First results of galactic observations with MAGIC

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Summary. During its first cycle, the MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescope was performing an observational campaign covering a total of about 250 hours on galactic sources. Here we review the results for the very high energy (>$100$ GeV) $\gamma$-ray emission from some of those sources.

1 Introduction: The MAGIC Telescope

The Major Atmospheric Gamma Imaging Cherenkov (MAGIC) telescope [1] is a very high energy (VHE) $\gamma$-ray telescope, operating in an energy band from 100 GeV to 10 TeV, exploiting the Imaging Air Cherenkov technique. Located on the Canary Island of La Palma, at $28^\circ 45' 30''$ N, $17^\circ 52' 48''$ W and 2250 m above sea level. The telescope has a 17-m diameter tessellated parabolic mirror, and is equipped with a $3.5^\circ$-$3.8^\circ$ field of view camera. See [2] for a complete description of the instrument.

In this work we show that MAGIC has the capability to contribute to the growing VHE $\gamma$-ray source catalogue by exploring the part of the Galactic sources observable from the Northern Hemisphere. The physic program developed with the MAGIC telescope includes both, topics of fundamental physics and astrophysics. In this paper we present the results regarding the observations of galactic targets. The results from extragalactic observations are presented elsewhere in these proceedings [3].

2 The Crab nebula and pulsars

The Crab nebula is a steady emitter at GeV and TeV energies, what makes it into an excellent calibration candle. This object has been observed extensively in the past over a wide range of wavelengths, up to nearly 100 TeV. Nevertheless, some of the relevant physics phenomena are expected to happen in the VHE domain, namely the spectrum showing an Inverse Compton (IC) peak close to 100 GeV, a cut-off of the pulsed emission somewhere between 10-100 GeV, and the verification of the flux stability down to the percent level. The existing VHE $\gamma$-ray experimental data
is well described by electron acceleration followed by the IC scattering of photons generated by synchrotron radiation (synchrotron self Compton process).

Along the first cycle of MAGIC’s regular observations, a significant amount of time has been devoted to observe the Crab nebula, both for technical and astrophysical studies. A sample of 12 hours of selected data has been used to measure with high precision the spectrum down to \( \sim 100 \text{ GeV} \), as shown in Figure 1. We have also carried out a search for pulsed \( \gamma \)-ray emission from Crab pulsar, albeit with negative results. The derived upper limits (95% C.L.) are \( 2.0 \times 10^{-10} \text{ ph s}^{-1} \text{ cm}^{-2} \) at 90 GeV and \( 1.1 \times 10^{-10} \text{ ph s}^{-1} \text{ cm}^{-2} \) at 150 GeV.

We also carried out a search for pulsed \( \gamma \)-ray emission from two millisecond pulsars PSR B1957+20 and PSR J0218+4232, albeit without positive result. The corresponding upper limits are \( F_{\text{PSR B1957+20}} \sim 2.3 \times 10^{-11} \text{ ph s}^{-1} \text{ cm}^{-2} \) for the steady emission and \( F_{\text{PSR B1957+20}} \sim 5.1 \times 10^{-12} \text{ ph s}^{-1} \text{ cm}^{-2} \) for the pulsed one.

![Fig. 1. Energy spectrum above 100 GeV from the Crab nebula measured by MAGIC in two different observation seasons.](image)

### 3 Supernova remnants

Shocks produced at supernova explosions are assumed to be the source of the galactic component of the cosmic ray flux. The proof that this is the case could be provided by observations in the VHE domain. The rationale is that the hadronic component of the cosmic rays –enhanced close to their source, i.e. the SNR– should produce VHE \( \gamma \)-rays by the interaction with nearby dense molecular clouds. Although recent data seem to indicate that this is the case, it is difficult to disentangle the VHE component initiated by hadrons from that produced by Bremsstrahlung and IC processes by accelerated electrons. Therefore more data in the TeV regime together with multi-wavelength studies are needed to finally solve the long-standing puzzle of the origin of galactic cosmic rays.

Within its program of observation of galactic sources, MAGIC has observed a number of supernova remnants. In particular, we are observing several of the brightest EGRET sources associated to SNRs, and the analysis of the acquired data is in
progress. On the other hand, we have confirmed the VHE $\gamma$-ray emission from the SNRs HESS J1813-178 \cite{7} and HESS J1834-087 (W41) \cite{8}. Our results have confirmed SNRs as a well established population of VHE $\gamma$-ray emitters. The energy spectra measured by MAGIC are both well described by an unbroken power law and an intensity of about 10% of the Crab nebula flux. Furthermore, MAGIC has proven its capability to study moderately extended sources by observing HESS J1834-087. Interestingly, the maximum of the VHE emission for this object has been correlated with a maximum in the density of a nearby molecular cloud. Although the mechanism responsible for the VHE radiation remains yet to be clarified, this is a hint that it could be produced by high energy hadrons interacting with the molecular cloud.

### 3.1 Galactic Center

We have also measured the VHE $\gamma$-ray flux from the galactic center \cite{9}. The possibility to indirectly detect dark matter through its annihilation into VHE $\gamma$-rays has risen the interest to observe this region during the last years. Our observations have confirmed a point-like $\gamma$-ray excess whose location is spatially consistent with Sgr A* as well as Sgr A East. The energy spectrum of the detected emission is well described by an unbroken power law of photon index $\alpha = -2.2$ and intensity about 10% of that of the Crab nebula flux at 1 TeV. The power law spectrum disfavours dark matter annihilation as the main origin of the detected flux. There is no evidence for variability of the flux on hour/day time scales nor on a year scale. This suggests that the acceleration takes place in a steady object such as a SNR or a PWN, and not in the central black hole.
4 The $\gamma$-ray binary LS I +61 303

This $\gamma$-ray binary system is composed of a B0 main sequence star with a circumstellar disc, i.e. a Be star, located at a distance of $\sim 2$ kpc. A compact object of unknown nature (neutron star or black hole) is orbiting around it, in a highly eccentric ($e = 0.72 \pm 0.15$) orbit.

LS I +61 303 was observed with MAGIC for 54 hours between October 2005 and March 2006 [10]. The reconstructed $\gamma$-ray map is shown in Figure 2. The data were first divided into two different samples, around periastron passage (0.2-0.3) and at higher (0.4-0.7) orbital phases. No significant excess in the number of $\gamma$-ray events is detected around periastron passage, whereas there is a clear detection ($9.4 \sigma$ statistical significance) at later orbital phases. Two different scenarios have been involved to explain this high energy emissions: the microquasar scenario where the $\gamma$-rays are produced in a radio-emitting jet; or the pulsar binary scenario, where they are produced in the shock which is generated by the interaction of a pulsar wind and the wind of the massive companion. See [11] for more details.

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