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PROPOSAL TO
DEPARTMENT OF ENERGY
FOR
THE APPLICATION OF TWO-DIMENSIONAL IMAGING
TO VERY HIGH ENERGY GAMMA RAY ASTRONOMY

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PART II.

PROGRESS REPORT.

Our progress over the past year will be discussed under the following headings:

(1) CRAB NEBULA.

In our report last year we discussed the detection of the Crab Nebula by this experiment. At that time the observations were still in progress and the data only partially analysed. We are pleased to report that further observations have confirmed our detection, that the detailed analysis revealed no systematic errors and that a lengthy paper which describes the technique in general, and these observations in particular, has been accepted for publication in the Astrophysical Journal (July, 1989). A preprint of this paper is included in the Appendix. Here we will give a brief summary.

The result is important for a number of reasons. It has strong statistical significance (9σ), it is an observation of a source which is one of the best studied objects in the sky, it demonstrates the power of a new detection technique and it identifies the primary flux as being electromagnetic in character. Although very recent, in a sense it is the first result in TeV gamma-ray astronomy since it is the first case where gamma-rays have been unambiguously identified.

The observations were made using the imaging atmospheric Cherenkov technique that was developed by us starting in 1982. The 10 Optical Reflector at the Whipple Observatory was fitted with an array of 37 phototubes, making it a fast, large aperture, camera, very suitable for recording the images of Cherenkov light flashes from air showers in the 0.5 to 5 TeV energy range. Computer simulations of air showers using Monte Carlo methods predicted that there would be significant differences in the appearance of the light images from gamma-rays from a discrete source in the center of the field of view of the camera and from an isotropically distributed background of showers from charged cosmic rays. Precise divisions of parameter space of the recorded Cherenkov light images into a gamma-ray domain (dominated by gamma-rays), and a much larger domain corresponding to background protons was predicted. It is important to note that the predicted differentation is based on two

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distinct factors: (1) an inherent difference in the size of the image because pion production angles in hadron-initiated showers are larger than the purely electromagnetic production processes in the gamma-ray initiated cascade; (2) a difference in the orientation of the major axis of the nearly elliptical images in which gamma-ray shower images from an on-axis source are radially distributed.

The observations were made between December, 1986 and February, 1988 and consisted of 175 pairs of runs on the Crab and a comparison region, each run lasting approximately 28 minutes. Only observations taken under ideal conditions were included in the analysis. The camera was triggered when any two of the inner 19 tubes exceeded a preset threshold; as each pixel was 0.5° this scale matched well the typical size of the expected gamma-ray events and also, because of the multiplicity of pixels, gave a large collection area. The trigger rate, which was conservatively set to get well-determined images, was 3-4 Hz.

A total of 652,974 showers were recorded from the Crab direction, compared with 651,801 from the comparison region. The excess of 1,173 (+1.0 sigma) was not significant. Separation of the measured images parameters into the pre-determined gamma-ray and background domains was then undertaken. <u>All</u> the gamma-ray domains showed an excess in the Crab direction. The most significant excess was obtained using the <u>Azwidth</u> parameter; this was predicted from the simulations since the parameter is sensitive to both the width of the image (expected to be smaller for gamma-ray events) and to the orientation of the images (directed to the center of the field of view for showers parallel to the camera optical axis). The difference in the values of <u>Azwidth</u> of showers in the Crab and comparison region is shown in Figure 1. Using the canonical gamma-ray domain separation of <u>Azwidth</u> $< 0.21^{\circ}$, the on-source total is 9,092, the comparison total is 7,929, and the difference is +1,163 (+8.9 sigma). This suggests that the gamma-ray signal is 15% of the selected showers from the Crab direction. 98% of the background has been rejected with a loss (according to the simulations) of about 50% of the gamma-ray signal.

There is no evidence for variability either on a run-to-run time scale or on a monthly scale. A search for periodicity at the known period of the Crab pulsar gave only an upper limit of 25% of the signal being

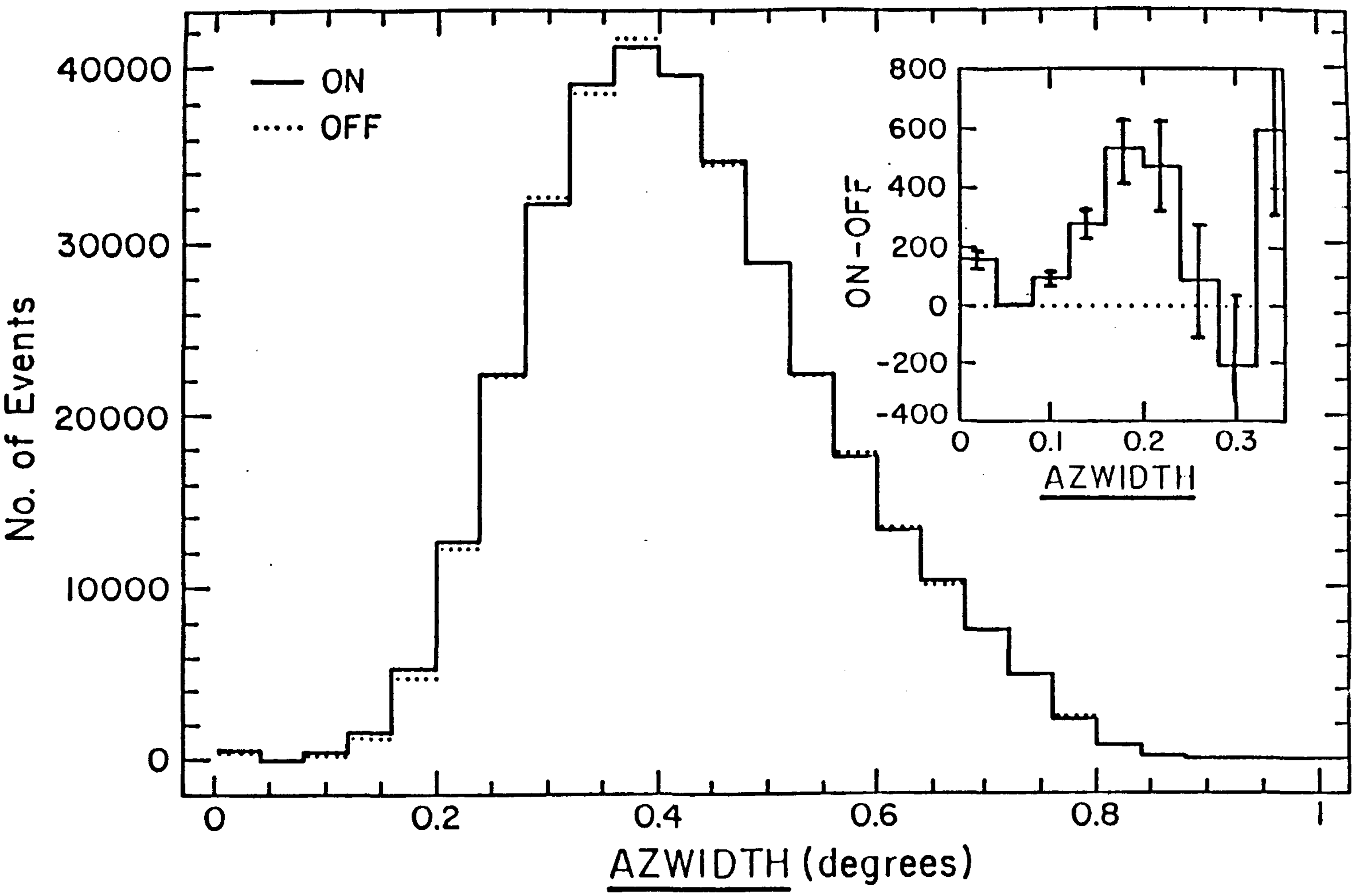


Figure 1. The distribution of the Azwidth parameters On and Off the Crab Nebula for observations by the Whipple Observatory Collaboration in 1986-8; the differences in the two distributions in the gamma-ray domain are shown in the inset.

