Is the Giant Radio Galaxy a TeV Gamma-Ray Emitter?


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For the first time an excess of photons above an energy threshold of 730 GeV from the giant radio galaxy has been measured.

The data have been taken during the years 1998 and 1999 with the HEGRA stereoscopic system of 5 imaging atmospheric Cherenkov telescopes. The excess of $10^7$ upper limit of the TeV γ-ray emission from this class of objects.

However, other types of AGN, e.g., blazar type objects, under large viewing angles: amongst these thenearby radio galaxy has been speculated to be a powerful accelerator of cosmic rays. For the first time an excess of photons above an energy threshold of 730 GeV from the giant radio galaxy has been measured at significance level above 4.4σ. is located at the center of the Virgo cluster of galaxies at a redshift of $z = 0.034$ and is a promising candidate among the class of giant radio galaxies for the emission of TeV γ-radiation. The detection of TeV γ-rays from – if confirmed – would establish a new class of extragalactic source in this energy regime since all other AGN detected to date at TeV energies are BL Lac type objects.

γ-rays: observations – galaxies: individual:

Aharonion et al.

Introduction

Active Galactic Nuclei (AGN) are believed to contain as a central “engine” a supermassive black hole which causes the development of large scale jets. Extragalactic TeV γ-ray emission has been observed so far from AGN only of the BL Lac type, i.e. objectsjecting matter toward the observer “line of sight.” In BL Lac type, the observed γ-ray emission is from a supermassive black hole with a mass $M_{\text{BH}} = 0.030$ and $M_{\text{kn}} = 501 (z = 0.034)$ belongs to the type of TeV γ-rays. Recently, the BL Lac type objects 1ES 1959+650 ($z = 0.047$) and the much more distant H 1426+428 ($z = 0.129$) have been detected to date at TeV energies from this class of objects.

The elliptical galaxy (right ascension $\alpha_{J2000.0} : 12^h30^m49.4^s$, declination $\delta_{J2000.0} : +12^\circ23'28''$, redshift $z = 0.0436$) has an optical extension of 8.3′ × 6.6′ (m87position) with a larger radio halo of 16′ × 12′ (m87.amerion1971). It contains a supermassive black hole with a mass $M_{\text{BH}} \approx 2 \times 10^9 M_\odot$ (M87, arms). The power of the jet is estimated to be $10^{44}$ erg s$^{-1}$ (m87.wen2000). The location of the jet is estimated to be in the central region of the Virgo cluster of galaxies, which itself is an interesting site for high-energy physics.

The VERITAS collaboration has identified the Whipple 10 m Cherenkov telescope in the year 2000 and 2001 for total and 0.9 σ (2001) leading to a 3 σ upper limit of $N_\gamma (E > 250 \text{ GeV}) < 2.2 \times 10^{-11}$ phot. cm$^{-2}$s$^{-1}$ (m87.wipple.crc2001).

The HEGRA collaboration has extensively observed in 1998 and 1999 with the stereoscopic system of 5 imaging atmospheric Cherenkov telescopes (IACT system, hegra, act, system1, 997). Abouthalf the total observation time (upper limit on the TeV γ-ray flux from was determined to be $N_\gamma (E > 720 \text{ GeV}) < 1.45 \times 10^{-12}$ phot. cm$^{-2}$s$^{-1}$.

In this Letter the results of the whole data set of the extensive HEGRA observations during the years 1998 and 1999 are reported, now also applying a more sensitive analysis method. Astrophysical conclusions concerning the nature of the observed excess are briefly discussed.
Observations and results of analysis

was observed in the years 1998 and 1999 with the HEGRA IACT system for a total of 83.4 h. There were no further observations with the HEGRA telescopes in the subsequent years. The major part of the data was taken with a 4 telescopesetup.

Table hegra observationsspecificsthe observation times and mean zenith angles of the individual HEGRA observations. The table can be converted into a mean energy threshold (defined as the peak detection rate for γ-showers) of 730 GeV for a Crab-like spectrum (Konopelko 1999). The analysis uses an extended OFF-region reducing the statistical error on the number of background events. A ring segment is chosen with an opening angle at the same radial distance to the center of the field of view as for the ON-source position (see also hegra mark 4 2002). The width of the ring is set to the diameter of the ON-source area in order to provide the same angular resp. OFF-source events. This ring segment background model is similar to the usage of a set of control regions (hegra as - off moff - source solid angle areas) and thus reduces the statistical error on the number of estimated background events. For a consistency check (and for a search for γ-ray sources in the field of view, see below) the so-called template background model has also been used (template model; see also hegra as - on moff).

For the image analysis, the mirror reflectivities and photocathode efficiencies – which degrade slowly with time – along with the factors converting from digitized photomultiplier signals to photoelectrons have been determined on a monthly basis. The shower reconstruction and the event selection cuts have already been described in previous publications (e.g. Aharonian 1999). The stereoairshowerdirectionreconstructionalgorithm #3 (Hofmann 1999) for an effective γ-hadron separation have been applied leading to a sensitivity gain as compared to the earlier analysis of the HEGRA observations. The optimum angular cut was derived using γ-ray events from the Crab nebula on the basis of a nearly contemporaneous data set at similar zenith angles. Table hegra represents the event selection cuts; the resulting event numbers and significances for the dataset are shown in Figure 2.

Only data of good quality were considered for the analysis, the most critical condition being the IACT system’s cosmic ray background trigger rate not deviating more than 30% from the rate expected for the current zenith angle. All observations were carried out in the so-called wobble mode targeting the object’s position (“ON”) as given in Section chapter1 shifted by ±0.5° in declination with respect to the center of the field of view. This observation mode allows for simultaneous estimation of the background (“OFF”) rate induced by charged cosmic rays (Aharonian 1997). The analysis uses an extended OFF-region reducing the statistical error on the number of background events. A ring segment is chosen with an opening angle at the same radial distance to the center of the field of view as for the ON-source position (see also hegra mark 4 2002). The width of the ring is set to the diameter of the ON-source area in order to provide the same angular resp. OFF-source events. This ring segment background model is similar to the usage of a set of control regions (hegra as - off - source solid angle areas) and thus reduces the statistical error on the number of estimated background events. For a consistency check (and for a search for γ-ray sources in the field of view, see below) the so-called template background model has also been used (template model; see also hegra as - on - moff).

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