A search for high energy γ-radiation from Mkn 421 using the imaging Cherenkov telescopes of the HEGRA collaboration[1]

D. Petry[2]

[1] *for a complete list of members see Fonseca et al.*

[2] *Max-Planck-Institut für Physik, München, Germany*

Abstract

The BL Lac object Markarian 421 was observed in 1994 and 1995 using the two imaging Cherenkov telescopes of the HEGRA experiment on the Canary island La Palma. No significant excess was found in the 1994 data. In winter 1994/95, new analysis software was developed by the author combining more thorough checks of the quality and consistency of the data with the standard Hillas parameter analysis [1]. Using this software, the data obtained in December 1994 to April 1995 from the second (larger) telescope was analysed and preliminary results are presented here.

1 Introduction

The HEGRA collaboration is operating in its existing detector complex at the site of the Observatorio del Roque de los Muchachos on the Canary Island of La Palma (28.75° N, 17.89° W, 2200 m a.s.l.) two imaging Cherenkov telescopes and intends to install four more. Data from about two years of atmospheric Cherenkov observations is already available. Among the observed objects are the Crab Nebula and the active galaxy Markarian 421 (Mkn 421).

As the nearest BL Lac object (redshift $z = 0.0308$), Mkn 421 has been studied by many authors in all wavebands. The attention of the cosmic ray community was drawn to it when the EGRET experiment aboard CGRO reported its detection in the 50 MeV to 10 GeV range [2]. Shortly after, the Whipple group announced their detection of gamma radiation from Mkn 421 between 0.5 and 1.5 TeV at a confidence level of 6.3 σ from 7.5/7.5 hours of on/off-source observations [3]. This detection is so far unconfirmed by another experiment.

The HEGRA collaboration's Cherenkov Telescope 2 (for a description see e.g. [5]) has an energy threshold of about 1 TeV. Hence, if there is no cutoff below this energy, a detection of radiation from Mkn 421 can be expected.

At the beginning of this year, Whipple reported to have seen two burstlike increases in the flux from Mkn 421, each on a timescale of a few days, between 10 May 1994 and 12 June 1994 [4]. During this period Mkn421 was also observed from the HEGRA site, but most of the data was taken at zenith angles greater than 30°. A preliminary analysis of this data has shown no significant excess.

Since this outburst Mkn421 is believed to have been emitting at a quiescent level of about half it's discovery level.

2 1995 observations and preliminary data analysis

In the period from 29-12-1994 to 27-4-1995 it was possible to take 79 hours of on-source observations of Mkn 421 with the HEGRA collaboration's Cherenkov Telescope 2. In a 23 minutes ON/OFF or OFF/ON rhythm, matching off-source observations were made. Neither the on- nor the two off-source positions contain bright stars. The observations were made at zenith angles between 9° and 55°.

From the total $2 \times 79 = 158$ hours of observations, 153 ON/OFF pairs were selected on the basis of weather information in the runbooks and daily extinction measurements from the Carlsberg Meridian Circle near the HEGRA site. This data was checked for correct telescope pointing and especially for the influence of artificial light sources (e.g. car headlights) which can cause temporarily very high rates but may not be noticed from the comparison of the total event numbers. A zenith angle limit of 45° was applied. 58 hours of good quality on-source data and matching off-source runs were retained.
To this data various quality cuts were applied:

1. The 61 pixels of the camera of Telescope 2 have plexiglas light guides in which penetrating muons radiate Cherenkov light. These can fake gamma-like events of low WIDTH. To overcome this problem an anti-coincidence shield consisting of a scintillator barrel around the camera with four attached photomultipliers is used. An event was rejected when one of these photomultipliers gave a signal of more than 3 standard deviations above its pedestal. This cut eliminates on average 5 % and depending on the zenith angle up to 15 % of the raw events.

2. Before each run, a set of 500 random triggers is recorded. From this data, the pedestal and the noise of each pixel is determined as the mean and the standard deviation. Before each series of runs, the gain of the photomultipliers is calibrated by recording 100 shots of a laser via an optical fibre onto a scintillator which is mounted at the center of the telescope, 5 m away from the camera.

   The hardware trigger condition is "2 out of all pixels above 20 photoelectrons" (applied to uncalibrated signals). In addition a software trigger was used which requires at least three *neighbouring* pixels to have a calibrated signal 4.25 standard deviations above their pedestal.

3. Events which had more than 25 pixels with a calibrated signal 4.25 standard deviations above their pedestal were rejected since the images of such events are very probably cut by the edges of the camera such that image parameters cannot be properly determined.

