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MAGIC upper limits on the Very High Energy emission from GRBs

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Abstract

Since the beginning of its operation in April 2005, the MAGIC telescope was able to observe ten different GRB events since their early emission phase. In the case of two bursts, observation started even while the prompt emission was still ongoing. Observations, with energy thresholds spanning between 80 and 300 GeV, did not reveal any γ-ray emission. Computed upper limits are compatible with a power law extrapolation, where intrinsic fluxes are evaluated taking into account the attenuation due to the scattering in the Metagalactic Radiation Field (MRF). We present a direct determination of the MAGIC sensitivity in "GRB mode" and the upper limits for the ten follow-up observations. At energies around 100 GeV, MAGIC is currently the fastest and most sensitive operational GRB detector in the world.

Introduction

The very upper end of GRB spectra has not yet been measured beyond 20 GeV, but there few hints for VHE emission, such as the observation by EGRET of the delayed GeV emission in GRB940217 [1] and the delayed second high-energy component of GRB941017 with spectral index $\beta = -1$ [2]. Observation in the VHE range can discriminate among the many competing emission models but, up to now, only upper limits on VHE emission are available. The situation is hopefully going to improve in the near future, with a detector like MAGIC that can combine a low threshold with fast reaction times.

MAGIC, with its 17 m ∅, is currently the largest Imaging Air Cherenkov Telescope (IACT) [3] and was purposefully built to explore the γ-ray sky at energies starting well below 100 GeV. Moreover, the telescope structure, consisting mainly of light carbon fiber tubes and aluminum knots to reduce weight and inertia, allows MAGIC to slew to any position in the sky in less than 100 s and, on average, within 40 s.

