Observation of BL Lac type AGNs with the equatorial mounted HEGRA Cherenkov Telescope

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Abstract

The first Imaging Atmospheric Cherenkov Telescope of the HEGRA collaboration, CT1, has been used to observe BL Lac type objects. This equatorial mounted telescope is on account of the mirror configuration and the camera equipment especially suited for the observation of point sources, such as AGNs. In this paper we present the studies of the two objects 3C66A and MS 0116, which have been monitored by CT1 between August and December 1998. No evidence for TeV emission was found.

1 Introduction

The study of BL Lac objects as possible TeV γ-sources is one of the major scopes of the HEGRA experiment. The two BL Lac objects Mkn 501 and Mkn 421 are well known TeV sources and under regular observation by our telescopes. During 1997 Mkn 501 showed a noticeable outburst with diurnal flux levels reaching ten Crab units (Aharonian et al., 1999a). The temporal coverage of the 1997 lightcurve of Mkn 501 measured with CT1 is unrivalled (Aharonian et al., 1999b).

According to the widely accepted model of AGNs, which explains the difference between their subtypes by the orientation of the relativistic jet with respect to the observer, an object appears as a blazar if the jets are orientated along the observer's line of sight. The relativistic jets are supposed to be the source of inverse Compton scattered γ-ray beams. In high frequency BL Lacs (HBLs), which form a subset of the blazar class, the non-thermal emission components, widely believed to be synchrotron and inverse Compton radiation of the relativistic electrons, have their peaks at high energies, and thus are likely candidates for detection at energies above 500 GeV with Cherenkov Telescopes. For the better understanding of these kinds of sources, the detection of further BL Lac objects is very important.

The blazar 3C66A has been reported by Neshpor et al. (1998) as a source of γ-ray emission. With the HEGRA CT1, the significant detection (greater than 5σ significance) of a flux comparable to the Crab flux is possible within 3.5 hours. The two objects, 3C66A and MS 0116, have each been observed for longer than 30 hours.

2 Experimental Setup

The HEGRA experiment is located on the Canary Island La Palma at the Observatorio Roque de los Muchachos at 2200 m above sea level, at 28.75°N, 17.89°W. It consists of several arrays of particle and Cherenkov detectors dedicated to cosmic ray research (Lindner, 1997). A total of six Cherenkov Telescopes is operated, five of them are alt-azimuth mounted and operating as a stereoscopic system of telescopes.

The equatorial mounted Cherenkov Telescope CT1 has undergone significant changes since its establishment as a prototype telescope in August 1992. In October 1997 it has been equipped with a new mirror dish of 33 aluminiumoxide coated hexagonal aluminium mirrors with a total reflecting area of 10 m^2. The camera consists of 127 photomultiplier tubes, which are arranged in a hexagonal tight packed structure, with a total field of view of 3.25°. The tracking accuracy of CT1 is better than 0.1°. For details on the hardware see eg. Rauterberg et al. (1995).

3 Observation

Between August and December 1998 we observed 3C66A for 37 hours at zenith angles between 14° and 35°, and MS 0116 for 69 hours between 3° and 45° zenith angle. The redshift is z=0.444 and z=0.0592 for 3C66A and MS 0116, respectively. The objects have been observed during each moonless night for at least 1 h exposure time, whenever observations were possible, regarding weather and atmospherical conditions.

Background data were recorded for a total of 51 h in the considered time period. In order to maximize ON-source observation time for different objects, the OFF-source data were not taken in ON/OFF cycles, but at times when no other source of major interest was visible, taking advantage of the isotropic nature of the hadronic background, see Petry and Kranich (1997) for details.

The absolute calibration and determination of the energy scale is difficult, as there is no artificial TeV γ-ray beam. Though the uncertainties concerning the energy spectrum of the Crab Nebula are about 50 % on the absolute scale (see Konopelko et al., 1999), this source is the accepted standard candle of TeV gamma-ray emission.

In the following analysis, measured data are presented in Crab units. Results in Crab units have the advantage to rely only on measured data and to be free from systematic uncertainties due to the Monte Carlo (MC) simulations of the air showers and the detector response. For this new mirror configuration, up to now MC data are not available in sufficient amount. 59 hours of CT1 data from the Crab Nebula of the considered time period have been taken into account. The energy threshold is estimated to be 700 GeV near the zenith.

4 Data analysis

We applied the standard gamma/hadron separation with static supercuts on the Hillas parameters, (see Hillas, 1985). These cuts were applied to all three sets of data. Only events with more than 60 photoelectrons have been accepted for further analysis, see Table 1 for details. As the energy threshold increases with the zenith angle, only events with a zenith angle smaller than 35° are considered in this paper.

Hillas Parameter	Cut
DIST	$0.7° < \text{DIST} < 1.05°$
WIDTH	$< 0.15°$
LENGTH	$< 0.30°$
CONCENTRATION	> 0.39
SIZE	> 60 ph.e.
ALPHA	$< 10°$

Table 1: The static supercuts applied to the Hillas parameters

For each source, the number of ON-source events ON_s, the number of OFF-source events OFF_s, and the observation time T_s were determined. In the same way, the values ON_c, OFF_c, and T_c for Crab data were determined. From these values ON_s, OFF_s (ON_c, OFF_c, respectively) we calculated the upper (resp. lower) limit of the number of counts MAX_s (resp. MIN_c) at 99 % confidence level, using the probability density function of the number of source events (Helene, 1983). The upper limits UL_s in Crab units are calculated from: $UL_s = \frac{MAX_s}{MIN_c} \times \frac{T_c}{T_s}$.

5 Results

The data from the 1998 observation period did not reveal any TeV γ-ray emission from the examined BL Lac type sources. The upper flux limits are 4.3 % Crab for 3C66A and 4.6 % Crab for MS 0116, at 99 % confidence level.

The obtained values are summarized in Table 2. Please note that the values MAX_s (resp. MIN_c) are upper (resp. lower) limits at 99% CL. The significance and flux in Crab units are calculated from MAX_s and thus are upper limits for the two BL Lac objects.

Source	3C66A	MS 0116	Crab
Obs. Time/min	2218	3937	3530
ON_s	557	1406	2533
OFF_s	700	1661	1135
Excess	-143	-255	1398
MAX_s	34	63	–
MIN_c	–	–	1240
Significance	$< 0.96\sigma$	$< 0.99\sigma$	$> 18.3\sigma$
Flux/Crab	< 0.043	< 0.046	1

Table 2: Results of the data analysis.

As BL Lac sources are known to be very variable, (eg. Mkn 501 was nearly not visible in the TeV range during 1996, see Bradbury et al., 1997, but showed high rates in a flare in the following year) further analysis on a diurnal basis is in preparation, in order to find possible flares and high states on a short time scale. A preliminary look showed no night of significant higher excess rate.

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