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THE TELESCOPE ARRAY PROJECT

(The Telescope Array collaboration)

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ABSTRACT

The current status of the Telescope Array project and the results of the development work will be reported. Prototype telescopes were installed at the Akeno observatory and Utah Fly's Eye site. A seven telescopes array, the prototype Telescope Array will be completed at Utah Fly's Eye site in the summer of 1997. The TeV gamma rays from the Crab Nebula and Mkn501 were successfully observed with these prototype telescopes.

1. INTRODUCTION

Recently, the highest energy cosmic rays above $10^{20}eV$ were discovered by the Fly's Eye experiment(Bird et al 1995) and the AGASA experiment (Hayashida et al. 1994). These cosmic rays have macroscopic energies of 50J and 30J, respectively. We find it difficult to explain their origins. Their trajectory must be straight in intergalactic space and in our galaxy because of their high rigidities. The propagation length is also limited due to the Greisen (1966), Zatsepin and Kuzmin (1966) effects. Therefore we expect nearby large accelerators (active astronomical objects) in their arrival direction. But we have failed to identify likely candidate sources. Their nature is a mystery. The Toplogical defect model which explain the

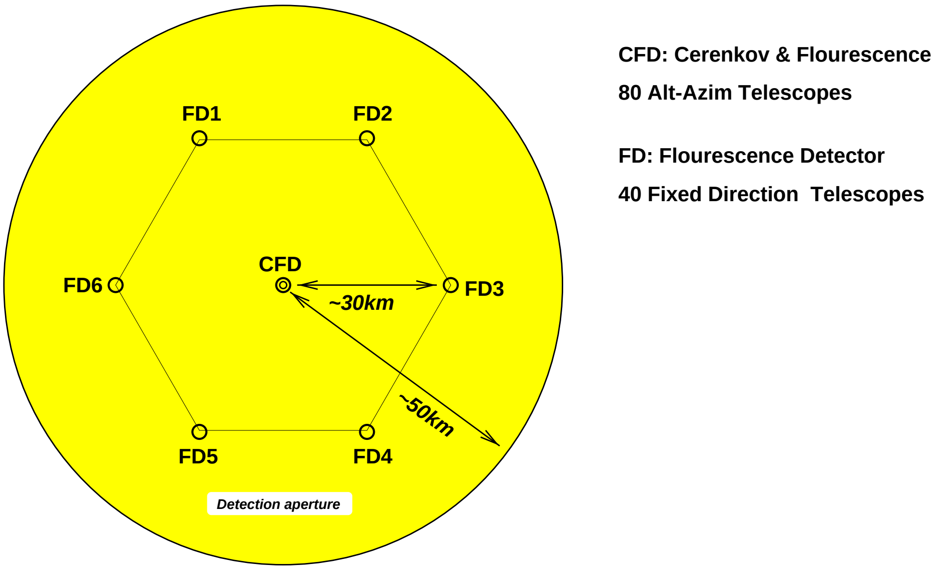

Figure 1: The conceptual design of detector station arrangement. Each station has 40 fixed directional telescopes which are dedicated for the detection of the highest energy cosmic rays. The central station (CFD) has also 80 steerable mount telescopes capable of doing TeV gamma ray astronomy.

highest energy cosmic rays as a decay products from cosmic strings and monopoles, and the relation with GRB's are discussed seriously. Anyway, in order to study the highest energy cosmic rays more quantitatively, we need a detector with a larger aperture.

In the last 10 years, several TeV gamma ray sources have been identified by the Whipple (Cawley et al. 1990), CANGAROO(Hara et al. 1993) and HEGRA IACT(Aharonian 1993) experiments. The Crab Nebula is one of the prominent TeV gamma ray sources. The origin of the gamma rays from Crab Nebula can be well explained by the S.S.C. (Synchrotron Self Compton) model, though there is the possibility of the existence of additional components as discussed by Aharonian and Atoyan (1995). More precise measurement of energy spectrum is required to obtain conclusive emission mechanism. Another astonishing discovery is the identification of the BL Lac type AGN's as TeV gamma ray sources. The strong TeV gamma ray flares of Mkn501 were observed by Whipple Telescope, HEGRA, CAT, and TA prototype detectors. The results from TA prototype detectors will be reported in this conference. The studies of variabilities of gamma ray flux will give us the informations about the high energy phenomena around the Black Hole existing at the center of AGN.

The improvement and the development of new detectors which have sensitivities greater than the current detectors by an order of magnitude in both energy regions are highly required.

2. TELESCOPE ARRAY DETECTOR DESIGN

In figure 1., the conceptual design of the station arrangement for the full scale Telescope Array is shown. It consists of seven stations with a separation of 30km between each adjacent station. This station arrangement (the number of stations and the distances between stations) is optimized for the detection of the highest energy cosmic rays. The estimated aperture for $10^{20}eV$ cosmic rays is larger than $30,000 km^2 str$.

Each station consists of 40 fixed directional telescopes with a camera of 1° pixel. Their field of view is $16° \times 16°$. They will cover 2π azimuth and 32° elevation of the sky near the horizon. Each telescope has a 3 meter diameter main dish consisting of seven segment mirrors.

The boundary six stations are dedicated for the studies of the highest energy cosmic rays and the deeply penetrating air showers initiated by high energy neutrinos.

