Monitoring Gamma-Ray Burst VHE emission with the Southern Wide-field-of-view Gamma-ray Observatory

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ABSTRACT: It is now well established that Gamma-Ray Bursts (GRB) can produce Very High Energy radiation (E > 100 GeV). We expect that next-generation instruments, such as the Cherenkov Telescope Array (CTA), will be able to observe them in detail. However, constraints on the target visibility and the limited duty cycle of Imaging Atmospheric Cherenkov Telescopes (IACT) reduce their ability to react promptly to transient events and to characterise their general properties. Here we show that an instrument based on the Extensive Air Shower (EAS) array concept, proposed by the Southern Wide Field-of-view Gamma-ray Observatory (SWGO) Collaboration, has promising possibilities to detect and track VHE emission from GRBs. Observations made by the *Fermi* Large Area Telescope (*Fermi*-LAT) identified some events with a distinct spectral component, extending above 1 GeV or even 10 GeV, which can represent a substantial fraction of the emitted energy and also arise in early stages of the process. Using models based on these properties, we estimate the possibilities that a wide field of view and large effective area ground-based monitoring facility has to probe VHE emission from GRBs.

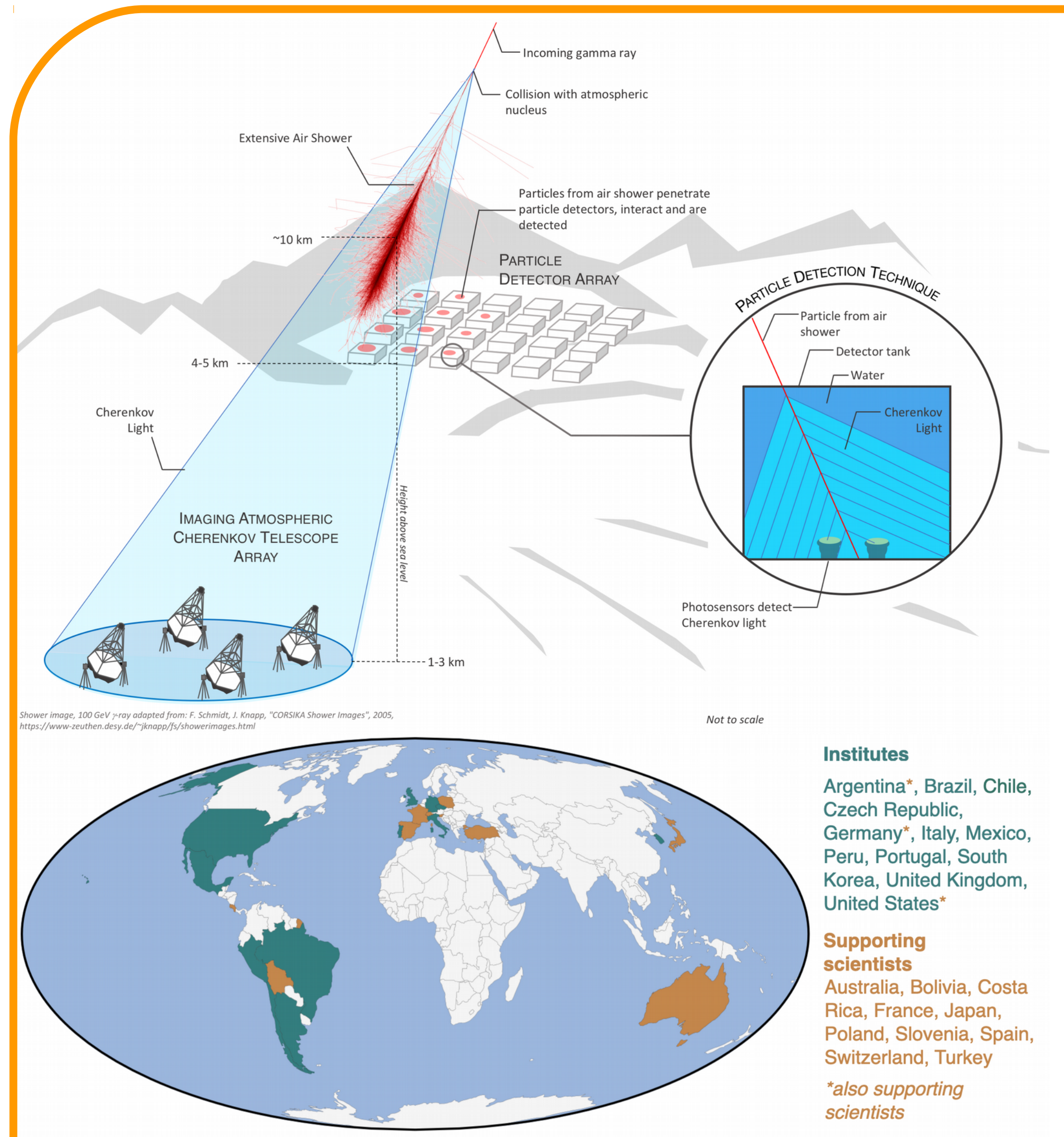

Fig. 1: Schematic representation of γ-ray observations with WCD based EAS arrays and IACT observatories (top). The SWGO collaboration country map (bottom)

