TEV GAMMA RAYS FROM MARKARIAN 421

(The Telescope Array collaboration)

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ABSTRACT

Observation of TeV gamma rays from Markarian 421 were achieved using two Cherenkov imaging telescopes of the Telescope Array prototype detectors with 3 m diameter at Akeno Observatory in Japan. Gamma rays from Mrk 421 were observed on May 12, 1996. This date is very close when the Whipple group observed rapid bursts.

1. INTRODUCTION

More than 50 active galactic nuclei(AGNs) have been detected as gamma-ray sources by the EGRET detector on board the Compton Gamma Ray Observatory with energies above 100 MeV. (Hartman et al. 1992, 1994; Fichtel et al. 1994) In contrast, only two of them, Mrk 421 and Mrk 501, are identified as the gamma-ray sources in the TeV energy range by atmospheric Cherenkov experiments.(Punch et al. 1992, Petry et al. 1996, Quinn et al. 1996) Both of them are known as nearby BL Lacertae class of the AGNs, which is a subset of the broader blazar class. Gamma ray variability for these sources has been observed.(Kerrick et al. 1995, Buckley et al. 1996) Extremely rapid bursts of TeV gamma rays from Mrk 421 were observed on May

7 and 15, 1996 by the Whipple Observatory collaboration. (Gaidos et al. 1996) The flux of the gamma rays together with the time scales of the flux variation will give strong constraints on the emission mechanism.

We have been observed Mrk 421 since November 1995 till May 1996 using two 3m diameter Cherenkov telescopes at an altitude of 900 m (920 g/cm^2 in atmospheric depth) at Akeno Observatory in Japan (138°30'E and 35°47'N). Our data set with 35 min observation time on May 12, 1996 which is close to the date the Whipple Observatory collaboration observed the rapid burst, also indicated a signature of gamma ray flare.

2. EXPERIMENTAL METHOD

Two Cherenkov telescopes were installed at Akeno Observatory with a distance 40m apart.(Fig.1)

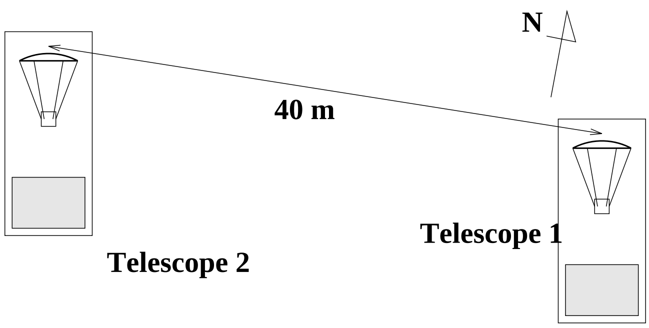

Figure 1: Two Cherenkov telescopes installed at Akeno Observatory.

The telescopes are protected by shelters in order to avoid dust, rain and light in the day-time. Reflector of the telescope consists of 19 hexagonal shape segment mirrors coated with aluminum and then anodized. Total mirror surface area of the telescope is 6m^2. Spot size of each segment mirror is around 4 mm. Reflectivity of each segment mirror is measured to be about 90% at 400 nm.

The telescope has altazimuth mount and is controlled by VxWorks local computers which is mounted on the telescope. The computers read the encoder outputs with an accuracy of 0.001° to estimate the tracking error, then feedback of this error is sent to the next step control for the telescope speed and the acceleration speed. These control cycles are done every 0.1 second and all tracking information is sent to the host computer. By scanning bright stars with photomultiplier camera, tracking accuracy was found to be better than 0.02°.

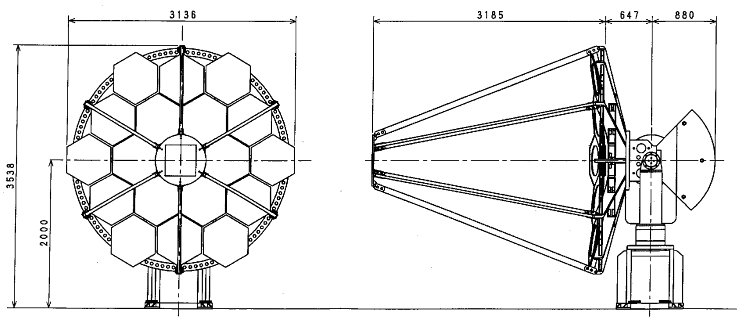

Figure 2: Front and side view of the Cherenkov telescope

At the focal plane of the telescope, a 256 pixel camera is mounted. The camera consists of 64 multianode photomultipliers(PMT), Hamamatsu R5900-03-M4, each of which has four channels of anodes. Quantum efficiency of the PMT is over 20 % between 300nm and 450nm. Field of view of a pixel of the PMT corresponds to $0.25^\circ \times 0.25^\circ$, then the field of view of the camera corresponds to $4^\circ \times 4^\circ$

The optical filter of Shott BG3 with a thickness of 4 mm are held on the PMT head with optical glue. This filter eliminates background light and accepts light between 300nm and 450nm. The internal transmission of the filter is better than 90% between 300 nm and 430 nm. It has a tapered shape: the window is 28mm $\times$ 28mm, and the plane contacting the PMT head is 24mm $\times$ 24mm. Therefore, it works not only as a filter of the light but also as a light collector. With this optical filter/collector, more than 90% of the light focused on the camera cluster is guided to the PMT photocathode. The optical and the electrical cross talk between four channels in the multianode PMT was examined and found to be less than 3%.

