N92-21929

Status of the Whipple Observatory Cerenkov Air Shower Imaging Telescope Array

C.W.Akerlof(1), M.F.Cawley(2), D.J.Fegan(4), S.Fennell(4), S.Freeman(1), D.Frishman(1), K.Harris(3), A.M.Hillas(5), D.Jennings(6), R.C.Lamb(6), M.A.Lawrence(3), D.A.Lewis(6), D.I.Meyer(1), M.Punch(4), P.T.Reynolds(6), M.S.Schubnell(1), T.C.Weekes(3)

(1) University of Michigan
(2) St. Patrick's College, Maynooth
(3) Harvard-Smithsonian Center for Astrophysics
(4) University College, Dublin
(5) University of Leeds
(6) Iowa State University

Introduction

Recently the power of the Cerenkov imaging technique in VHE gamma-ray astronomy has been demonstrated by the detection of the Crab nebula at high statistical significance by the Whipple collaboration [1]. This was independently confirmed using a similar method by the University of Michigan group [2]. In order to further develop this technique to allow the detection of weaker or more distant sources a second 10 m class reflector has been constructed about 120 m from the original instrument. Figure 1 shows the location of the two reflectors on the 2300 m ridge of Mount Hopkins, Arizona. The addition of the second reflector will allow both a reduction in the energy threshold and an improvement in the rejection of the hadronic background. The design and construction of the second reflector, GRANITE (Gamma Ray Astrophysics New Imaging TElescope) [3] is described below.

Mount and Optical Support Structure

The mount was manufactured by McDonnell Douglas to be used as a solar concentrator for electrical power generation. It consists of a pedestal with an elevation over azimuth drive system and a parabolic dish framework of 7.62 m focal length. The dish was modified to accommodate our mirror mounting system by welding brackets to the frame to hold the **aluminum** bars to which the mirror mounting plates are bolted. The pedestal and drive were installed in October 1990 and the dish elements were attached in March 1991. Two views of the reflector are shown in Figure 2. The elevation and azimuth are driven by identical 1/2 hp 480 V motors running at 1760 rpm through helical gear systems. Motion of the dish is governed by a microprocessor controller located in the pedestal which reads the mount sensors and switches power to the motors accordingly. This in turn is controlled through a serial line by either a hand-held remote control or a DEC PDP-11/23 computer. The computer software is a version of the solar tracking program modified to track sidereally and to communicate with the GRANITE data acquisition computer.

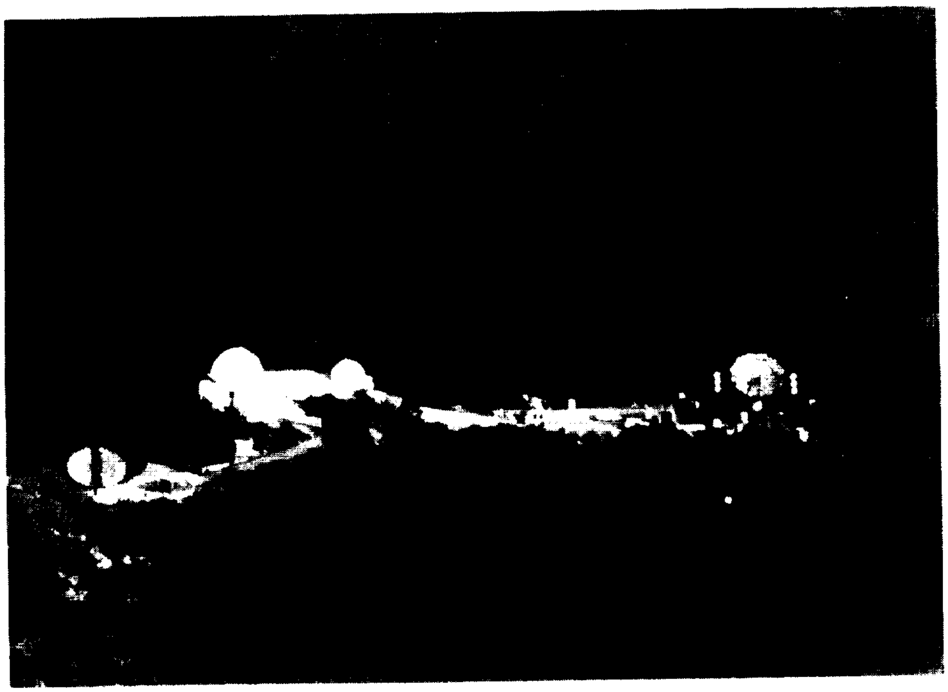

Figure 1: The Whipple Observatory Cerenkov imaging reflectors. The original 10 m reflector is on the right. The central building houses 1.5 m and 1.2 m optical telescopes.