Context

The detection of GRBs in the VHE domain [1,2] and in coincidence with Gravitational Waves [3] opened a path that will likely drive the development of High Energy and Multi-Messenger Astrophysics. Since GRBs are produced by ultra-relativistic shocks of highly magnetized material, which is accelerted in the rapid accretion that occurs on a newly formed *magnetar* or black hole, after the collapse of a very massive star or the merger of a binary compact stellar remnant, VHE emission is predicted by several theories and its observation will be crucial to test the most accurate models. During its monitoring campaign, *Fermi*-LAT detected an energetic spectral component, extending above 10 GeV and, sometimes, arising within few seconds from the burst onset. The detection of more energetic photons, with *E* > 100 GeV, however, requires large collecting areas, such as those offered by IACTs and Water Cherenkov Detector (WCD) based arrays (Fig. 1).

While IACTs are effective in executing follow-up studies, their limited field of view and low duty cycle affects their chances to observe GRBs from their earliest stages. In this contribution, we use the data of the 2nd *Fermi*-LAT GRB Catalog (2FLGC) [4] to estimate the expected VHE fluxes in different scenarios. We show that SWGO can open an unprecedented window on GRB early emission and provide, in combination with LHAASO, an effective alert system, if able to operate in the sub-Tev domain.

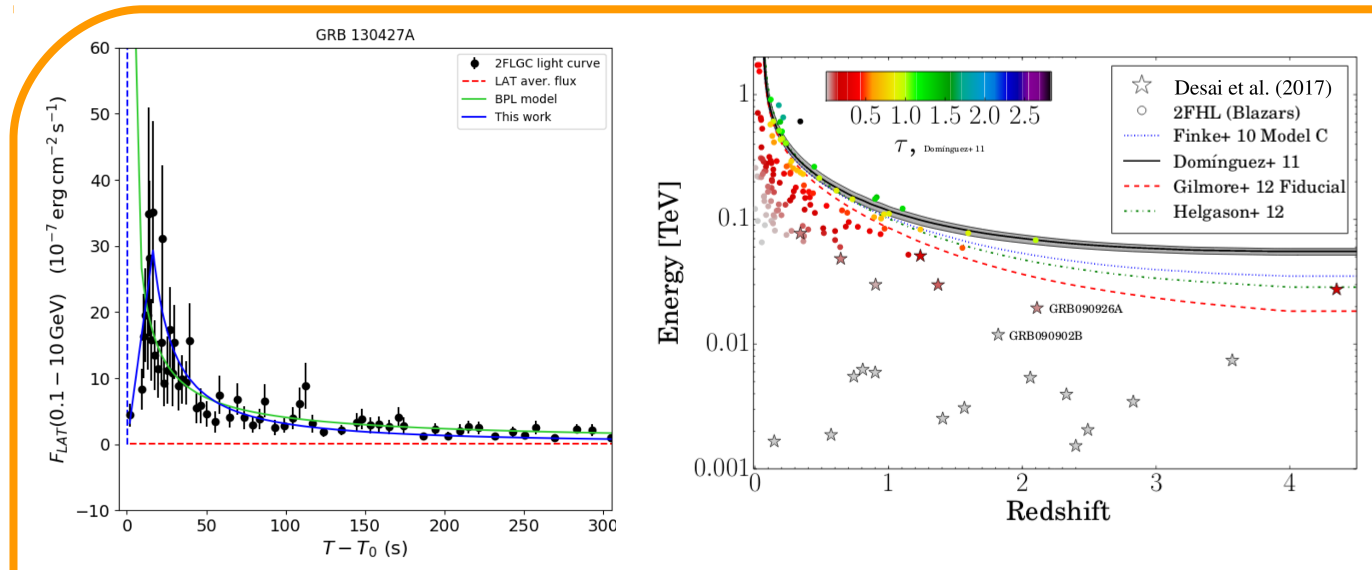

Fig. 2: HE light curve of GRB 130427A, as seen by *Fermi*-LAT in the 0,1-10GeV range (left). EBL opacity as a function of E and z (plot from [5], right)

Methodology

We use 2FLGC data to extract spectral and temporal information on the HE properties of the bursts detected by *Fermi*-LAT in 10 years (Fig. 2).

Applying different redshift models, to account for EBL opacity effects [6], we can extrapolate the spectra to the VHE domain. The approach can be considered conservative, because of lack of reliable measurments on the early time emission and due to the evidence of VHE radiation exceeding the LAT extrapolation in some events [1,7].