pulsed. The total flux is 1.8 x 10^{-11} photons-cm^{-2}-s^{-1} above 0.7 TeV and is in agreement with a measurement made with an earlier version of the camera in 1983-85 and with a non-imaging observation made in 1969-72. As with most measurements made using these techniques a factor of 1.5 uncertainty in both energy and flux estimates should be assumed. This may be the first detection of a truly steady source of gamma-rays which could provide the much needed standard candle for calibration purposes.

Since the detection technique depends on the <u>difference</u> in the properties of gamma-ray and proton showers, the detection demonstrates that there is nothing unusual in the development of the atmospheric electromagnetic cascades in the energy region around 1 TeV. Hence if an anomalous signal is detected <u>at these energies</u>, it must come from an inherent property of the shower-initiating particles themselves.

Further work on this source since the completion of this paper includes:

(i) if we assume that the Crab is a source, we can use it to refine the gamma-ray selection technique; in practice it is found that the "cuts" predicted by the simulations are close to optimum;

(ii) we have investigated the possible source of origin of the unpulsed gamma rays; the Compton-synchrotron model for the nebula is one possibility. Ping-wai Kwok is working with K.Cheng (University of Hong Kong) on possible unpulsed emission from the pulsar.

(iii) extended search in the data base for short term periodic emission;

(iv) determination of energy spectrum;

(v) we have made new observations with the High Resolution Camera beginning in October, 1988, these observations are still in progress; to assist in the analysis we are also optically monitoring the pulsar with the nearby 61cm telescope. These data have not yet been analysed.

(2) HERCULES X-1.

This continues to be one of the most interesting objects in VHE gamma ray astronomy (see Physics Today, Nov., 1988). After five years of observation the Whipple Observatory now has the largest database of TeV observations of this object.

Four groups have reported detections at TeV energies, two at PeV energies. Our global analysis of a four year database of observations of this source with our 37-element camera has now been completed. Breaking the data into non-overlapping 30 minute intervals and searching for power at all periods between 0.5 and 3.0 seconds we find an unusual concentration of activity within two independent periods of the canonical Hercules X-1 rotation period. This corresponds to 25 occurrences when 12 are expected, the only period where we see this concentration. Conservatively taking all degrees of freedom into account we estimate this as having less than 1 % of chance occurrence. It should be emphasised that these occurrences are generally independent of the other eight incidences in which we have reported emission because of the way in which the 30 minute intervals were selected.

The most interesting Hercules X-1 observations occurred in 1986. These imply both unusual astrophysics and unusual physics. The observations were reported by three groups and are summarised in Table 1. The observations have two unusual features: (i) the period detected is shifted to the blue side from the canonical neutron star rotation period by 0.16%; (ii) the primaries do not appear to be photonic in nature.

The shift in period is clear from the composite periodograms shown in Figure 2. It should be emphasised that these are not overlapping observations but are spread over a time interval of three months. The Haleakala observations were taken at a time when the source was not visible to the two mainland observatories. The flux seen at TeV energies in the Whipple outburst was sufficiently low that it would not have seen by the Los Alamos array for any reasonable value of spectral index. The Whipple telescope was shut down for the summer monsoon during the two Los Alamos outbursts; this burst was so strong that it would have been far stronger than the TeV signals seen earlier for even a very flat spectral index (Figure 3). Although our previous reports of outbursts had shown a tendency for the detected period to be somewhat to the blue of the x-ray period, this is the largest shift observed. It is also the strongest power seen by us.

The probabilities shown in Table 1 are from the original publications. In each case the authors have assumed there was no period defined i.e. they have ignored the existence of the other observations. The Los Alamos probablity may be slightly overestimated, since it has been taken as the simple product of the d.c. and periodic probabilities. It is difficult to arrive at a total statistical probability of the

Table 1.

Hercules X-1 Detections in 1986.

Observatory	Haleakala	Whipple	Los Alamos
Date	13 May,1986	11 June,1986	24 July,1986
Period(seconds)	1.23593 $\pm$0.00018	1.23579 $\pm$0.00020	1.23568 $\pm$0.00020?
Duration(minutes)	15	25	30 (301) 30
Light-curve	Narrow/broad	Broad	Narrow
Probability	0.07	0.09	0.00002
Statistic	Rayleigh	Rayleigh	Protheroe
Energy(TeV)	0.4	0.6	200
Flux(cm^{-2}-s^{-1})	5.10^{-10}	2.10^{-10}	2.10^{-11}
Gamma-ray identification	No info	No	No

