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Is the giant radio galaxy M87 a TeV gamma-ray emitter?

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Abstract

For the first time an excess of gamma-rays above 730 GeV has been observed from the giant radio galaxy M87. The excess with a significance of 3.5 σ has been measured with the HEGRA stereoscopic system of 5 imaging Cherenkov telescopes. M87 is the first object from the class of radio galaxies observed at TeV energies.

Introduction

The giant radio galaxy M87 is a promising candidate for TeV gamma-ray emission since it is supposed to be a powerful accelerator of cosmic rays, it is nearby (16 Mpc) and it shows a high jet power (10^{45} erg/s).

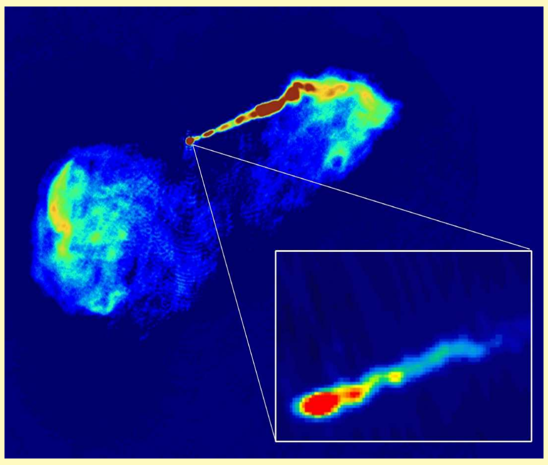

Fig. 1: VLA radio image of M87

M87

M87 is located at the center of the Virgo cluster and is supposed to contain a supermassive black hole of $\approx 2 \times 10^9 M_\odot$. The angle of the relativistic jet to the observer's line of sight is 30–35 deg.

Sites and processes

Several sites and processes for the production of TeV gamma-rays at M87 are conceivable:

- Inner jet
- Large scale jet (knots, hotspots)
- Larger scales, i.e. the interstellar medium of M87
- Neutralino annihilation

HEGRA Experiment

The TeV gamma ray excess from M87 has been measured with the system of 5 imaging atmospheric Cherenkov telescopes of the HEGRA collaboration using the stereoscopic observation mode [1].

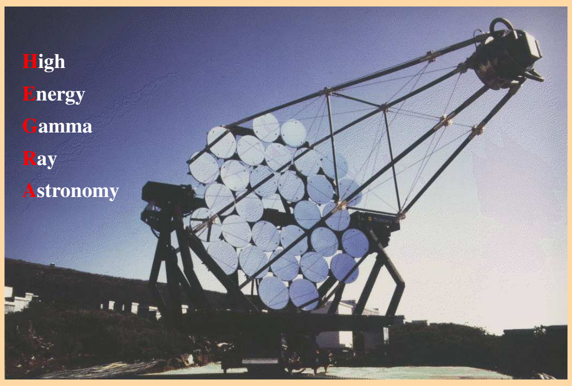

Fig. 2: One of the HEGRA Cherenkov telescopes on the Canary island La Palma

Stereoscopic observations

The HEGRA experiment of TeV gamma-ray astronomy has pioneered the stereoscopic observation technique: Air showers initiated by primary gamma-rays are observed simultaneously from different viewing angles with up to 5 imaging Cherenkov telescopes resulting in an improved angular and energy resolution as well as background suppression.

Characteristics of the System telescopes

- Field of view: 4.3 deg (diameter)
- Energy threshold: E $\geq$ 500 GeV
- Energy resolution $\leq$20%
- Angular resolution $\leq 0.1^\circ$
- Cosmic ray background rejection up to a factor $\approx$100

References:

[1] Daum, A., et al., 1997, *ApJ* 322, 706

Results

(preliminary)

The HEGRA data of 1998 and 1999 reveal an excess of 107 $\pm$ 27 gamma-ray events above 730 GeV from the direction of M87. The excess builds up at a constant rate during the $\approx$70h of observation [2].

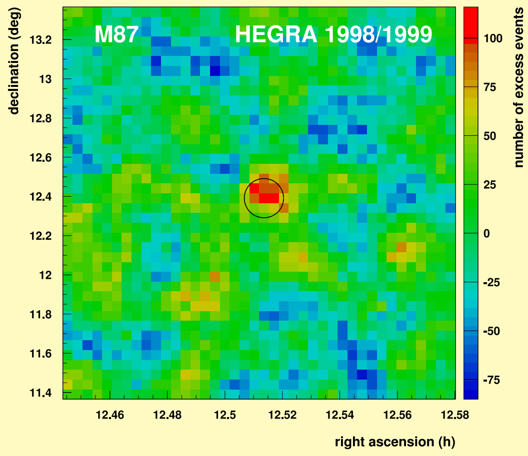

Fig. 3: Skymap ($2^\circ \times 2^\circ$ field with $0.02^\circ \times 0.02^\circ$ binning). The black circle indicates the angular resolution of the telescope system. Each bin comprises excess events from a radius of 0.13 deg around its center.

Flux

Converting the excess into a gamma-ray flux yields:

F(E>730GeV) $\approx$ (1.4$\pm$0.4) $\times$ 10^{-12} erg cm^{-2} s^{-1}

This corresponds to 3% of the Crab flux

Significances

With different analysis methods and background estimates, the excess is confirmed at significance levels ranging from 3.2 to 4.1 σ. (Significances have been calculated according to Li and Ma 1983 [3])

References:

[2] Aharonian, F., et al., to be submitted to *A&A*

[3] Li, T. and Ma, Y., 1983, *ApJ*, 272, 317

Conclusion

Indication for TeV gamma-ray emission from the giant radio galaxy M87 has been found at the 3.5 σ-level. If this result is confirmed with the next generation instruments (H·E·S·S, CANGAROO, MAGIC, VERITAS), this would be the first detection of TeV gamma-rays from an object of the class of radio galaxies.

Future experiments may also be able to locate the site of gamma-ray production at M87 and decide on the process of gamma-ray production by measuring the energy spectrum.