Results

Combining the properties of obsevrved and modelled GRBs, it can be estimated that an integrated sensitivity limit of:

$F_{lim} \approx 5 \times 10^{-9}$ ph cm^{-2} s^{-1}

in approximately 1000s of observation can detect 10% of the brightest LAT GRBs (Fig. 3). If SWGO and LHAASO [r] can observe the sub-TeV window, their total FoV would cover nearly the whole sky (Fig. 4)

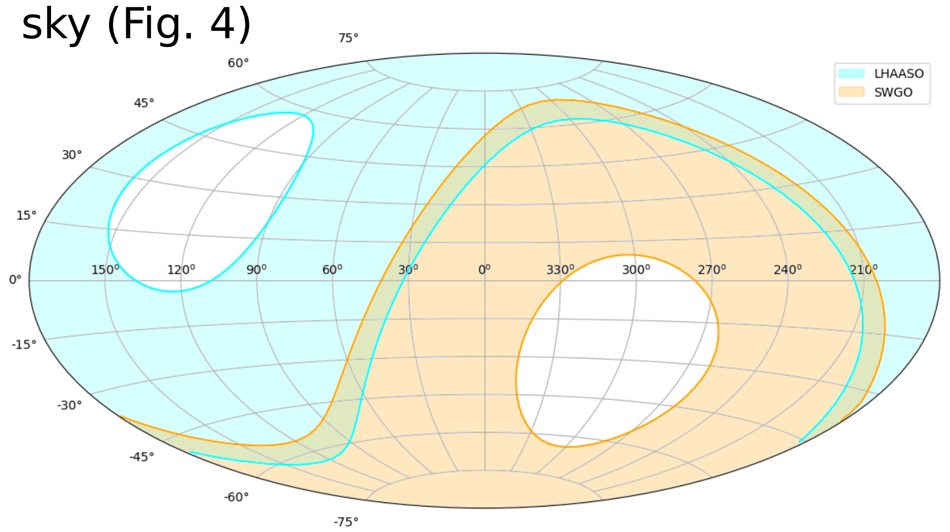

Fig. 4: Expected sky coverage from the combined FoV of SWGO (orange shading) and LHAASO (cyan shading)

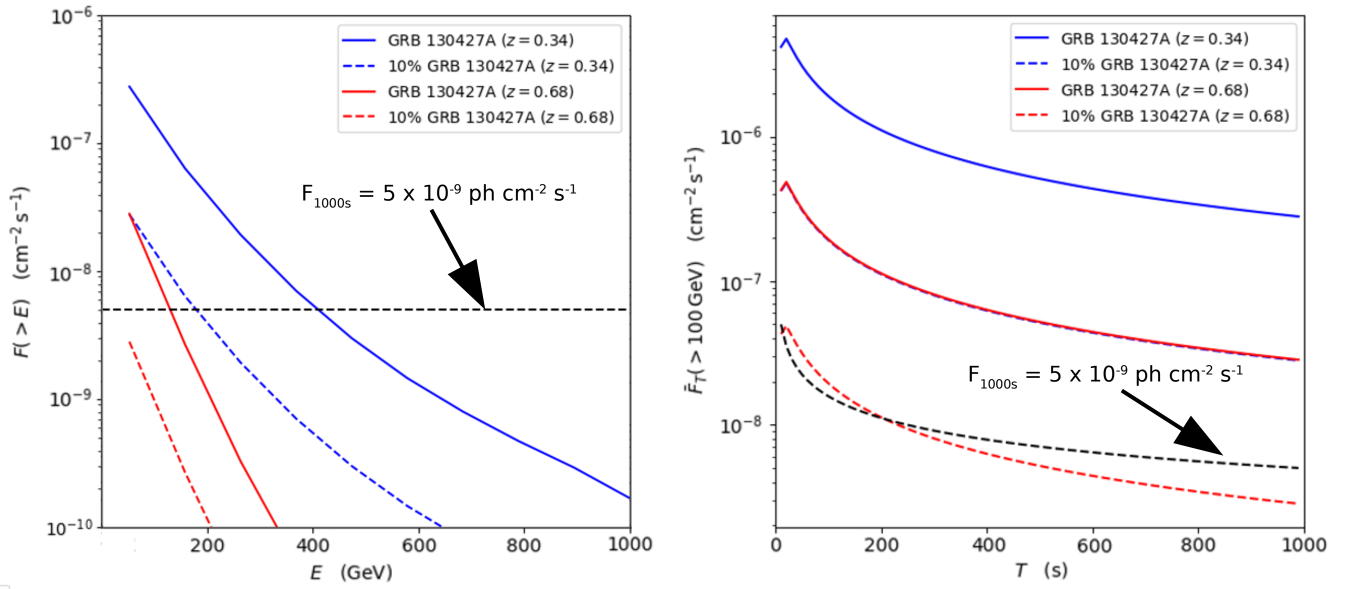

Fig. 3: Average integrated VHE photon flux vs. E in 1000s (left) and instantaneous flux vs. Time (right) for different GRB models.

References

[1] MAGIC Collaboration 2019, *Nature*, 575, 455
[2] Abdalla et al. 2019, *Nature*, 575, 464
[3] Abbott B. P., et al. 2016, *Phys.Rev.Lett.*, 116, id.061102
[4] Ajello M., et al. 2019, *ApJ*, 878, 52
[5] Desai A., et al. 2017, *ApJ*, 850, 73
[6] Domínguez A., et al. 2011, *MNRAS*, 410, 2556
[7] Acciari V. A., et al. 2021, *ApJ*, 908, 90

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