The energy spectrum of high energy gamma rays from Mrk501 by the stereoscopic analysis

The Utah Seven Telescope Array collaboration

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Abstract

We have developed the energy measurement method which based on stereoscopic observation with multiple telescopes for TeV gamma rays. Energy resolution obtained by this method was 23%. The energy spectrum of the gamma-ray flares of Markarian 501 in 1997 was also obtained using this techniques. We have confirmed the bending or the cutoff of the energy spectrum around several TeV.

1 Introduction:

Precise measurement of the gamma-ray energy spectrum in the TeV region from nearby extra-galactic objects is one of the important objectives. We expect cutoff in their energy spectrum by the interaction with the infrared photons in the inter galactic space. The cutoff energy depends on the distance of the objects and density of infrared photons (Stecker and M.Salamon 1997). If we can measure the cutoff energy precisely as a function of redshift z, we can give constraints on the Hubble constant and the infrared photon density experimentally. The maximum energy of the electron acceleration in the AGN jet is another interesting topic.

It will represent the physics state of the jet and the super massive black hole which is supposed to exist at the center of the AGN.

The most promising way to measure the gamma-ray energy in the TeV region is the stereoscopic observation of the Cherenkov light from the air showers event by event. With this method, the axis of air shower, the arrival direction, the intersection of the axis and the ground (core location) and the amount of Cherenkov photon are detected more precisely. Making use of these advantages, we tried to calculate the differential energy spectrum of TeV gamma rays.

Using the Monte Carlo Simulation, we derived the relation between the primary energy of gamma rays and several parameters, ADC value(ADCsum), the zenith angle, and the core distance which is the distance between the shower axis and the telescope. In this procedure, we compared parameter distributions of experimental data with those of simulation data and we found good agreement. Using this method, we have determined the differential energy spectrum of the gamma rays from Mrk501.

2 Experiment:

The Utah Seven Telescope Array has been in operation at Cedar Mountain(1,600 m a.s.l.), Dugway in Utah (40.33° N, 113.02° W). Each telescope is arranged at the grid of a regular hexagon and at the center with a separation of 70m. We have started the operation with three telescopes since March, 1997.

Each telescope has a 3 m diameter dish with nineteen hexagonal segment mirrors and total effective mirror area of 6 m^2. The 256 channel camera with 0.25 degree pixels is mounted on the focal plane of each telescope. This camera is made of multi-anode photomultipliers(MAPMT) having 4 pixels.

Details of this experiment are reported in OG.4.3.25.

3 Analysis:

In order to determine primary energies, directions and core positions from images of Cherenkov light of air showers generated by TeV gamma rays and cosmic rays, we used a simulation based of the code of CORSIKA.

From shower images on the cameras of multiple telescopes, image parameters are calculated and a shower axis is obtained. A detector-shower plane which includes the position of the telescope and the shower axis is determined for each telescope. Then we can determine the intersection line of these planes, which corresponds to the three-dimensional shower axis. Core location of the shower is determined as the intersection point of the shower axis and the ground plane. Figure 1 shows these procedures and the resolution. Position resolution obtained by this method is 12 m in which 50 % of the total events are included.

The relation between the total ADC counts and the primary energy of gamma rays is estimated as a function of zenith angle and core location. Based on this relation, the primary energy of gamma rays is determined event by event. The energy resolution obtained from this analysis is estimated to be 23 % (Figure 2.a).

4 Energy spectrum:

For the analysis in this paper, we use all of the events that were detected by two telescopes. In the case of the observation using three telescopes, there are three combinations of two telescopes. It means the efficiency of the observation using three telescopes is three times higher than two telescopes. The data used in this paper was acquired from the beginning of April to the end of the July 1997. In April, two telescopes were operated and one more telescope joined to the observation since May. Total observation time was 137.6 hours.

