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Discovery of >160 GeV γ-rays from 1ES 1101-232 ($z = 0.186$) with H.E.S.S.

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The system of four H.E.S.S. (High Energy Stereoscopic System) atmospheric Cherenkov telescopes is complete and operational since December 2003. Since the commissioning of the experiment in June 2002, a considerable amount of observation time has been dedicated to observations and monitoring of active galactic nuclei (AGN). For several objects simultaneous observation campaigns were carried out in other wavelength bands. In addition to the understanding of the intrinsic acceleration mechanisms of these objects, the observations of AGN also provide an indirect measurement of the Extragalactic Background Light (EBL) via the absorption of very high energy (i.e. in the GeV/TeV energy regime) gamma-rays by e^+e^- pair production with EBL photons. To this end it is important to study spectra of AGN at different redshifts. To date, the redshifts of AGN detected at very high energies range from 0.004 to 0.129. Here we report on the detection (9 σ) of the BL Lac object 1ES 1101-232, at a redshift of $z = 0.186$, with the H.E.S.S. Cherenkov telescopes.

1. Introduction

The H.E.S.S. Cherenkov telescope experiment, located in the Khomas Highlands (1800 m a.s.l., 23° S 16° E) of Namibia, is operational since June 2002. Each of the four telescopes consists of a tessellated mirror dish (total reflective area of 107 m^2) on a steel mount and a 5° field-of-view photomultiplier camera (960 pixels) located at a focal distance of 15 m. The Cherenkov technique is based on the detection of Cherenkov light emitted by the secondary shower particles in the atmosphere. The H.E.S.S. system of four Cherenkov telescopes makes use of the stereoscopic reconstruction technique (pioneered by HEGRA), where a shower is observed simultaneously with several telescopes from different viewing angles, allowing a complete geometrical reconstruction of the shower, and the estimation of shower direction and energy on an event-by-event basis. All four telescopes are completely integrated in a stereoscopic system since December 2003. Since beginning operation, numerous exciting new results have been obtained, many of which are presented at this conference. The high performance of the H.E.S.S. telescopes demonstrates that Cherenkov astronomy has entered a new era, where not only a few but many sources of new and different classes are detected.

Among the class of active galactic nuclei (AGN), high frequency peaked BL Lacs (HBL) are known to emit very high energy (VHE) γ-rays since the detection of Mrk 421 above 300 GeV by the Whipple group [16]. In the following years several AGN were detected at very high energies by different groups. A summary of the significant detections ordered by redshift is given in Table 1. The spectral energy distribution (SED) of AGN stretches 20 decades over the complete electromagnetic spectrum, from radio to VHE γ-ray emission. It is generally believed that the lower part of the SED (from radio to X-rays) is due to synchrotron radiation of relativistic electrons in ambient magnetic fields. Different models for the explanation of the high energy part of the SED have been proposed. In leptonic models, the high energy emission is assumed to result from inverse Compton scattering of accelerated electrons off a seed photon population (e.g., synchrotron radiation,

Table 1. AGN-detections in the GeV/TeV energy regime by different Cherenkov experiments.

Name	redshift	object type	First detection	Confirmation
M 87	0.0043	radio galaxy	HEGRA [2]	H.E.S.S. [7]
Mrk 421	0.030	HBL	Whipple [16]	many
Mrk 501	0.034	HBL	Whipple [17]	many
1ES 2344+541	0.044	HBL	Whipple [8]	HEGRA [4]
1ES 1959+650	0.047	HBL	7 Telescope Array [13]	many
PKS 2005-489	0.071	HBL	H.E.S.S. [6]	–
PKS 2155-304	0.116	HBL	Mark 6 [9]	H.E.S.S. [5]
H 1426-428	0.129	HBL	Whipple [11]	HEGRA [1]
H 2356-309	**0.165**	HBL	**H.E.S.S. [15]**	–
1ES 1101-232	**0.186**	HBL	**H.E.S.S. (this paper)**	–

radiation from the accretion disk). In hadronic models, the γ-rays are produced in interactions of relativistic protons with matter, ambient photons or a magnetic field, or with ambient photons and a magnetic field. Due to e^+e^- pair production from the interaction of GeV/TeV γ-rays with photons of the EBL, the observed SED of a distant object such as an AGN is expected to be attenuated and distorted in the VHE regime. Therefore, GeV/TeV observations of distant AGN can be used to constrain the flux and shape of the EBL.

With a peak of the synchrotron component of the SED at $\approx$1 keV, 1ES 1101-232 is an extreme case of an HBL, making it a good candidate for emission at very high energies [18]. In Figure 1, a spectral energy distribution obtained from archival data is shown. In the high energy band upper limits from EGRET and the Durham Mark 6 Cherenkov telescope [10] are given.