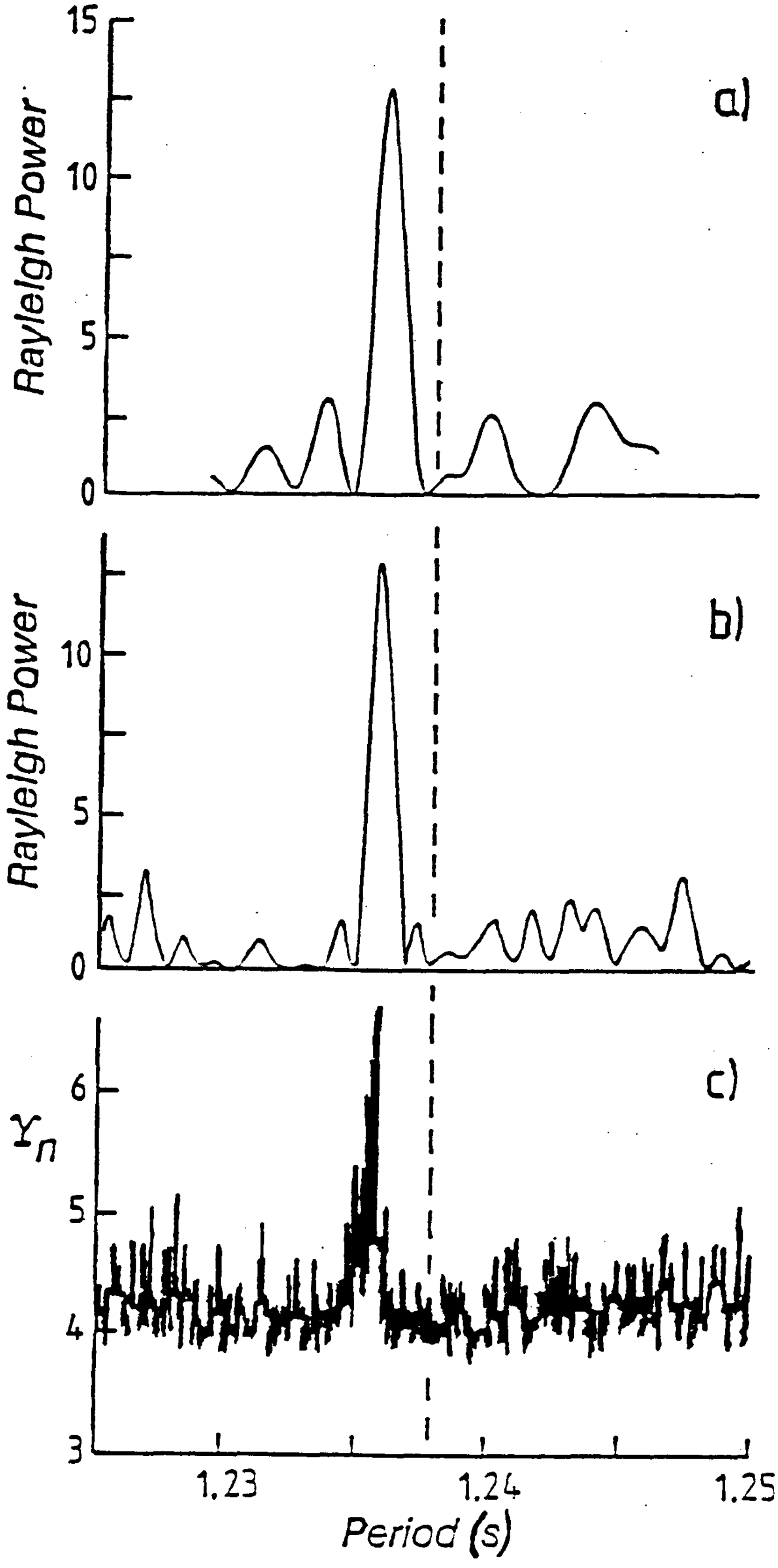


Figure 2. Power as a function of period for three sets of observations of Hercules X-1 in 1986: (a) Haleakala Observatory, 13 May, 1986; (b) Whipple Observatory, 11 June, 1986; (c) Los Alamos experiment, 23 July, 1986.

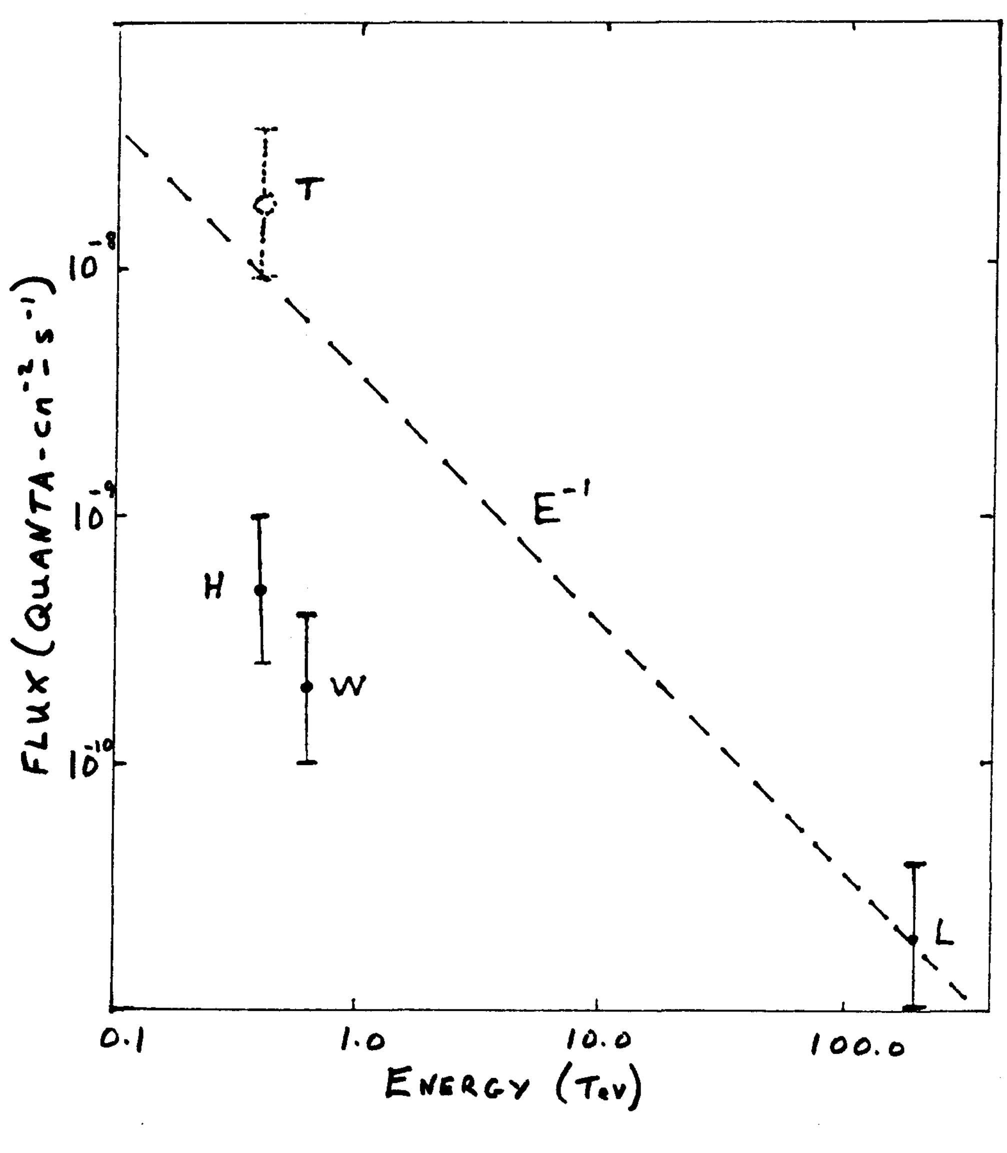


Figure 3. Flux levels from the three detections in Figure 2; an arbitrary factor of two uncertainty in absolute flux has been assumed. A power law with integral index = -1 is shown as a dashed line; for reference the possible detection by the Tata group is shown as a dotted point (T).

effect being genuine. If one observation is taken as defining the period, then the other two observations would suffer no penalty for period search so that the combined probability of the three observations might be as low as 10^{-7}.

The shift in period can be accommodated in some models of the source; in these the gamma-ray production takes place under certain conditions at a location in the rotation disk which is not corotating with the neutron star. It is difficult to understand how these conditions could persist for more than 100 days and then disappear.