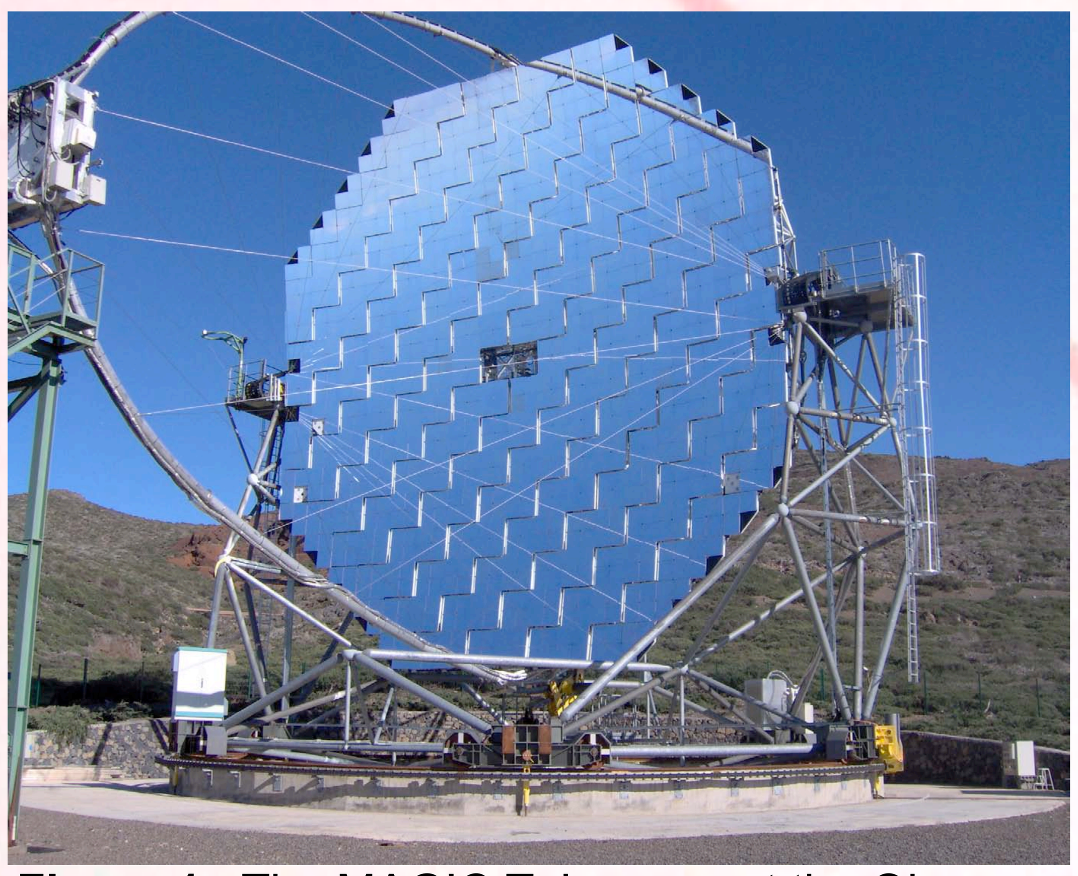

Figure 1: The MAGIC Telescope at the Observatorio del Roque de Los Muchachos, La Palma.

GRBs observed by MAGIC

MAGIC has an automatic alert system connected to the GCN that is active since July 15th 2004. Since then, about 200 GRBs were detected by HETE-2, INTEGRAL and SWIFT, and ~100 had their coordinates promptly broadcast by the GCN. Delays from the onset of the burst were of the order of several se-conds to tens of minutes ($\Delta t_{\mathrm{alert}}$). Since April 2005, MAGIC reacted to 9 Swift GRBs and one HETE burst (GRB060121) being able to observe the GRB location within few minutes. The observation of GRB050713a and GRB050904 started while their prompt emission phase (duration: T_{90}) was still

GRB name	GRB onset [UT]	$\Delta t_{\mathrm{alert}}$ [s]	Δt_{obs} [s]	T_{90} [s]	<ZA>	est. E_{th} [GeV]	Redshift z
GRB050421	04:11:52	58	108	10	50°	290	-
GRB050502	02:14:18	18	277	20	42°	190	3.8
GRB050505	23:22:21	540	717	60	55°	400	4.3
GRB050509a	01:46:29	16	131	12	50°	290	-
GRB050713a	04:29:02	13	40	70	49°	270	(0.4-2.6)
GRB050904	01:51:44	82	145	225	20°	95	6.3
GRB060121	22:24:54	15	583	2	42°	190	
GRB060203	23:55:35	171	268	83	44°	210	
GRB060206	04:46:53	16	59	11	10°	85	
GRB060825	02:59:58	21	55	8	15°	90	

Table 1: Δt_{obs}: delay before the acquisition started. E_{th}, the energy threshold, depends strongly upon the average zenith angle <*ZA*> of collected data.

Sensitivity of MAGIC in GRB-mode

On October 11th 2005, MAGIC received a GRB-alert (GRB051011-02) from INTEGRAL [4], but the satellite had been actually triggered by the Crab Nebula, the standard source at VHE energies. This allowed a **blind test** of MAGIC performance, as it observed for 2814 s the well-known source. While on "**GRB mode**", the sensitivity of the telescope was somewhat worse than during the standard data acquisition, having the following 5σ-detection fluxes:

1 min: 5.8 Crab Units between 80 and 350 GeV
1 min: 1.8 Crab Units between 350 GeV and 1 TeV
30 min: 1.1 Crab Units between 80 GeV and 350 TeV
30 min: 0.34 Crab Units between 350 GeV and 1 TeV

Flux upper limits on observed GRBs

No significant excess was seen in any of the observed bursts, and upper limits on the fluence were calculated for 0.5 hour of acquisition. For GRB050713a and GRB050904, upper limits are also provided for the prompt emission phase

GRB name	Lower energy bins [GeV]	Fluence upper limit [10^{-8} erg·cm^{-2}]	Fluence upper limit [Crab Units]	Observation time [s]
GRB050421	225-300	1.8	0.1	1800
	300-400	1.6	0.1	
GRB050502	175-225	35	1.7	1800
	225-300	14	0.8	
GRB050505	400-1000	1.0	0.1	1800
GRB050509a	225-300	21	1.2	1800
	300-400	33	2.2	
GRB050713a	200-500	5.9	0.4	1800
	200-500	3.4	4.1	90
GRB050904	80-175	7.7	0.3	1800
	80-175	1.0	0.5	133
GRB060121	175-225	3.4	1.1	1800
	225-300	6.1	0.4	
GRB060203	175-225	5.1	0.3	1800
	225-300	4.2	0.3	
GRB060206	80-125	5.0	0.2	1800
	125-175	0.7	0.3	
GRB060825	80-125	preliminary	0.7	1800
	125-175		1.0	

Table 2: 95% CL upper limits for the observed GRBs in the lower energy bins. For GRB050713a and GRB050904, the limits are also computed for the early emission phase. Limits are set according to the prescription in Rolke et al. [5], adding a global systematic uncertainty of 30% in the sensitivity estimate.