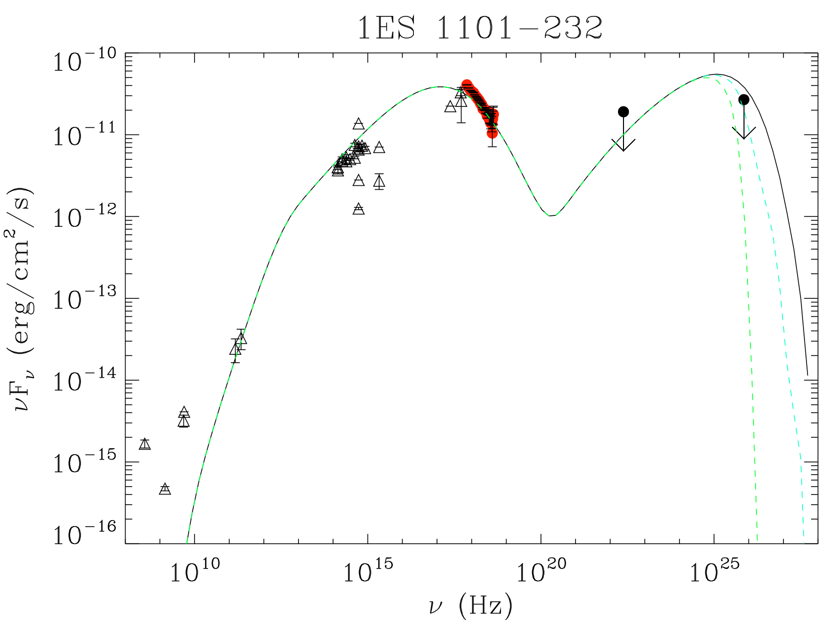

Figure 1. Spectral Energy Distribution of 1ES 1101-232 as obtained from archival data (NED). In the γ-ray band, upper limits from EGRET and the Mark 6 Cherenkov telescope are given. A simple one-zone homogeneous Synchrotron Self Compton model (solid line), including two different EBL absorption models (dashed lines) is shown. RXTE data was taken simulataneously with the H.E.S.S. data presented in this paper. Other data are non-simultaneous. Note that due to a larger scale of the radio emission the model is poorly fit in this wavelength band.

2. Data Analysis & Results

H.E.S.S. data is taken in runs with a duration of the order of 30 - 60 minutes. Before data analysis, quality selection criteria are applied on a run-by-run basis. The most important criteria are the mean (zenith-angle corrected) trigger rate and its stability, weather conditions and hardware status. The reconstruction method used in this paper makes use of the stereoscopic information from the telescopes, and a 3D shower model to reconstruct a 3D picture of the observed shower [12]. For each detected shower, the direction, energy and 3D-width (used for γ-hadron separation) are reconstructed. The results obtained from this method are compatible with the H.E.S.S. standard analysis method [5]. The object was observed with an offset of $0.7°$ (partly $0.5°$) in declination relative to the camera center (wobble mode). Events having a reconstructed direction within a circle of $0.1°$ around the object position (signal region) are counted as on-source events ($\mathrm{N_{on}}$). The background ($\mathrm{N_{off}}$) is estimated from 7 control regions of the same size and located at the same radial distance to the camera center as the on-source region, resulting in identical camera acceptances for both, on- and off-source data.

In the years 2004 and 2005, ~60 h of data were taken on 1ES 1101-232. A total of 39.5 h live-time remains after application of the quality selection criteria and a dead-time correction. The mean zenith angle of this clean data set is 25°, resulting in an energy threshold of 160 GeV (after analysis-cuts) for the analysis used. The analysis yields a total number of on-source events of $\mathrm{N_{on}} = 5153$ and off-source events $\mathrm{N_{off}} = 31440$ (total normalization factor $\alpha = 1/7$), resulting in an excess of 661.6 γ-rays and a significance of $9.0\,\sigma$. In Figure 2, the distributions of the reconstructed squared angular distance (θ^2) of on- and normalized off-source events are shown. The excess is clearly visible in the signal region ($\theta^2 < 0.01\,\mathrm{deg}^2$). Figure 3 shows the