A more serious dilemma arises from the identity of the primaries giving the signal. Using identical methods of analysis as used in the analysis of observations of the Crab Nebula, we find that the Hercules X-1 signal is similar to the background cosmic ray events and does not display any gamma-ray character (Figure 4). The Haleakala experiment does not discriminate between gamma rays and background events. The Los Alamos array includes a muon detector and measures the muon-to-electron ratio; for the events in the Hercules X-1 signal, this ratio is at least as high as the background events. Thus in the two experiments that can identify the primary, it appears that the primaries from Hercules X-1 are <u>not</u> gamma rays; this is particularly perplexing in the TeV result where the physics is relatively well-understood and where gamma rays have been positively identified from another source.

An examination of the 25 intervals of pulsed emission in the global analysis confirms this conclusion that the TeV signal that we observe does not have the characteristics of a gamma-ray signal but is generally similar to the background.

(3) CYGNUS X-3.

This was reported as long ago as 1973 as a VHE gamma-ray source; in as many as 15 published papers it has been reported as a source from energies of 100 MeV to 0.5 EeV. On the basis of its very great variability at radio wavelengths (which certainly points to the presence of non-thermal processes), this source would be selected as a prime target for gamma-ray emission. Hence its identification as a very high energy source should come as no surprise.

The report by the University of Durham group of the detection of a

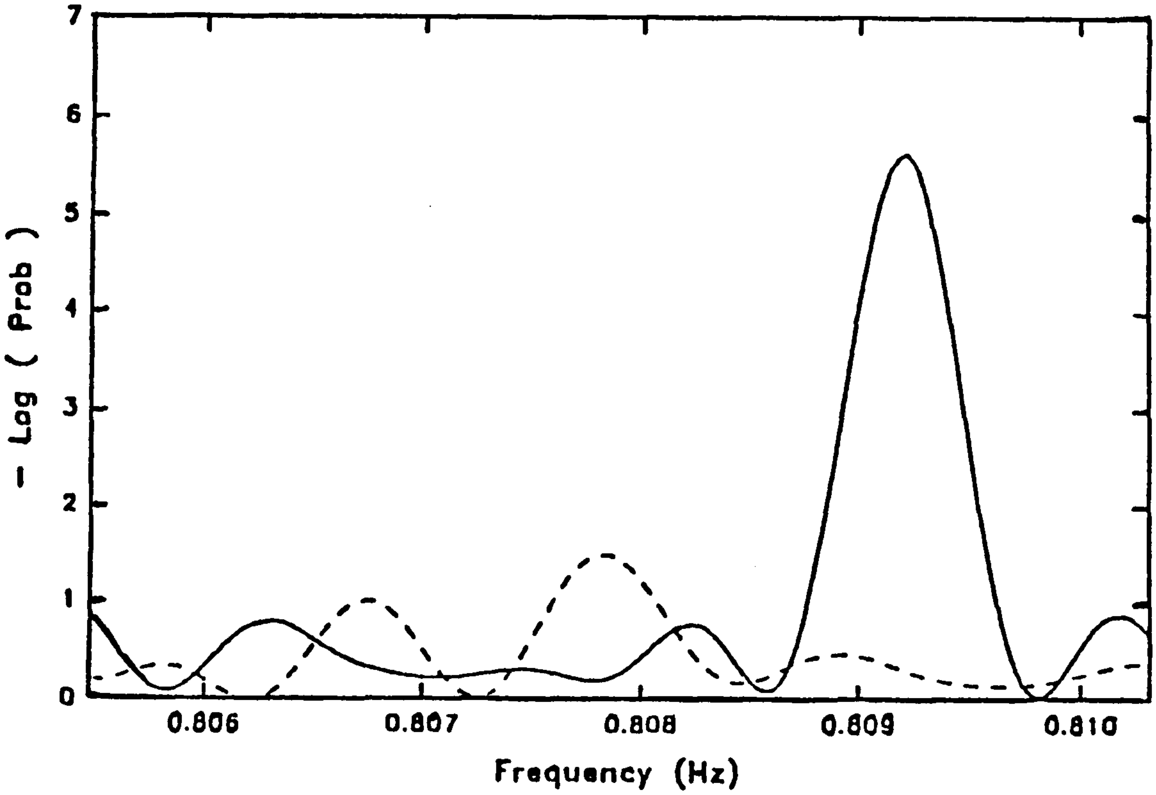


Figure 4. Power in the Whipple Observatory observation of Figure 1 plotted as a function of frequency: solid line = all data (no selection); dashed line = gamma-ray selected data.

periodicity of 12.5908ms in data taken on Cygnus X-3 is indicative of the presence of a fast pulsar in the system. This would suggest that the rotation of the neutron source is the source of the high energy particle acceleration, a result of major astrophysical significance. Although the Durham group reported confirmation of the effect in an enlarged database, the effect has not received an independent confirmation.

We have made a search in our database for this periodicity with null results. These results have been summarised in the paper "Search for a 12.59 ms Pulsar in Cygnus X-3" which will be published as a Letter in Astronomy and Astrophysics. A preprint is included in the Appendix.

A null result has also been reported by the VHE group at the Tata Institute. Also the periodicity has not been seen at any other wavelength. For the moment the existence of the pulsar must be considered doubtful although it is always difficult to disprove the existence of a transient source. To complicate the issue the Crimean group have reported the detection of a periodicity of 9.2ms in archival data with equally high statistical probability. We are now searching for this periodicity in the same database and are continuing observations of Cygnus X-3 (which is still considered a source of VHE gamma rays with 4.8 hour periodicity).

(4) OTHER SOURCES.

Data analysis continues on a variety of other objects that have been claimed as VHE sources or which are suspected to be VHE sources. To date only Quick Look analysis on the raw data has been completed on most of these; now that the Crab has been established as a source and the imaging selection has been shown to be effective, all of this data will be fully analysed using this selection. In the case of the HRC observations the selection procedures are not yet finalised. The sources include:

(i) 4U0115+63. This was reported as a VHE source by the Durham group. There was some evidence for a confirmation in our early database but this was not supported by more extended observations. A complete analysis of all observations of this source is now in progress at I.S.U.

(ii) CTB109. Also known as 1E2259+58, this system contains a pulsar of period 7.0s. These data are being analysed at St. Patrick's College, Maynooth.

(iii) CTB80. This is a 40 ms pulsar which may have been seen as a 100 MeV source in the Cos-B database. Preliminary analysis of data taken in 1987 by Vacanti in Tucson does not support the hypothesis that this is a VHE source. This analysis is continuing.

(iv) V0332. A binary system with period 4.4s, these data are being analysed at ISU.

(v) PSR1957+20. The "black widow" binary in which a pulsar is apparently causing the gradual evaporation of its companion; this was observed with the 10m Reflector in 1988 and the data are being analysed at FLWO.

(vi) CR013+1. This is the source with the hardest spectrum in the Cos-B catalog. It was observed with the HRC in the spring of 1988; the data is being analysed at FLWO.

(5) THE HIGH RESOLUTON CAMERA.