Signals from the PMTs are amplified and then fed to data acquisition system at the telescope mount. Output charges and timings of the pulses from the PMTs are measured for each of 256 ch. Threshold level of discriminators were controlled by a computer to have a constant counting rate from each PMT, and were set to voltages corresponding to around several photoelectrons for the present experiment. We required at least five hit channels in a subcluster of 4ch$\times$4ch PMTs for triggering events. Gain of the PMTs and amplifiers were monitored by using a blue LED which flushed every 1 min.

A new tracking method called the 'raster scan' is employed. During the raster scan the center of the field of view of the camera scans inside a square region of $1^\circ/\cos(\mathrm{dec})\times 1^\circ$ in right ascension and declination plane centered the target of Mrk 421.

We have observed Mrk 421 for 31.04 hours in total from Mar 1996 until May 1996. We labeled the data set into three categories of 'excellent', 'good' and 'poor' depending on weather condition. We used only the 'exellent' data set of 8.42 hours on Mar 22, Apr 11,12,16 and May 12 for the present analysis.

3. RESULTS

Image processing to select events for which the image concentrates in geometry and timing were made to reject background photons coming from the night sky. Usual image analysis (Weekes et al. 1989) was carried out.

A distribution of the alpha parameter for Mrk 421 on May 12, 1996 for 35 min observation

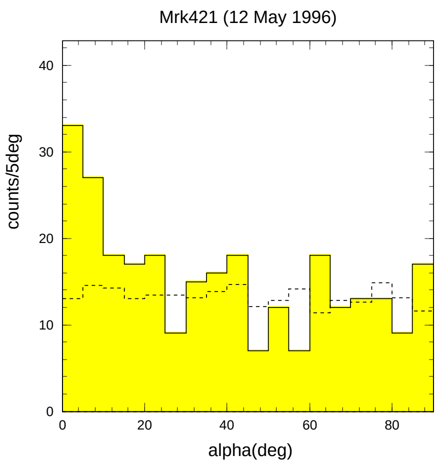

Figure 3: Distribution of the alpha parameter for Mrk421 on May 12,1996.

time is shown in Fig. 3 for which the alpha distribution for two telescopes are added. Clear excess of events were found at small alpha region less than 15° in this distribution.

A map of significance value of the excess events for this date is shown in Fig. 4. The excess events are found to be concentrated at the center of the map where Mrk 421 exists. Chance probability to have excess events at the center in the map will be very small. Whipple Observatory collaboration observed very rapid bursts on May 7th and 15th and no significant flare on 12th and 13th. Observable time range is different at Akeno and Whipple. Therefore there would be strong burst on May 12th again based on our data. Although we also examined other available 'exellent' data set similarly, we did not find such kind of signature at all.

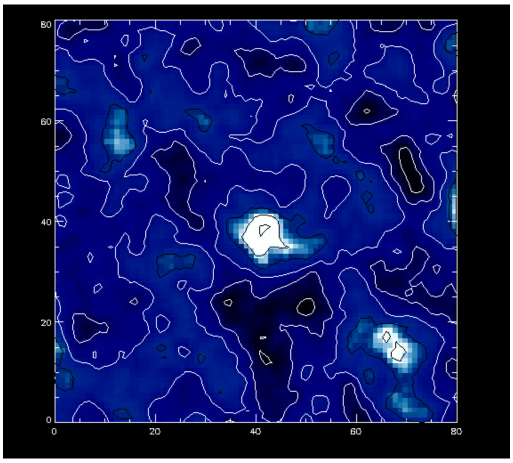

Figure 4: Map of significance value of excess events in right ascension and declination plane of $5° \times 5°$ centered at the position of Mrk 421 on May 12, 1996.

Besides the present detection of the gamma-ray signature from Mrk 421, we have successfully detected gamma rays from Crab Nebula and Mrk 501 using data observed by two telescopes at Akeno Observatory and two at Utah Fly's Eye site. (Aiso et al.[a] 1997) Three Cherenkov telescope were constructed in 1996 and in operation at present at Utah Fly's Eye site. Four more telescopes are under construction at the same site. (Aiso et al.[b] 1997) We will be able to observe many celestial objects such as active galactic nuclei, supernova remnants, pulsars and so on in very near future.

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