

# Results of the analysis of several galactic sources observed by MAGIC

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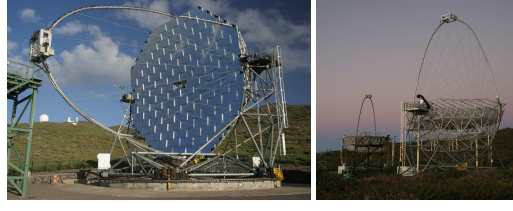
**Abstract** One of the tasks carried out by the Astroparticle Physics Group of the IAC is the analysis of objects observed by the MAGIC telescope looking for very high energy gamma-ray emission. The main goal of these observations is to search for acceleration of cosmic rays sites and the identification of accelerated species. We have analysed MAGIC data of five observed objects, and the results are presented here. These objects are: three Supernova Remnants (IC443, W44, W66), the Globular Cluster M13 and the region of star formation M42. High energy  $\gamma$ -ray emission has been found in one of these objects.

## 1 The MAGIC Telescope

The **MAGIC Experiment** (*Major Atmospheric Gamma Imaging Cherenkov*) is a ground based gamma-ray telescope located in the Roque de los Muchachos Observatory of the IAC <sup>1</sup> (La Palma); (Figure 1). It is a new generation Cherenkov telescope with a trigger threshold of 80 GeV. Its energy detection range extends from 80 GeV to 10 TeV, overlapping with the upper energy threshold of satellites such as EGRET or GLAST. The design of the MAGIC was a technological challenge because the existing technology is taken to the limit [2, 4]. One of its main characteristic is its octagonal parabolic reflector of 17 m of diameter resulting in an area of 240 m<sup>2</sup>, which allows to obtain three times more light than a conventional Cherenkov telescope of 10 m. The MAGIC collaboration is building a second telescope, MAGIC-II, similar to MAGIC with improved technology and located at a eighty five metres of distance (Figure 1), which will be operating in 2009. The operation of both telescopes in stereoscopic mode will allow to improve the spatial resolution and sensitivity of the MAGIC experiment.

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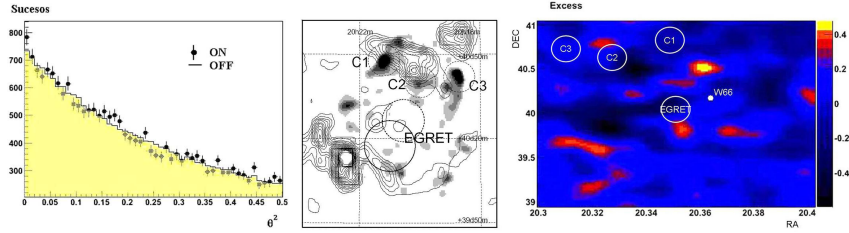
<sup>1</sup> The MAGIC telescope is operated on the island of La Palma by the MAGIC Collaboration in the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias 1



**Fig. 1** (Left) General picture of MAGIC telescope in park position. (Right) Joint image of the two telescopes, with MAGIC-II under construction, located in Roque de los Muchachos Observatory of the IAC (La Palma).

## 2 Supernova Remnants: W44, W66 y IC443

**W44** (G34.7-0.4) is a symmetric supernova remnant of 30 arcmin of size in sky, an age of  $10^4$  years, at 2.9kpc of distance from earth. Its shape has a shell in radio and a thermal center emitting in X rays [5, 7]. The measured flux by EGRET from this source is  $9.9 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1}$ , with a spectral index of  $1.93 \pm 0.10$  [8, 9, 10]. This source was observed by MAGIC in July 2005, resulting in 14h of good quality data. The analysis of this data resulted in no significant signal of gamma rays in the direction of the source (Figure 2). An upper limit on W44 was imposed by the Whipple observatory at  $F(E > 250 \text{ GeV}) = 8.5 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}$  [12], which allows to set an even more restrictive upper limit for  $\gamma$ -ray emission at the source position at the level of 5% of crab at 100 GeV. This implies that there is a break in the spectrum between 10 GeV and 100 GeV.

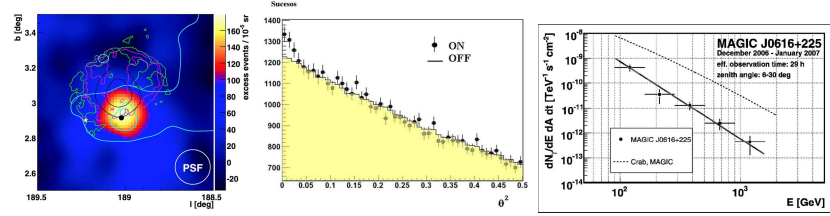


**Fig. 2** (Left) Histogram for W44 comparing the signal (ON) with the background (OFF) of the distribution of the success as a function of the angular distance to the square to see that there is no excess in the position of the source represented by the zero point. (Center) ASCA GIS X-ray image of EGRET source corresponding to W66 in the 4-7keV energy band. Radio contours are drawn as well as the C1, C2 and C3 regions of the remnant. (Right) Map of the gamma ray excess from 200 GeV in Astronomical coordinates. The position of W66, of the EGRET source and the C1, C2, C3 elements of the association are also drawn. As we can see there is no significant signal in the position of W66.

