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First Observation of the Giant Radio Galaxy M87 in the 100 GeV Energy Domain with the MAGIC Telescope

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We report preliminary results from the observations of the giant radio galaxy M87 in the 100 GeV energy domain of γ rays with the MAGIC imaging atmospheric Cherenkov telescope. These observations, carried out from March to May 2005, have been the first phase of an observation campaign which will be continued in 2006. Contemporaneous X-ray observations are planned as a part of the campaign.

1. The Giant Radio Galaxy M87 as a GeV-TeV γ-Ray Emitter

The giant radio galaxy M87, extensively studied from radio to X-ray wavebands, is located in the Virgo cluster of galaxies at a distance of ∼16 Mpc (redshift z = 0.00436). This object is believed to contain as a central 'engine' a supermassive black hole with a mass $M_{BH} \approx 2 - 3 \times 10^9\ M_\odot$ [1], which powers the observed kpc scale non-thermal jet.

Extragalactic GeV-TeV γ-ray emission has been detected so far from active galaxies only of the BL Lac type, with exception of Cen A [2]. A common characteristic shared by these objects is the ejection of matter in a jet oriented very close to the observer's line of sight. Radio galaxies also exhibit relativistic mass outflows, though, in contrast to blazars, under large viewing angles: 30°–35° in the case of M87 [3].

Recent models developed for M87 suggest that this object can be considered a misaligned blazar. This means that its overall spectral energy distribution (SED) should have a double-peaked structure. In the leptonic scenario in particular, the first component, ranging from radio to X rays, is generally interpreted as being a result of synchrotron emission of the relativistic electrons in the jet, supported by recent observations with the *Chandra* X-ray Observatory [4]; the second component, on the other hand, is believed to be inverse Compton emission of the same electron population and may peak at 100 GeV [5]. Also in the hadronic scenario [6] M87 should exhibit two broad spectral components, where the second one may also peak at 100 GeV [7].

There are also other important motivations for studying M87 in VHE γ-rays. This active galaxy has been speculated to be a powerful accelerator of ultra high energy cosmic rays [8]. Observations of VHE γ-rays from this object, relatively close to us (16 Mpc), may therefore help to clarify the extragalactic origin of cosmic rays. Furthermore, the huge mass of M87 makes it also a promising target for indirect search for dark matter through the detection of γ rays from the hypothetical neutralino annihilation [9, 10, 11].

M87 was observed with the HEGRA stereoscopic system of five imaging atmospheric Cherenkov telescopes (IACT's) in the years 1998 and 1999 for more than 80 h. An excess of TeV γ-rays at a significance level above 4σ was found, corresponding to an integral flux $N_\gamma(E > 730\ \mathrm{GeV}) = (0.96 \pm 0.23) \times 10^{-12}$ phot cm^{-2} s^{-1} (3.3% of the Crab flux) [12]. This detection, if confirmed, would make M87 the first active galaxy observed at very high energies not belonging to the BL Lac class. Recently the HESS Collaboration has reported a tentative detection on a lower flux level (approx. 1% of the Crab flux), at an energy threshold close to TeV, from observations performed with its stereoscopic system of IACT's in the years 2003 and 2004 [13].

2. The MAGIC Telescope

The MAGIC imaging atmospheric Cherenkov telescope [14] is located at the same place as the HEGRA array, on the Canary island of La Palma (28° 45' N, 17° 53' W; 2200 m a.s.l.). A considerable effort in technical progress has been made in order to achieve a better sensitivity; and especially a very low energy threshold (less than 100 GeV), thanks to a large parabolic tessellated mirror of 17 m diameter. The telescope camera, with a 3.5° field of view (FOV), is equipped with 576 high quantum efficiency photo-multiplier tubes (PMT's). 397 PMT's of 0.1° FOV each make up the inner area of the camera, which is surrounded by 180 0.2° FOV PMT's. The telescope is fully operational since August 2004.

3. Data Set

MAGIC observations of M87 have been carried out from March to May 2005 in the ON/OFF mode. In order to achieve an energy threshold as low as possible, the source has been observed at low zenith angles, mainly between 16° and 30°. The total pre-selection exposure time amounts to 13.3 h (ON-source) and 5.6 h (OFF-source). OFF-source (background) observations were performed by tracking a sky region with an offset in right ascension $\Delta\alpha = +12$ min with respect to the object position.

Several a priori cuts have been applied to the collected data in order to reject runs with technical problems; and also to reject runs taken under bad weather conditions, by monitoring the telescope trigger rate. After the application of these selection criteria the total cleaned data, which is shown in Tab. 1, yields an observation time of 10.9 h (ON-source) and 5.3 h (OFF-source).

Table 1. Selected data set from the MAGIC observations of M87 in 2005.

Date	Observation Time	
	ON (h)	OFF (h)
15 March	1.0	0.3
6–12 April	5.9	3.0
28 April – 8 May	4.0	2.0
Total	10.9	5.3

4. Preliminary Results

Data analysis is still in progress, and preliminary results will first be presented orally at ICRC 2005.

5. Conclusions and Outlook

The giant radio galaxy M87 has been observed for the first time with the MAGIC telescope from March to May 2005, for a total of 10.9 h (ON-source) remaining after cuts on the data quality. Data analysis is in progress and first results will be presented at ICRC 2005.

Observations are planned to be continued in 2006, up to a total observation time of iniatially 100 h. They are also planned to be carried out in the 'wobble' mode, by tracking the source with a slight offset in the sky position at which the telescope is pointed, which allows for simultaneous source and background observations.

Joint monitoring campaigns with X-ray observatories, in particular with *Chandra*, are also foreseen. These joint observations will allow to perform a diagnosis of the population of high-energy electrons and also a simultaneous study of the source variability in X and γ-ray wavebands. In this sense, *Chandra*'s high spatial resolution (M87's scale: 78 pc arcsec $^{-1}$, *Chandra*'s FWHM: 0.2 arcsec) will be crucial to identify the γ-ray production sites.

Concerning the search for dark matter, the variability study in the joint campaigns may also help to separate the steady contribution due to the hypothetical neutralino annihilation from the variable radiation due to AGN processes. Surplus value of the joint observations is obtained by combining with archival data of M87 in X rays; a very deep exposure is then achieved, which can be used to further constrain models of the dark-matter profile.

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