Our major technical improvement this year has been the installation and testing of the High Resolution Camera on the 10 m Reflector. Although this was largely constructed the previous year, it was not installed until March, 1988 to allow a full season of observations of the Crab Nebula with the existing 37-element camera. The basic camera head consists of 91 close-packed phototubes of diameter 2.9cm arranged in a hexagonal pattern. The tubes are surrounded by a guard ring of 18 phototubes of 5.0 cm diameter. The size of phototube is dictated by the desire to extract the maximum angular resolution taking into account the measured optical aberrations of the 10 m Reflector. The basic element used is the Hamamatsu phototube, R1398 which was chosen for its fast response, high quantum efficiency in the blue, and large photocathode sensitive area. The guard ring phototubes were those used in the previous camera (RCA6342/IV).

The camera is arranged in five concentric hexagonal "rings" which are designated as Zones 0 through 5 (Zone 0 is the inner tube, Zone 5 is the outer ring of 30 tubes, etc.). To minimize dead-space between the phototubes, the electrostatic and magnetic shields are coated on the outside of the phototube. A center to center spacing of 3.2cm is therefore possible. Because of the closepacking and large photocathode effective area, the camera is 62.5% photocathode sensitive within the outer ring (Figure 5).

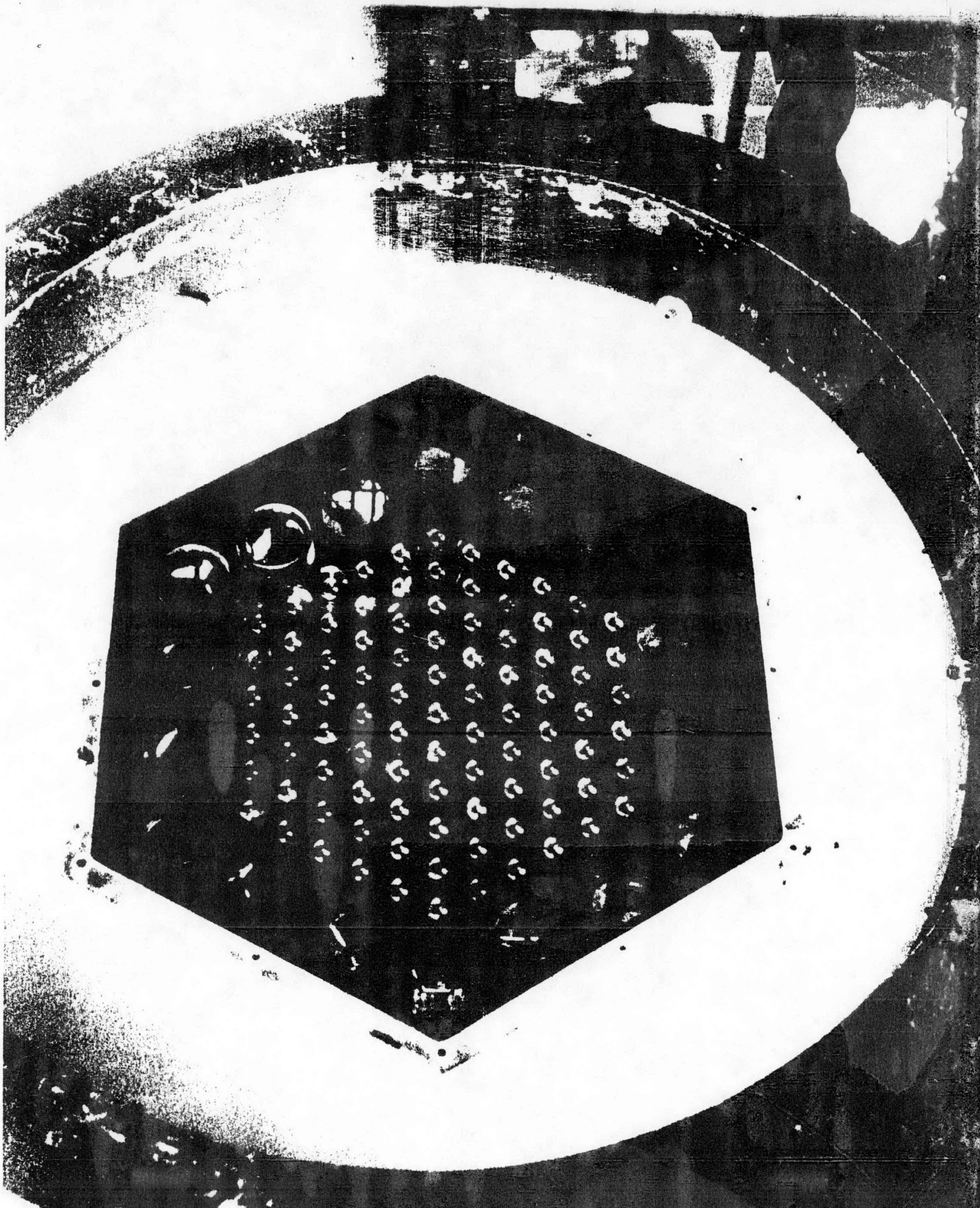


Figure 5. Picture of the elements of the High Resolution Camera (HRC) in the focal plane of the 10m Reflector.

The dynode chains on the phototube bases are encapsulated and the signal is taken directly through 50 m of RG58 coaxial cable to the trigger and processing electronics. Each phototube has an individual high voltage power supply which is used to control the gain. No padding lamps are used initially but these may be added later.

Unlike the elements in the earlier camera, the R1398 phototubes have quartz windows giving increased response in the near ultraviolet. As proton showers have an enhanced ultraviolet component (because of the local muon component), increased sensitivity in the near-ultraviolet is disadvantage in a non-imaging system. In fact it has been used as a anticoincidence to reject the background events. In an imaging system the increased sensitivity to the muon component is a definite advantage as it permits increased discrimination on the basis of the enlarged shower images that the muon component produces.

The camera went into regular operation on the observation of sources in May, 1988. No major technical problems were encountered. With new mirrors (installed in September, 1988), the counting rate at the zenith for a 2/91 trigger was 350 per minute. The energy threshold has not yet been fully determined but by extrapolation from the old camera is of order 0.3 to 0.4 TeV. For the 1/91 trigger we get a rate of 1800 per minute (30 Hz); we estimate the energy threshold here is less than 0.1 TeV although it has yet to be established if this is a stable mode of operation. <u>We believe this is the lowest threshold that any Cherenkov telescope has been operatated at to date.</u> One unusual and unexpected feature of the HRC is that the zenith angle distribution is extremely flat. Typically groundbased telescopes can only operate out to zenith angles of 30^{o}; we find that the counting rate with the HRC has not fallen appreciably out to 50^{o}. The small pixel size is thus demonstrated to be a better match to even the proton showers over a wide range of zenith angles; it should be an even better fit to gamma-ray showers although this has yet to be demonstrated by simulations and measurements. In principle this permits sources to be monitored for a longer continuous observations.