Figure 3.a shows the primary energy distribution of the detected air showers assuming the primary particles are gamma rays. We calculate the energy distributions in the on-source and in the off-source region, respectively. With this figure, the energy distribution of gamma rays from Mrk501 can be estimated. Subtracting off-source events from on-source events, the energy distribution of the gamma rays is obtained. Taking into account the effective area and the observation time, differential energy spectrum of the gamma rays from Mrk501 is calculated. Figure 3.b)

5 Conclusion:

We have developed energy determination method for gamma rays using stereoscopic technique. Accuracies of core location determination and energy determination are 12m and 23%, respectively. Note that the image parameters like WIDTH and LENGTH are not used except to determine the image axis in this analysis. We have obtained the differential energy spectrum of the gamma-ray flare of Mrk501 in 1997. The flux of the gamma rays is well represented by a differential power spectrum with an index of -2.5 between 700 GeV and 3 TeV and the steepening effect seems to appear above several TeV.

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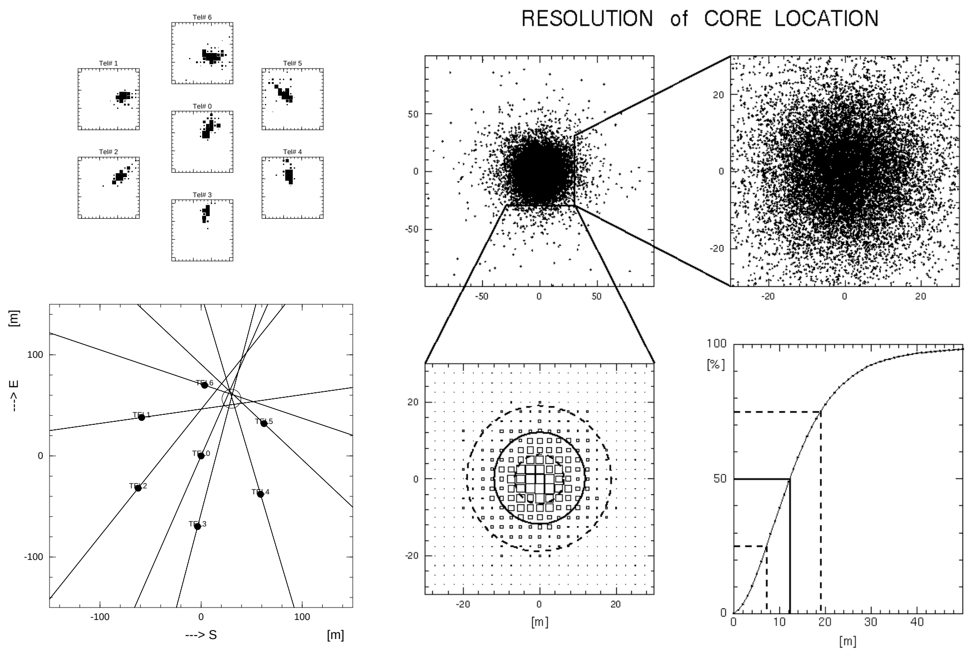

Figure 1: (a) The Left top figure shows the images of air shower initiated by gamma ray made by Monte Carlo simulation. Left bottom panel shows the arrangement of the telescopes, core location and line of intersection of the shower plane and ground. The real core location is given by the white circle. (b) Right panel shows the resolution of core location calculated by the Monte Carlo simulation. The center of each panel is the real core location. The estimated core location from the shower plane are plotted in the area of 200 m and 60 m. The bottom right panel shows the number of the estimated core locations in each area. It shows boundary in which 50% of the total events are contained is 12 m.

