

The MAGIC Telescope - prospects for GRB research

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Abstract. The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) Telescope collaboration is constructing a large Cherenkov telescope (17 m diameter) for the exploration of the gamma-ray energy regime above 10 GeV with high sensitivity. One of the highlights in the science program of this future observatory are the plans for fast follow-up observations of GRBs. By “fast” we mean delays of less than 30 s between notification and the beginning of observations. The expected gamma counting rates are of the order of 100 Hz for a EGRET counting rate of 0.1 Hz above 100 MeV and a spectral index of 2.0 (this would correspond to a fluence of 10^{-5} erg cm⁻² for 60 s burst duration).

The good photon statistics will permit determination of spectra, search for cutoffs and measurement of light-curves with a time resolution of the order of 1 s.

Key words: gamma-rays: bursts — gamma-rays: observations

1. Introduction

The Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) Telescope will be a large imaging air Cherenkov

telescope for ground-based γ -ray observations above 10 GeV. Details of its design, the scientific motivation, the feasibility of the project, and other issues have been described elsewhere (Barrio et al. 1998). The telescope is expected to become operational by the middle of 2001.

The telescope is optimised to achieve the lowest energy threshold and highest flux sensitivity achievable with present technology. This makes it applicable to a large range of astrophysical research fields:

- Blazars (study of EGRET blazars, possible discovery of additional sources).
- Cosmology (measurements of the near-infrared background via γ - γ absorption).
- Investigation of the pulsed γ -ray emission from pulsars.
- Search for gamma-emission from Supernova remnants. (and hence search for evidence of production and acceleration of cosmic rays).
- Search for decay/annihilation line-emission from WIMPs clustering at the galactic centre.
- Identification of “unidentified EGRET sources” (position accuracy $\approx 1.2'$).
- Search for high-energy counterparts of gamma-ray bursts.

The last part of this scientific program will briefly be discussed in this article.

2. Fast follow-up observations

In order to make fast follow-up observations of GRBs possible, the MAGIC Telescope will have an interface (probably a socket connection) to the GRB Coordinate Network GCN (Barthelmy et al. 1994 and these proceedings) and a secondary ground station for direct communication with HETE II (Ricker et al., these proceedings). HETE II is a dedicated GRB research satellite which is expected to be launched in 2000. It will provide approx. 30 burst positions per year with accuracies better than 10 arcmin. These notifications are expected to arrive with a delay of less than 5 s. The MAGIC Telescope is specially designed to have

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low inertia such that the telescope can be positioned on any point in the sky within less than 30 s.

In case of a notification, a fast check of the observability of the GRB location will be performed. If the decision is positive, the present observations will be stopped immediately and a special fast drive will position the telescope on the GRB which will then be observed for the remaining night-time and probably also the following night in order to detect possible delayed emission.

Taking into account a decision time of 5 s at our site, we expect the reaction time between the actual start of the burst and the start of the follow-up observation to be 30 ± 10 s. The MAGIC Telescope will thus be able to perform observations of non-delayed emission of all bursts with durations above 30 s. This is the position of the right-most peak in the BATSE burst duration (T_{90}) distribution (see e.g. Kouveliotou et al. 1995) and corresponds to a fraction $\approx 33\%$ of all bursts which trigger BATSE on the 64 ms time scale.

The telescope will be built on the Canary Islands (Tenerife or La Palma). Cherenkov telescopes can only observe during the night. Observations will be possible up to zenith angles of $\approx 80^\circ$, i.e. about 40% of the total sky (4π) will be accessible. Assuming 30% of the nights to have bad weather and taking into account that the presence of the moon can prevent observations of certain positions, we arrive at a duty cycle of $\approx 10\%$.

The effective field of view of the photo-sensor camera of the MAGIC Telescope is 1.6° in diameter. We will therefore be able to safely observe any of the positions provided by HETE II and also some from the GCN and expect ≈ 5 serious immediate follow-up observations per year. For delayed emission (time-window of the order of an hour up to several days) this number will be larger.

