Status, First Results and Prospects for MAGIC

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Abstract. MAGIC is the world-largest Imaging Air Cherenkov Telescope (IACT) for Very High Energy (VHE) γ-ray astronomy and operates in the range from $\sim$50 GeV to $\sim$10 TeV. In this paper we will briefly summarize the status of the project, including the construction of a second (MAGIC-II) telescope, and review the results obtained from the first observations.

1. Introduction: The MAGIC Telescope

MAGIC is a telescope for VHE γ-ray observation by exploiting the Imaging Air Cherenkov technique. It has been built on the Roque de los Muchachos Observatory, in La Palma (Spain) between 2001 and 2003. After one year commissioning the apparatus, the first observation cycle started in fall 2004. MAGIC incorporates a number of technological improvements with respect to previous generations of telescopes, and yields the lowest energy threshold ($\sim$50 GeV) of currently existing IACTs.

MAGIC has a 17 m tessellated mirror, of a parabolic shape to preserve the time structure of the Cherenkov flashes –hence maximizing the signal-to-noise ratio with respect to the Night Sky Background light–, and a reflectivity of about 80%. The mirror is mounted on a light weight space frame (8 tons) composed of carbon fiber tubes, allowing an arbitrary repositioning of the telescope in less than 60 s. The focusing of the mirrors is corrected for mechanical deformations of the frame at different positions using an "Active Mirror Control". Thanks to this system, the RMS of the Point Spread Function is less than 0.1°.

The camera comprises 397 (180) hemispherical, low gain photomultiplier tubes (PMTs) of 0.1° (0.2°) diameter each, for the inner (outer) field-of view (FOV), thus covering a total FOV of 3.5° diameter. The PMT quantum efficiency (QE) has been enhanced to 30% and extended to the UV by a diffuse, wavelength shifter doped lacquer coating of the window [1]. The PMT signals are amplified at the camera, converted back into optical signals by Vertical Cavity Emitting Lasers and transmitted over 162 m long optical fibers to the 82 m away counting house. This reduces drastically the weight and size of the cables and protects the signals from electromagnetic pick-up. The analog signals are finally digitized by dual range, 8 bit, 300 MHz Flash ADCs. MAGIC is equipped with a two-level trigger system with programmable logic [2]. The first level requires a four-fold next neighbour coincidence within a 5 ns window while the second level imposes topological constraints on the event images.

A low energy threshold is very important because of the past observational gap (10-300 GeV) between the satellite-borne detectors and ground-based telescopes. Among other reasons, a low threshold will allow the study of the spectral cut-off of many EGRET sources not detected yet at VHE, the search for VHE pulsed emission from pulsars, the detection of high-z active galactic nuclei (AGNs) and, in combination with the fast repositioning, the observation of the prompt emission of gamma ray bursts (GRBs).

2. Observations and Results

The performance of the telescope has been experimentally evaluated and found in good agreement with the expectations and Monte Carlo simulations. For the time being we are routinely performing analyses above 100 GeV, where the performance of our instrument is fully understood. Since fall 2004 the first MAGIC telescope is regularly collecting data from a long list of astrophysical objects. Four galactic and four extra-galactic objects have been seen so far by MAGIC, one of which is a new discovery.

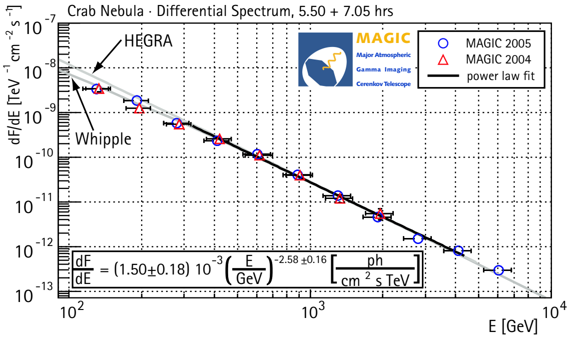

Figure 1. Crab spectrum measured by MAGIC.

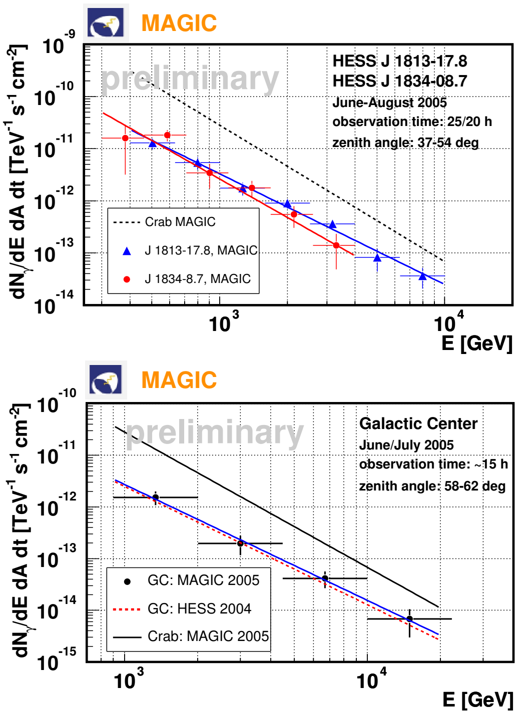

Figure 2. Energy spectra of HESS J1813-178, HESS J1834-08 (top) and Galactic Center (bottom) measured by MAGIC.

