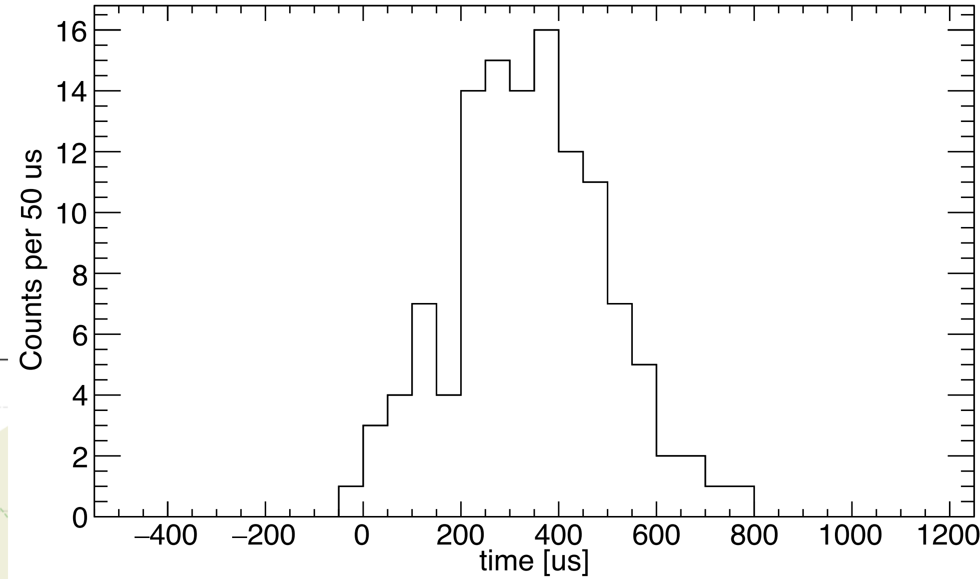
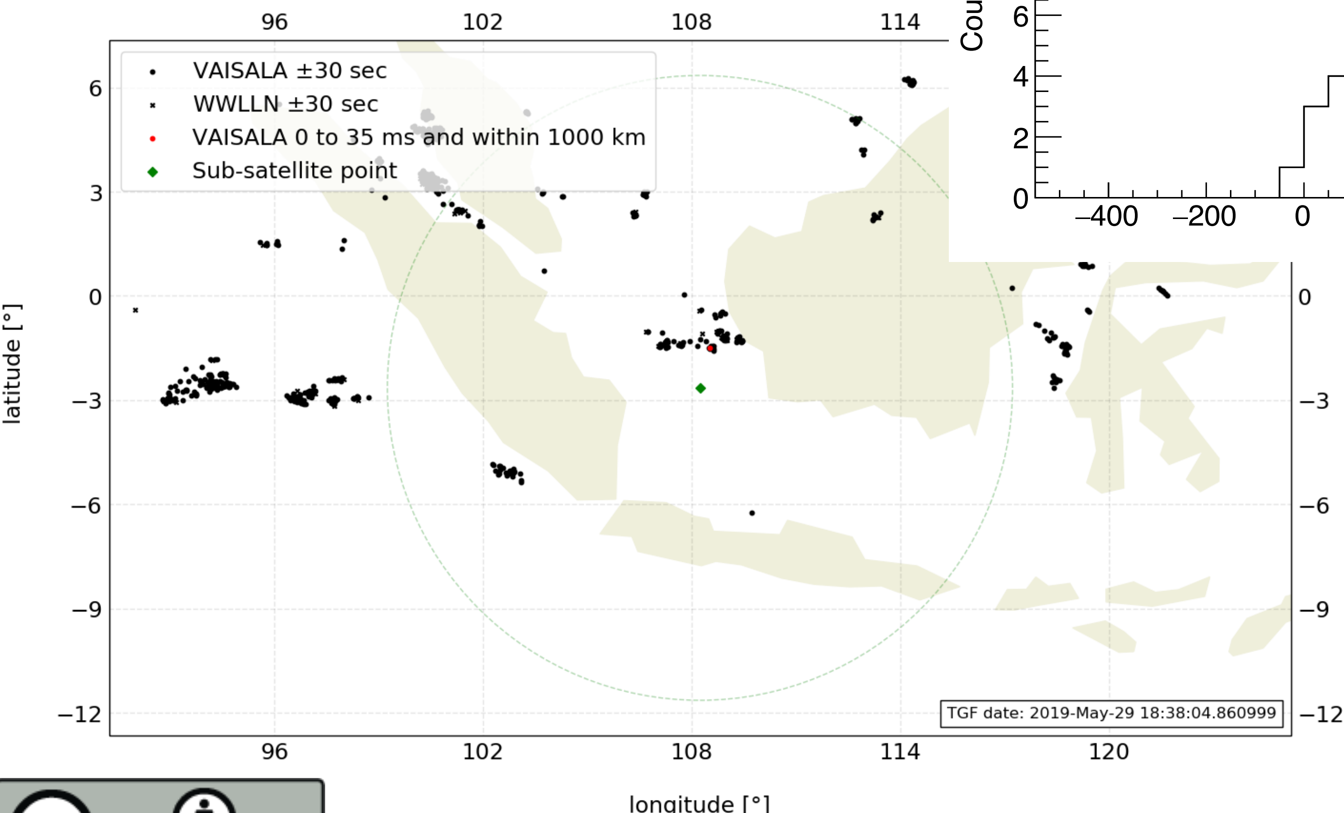
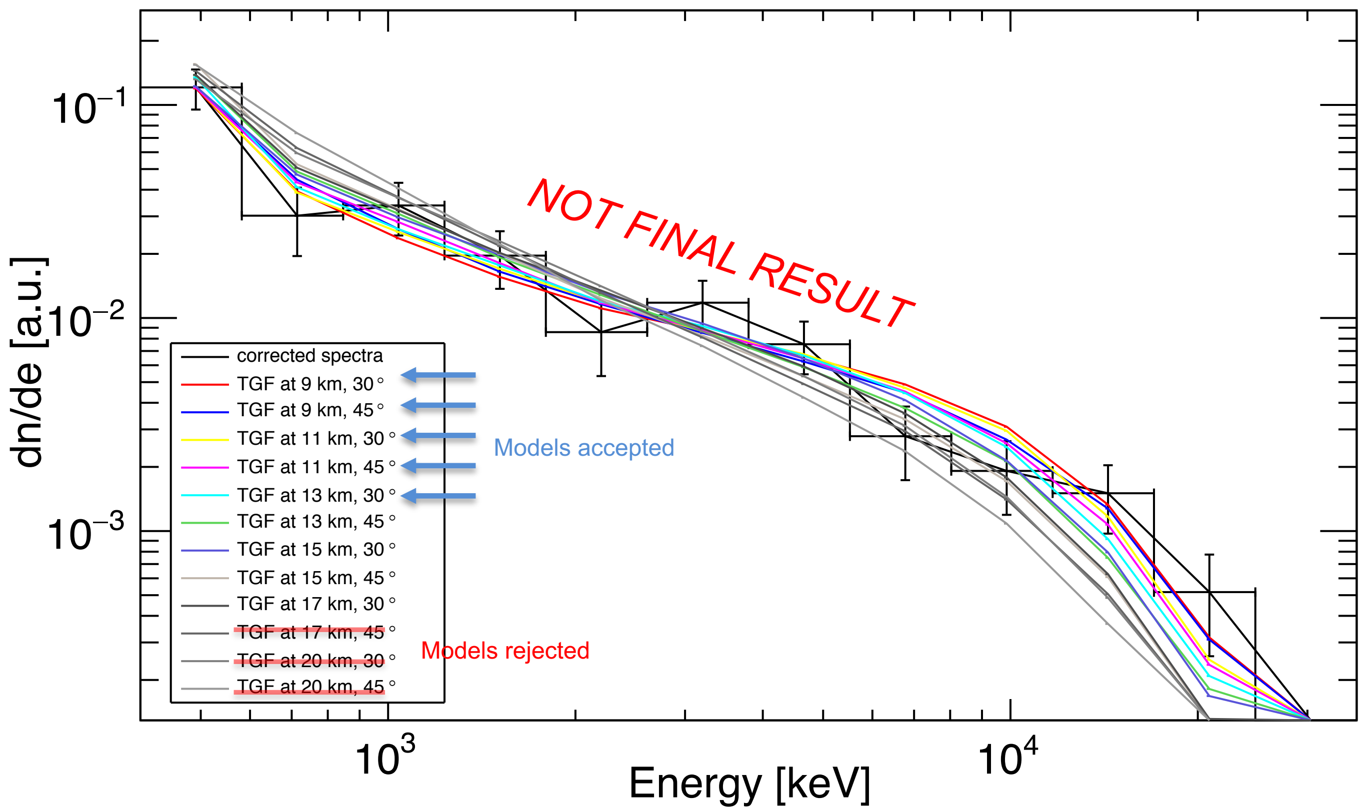
- Date: 2019-May-29 18:38:04.860999
- 119 HED counts used to build spectrum
- VAISALA match
  - 132 km from sub-satellite point (18° off nadir angle)





Preliminary results on a single TGF

- Statistical analysis comparing the measured spectra to simulations shows that some models can be rejected, some models are accepted and some models are inconclusive.



Conclusions and future work

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- A full workflow is implemented:
    - Processing of observed data
    - Modeling TGF spectra including propagation through the atmosphere, the ASIM mass model, and instrumental effects

- LED data can be included in analysis when data are available

- We have started the modelling of several TGFs suitable for spectral analysis and more TGFs are waiting for data processing.

References and acknowledgements

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