3. Expected performance

The expected performance in terms of sensitivity is summarised in Fig. 1. This is the performance we expect for the second phase of the project in which high quantum efficiency hybrid photo sensors will replace the photo-multipliers of the telescope's camera. In the first phase our threshold will be ≈ 30 GeV, in the second phase 10 GeV. It is not yet clear how soon the second phase will follow the first. The sensitivity at energies > 30 GeV is to a good approximation independent of these changes.

Given the diverse shape of GRB light-curves it is difficult to predict an average counting rate for gamma-rays in successful burst observations. We note instead that the MAGIC Telescope will have an effective collection area for primary gamma photons of 10^8 cm² at the threshold rising to 10^9 cm² at 100 GeV. For a hypothetical counting rate of 0.1 Hz for EGRET above 100 MeV, we expect (assuming a spectral index of 2.0) a counting rate of ≈ 100 Hz above 10 GeV. A rate of ≈ 6 Hz for 30 s will suffice for a 5σ detection with a moderate background rejection applied. For

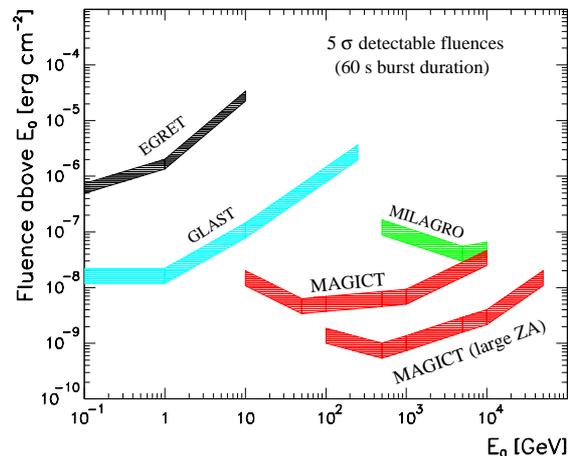


Fig. 1. The fluence sensitivity of the MAGIC Telescope (MAGICT) compared to other experiments (MAGICT refers to observations at zenith angles up to $\approx 30^\circ$, “MAGICT large ZA” to those at $\approx 70^\circ$). The fluence sensitivity at threshold E_0 is defined here as the total fluence above E_0 which is necessary for a 5σ detection of the burst above that threshold. A total burst duration of 60 s and a differential spectral index of 2.6 is assumed. For MAGICT the actual observation time is assumed to be only 30 s taking into account the reaction time. For all other detectors the observation time is assumed to be equal to the burst duration

strong bursts such as GRB 930131, gamma counting rates of the order of 1 kHz may occur. The data acquisition will therefore be prepared to sustain such rates without additional dead-time.

4. Conclusions

The MAGIC Telescope will be able to make a major contribution to GRB research by providing high sensitivity measurements in the (for GRBs) essentially unexplored regime above 10 GeV. The high counting rates in strong bursts will also permit to study the shape of the light-curve in more detail than previously possible (time resolutions of the order of 1 s). Search for small delays with respect to the low energy emission is thus possible. As an interesting side-result this may provide one of the best possible lower limits to the quantum gravity energy scale as pointed out by Amelino-Camelia et al. (1998).

References

- Amelino-Camelia G., et al., 1998, Nat 393, 763
- Barrio J.A., et al., 1998, The MAGIC Telescope design report, Max-Planck-Institut für Physik, Munich, report MPI-PhE/98-5
- Barthelmy S.D., et al., 1994, in “Proceedings of the Second Huntsville Workshop”, Fishman G., Brainerd J., Hurley K. (eds.), AIP 307, 643
- Kouveliotou C., et al., 1995, in “Proceedings of the Second Huntsville Workshop”, Kouveliotou C., Briggs M.S., Fishman G. (eds.), AIP 384, 42