To permit an accurate comparison between the predicted and measured performance of the camera an assessement of the noise in the phototubes under operating conditions was made. A series of laboratory measurements, similar to those performed on the previous camera, had the following results for the new camera elements:

(i) the conservative triggering threshold is 42 d.c. (50 p.e.) in two of the ninty-one phototubes; This threshold is out of noise so that in principle it is possible to run single-fold i.e. 1/91;

(ii) the standard deviation of the fluctuations in the measured night-sky noise in the 25 nsec gate is 3.0 d.c.;

(iii) the conversion for digital counts to photoelectrons is 1 d.c. = 1.2 p.e.;

(iv) the attenuation between the phototube outputs and the inputs to the ADC's is 37%;

(v) as expected the statistical noise in the phototubes is characterised by a variance that is intermediate between a Poisson and an exponential distribution; the measured noise from the night-sky is 1.76 times the Poisson value.

(6) INDEPENDENT TRIGGER

A major activity this year has been the addition of an independent trigger derived from six 1.5m aperture detectors mounted on the side of the 10m reflector. The frame to hold the mirror assemblies were constructed locally at Mount Hopkins; the supports to hold the mirrors on these frames and to support the phototubes were fabricated in Ames. The 1.5 m mirrors were on hand but were found to have poorer optical quality than that normally associated with searchlight mirrors. We are attempting to improve these optical properties before mounting the mirror assembly which otherwise is ready to be mounted to the reflector. This trigger will also hold two ultraviolet solar blind phototubes which will measure the uv to visible light ratio in our gamma-ray events; EMI have been unable to produce the phototubes to meet specification so we are investigating the use of a wide-band tube with solar blind filter. It is planned to have this independent trigger and uv/visible system mounted and in operation by April, 1989.

(7) MIRROR RECOATING.

When the 10 m Reflector was constructed in 1968, it was realised that the mirror coating would be shortlived because of continuous exposure to the elements. Experience has shown that the mirror lifetime is typically 3-4 years. The cost of stripping, coating and overcoating a mirror is currently of order $150. In the summer of 1988, we had 160 mirrors recoated so that by the fall we had a reflector with almost optimum refecting properties. This was evident in the low energy threshold achieved with the HRC and indicates that the current program of recoating approximately 80 mirrors per year should be maintained.

However in the longterm it is desirable to have a permanent cover for the mirrors; it is not practical to build a conventional astronomical telescope dome (cost in excess of one million dollars). However a roll-away split shell mirror cover is possible (Figure 6). Funds to construct a structure of this kind have been requested from the Smithsonian Institution's Reconstruction and Redevelopment Fund. In FY90 it it hoped to get an allocation of $30k towards the detailed design of the cover; in FY91 we estimate we could construct the cover with $300k from the same source. With such a cover the yearly mirror recoating could be dispensed with and the average mirror reflectivity would be much higher. With mirrors that are protected from the elements when the reflector is not in use, we estimate a coating lifetime in excess of 10 years.

(8) MONTE CARLO SIMULATIONS.

There is not a gamma-ray source in the TeV energy region that is strong enough to use as a standard candle of photons to test and calibrate a new detector. Fortunately at TeV energies electromagnetic interactions are sufficiently well understood that Monte Carlo simulations of air shower development can be made with confidence. These can be used to predict the atmospheric Cherenkov radiation and, if the optical properties of the detector are well known, then the expected response of the telescope to a discrete source of gamma-rays can be determined. Any detection must be made in the presence of an isotropic background of showers from charged cosmic rays; here the interaction processes are not so well determined but the predictions can be compared with the measured background. Confidence can be felt in the simulation process if there is good agreement between predicted and measured background.

The original detailed simulations of the gamma-ray and background

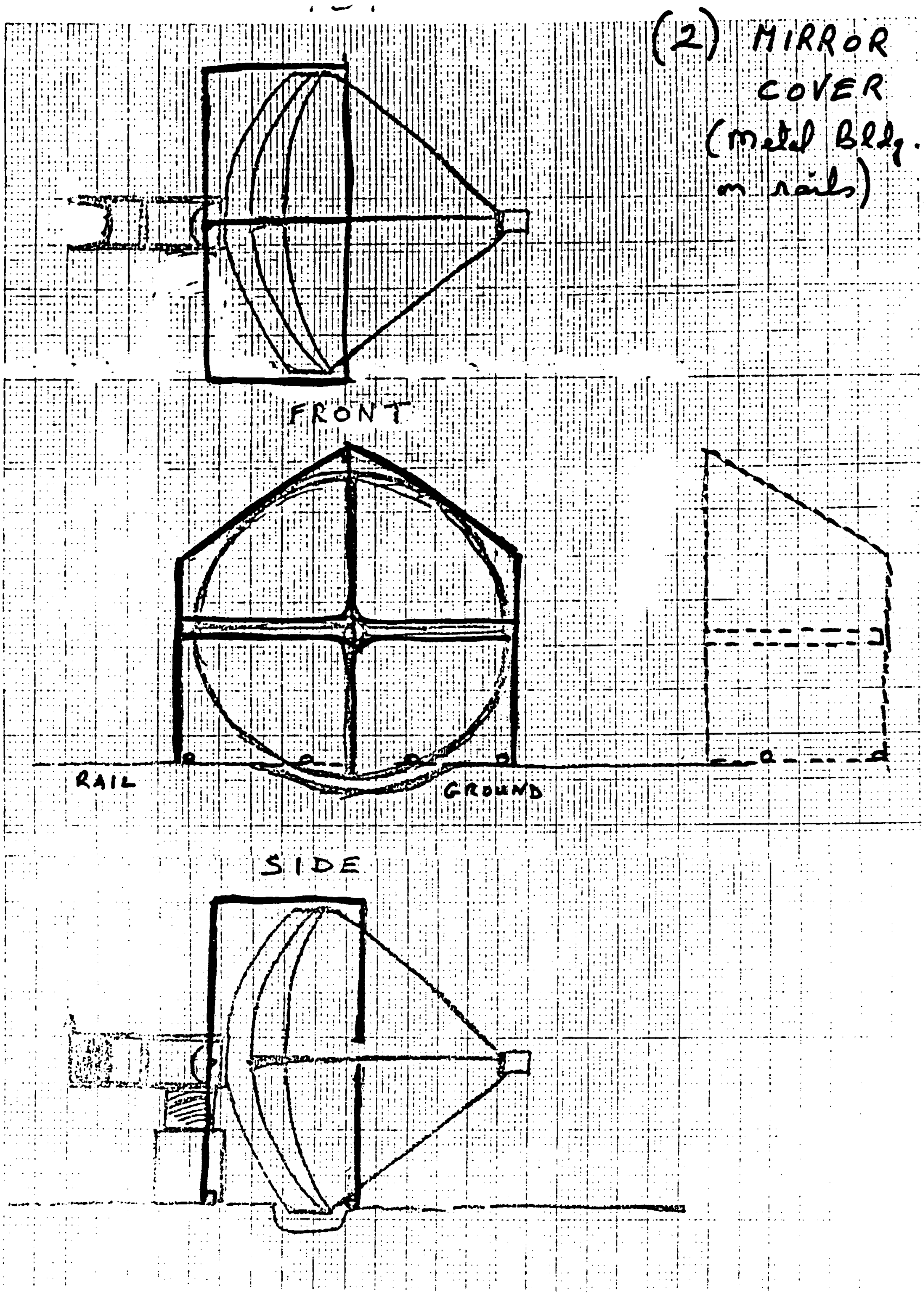


Figure 6. One of the concepts currently being considered for the 10m mirror shelter. The two parts roll away when the reflector is in use; the mirrors are protected for more than 90% of the time including all periods of bad weather greatly increasing the lifetime of the mirror coatings.

proton shower images in our 37-element camera were made in Leeds. These calculations were made specifically for the Whipple Observatory location and assumed an isotropic power-law distribution of background proton showers (differential exponent = -2.65) and a discrete source of gamma rays (differential exponent = - 2.25). The methodology of defining the images in terms of a small number of parameters is described elsewhere (Weekes et al., Appendix); here the efficacy of the method is demonstrated in the detection of a weak flux from the Crab Nebula.