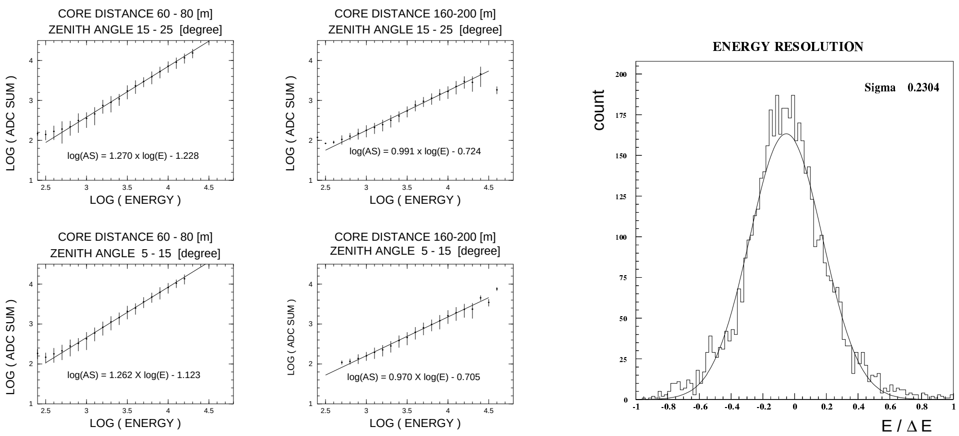

Figure 2: (a) Left panel shows the relation between primary gamma-ray energy and ADC sum in each core distance and each zenith angle. (b) Right panel shows the energy resolution of this analysis calculated by the Monte Carlo simulation. According to this figure, the energy resolution of this analysis is shown to be 23 %.

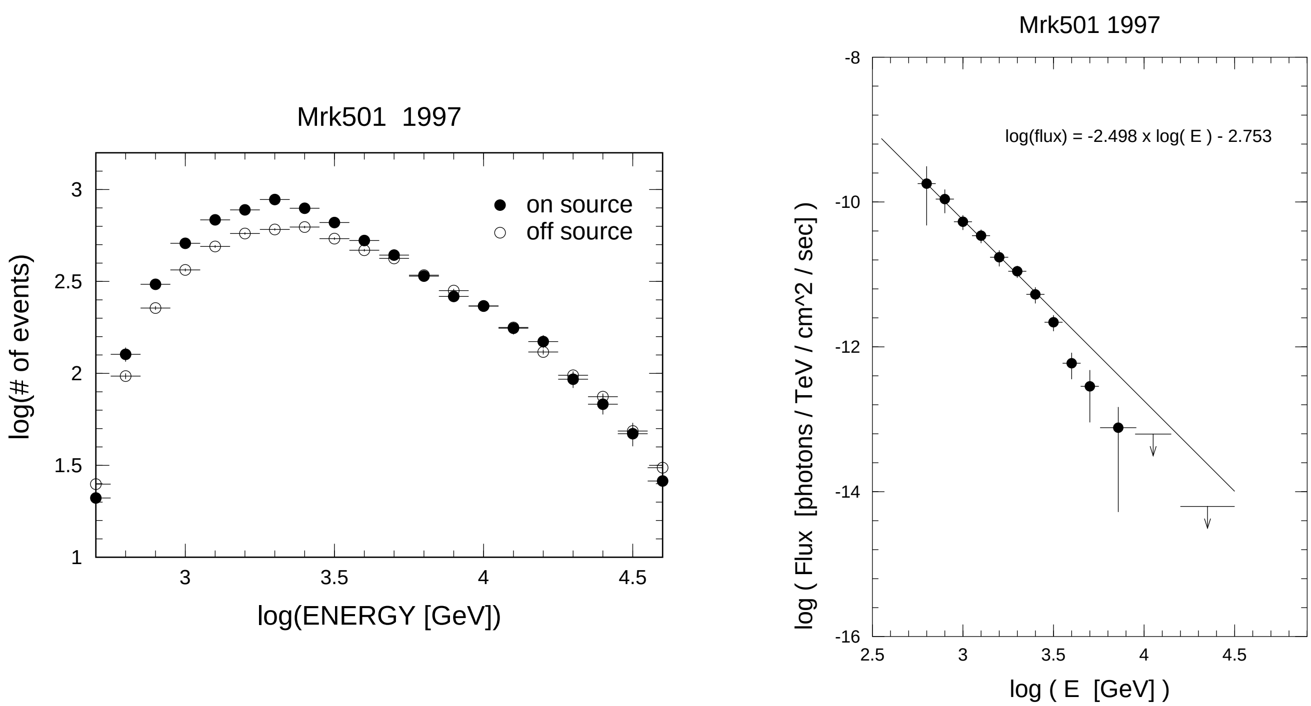

Figure 3: (a) Left panel shows the distribution of the primary energy of the air showers which are detected by more than two telescopes. The on source area and the off source area are presented. (b) Right panel shows the result of the calculation of the differential energy spectrum of the gamma rays from Mrk501 observed in 1997 obtained by the stereo analysis.