Flasher calibration of the T1 and T2 CANGAROO telescopes and TeV gamma ray observation of Markarian 421 and EXO 055625-3838.6 BL Lacertae blazars

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Contents

Abstract v

Declaration vi

Acknowledgments vii

Preface viii

List of abbreviations, units and symbols: Table 1 of 2 ix

List of abbreviations, units and symbols: Table 2 of 2 xi

1 Introduction 2

1.1 Strongly ionizing radiation from space 2

1.2 A brief history of Gamma Ray Astronomy 5

1.2.1 X-ray and Gamma Ray satellite detectors 5

1.2.2 A history of ground based gamma ray observatories 10

2 TeV gamma ray blazar emission and imaging of Čerenkov events 14

2.1 Čerenkov imaging of atmospheric showers 14

2.1.1 Čerenkov radiation 16

2.1.2 Hillas parameters for gamma ray showers 19

2.2 Blazar electronic emission models 21

2.2.1 Inverse-Compton scattering emission 23

2.2.2 Synchrotron radiation 25

2.2.3 Synchrotron Self Compton (SSC) emission 28

2.2.4 Doppler boosting 32
2.3 Blazar hadronic emission models 34
2.4 Extragalactic Background Light (EBL) absorption 37
2.4.1 TeV gamma ray attenuation due to pair production 38
2.4.2 Extragalactic background light prediction models 39
2.4.3 The effect of the EBL on the spectrum of Markarian 421 42

3 The CANGAROO Imaging Atmospheric Čerenkov Telescopes 47
3.1 The CANGAROO-II 10 metre Imaging Atmospheric Čerenkov Telescope 47
3.1.1 The CANGAROO-II dish and mirrors 47
3.1.2 The CANGAROO-II camera 51
3.1.3 The CANGAROO-II electronics modules 56
3.2 The CANGAROO-III 10 metre Imaging Atmospheric Čerenkov Telescopes 57
3.2.1 The CANGAROO-III project 57
3.2.2 The CANGAROO-III camera 59
3.2.3 CANGAROO-III photomultiplier tube specifications 62
3.2.4 Winston light guides 65
3.2.5 Crosstalk effects 67
3.2.6 The T1 and T2 electronic data acquisition system 68
3.2.7 Stereoscopic data acquisition 78

4 The flasher calibration experiment 80
4.1 The custom-made flasher apparatus 80
4.1.1 Description of the flasher apparatus 80
4.1.2 Seasonal flasher calibration 84
4.1.3 Flasher apparatus LED emitters 85
4.2 Calibration of the flasher apparatus 87
4.2.1 Description of the PIN diode monitor apparatus 87
4.2.2 Measurement of the flasher output using the PIN diode monitor 89

5 Flasher calibration: Analysis and results 97
5.1 Flasher field measurements and data file calibrations 97
5.1.1 Introduction 97
5.1.2 T1 discriminator settings for flasher calibration 100

5.1.3 Background light affecting ADC count . . . 101
5.1.4 Flasher calibration procedure . . . 104
5.1.5 LED flat fielding . . . 106
5.1.6 ADC pedestals . . . 110
5.1.7 Pixels corrected in the flasher image via "bad channel" correction 112
5.2 T1 flasher calibration analysis . . . 114
5.2.1 Anomalous diffraction effects in the flasher image . . . 114
5.2.2 Flasher image movement in the camera field of view . . . 123
5.2.3 Size of the flasher image . . . 131
5.2.4 Measurement of the flasher output using a single photomultiplier tube detector . . . 134
5.2.5 Earlier abandoned attempts at pixel correction in the T1 camera 135
5.3 T2 flasher calibration analysis . . . 140
5.3.1 T2 flasher calibration introduction . . . 140
5.3.2 T2 cross-correlation analysis of the flasher image . . . 143

6 Attempt at cosmic ray zenith angle calibration of the T1 telescope 151
6.1 Introduction . . . 151
6.2 Zenith cosmic ray calibration results . . . 152

7 Gamma ray source analysis of the Markarian 421 and EXO 055625-3838.6 BL Lacertae blazars 156
7.1 Markarian 421 results . . . 156
7.1.1 Introduction . . . 156
7.1.2 Markarian 421 data acquisition files . . . 157
7.1.3 Markarian 421 Monte Carlo simulation results . . . 161
7.1.4 Mkn 421 observational data analysis results . . . 167
7.2 EXO 055625-3838.6 results . . . 183
7.2.1 Introduction . . . 183
7.2.2 EXO 055625-3838.6 data acquisition files . . . 184
7.2.3 EXO 055625-3838.6 Monte Carlo simulation results . . . 186
7.2.4 EXO 055625-3838.6 observational data analysis results . . . 190