Mirrors

The mirrors are hexagonal elements measuring 46 cm across the flats. They were designed to be robust and to withstand many years of use in an exposed position without significant degradation of the optical quality. The mirrors were fabricated by cutting 5 cm thick foam glass to the required hexagonal shape and then grinding the desired figure into the material using abrasive paper glued to an aluminium form with the appropriate curvature. Then epoxy was applied to both the foam glass and a hexagon of 0.7 mm thick back-aluminized glass and the two pieces pressed together with a weighted form identical to that used in the grinding process. Only a few pounds of weight were required to deform the thin glass to the desired shape; no heating is used. Finally the outer edge was beaded with polyurethane caulk and the foam glass painted with mastic and latex paint to enhance durability. This construction technique using second surface reflection and durable materials produces mirrors which can be washed if necessary and will not require recoating. Resistance to hail damage was tested by dropping ice cubes onto the mirrors from 15 m. Should the glass be shattered at a point the adhesive tends to limit the propagation of the cracks. A test mirror has been mounted on the 10 m reflector for over a year with no sign of deterioration. Four different focal lengths were fabricated to approximate the parabola defined by the structure of the reflector. The rms error in all the mirror surfaces was measured to be less than 0.3 mr [4].

The mirrors have a 15 cm square plate epoxied to the back to facilitate mounting. They are mounted by a three point system with two threaded adjusters to allow for alignment. The three mounting rods are attached to an aluminium plate which is bolted to the mirror bars on the dish. A total of 366 mirrors are currently mounted on the reflector giving a reflective surface of 66.3 m^2. The total mass of mirrors and mounting system is approximately 1550 kg.

The alignment of the mirrors was performed using a retro-reflection technique. The alignment device consists of a 10 mW He-Ne laser mounted on an optical bench aligned with the optic axis of the dish. The optic axis is defined by a similar laser mounted on the reflector. The alignment beam, expanded to cover the area of a single mirror, is reflected from each of the mirrors in turn and the mirror orientation adjusted to reflect the light back along the outgoing path to a screen placed around the laser exit aperture.

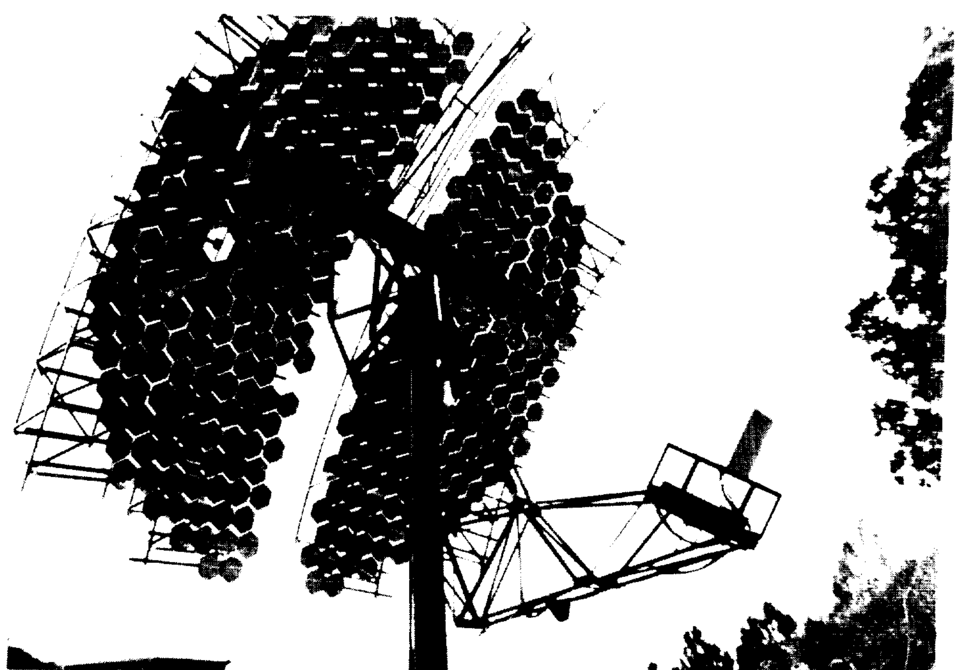

Figure 2a: The 11m reflector in a stow position, facing north and about 30 degrees below the horizontal.