The case of GRB050713a and GRB050904

MAGIC started acquiring data on GRB050713a only 40 s after the burst [6]. **GRB050713a** was a bright burst of duration T_{90} = 70 s and fluence of 9.1×10^{-6} erg·cm^{-2} in the 15-350 keV band. No significant excess is observed by MAGIC The observation of **GRB050904** began after 92 s (burst duration T_{90} = 225 s). It had a fluence of 5.4×10^{6} erg·cm^{-2} in the BAT band (15-350 keV), but, as expected from its large redshift (z = 6.29) [7], no signal is seen by MAGIC.

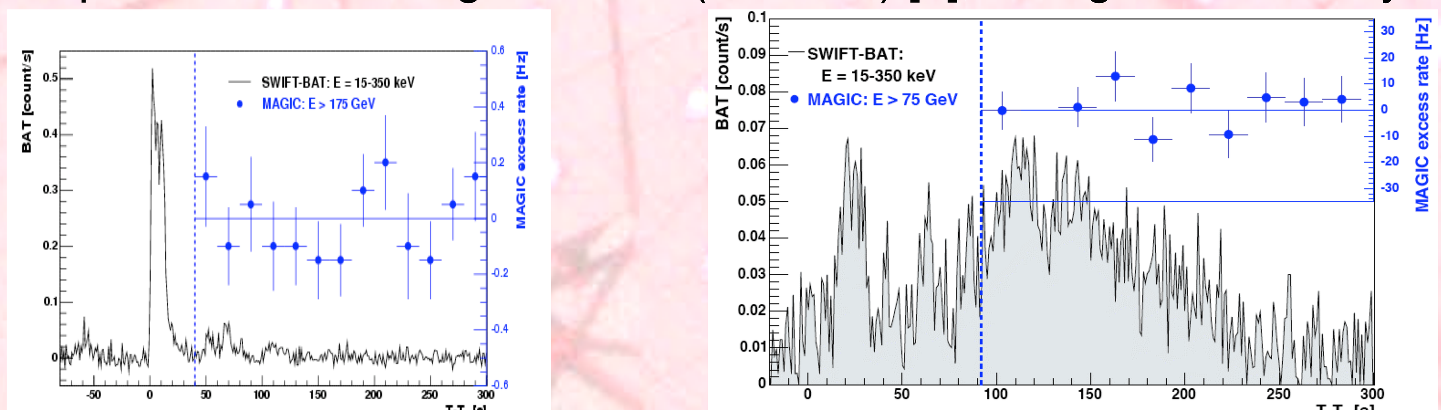

Figure 2: Emission profiles of GRB050713a (left) and GRB050904 (right) by BAT (15÷350 keV) and the event rate of MAGIC, after cuts, in 20 s time bins.

Conclusions

MAGIC was able to observe part of the prompt and the early afterglow emission phase of many GRBs as a response to the alert system provided by the GCN. It was also proven that, while in **GRB mode**, MAGIC can easily detect in 90 s sources at Crab level. Moreover, compared with the other Cherenkov facilities, MAGIC has the lowest energy threshold and can slew faster. For these reasons, MAGIC is currently the best GLAST partner at VHE for prompt GRB observations. In the next future, with the construction of a second telescope, enhancing MAGIC sensitivity, the situation is going to improve, but what is really needed for prompt GRB observation at VHE is a nearer GRB.

References

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[6] Albert, J. et al., "Flux UL of γ-ray emission by GRB050713a from MAGIC observations", ApJ 641, L9 (2006) and refs therein.
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