8 Conclusions **195**

8.1 Flasher Calibration 195

8.1.1 T1 flasher image movement analysis 195

8.1.2 T2 flasher image movement analysis 198

8.2 HBL Lacertae blazar source analysis 199

8.2.1 Conclusions from the Markarian 421 source analysis 199

8.2.2 Flaring state of Markarian 421 during 2001 202

8.2.3 Conclusions from the EXO 055625-3838.6 source analysis 205

A Circuit diagrams of the flasher apparatus and PIN diode monitor **208**

B T1 and T2 flasher calibration data files **211**

C T1 flasher calibration: Mean ADC Pedestals **215**

D T1 flasher calibration: Pedestal difference between the sample mean ADC and histogram calculated mean ADC **232**

E Two-dimensional flasher calibration image results from T1 and T2's camera **249**

F T1 and T2 flasher calibration results & weather station data **255**

G Logbook data from 24/2/01, 25/2/01 and 2/1/01 flasher calibrations, supporting "square structure" **260**

H CANGAROO-II (T1) TeV blazar observation summary: Data files **263**

I T1 Monte Carlo simulation results: Proton showers **267**

J Markarian 421 and EXO 055625-3838.6 *alpha* plot results from T1 **274**

K Incremental significance (S, Li & Ma (1983)) plotted against 5° *alpha* distributions from Tables 7.2 and 7.3 **283**

Bibliography **288**

Abstract

Calibration tests were made on the T1 and T2 telescopes of the CANGAROO collaboration in 2001 to 2003, using a custom-made LED light flasher apparatus to test the two (T1 and T2) telescope responses to a fixed amplitude light signal. The flasher apparatus was set up (a kilometre distance from the telescopes), to trigger the telescopes with a 10 nanosecond or 20 nanosecond pulse width flash, running at a rate of 1 kilohertz. Measurement of the light intensity of the flasher was achieved by using a custom-made PIN diode monitor coupled to the flasher output. After data analysis, it was found that the principal flasher signal amplitude variation (from month to month) as measured by a telescope, was due to errors in the encoders upon slewing and parking the telescope. This effect was found and measured by taking the two dimensional cross-correlation of the flasher pixel images (acquired in the camera of the two telescopes), taken monthly. Measurement of the T1 telescope energy threshold was attempted, using cosmic ray showers at the zenith, on two separate occasions. Finally, 2313.9 on-source minutes of data on the HBL Lac. blazar, Markarian 421 data was acquired by T1 in 2001 to 2003, and 1013 on-source minutes of data on the BL Lac. blazar EXO 055625-3838.6 were acquired in 2002 and 2003, by T1. From *alpha* plot distributions (where $alpha \leq 40^{\circ}$), it was found that the TeV gamma ray signal significance for Markarian 421 was 2.8 σ (in 2001-03); 3.3 σ (in 2001) and 0.4 σ (upper limit in 2002-03). Furthermore, from ($alpha < 20^{\circ}$) to maximize signal over noise, the significance for Markarian 421 was found to be 3.5 σ (2001-03); 3.5 σ (in 2001) and 1.2 σ (upper limit in 2002-03). The TeV gamma ray signal significance (where $alpha \leq 20^{\circ}$), was 2.2 σ for EXO 055625-3838.6 over 2002-03.

Declaration

This thesis does not contain work which has been accepted for any other award in any university. Nor does it contain work which has previously appeared elsewhere, except where referenced within the text. It is available to be photocopied/downloaded and lent from the University (Barr-Smith) Library. I give permission for digital versions of this thesis to appear on the internet, provided all acknowledgments to the author and reference to this work are made, and no changes to this thesis is permitted without written authorization from the author.

David Swaby

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Non est ad astra mollis e terris via.

Preface

In the following chapters, most italicized words with the first letter capitalized, represents a trade name (or experiment name), for a component (electronic) module or software, e.g. *Nichia.* Words in standard capitals are usually abbreviations, e.g. CANGAROO (see the list of abbreviations, units and symbols tables at the beginning of this thesis). Words that are in bold text often represent: 1. Raw or calibrated telescope data format, e.g. **calib10a**. 2. A measured variable, e.g. **ievent**. 3. An ion e.g. $\mathbf{He}^{++}$.