Figure 2b: The 11m reflector at about 45 degrees elevation.

Camera and Electronics

The camera currently at the focus of the reflector consists of 37 photomultipliers of 5 cm diameter (Amperex XP2230) each with a 0.5 degree field of view. This camera design is essentially identical to that used previously in the Whipple Observatory 10 m reflector [5]. The focus box includes a motorized shutter system to protect the photomultipliers during daylight. The camera will be upgraded to 109 photomultipliers to match the current configuration of the 10 m reflector as funds allow.

The data acquisition system has been designed to extract as much information as possible from each event. For every photomultiplier pulse the integrated charge, arrival time and pulse width will be measured. The recording system is able to operate both independently and in coincidence with the 10 m reflector and with event burst rates of up to 1 kHz. Two levels of trigger are implemented: a low-level trigger accepted in coincidence with a signal from the remote dish or a higher level trigger recorded independently of the status of the remote instrument. The front-end electronics are an in-house design incorporating two discriminators and a wide band amplifier for each channel [6]. The majority of the remainder of the electronics are commercial CAMAC modules, controlled by an in-crate LSI-11 microcomputer. The LSI-11 writes the data in a memory buffer which is read out by the VAXstation 3200 which controls the overall data acquisition system and also the photomultiplier high voltage supply. The UTC time of each event will be established by a GPS clock to an absolute accuracy of 750 ns. In addition events at both reflectors will be tagged by a counter module clocked at 20 MHz to facilitate offline matching of coincident events. This will also allow the Cerenkov light signals in the two telescopes to be correlated to an accuracy of better than 1 ns.

Anticipated Performance

It is estimated that the combined effect of stereoscopic imaging and a lowered energy threshold will permit roughly an order of magnitude increase in flux sensitivity for showers imaged in both telescopes. The angular resolution for these events will be approximately one arc-minute [7], and the energy threshold is expected to be 100 GeV, with a trigger rate of approximately 50 Hz. The angular resolution exceeds that of any gamma ray detector, whilst the energy threshold approaches the upper energy limit of the EGRET instrument on GRO. The stereoscopic imaging will allow the arrival direction and ground impact point of showers to be determined unambiguously. This will enable accurate measurement of the sensitive area of the telescope, resulting in better measurements of energy spectra and absolute flux levels.

The GRANITE twin telescope system will serve as a prototype for a much larger array of imaging detectors, CASITA (**Cerenkov** Air Shower Imaging Telescope Array). In an array the Cerenkov light pool would be sampled by a number of imaging detectors simultaneously, giving further improvements in rejection of the hadronic background. A high altitude site combined with a large Cerenkov light collecting area will lower the energy threshold, and triggering on coincidences between the detectors will enable the array to operate at very low light levels. Improved optics and higher resolution cameras will enhance the hadron rejection obtained by imaging. Operation of GRANITE will assist in the determination of the optimum design parameters for a future imaging telescope array both directly and by providing a check on simulations performed for this purpose.

References

[1] Vacanti G. et al. Ap. J. 377, 467 (1991)
[2] Akerlof C.W et al. Proceedings of the Gamma-Ray Observatory Workshop, G.S.F.C., Ed. W.N Johnson, **4-49**, (1989)
[3] Akerlof C.W et al. Nucl. Phys. B., 14A, 237 (1990)
[4] Weaverdyck C et al. 1991, submitted to N.I.M
[5] Weekes T.C et al. Ap. J. 342, 379, (1989)
[6] Levy H. et al. N.I.M. A292 715, (1990)
[7] Akerlof C.W et al. Ap. J. Lett. 377, L97 (1991)