4. After the calculation of the image parameters (see below) a concentration cut is applied to eliminate further muon induced events:

   $$\mathrm{CONC} < 0.95$$

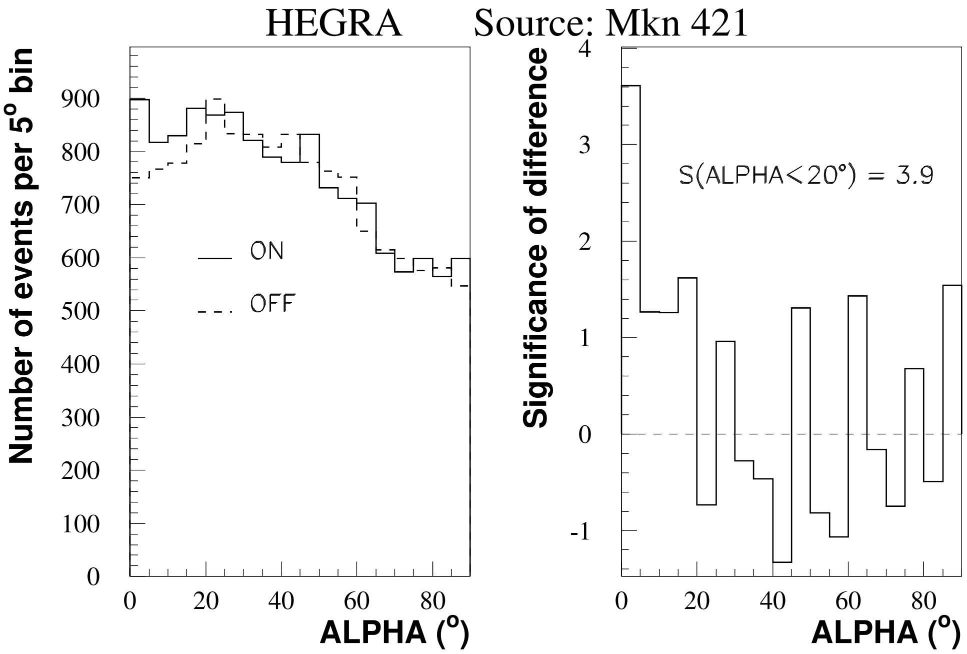

Figure 1: The distribution of the image parameter ALPHA for events which passed all quality cuts and the shape cuts (left), and the distribution of the significance of the difference ON - OFF in standard deviations according to [7] (right).

5. The telescope's camera has a hexagonal field of view with 3.9° diameter consisting of 4 rings of hexagonal 0.43° diameter pixels round a central pixel. Images which have a distance of their centroid to the center of the camera of less than a pixel diameter are rejected because the image parameters describing the direction of their major axis (MISS, ALPHA) are not well defined.

The image preparation which precedes the image parameter cuts described above consists of three steps:

1. All pixels are accepted to be part of the image which have a calibrated signal 4.25 standard deviations above pedestal *and* which have a neighbour which satisfies the same condition. These pixels form the image core.

2. All pixels which have a neighbour in the core *and* a calibrated signal 2.25 standard deviations above their pedestal are accepted into the image boundary.

3. Pixels which are neither part of the core nor the boundary are set to zero.

The values 4.25 and 2.25 were for a first attempt taken from [6] where a similar method is used, but they still have to be optimized to our instrument. For a description of the image parameter calculation see also [6]. Based on earlier Monte Carlo studies by [5] carried out for the first telescope, the following loose image parameter cuts were applied in addition to the quality cuts to obtain the result shown in figure 1.

1. $0.05 < \mathrm{WIDTH} < 0.2$
2. $0.1 < \mathrm{LENGTH} < 0.4$
3. $\mathrm{DIST} < 1.1$

Figure 1 shows the ALPHA distribution of 13477 on-source events and 13172 off-source events which passed the above selection procedure. Below 20° an excess of 315 events with a significance of 3.9 σ (calculated according to [7], equation 9) is observed. An AZWIDTH cut of $0.05° < \mathrm{AZWIDTH} < 0.2°$ if applied to the data without the cuts on LENGTH and WIDTH, results in 319 excess events with a significance of 3.3 σ. With this approach and removing the influence of the star ζ Tauri, an excess of 700 events with a significance of 4.3 σ was obtained from 33 hours of Crab nebula observations.

We conclude that with non-optimized cuts a significant signal has been seen. This result is preliminary as there is still a dedicated Monte Carlo study to be carried out in order to optimize the cut parameters and determine the exact efficiencies of the cuts applied and their impact on the effective collection area taking into account the anticipated spectrum of Mkn 421. Detailed results will be presented at the conference.

References

[1] Cawley, M.F. et al., 1985, Exp. Astron., **1**, 173

[2] Lin, Y. C. et al., 1992, ApJ, **401**, L61

[3] Punch, M. et al., 1992, Nature, **358**, 477

[4] Kerrick, A. D. et al., 1995, ApJ, **483**, L59

[5] Krennrich, F., 1994, Towards a Major Atmospheric Cherenkov Detector III, Universal Academy Press, Tokyo

[6] Reynolds, P. T. et al., 1993, ApJ, **404**, 206

[7] Li, T. P. and Ma, Y. Q., 1983, ApJ, **272**, 317