List of abbreviations, units and symbols: Table 1 of 2

AC	Alternating Current
ADC	Analogue to Digital Conversion
AGN	Active Galactic Nuclei
ASCA	Advanced Satellite for Cosmology and Astrophysics
BNC	Bayonet Neill-Concelman connector
CAMAC	Computer Automated Measurement And Control
CANGAROO	Collaboration between Australia and Nippon (Japan) for a GAmma Ray Observatory in the Outback
CCD	Charge-Coupled Device
CCMP	Cross-Correlation Maximum Position
CGRO	Compton Gamma Ray Observatory satellite
CIB	Cosmic Infra-red Background
CMB	Cosmological Microwave Background
CMOS	Complementary Metal-Oxide Semiconductor
CPU	Central Processing Unit
DAC	Digital to Analogue Conversion
DAT	Digital Audio Tape format
dec.	declination: Degree angular coordinate north or south of the celestial equator (see RA)
DC	Direct Current
DSM	Discriminator and Summing Module
DVM	Digital Volt Meter
EGRET	Energetic Gamma Ray Experiment Telescope
EAS	Extensive Air Showers (atmospheric particle showers by cosmic/gamma rays from space)
EBL	Extragalactic Background Light
EIC	External Inverse Compton
EXO	European X-ray Observatory satellite
FoV	Field of View
FWHM	Full Width at Half Maximum
GLAST	Gamma-ray Large Area Space Telescope satellite
GPS	Global Positioning System
HBL Lac.	H (H=high; GeV-TeV energy peaked) BL Lacertae blazar sources
HEGRA	High Energy Gamma Ray Astronomy collaboration.
HESS	High Energy Stereoscopic System collaboration
HV	High (DC) Voltage
IACT	Imaging Atmospheric Čerenkov Telescope
IC	Inverse-Compton
ICRR	Institute for Cosmic Ray Research, at the University of Tokyo, Japan
ID	IDentification
IR	Infra Red
LED	Light Emitting Diode
MAGIC	Major Atmospheric Gamma Imaging Čerenkov collaboration
MC	Monte Carlo
ND	Neutral Density polymer film broad spectrum light filter
NIM	Nuclear Instrumentation Module
NSB	Night Sky Background
Op. amp.	Operational amplifier
PC	desktop Personal Computer
PDM	PIN Diode Monitor
p.e.	photo-electron
PMT(s)	Photo Multiplier Tube(s)

List of abbreviations, units and symbols: Table 2 of 2

p-n	positive (p-type) and negative (n-type); combined (p-n) semiconductor diode junction
PRR	Pulse Repetition Rate
P/V	Peak-to-Valley ratio of a single electron spectrum peak in a photomultiplier tube
RA	Right Ascension: Celestial equatorial coordinate in hours, minutes & seconds (see dec.)
RMS	Root Mean Square
ROSAT	ROentgen SATellite
RXTE	Rossi X-ray Timing Explorer satellite
SED	Spectral Energy Distribution
SI	*Le Système International d'unités*, International System of (metric) Units
SSC	Synchrotron Self-Compton
STACEE	Solar Tower Atmospheric Čerenkov Effect Experiment
T1	the CANGAROO-II telescope (first (T1) telescope in the CANGAROO-III array)
T2	second (T2) telescope in the CANGAROO-III array
T3	third (T3) telescope in the CANGAROO-III array
T4	forth (T4) telescope in the CANGAROO-III array
TDC	Time to Digital Conversion
UV	ultraviolet
VERITAS	Very Energetic Radiation Imaging Telescope Array System collaboration
VME	Versa-Modular Eurocard
VR	Variable Resistor
mA	milliampere = 10^{-3} ampere, SI unit of electrical current
μA	microampere = 10^{-6} ampere
dB	decibel, dimensionless logarithmic unit of intensity measurement
eV	electronvolt $\approx 1.6 \times 10^{-19}$ joule, SI energy unit
MeV	megaelectron volt = 10^{6} electronvolts
GeV	gigaelectron volt = 10^{9} electronvolts
TeV	teraelectron volt = 10^{12} electronvolts
μF	microfarad = 10^{-6} farad, SI unit of capacitance
nF	nanofarad = 10^{-9} farad
pF	picofarad = 10^{-12} farad
Hz	hertz, SI frequency unit
kHz	kilohertz = 10^{3} hertz
MHz	megahertz = 10^{6} hertz
GHz	gigahertz = 10^{9} hertz
Jy	jansky, radio astronomy unit of electromagnetic flux density = 10^{-26} $\mathrm{Wm^{-2}Hz^{-1}}$
MJy	megajansky = 10^{6} jansky
μm	micrometre = 10^{-6} metre
Ω	ohm, SI unit of impedance or resistance (DC)
kΩ	kilohm = 10^{3} ohms
MΩ	megohm = 10^{6} ohms
ns	nanosecond = 10^{-9} second
sr	steradians, SI solid angle unit
mV	millivolt = 10^{-3} volt, SI electrical potential difference unit
W	watt, SI unit of power = kg $\mathrm{m^{2}s^{-3}}$
$\mathrm{Wm^{-2}}$	watt per square metre
nW	nanowatt = 10^{-9} watt
c	velocity of light in a vacuum constant; 3×10^{8} m $\mathrm{s^{-1}}$
I	electrical current: ampere. (Unless I is specified as intensity or flux amplitude)
λ	wavelength: metres
ν	frequency: hertz
V	electrical potential: volt