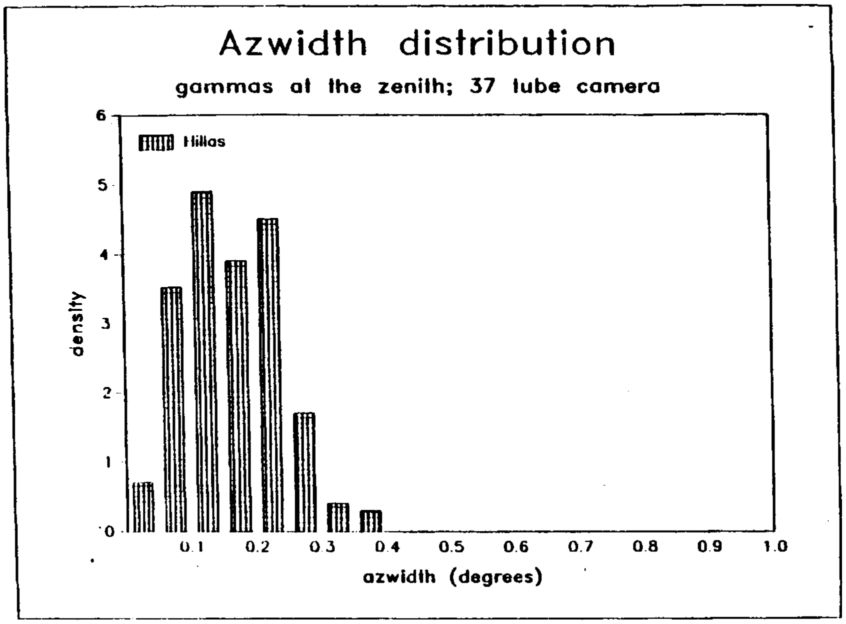
As a check on these simulations a completely independent calculation has been made at ISU using a program originally developed by Stanev at Bartol, and modified by Sembrowski at Purdue and by Macomb at ISU. The gamma-ray simulations for the 37-element camera have been completed and these are in essential agreement with the Leeds calculation (Figure 7) and with our Crab measurements. These calculations will be extended to include proton showers and to predict the response at different zenith angles. It will also be used to predict the optimum cuts for the HRC.

The HRC response is also being determined in Tucson using a large bank of simulated gamma-ray and proton showers from Leeds; these can be sampled using different camera configurations. We take into account: (i) the known optical aberrations of the 10 m Optical Reflector; (ii) the contribution from background light from the night-sky; (iii) pointing errors in tracking a point source.

In Figure 8 we show a comparison of the HRC parameter distributions for a single parameter, Azwidth; this parameter was found to be effective in gamma-ray discrimination in the previous camera. A comparison is shown between gamma rays and protons and between the measured and predicted background (presumably all protons). Although these simulations are still incomplete it is clear that the maximum discrimination will be achieved in Zones 1,2 and 3 with cut-offs of <0.25 , <0.20 and <0.15 respectively.

The gamma-ray signal is sufficiently small that the two outer zones can be effectively used as "OFF" source observations and the gamma-ray signal can determined from the ratio of the number of selected Azwidth images in the inner zones to the number in the outer zones.

Analysis of these simulations is continuing to determine the optimum



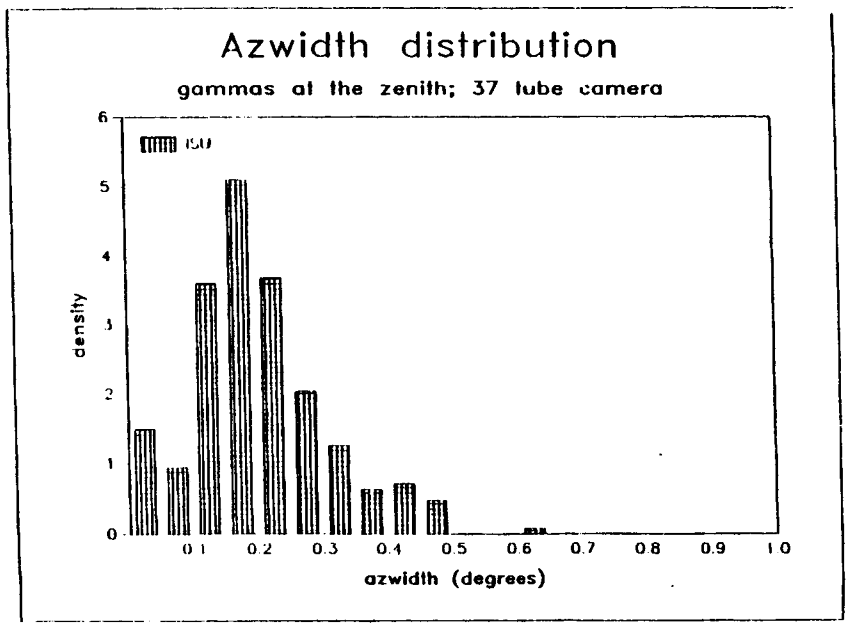


Figure 7. Results of simulations of the <u>Azwidth</u> distribution of gamma-ray showers performed by Daryl Macomb at ISU (lower histogram); these simulations give substantially the same results (within statistics) as the independent calculations by Hillas (top histogram) at Leeds.