The central station also has 80 steerable telescopes which have 1024 pixel (0.25° per pixel) high resolution cameras and a 3m diameter main dish segmented 19 mirrors. This design gives the central station the capability to study not only the highest energy cosmic rays but also the high energy gamma rays with cerenkov mode. 80 telescopes are divided into 20 locations, and at each location, four telescopes are installed close together. The trigger will be generated using the signals of four telescopes. It will minimize the effect from the background photons and reduce the threshold energy for gamma ray detection to 100 GeV, giving us a wide energy band. These multiple telescope system in the TeV gamma ray astronomy will give us the special opportunity, doing survey observation in the all sky, monitoring the AGN's and searching GRB's in TeV energy region.

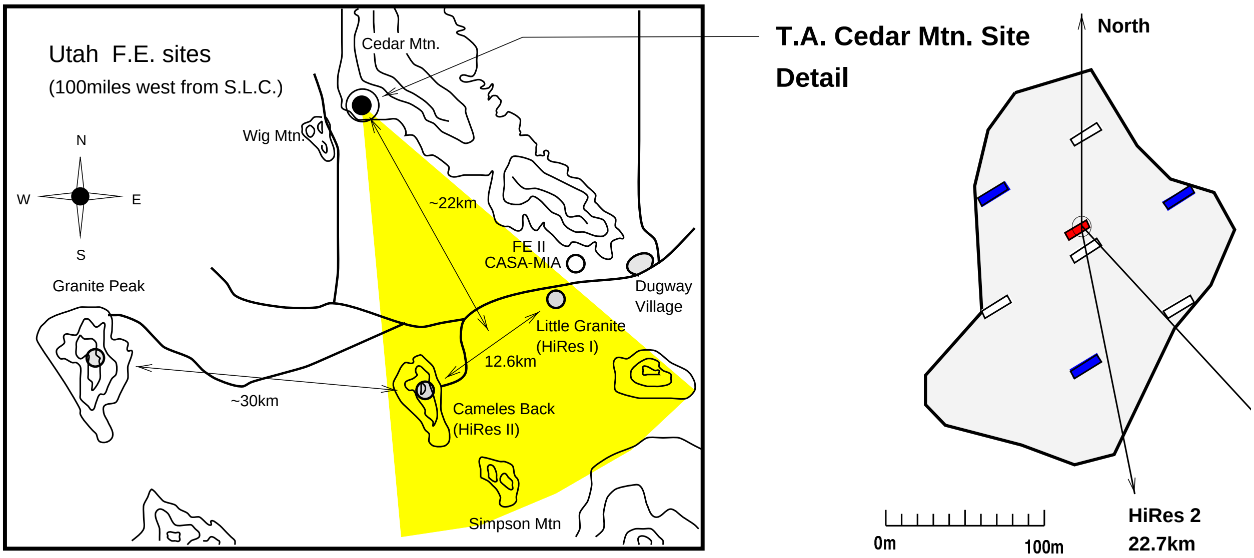

Figure 2: The telescope arrangement of a seven telescope array (Telescope array prototype) under construction at the Utah Fly's Eye site. Three telescopes are already in operation. This prototype will be completed in the summer of 1997. The distance between this prototype and the HiRes I and HiRes II is about 22km (Al-Seday et al. 1996). Stereoscopic observations of the highest energy cosmic ray can be done with these three stations. This prototype works as a TeV gamma ray detectors, too. The stereoscopic observation and intertelescope triggering method for the TeV gamma rays will give us the better angular resolution, the better hadron rejections, and lower threshold energy.

3. PRESENT STATUS

The development work is progressing for the Telescope Array project. The steerable mount telescope, the photomultiplier camera, the data acquisition system, the online sky monitoring system, and the shelters are under development.

The main dish of prototype telescope consists of 19 hexagonal shape segment mirrors coated with aluminum and then anodized. Total mirror surface area is $6m^2$. The mirror base is made of pyrex glass. The spot size of each segment mirror is about 1mm. The reflectivity at 400nm is about 90%. At the focal plane of the telescope, the prototype camera of 256ch is installed. The camera consists of packed 64 multi anode photomultipliers, each with four anodes. The optical filter of shott BG3 with a thickness of 4mm are held on the photomultiplier head with optical glue.

For the online monitoring of the sky condition, a lidar system is under development. A Nd:YAG laser with a third harmonic at 355nm gives a beam which is very close to the major line of air scintillation light. The Nd:YAG laser has been used to simulate the air scintillation light from the giant air showers at Akeno observatory, and we found that the accuracy of arrival direction determination with our telescopes is better than 0.03°.

The prototype detectors have been constructed at the Akeno observatory and at the Utah Fly's Eye site. The TeV gamma ray observation were carried out and the gamma rays from Crab Nebula and the gamma ray flares of Mkn501 were successfully detected as presented in this conference. The intensity of gamma rays from Mkn501 became stronger than the Crab by a factor of 2-4. The transient phenomena something like a AGN flares and GRB's can be studied efficiently with wide FOV system or a system with many telescopes. The telescope array prototype and the central 80 alt-azimuth telescopes in the full scale system will become the powerful instruments for the study of the transient phenomena.

After the current development work, we hope to start the construction of the full scale telescope array around 2000. The total amount of the construction cost is $60M, for which we expect fruitful results on cosmic ray physics in a wide energy range. The site survey for the full scale telescope array continues, but the first candidate site is the same site as the north Auger array, Millard county, Utah.

The advantage to installing the Telescope Array in the same site of the Auger array is to confirm the determination errors of the shower parameters between two quite different methods. The longitudinal shower development, the lateral distribution of shower particles, and the ratio of the number of muons and electrons in the shower can be measured by the fine resolution optical detector (Telescope Array) and the ground array (Auger array). In order to clarify the origin of the highest energy cosmic rays, the study of the chemical composition plays a key role.

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