**W66** (G78.2+2.1) is a shell type supernova remnant extending 60 arcmin in the sky, and located in the Cygnus regions close to an OB association. Its estimated age is 5400 years and it is at 1.5kpc from Earth. In this region, a gamma

ray source was found by the COS-B satellite [13] and confirmed and catalogued as 3EGJ2020+4017 by EGRET (Figure 2, [16]). It is one of the brightest unidentified gamma-ray sources with a observed flux of  $1.2 \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$  in 100 MeV and spectral index of  $2.08 \pm 0.04$  [6, 8, 9, 10]. W66 was observed for MAGIC between April and July 2006 obtaining 16h of good data. Our analysis does not exclude high energy gamma rays from this region because there might be some *hot spots* (Figure 2) in the region, although they are far from the EGRET source.

**IC443** is a shell type supernova remnant extending 45 arcmin of diameter in the sky. It is located at a distance of 1.5 kpc, close to Gemini A and its age is estimated to be of 2800-3400 years. In the energy band around 100 MeV, this source was detected and catalogued by EGRET as 3EGJ0617+2238, with a measured flux of  $5.9 \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1}$  and spectral index of  $2.01 \pm 0.06$  [6, 8, 9, 10]. It was observed by MAGIC and the subsequent analysis resulted in a new gamma ray source catalogued as MAGICJ0616+225 (Figure 3, [1]), which is spatially coincident with IC443 and marginally to the EGRET source. The data was obtained in December 2006 and January 2007, and the resulting signal has a significance of  $5.7\sigma$ . The measured differential spectrum is well fitted by the power law given by  $dN_\gamma/(dAdt dE) = (1.0 \pm 0.2) \times 10^{-11} (E/0.4 \text{ TeV})^{(-3.1 \pm 0.3)} \text{ cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$ , shown in (Figure 3).



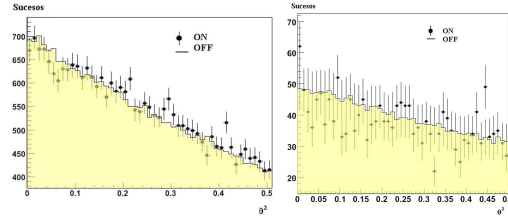
**Fig. 3** (Left) Map of the gamma ray excess in the direction of the source of IC443 for 150 GeV in Galactic coordinates.  $^{12}\text{CO}$  contours (blue), 20cm VLA radio (green), X ray of Rosat (purple) and gamma ray of EGRET (black) are also drawn. (Center) Histogram for IC443 comparing the signal (ON) with the background (OFF) of the distribution of the excess as a function of the angular distance to the square to see that there is no excess in the position of the source represented by the zero point. (Right) Very high gamma ray spectrum for MAGICJ0616+225. The continuous line shows a fit of the points to a power law. The dotted line shows the spectrum of the Crab Nebula (Crab), measured by MAGIC.

### 3 Other sources: M13 y M42

**M13** is a globular cluster located at 7 kpc from Earth, which extends 16.6 arcmin of total size in sky, and has an age of  $24 \times 10^9$  years. In its interior, the presence of 5 pulsars with a time scale of milliseconds has been confirmed, but the estimated number of such pulsars amounts to the order of hundreds in the literature, which should contribute to the bulk gamma ray emission of M13, thus a measure of this flux sets constraints in the number of pulsars [3, 14]. The Whipple collaboration [11] reports an upper limit in the gamma-rays flux around 500 GeV of  $1.08 \times 10^{-11}$

$\text{cm}^{-2} \text{s}^{-1}$ . M13 was observed by MAGIC in June-July 2007, obtaining a total 21h of good data but no significant gamma ray signal has been found (Figure 4).

**M42** is open stellar cluster with a big reflexion nebula, with a size 45 arcmin of diameter. It is  $5.5 \times 10^6$  years old, and its distant to Earth is 0.4kpc. The MAGIC telescope observation of this object has focused in a region where the HEGRA collaboration had detected a marginally significant signal [15], resulting in a 3 Crabs flux level at 500 GeV of energy. This region was observed in October 2007 during 5 days obtaining almost 5h of good data. The analysis of this data results in no significant signal of gamma ray emission (Figure 4).



**Fig. 4** Histogram for M13 (left) and M42 (right) comparing the signal (ON) with the background (OFF) of the distribution of the sucess as a function of the angular distance to the square to see that there is no excess in the position of the source represented by the zero point.

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