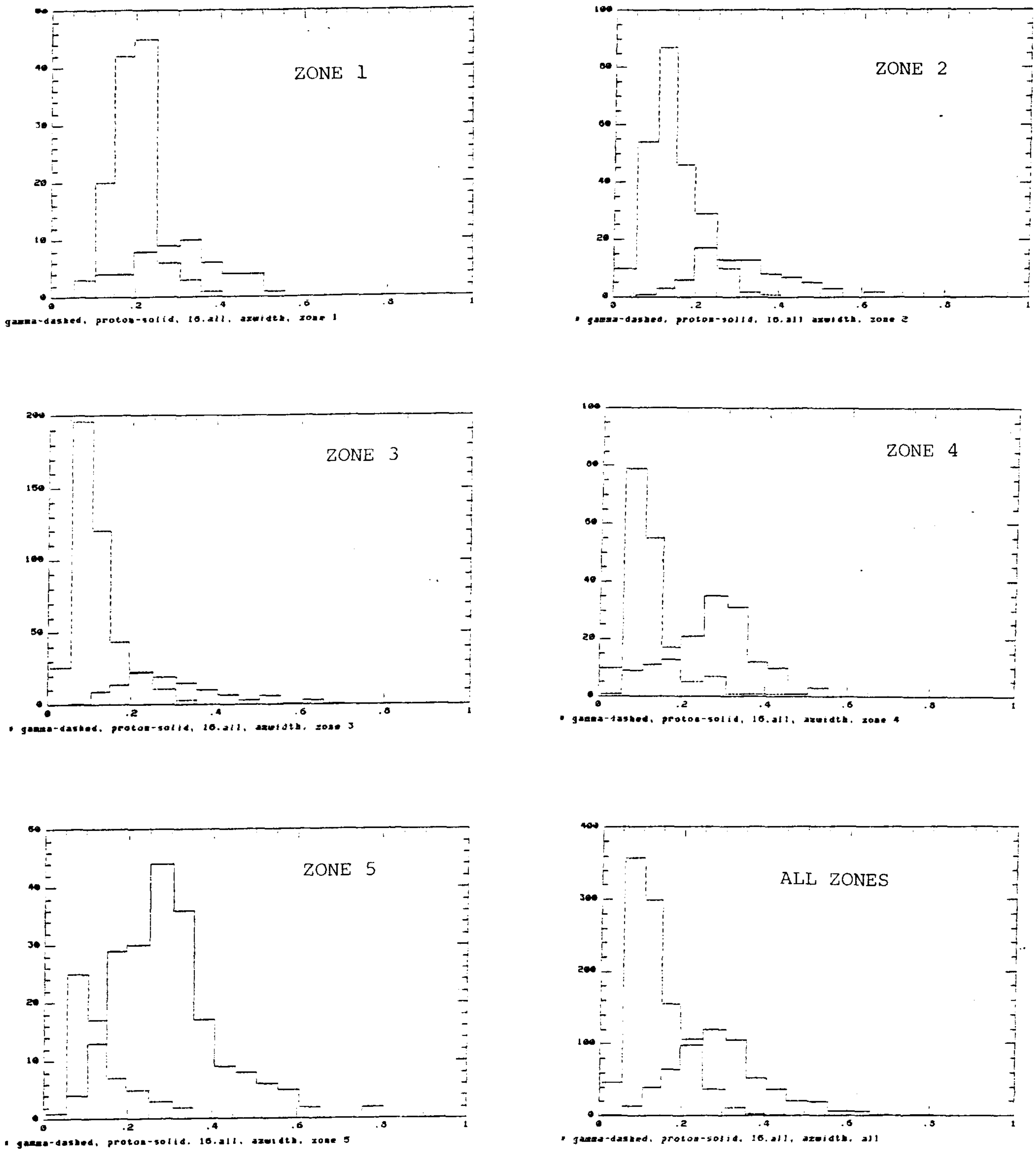


Figure 8. Predicted seperation of the measured <u>Azwidth</u> parameter for gamma-ray and proton showers as measured by the HRC as a function of Zone. Although the results are preliminary it is apparent that the bulk of the signal is received in the first three zones where the maximum discrimination occurs.

method of gamma-ray event discrimination; it is expected that the ultimate gain in flux sensitivity over the 37-element camera will be a factor of 2 to 3 (or a factor of 6 to 10 over a comparable non-imaging telescope).

(10) OPTICAL DESIGN OF LARGE REFLECTORS.

In preparation for the development of a second imaging camera (the GRANITE proposal), we have made a study of the optical aberrations of large, tesselated reflectors. This involved a detailed analysis of the existing f/0.7 10m reflector which will shortly be submitted for publication (Lewis, in preparation). The overall shape of the new reflector can be parabolic (which implies that the photons striking different parts of the reflector arrive simultaneously at the focal plane) or spherical like the the existing reflector. The spherical design reduces off-axis aberrations and simplifies construction and alignment since all elements have the same focal length. Since the proposed GRANITE reflector will be a test bed for improving the atmospheric Cherenkov technique using imaging, a parabolic design is favored. A parabolic reflector with comparable dimensions to the present reflector would have slightly superior image quality at the center of the field of view, comparable quality 1^{o} off axis, and slightly inferior quality 1.5^{o} off axis. These considerations will have a major influence on the final detailed design of GRANITE.

(11) STATISTICS

Periodic sources, e.g. binary x-ray sources such as Hercules X-1, can be detected as a d.c. excess in the number of events from the source direction or through the detection of a known period, usually the pulsar rotation period or the orbital period, in showers from the direction of the source. When both a d.c. and a period are measured, it is possible to make improved estimates of (i) the probability that an effect is a statistical fluctuation, (ii) the flux of gamma rays from the source assuming the effect is real, (iii) the consistency of the observed d.c. excess with the observed strength in the periodic signal. Analytical expressions have been found for these three estimates and a paper (Lewis,1989) has accepted for publication in Astronomy and Astrophysics. Application of these methods to the search for the 12.59ms pulsar in

Cygnus X-3 (see (c) above) led to an unambiguous negative result.

(12) SOUTH POLE EXPERIMENT

We were invited by the South Pole Air Shower Experiment (SPASE) collaboration (Bartol Research Institute-Leeds University) to send a pilot atmospheric Cherenkov experiment to the South Pole for the 1989 austral winter to test the feasibility of TeV gamma-ray observations from this site. The high elevation, clear skies, continuous exposure for six months to sources at southern declinations, and the possibility of observing SN1987a make this an attractive prospect. However the extreme environment, the remote location, and the unknown effect of aurora on the sensitivity suggests that it would be prudent to do a pilot experiment before locating a major experiment at this site. Using existing components a semi-automated experiment (involving fresnel lenses, phototubes, pulse counting electronics and an Apple computer) was assembled and tested at Mount Hopkins; the winter-over observer for SPASE spent three weeks at the Whipple Observatory learning how to set up and operate the experiment. The small experiment was shipped to the South Pole in November and has been set up for operation in March, 1989.

In collaboration with the University of Wisconsin, Purdue University, the University of Florence and the Bartol Institute, it is planned to build (with NSF support) a follow-up experiment for the austral winter of 1990.

(13) GALACTIC PLANE EXPERIMENT

As described in last year's report we have built a wide angle gamma-ray telescope whose express purpose is to survey the galactic plane for possible gamma ray emission. This consists of 4 1.5m telescopes operated in coincidence with readout into an Apple computer every 30 s. The telescope is operated in a fixed drift-scan mode with the galactic plane scanned once per night. It has been regularily operated since May, 1988.

(14) AIR SHOWER EXPERIMENT

The Smithsonian Astrophysical Observatory in conjunction with the University College, Dublin and the University of Hong Kong operates a small air shower array in the vicinity of the 10m Reflector. This array of 12 1m^2 scintillators has a energy threshold of 0.1 PeV and a flux sensitivity about that of the Kiel array that first detected Cygnus X-3.

It has been in regular operation since September, 1986. The data analysis is performed at U.C.D.

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