



Upper limits on the very high energy emission from GRBs observed by MAGIC

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The MAGIC collaboration has developed a dedicated observational strategy to report rapidly towards gamma-ray bursts (GRBs). In this contribution we present the information extracted from the large sample of the GRBs observed by MAGIC from 2013 to 2019. None of these GRBs were significantly detected, and this study aims to shed light on the reasons behind those non-detections. The same strategy had led to the successful detection of two GRBs at Very High Energies (VHE, $E > 100$ GeV). We describe the details of the MAGIC GRB observational procedure and the general properties for each observed GRB. The lack of detection can be attributed either to unfavourable conditions or GRB intrinsic properties, such as the magnetic field's energy density, the bulk Lorentz factor, or the emitting region's size. For the presented sample of GRBs, we show the methods used to obtain flux upper limits in the VHE range, and propose physical implications of the non-detection of VHE emission. These results constitute an essential reference point to study the broadband emission of GRBs, and for the Cherenkov telescope community to organize future follow-ups of GRBs at VHE energies.

Detection of VHE emission from gamma ray bursts has been one of key scientific goals of Cherenkov telescopes for decades (see e.g. [1]). The search for VHE GRBs has been one of the most difficult challenges for all very high energy telescopes, given the cosmological nature and the random occurrence of these sources on the sky.

This research required the development of alert systems and analysis methods optimized for non-standard observing conditions to avoid losing the few opportunities for revealing the most interesting events ([2, 3]).

The MAGIC telescopes are designed to perform fast follow-up of GRBs

- Very light carbon fiber structure \rightarrow slewing speed of $7^\circ/\text{s}$
- Low energy threshold (~ 50 GeV at zenith, ~ 30 GeV with SumTrigger).
- High sensitivity at low energies \rightarrow detection of transient emission in short time scales.
- MAGIC's field of view of $3.5^\circ \rightarrow$ Need external triggers in order to perform GRB follow-up.
- Development of automatic alert system (AAS) to receive GRB alerts from the Gamma-ray Coordinates Network (GCN), validate them and check if the target is visible from the MAGIC site

Automated procedure: updated in 2013:

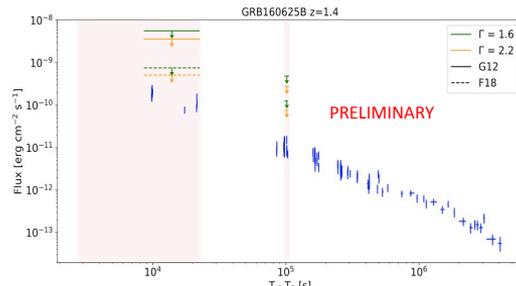
- Wobble pointing used during GRB follow-up
- Data acquisition system not stopped but only reconfigured during the automatic procedure

This study uses GRBs observed (but not detected) by MAGIC from the upgrade in 2013 to December 2019 (see figure 1).

- 41 GRBs were analyzed.
- Excluded GRBs observed with bad weather conditions (low atmospheric transmission, high humidity or strong winds), or just by one telescope or with strong moonlight

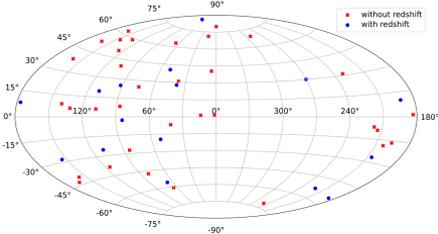
Fig. 2

- Analyses of GRBs done with MAGIC standard software package MARS [4].
- GRBs observed in different observational conditions (moderate moonlight [5] or not optimal weather conditions [6]).
- Upper Limits (ULs) on the deabsorbed photon flux emitted in the VHE domain calculated with the method of Rolke et al. [7] with a 95% Confidence Level (CL) and a total systematic uncertainty of 30%.
- The deabsorbed differential photon spectrum modeled with a power law (assuming photon index of 1.6 and 2.2 \sim asymptotic behaviours expected in the SSC spectrum).
- Two different models for the estimation of the Extragalactic Background Light (EBL) absorption Franceschini et al. [8](F18), and Gilmore et al. [9] (G12).
- For a subsample of GRBs with a good X-ray coverage contemporaneous to the MAGIC observation window, we provided a comparison between the estimated MAGIC ULs and the soft X-ray flux, as shown in figure 2.



VHE ULs overlaid to SWIFT/XRT X-ray light curve. In pink the MAGIC observation window

Fig. 1



References

- [1] Connaughton V., et al., 1997, *Apl*, 479, 859. [2] Berti A., et al., 2019, *ICRC*, 36, 633 [3] Berti A., et al., 2019, arXiv:0907.0043 [5] Ahnen M. L., et al., 2017, *Aph*, 94, 29 [6] Fruck C., Gaug M., 2015, *EPJWC*, 89, 0200 [7] Rolke W. A., López A. M., Conrad J., 2005, *NIMPA*, 551, 493 [8] Franceschini A., Rodighiero G., 2018, *A&A*, 614, C1 [9] Gilmore R. C., et al. 2012, *MNRAS*, 422, 3189