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

J. ALBERT[1], K. BERGER[1], T. BRETZ[1] D. ELSÄSSER[1], D. KRANICH[2], K. MANNHEIM[1], M. MEYER[1]
ON BEHALF OF THE MAGIC COLLABORATION
[1] *Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany*
[2] *ETH Zürich, CH-8093 Hönggerberg, Switzerland*

albert@astro.uni-wuerzburg.de

Abstract: Since 2005 the giant radio galaxy M87 has been observed in the 100 GeV energy domain with the MAGIC Telescope. Results from the analysis will be presented at ICRC 2007.

Introduction

The giant elliptical galaxy M87 is the dominant object in the Virgo cluster of galaxies. M87 is classified as a radio galaxy of Fanaroff-Riley Class I (FR I). Its one-sided jet is the highest surface-brightness one in the optical, radio and X rays. It may be powered by a supermassive black hole with a mass of $M \sim 3 \times 10^9 M_\odot$ ([1]). M87's proximity (distance ∼16.3 Mpc, [2]; which corresponds to a scale of 78 pc arcsec^{-1}) allows to study jet features with unparalleled spatial resolution from radio to X rays.

Furthermore, M87 is until now the only radio galaxy detected in the very high energy (VHE) domain of γ-rays ($E_\gamma > 100$ GeV): $E_\gamma > 730$ GeV ([3]), $E_\gamma > 400$ GeV ([4]). VHE emission from other active galaxies has been detected so far only from objects of the BL Lac type, which eject relativistic matter in a jet oriented very close to the observer's line of sight ([5]). Radio galaxies also exhibit relativistic mass outflows like blazars, though under large viewing angles. In that scenario, M87 can be regarded as a misaligned BL Lac object ([6]) with a jet angle of $\sim 30°$ ([7]). This means that its overall spectral energy distribution (SED) should have a double-humped 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. Concerning the second spectral component, it is believed to be inverse Compton scattering of the synchrotron photons by the same electron population (synchrotron self-Compton model, SSC), which should peak at 100 GeV ([8]). Also in the hadronic scenario M87 should exhibit two broad spectral components. According to the synchrotron-proton blazar (SPB) model ([9]), the low-energy component can be explained as synchrotron radiation by a primary relativistic electron population that is injected together with energetic protons into a highly magetized emission region. In that context, the high-energy component, which should also peak at ∼100 GeV, is dominated either by $\mu^\pm/\pi^\pm$ synchrotron or proton synchrotron radiation depending on whether the primary electron synchroton component peaks at low or high energies, respectively. The SPB model also provides a mechanism to accelerate protons to ultra-high energies, which makes M87 an excellent candidate for a source of ultra-high-energy cosmic rays (UHECR's).

M87, on the other hand, is considered a promising target for the indirect search for hypothetical supersymmetric dark matter. This would consist in the detection of γ-rays produced in the annihilation of neutralinos in M87 halo ([10], [11]).

M87 was observed with the HEGRA stereoscopic system of five 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 $N_\gamma(E > 730 \text{ GeV}) = (0.96 \pm 0.23) \times 10^{-12}$ cm^{-2} s^{-1} (3.3% of the Crab flux) ([3]). Between 2000 and 2003 data were taken with the Whipple telescope above 400 GeV during 39 h ([12]). This resulted in a 99% confidence level upper limit on the photon flux to be $N_\gamma(E > 400 \text{ GeV}) \leq 6.9 \times 10^{-12}$ cm^{-2} s^{-1} (8% of the Crab flux). Recently the H.E.S.S. Collaboration has claimed a detection above 400 GeV with a statistical significance of 13σ from observations in the years 2003-2005, for a total time of 89 h, ([4]). Two separate energy spectra have been reported by H.E.S.S. for data collected in the years 2004 ($\sim 5\sigma$ significance) and 2005 ($\sim 10\sigma$ significance), with spectral index $\Gamma = 2.62 \pm 0.35$ and $\Gamma = 2.22 \pm 0.15$, respectively ([13]). Hence those data show evidence of high variability on a year-by-year basis, and also on time-scales of days in 2005. On the other hand, both HEGRA and H.E.S.S. results are compatible with a point-like source which includes M87 nucleus.

Observations with the MAGIC Telescope

MAGIC (Major Atmospheric Gamma Imaging Cherenkov Telescope) [14] is located on the Canary island of La Palma (28° 45' N, 17° 53' W; 2200 m a.s.l.). MAGIC has as a main feature a large parabolic tessellated mirror of 17 m diameter. This allows to reach a very low energy threshold (trigger threshold is about 50-60 GeV in zenith position). The telescope camera, with a 3.5° field of view, is equipped with 576 high quantum efficiency PMT's. Spatial resolution for individual events amounts to ~ 0.1 degrees. The telescope is fully operational since August 2004.

M87 was observed with MAGIC in two different epochs: spring 2005 and winter-spring 2006. Observations in the year 2005 were carried out in a standard ON/OFF mode, i.e. alternate tracking of the source (ON-source) and of a background region (OFF-source). The tracked background region in the sky was determined to have an offset in right ascension $\Delta\alpha = +12$ min with respect to the object position. In the year 2006 observations were carried out in the *wobble* mode, by tracking the target with a slight offset in the sky position at which the telescope is pointed, which allows for simultaneous source and background observations.

For the analysis only data of good quality were considered. Data collected under bad weather conditions were rejected, according to the stability of the telescope trigger rate, and also those with technical problems.

Data were processed by using MAGIC Analysis and Reconstruction Software (MARS; [15]). A description of the different analysis steps may be found in [16] and in [17].

Results from the analysis will be presented at ICRC 2007.

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