The Crab Nebula is a steady emitter at GeV and TeV energies, what makes it into an excellent calibration candle. It was detected by MAGIC soon during the commissioning phase. Since then, a significant amount of time has been devoted to observations of the Crab Nebula, both for technical and astrophysical studies. From the former ones we have evaluated the performance of the telescope [3, 4]. On the other hand, a sample of 12 hours of selected data has been used to measure with high precision the spectrum down to ∼100 GeV, as shown in figure 1 [3]. We have also carried out a search for pulsed γ-ray emission from Crab and two millisecond pulsars [5], albeit without positive result.

Within its program of observation of galactic sources, MAGIC has confirmed the VHE γ-ray emission from the supernova remnants (SNRs) HESS J1813-178 and HESS J1834-08 [6] shortly after their discovery by HESS [7]. Our observations have confirmed SNRs as a well established population of VHE γ-ray emitters. We have also measured the VHE γ-ray flux from the Galactic Center (GC), whose high energy emission has been of very much interest during the last years. The energy spectrum of these three sources measured by MAGIC is shown in figure 2. All spectra are well described by unbroken power laws. In the case of the GC, the result disfavours dark matter annihilation as the main origin of the detected flux. Furthermore, there is no evidence for variability of the flux on hour/day time scales nor on a year scale (by comparison with HESS results obtained one year before). This disfavours the typical variable acceleration observed so far from VHE γ-ray emitting black holes in favour of steady acceleration mechanisms seen in e.g. SNRs.

MAGIC has added a new member to the list of VHE γ-ray emitters: the distant AGN 1ES 1218+304 ($z = 0.182$). This discovery enlarges the so-called γ-horizon at these energies and has allowed to constrain models of the metagalactic radiation field (MRF). This can be done by unfolding the effect of γ-ray absorption by pair production in the MRF from the measured spectrum. Figure 3 shows the measured and intrinsic spectra (assuming an MRF model best-fitted to the deep optical and infrared galaxy surveys [8]) of 1ES1218+304.

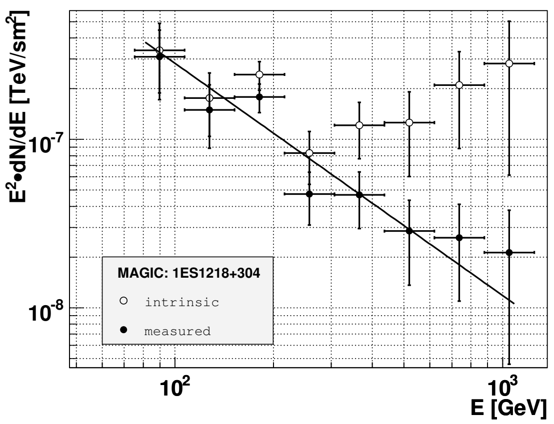

Figure 3. 1ES 1218+304 measured and intrinsic spectra.

In addition, three well-known, extragalactic, variable γ-ray sources have been studied by MAGIC. 1ES 1959+650 was detected in the lowest ever observed emission state and the spectrum could be extended considerably down to $\sim$ 200 GeV [9]. Mrk 501 and Mrk 421 were both observed in a relatively high state of flaring during 2004 and 2005 [10]. On July 1st, Mrk 501 exhibited a particularly intense flare, which is an object of ongoing extensive studies searching for fast flux variations.

MAGIC has observed more than 10 GRBs since April 2004. Of particular interest is GRB050713a, which was observed by MAGIC only 40 s after the detection by the SWIFT satellite. The analysis of the data shows no significant signal above $\sim$ 150 GeV [11].

3. MAGIC-II

In 2007, MAGIC will increase its power by adding of a second telescope, currently under construction at 80 m distance from the existing one. It will be a clone of the current MAGIC, with improved PMTs (new generation PMTs with a QE exceeding 35% or HPDs with a QE of 50% around 500nm [12]) and an ultra-fast readout (2.5 Gsamples/s [13]). Operating the two telescopes in coincidence will allow us to lower the threshold to $\sim$ 30 GeV and improve the sensitivity by a factor 2.

4. Conclusions

Observations with the MAGIC telescope have started in fall 2004. Known sources are confirmed in a few hours of observation time, and new results already emerge from a broad observation program. Many galactic and extragalactic sources are under study, out of which eight have been detected. MAGIC is producing high quality spectra above 100 GeV and has discovered a new –distant– AGN. Moreover, MAGIC has proven its fast steering capability by the observation of a GRB only 40 s after its detection by SWIFT. With the construction of the second MAGIC telescope the threshold will be further reduced and the sensitivity improved.

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