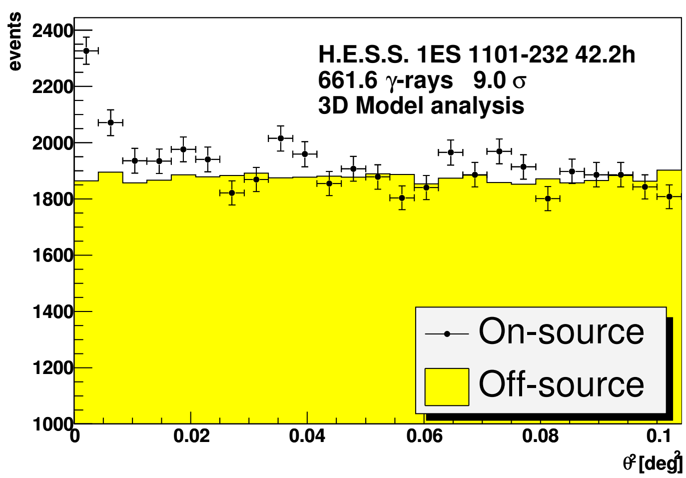

Figure 2. Distribution of reconstructed squared angular direction for 1ES 1101-232. The distribution from the on-source region is represented by the points. The normalized background distribution from 7 control regions is given by the filled histogram.

observed flux of 1ES 1101-232 in each observation night in 2004 to 2005. The result of a fit of a constant to the whole 2004/2005 lightcurve is shown as a dashed line (χ^2 probability of 18 %). No evidence for nightly flux variability is seen in these data. Searches for variability were also carried out on different time scales. No evidence for strong variability was found on any time scale. The apparent flux stability of 1ES 1101-232 in the 2004-2005 H.E.S.S. data might indicate that during our observations the AGN was in a low state of emission. Given the high redshift of 1ES 1101-232, the results of a spectral analysis will provide a strong constraint on the spectral energy distribution of the EBL. The H.E.S.S. results from 1ES 1101-232, including a spectrum, will be presented in detail at the conference.

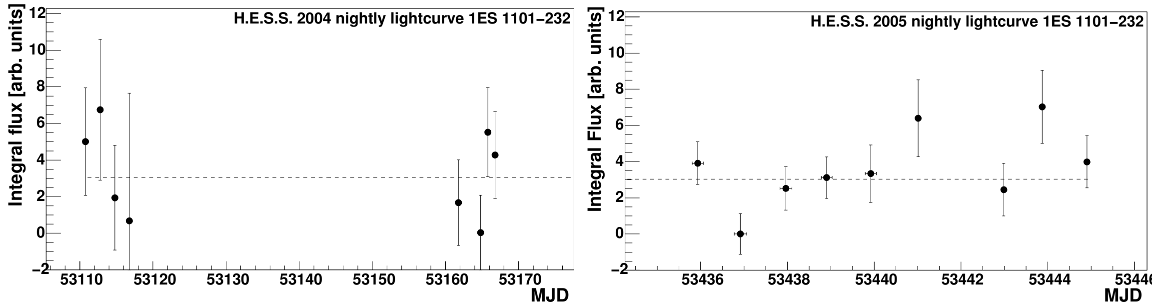

Figure 3. Night-by-night light-curve of the differential flux above 200 GeV for 1ES 1101-232 in the years 2004 (left) and 2005 (right). The dashed line represents a constant fit to the total 2004/2005 lightcurve.

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References

[1] F.A. Aharonian et al. (The HEGRA Collaboration), A&A, 384, L23 (2002)
[2] F.A. Aharonian et al. (The HEGRA Collaboration), A&A, 403, L1 (2003)
[3] F.A. Aharonian et al. (The HEGRA Collaboration), A&A, 406, L9 (2003)
[4] F.A. Aharonian et al. (The HEGRA Collaboration), A&A, 421, 529 (2004)
[5] F.A. Aharonian et al. (The H.E.S.S. Collaboration), A&A, 430, 865 (2005)
[6] F.A. Aharonian et al. (The H.E.S.S. Collaboration), A&A, 436, L17 (2005)
[7] M. Beilicke et al., these Proceedings (2005)
[8] M. Catanese et al., ApJ, 501 616 (1998)
[9] P. M. Chadwick et al., ApJ, 513, 161 (1999)
[10] P. M. Chadwick et al., ApJ, 521, 547 (1999)
[11] D. Horan et al., ApJ, 571, 753 (2002)
[12] M. Lemoine-Goumard & B. Degrange, AIP Conference Proceedings 745, 697 (2004)
[13] T. Nishiyama et al., Proc. of the 26th ICRC, Salt Lake City (1999)
[14] D. Petry et al., ApJ 580, 104 (2002)
[15] S. Pita et al., these proceedings (2005)
[16] M. Punch et al., Nature 358, 477 (1992)
[17] J. Quinn et al., ApJ, 456, L83 (1996)
[18] A. Wolter et al., A&A, 335, 899 (1998)