List of Figures

1.1 A sketch of the EGRET gamma ray observatory aboard the CGRO satellite. . . . 7

1.2 The third EGRET catalogue map in galactic coordinates. The size of the symbol on the map represents the intensity of the source as seen by EGRET, Hartman *et al.* (1999) [75]. 8

1.3 Distribution of high significance TeV gamma ray sources in galactic coordinates: HBL Lac.; *asterisks*, LBL Lac.; *cross*, radiogalaxy; *dot*, star-burst galaxy; *plus*, SNR; *diamonds*, plerions; *triangles*, binary system micro-blazar; *square*, OB star association; *circle*. These were the majority of TeV gamma ray sources at the time the observation of the two gamma ray sources in this thesis were taken. 11

2.1 From Weekes (1988) [167]. A Monte-Carlo simulation showing the vertical and horizontal EAS profile (to an altitude of 20 km above sea level), of a 250 GeV cosmic ray proton (left) and 250 GeV primary gamma ray (right). 15

2.2 From Rowell (1995) [151]. A sketch of a particle traveling at high velocity ($v > c/n$) through a dielectric medium of refractive index (n), will form an optical shock front with constructive interference at CB 17

2.3 From Dazeley (1999) [52]. A schematic diagram showing representations of the shape Hillas Parameters from the ellipsoid. 20

2.4 From Bradt (2008) [38]. Head-on IC scattering frames of reference: (b) Before collision in the relativistic electron rest frame, becoming a normal Compton scattering event. "The incident photon in S', has been Doppler shifted to higher energy ($h\nu'$), because of the motion of this frame relative to an observer at S.", [38]. (c) After scattering in S' frame. "The photon having been backscattered with energy ($h{\nu_s}'$), moves to the right with slightly less energy.", [38]. (d) The scattered photon has a much higher energy ($h\nu_s \gg h{\nu_s}'$), having been transformed back into the observer's rest frame, S. Diagram (a) is not shown due to its superfluity in our case. 24

2.5 From Rybicki & Lightman (1979) [152]. Sketch showing helical gyro-rotation of a particle in an uniform **B**-field. Particle velocities and acceleration is shown. 26

2.6 From Rybicki & Lightman (1979) [152]. Sketch showing emission cones at various points of the particles trajectory, emitting synchrotron radiation. 27

2.7 From Bradt (2008) [38]. Sketch showing a simplistic model of the Synchrotron Self-Compton emission process. 28

2.8 From Bradt (2008) [38]. Theoretical Spectral Energy Distributions (SED) from SSC emission, for blazars across a broad frequency range showing observational wavelengths (grey shaded areas). The SED of blazars though SSC emission shows a classic "double hump". The LBL (Low energy peaked BL Lac.) blazars SED is shown as a solid line where synchrotron emission occurs in radio to optical energies and X-ray though IC emission from the same synchrotron electrons (higher energy peak). The HBL (High energy peaked BL Lac.) blazars (shown as a dotted line) are emitting synchrotron X-rays (low energy peak) and IC scattering though to GeV-TeV gamma rays (higher energy peak). The SEDs of LBL versus HBL blazars may be compounded by Doppler shift. 31

2.9 From Bradt (2008) [38]. Beamed radiation from a fast moving ($\gamma = 10$) source, emitting isotropically in the rest frame. The beam includes half the rays lying within the inner cone of the half-angle ($\sim 1/\gamma = 5.7°$, equation 2.22) at this Lorentz factor. The outer cone half-angle is situated at $\delta = 1$ ($\nu = \nu_0$, equation 2.23), at 25.2° representing a null Doppler shift at this location. Angles greater than this will be observed to be Doppler red-shifted. 33

2.10 From Protheroe & Mücke (2001b) [141]. Showing best-fit model in comparison to the flaring data from Markarian 501 in 1997 from Catanese *et al.* (1997) [43]. Dot-dashed line is the input target spectrum (Mücke & Protheroe (2001) [125]). Straight-solid lines: Parameterization from the synchrotron spectrum observations (from Beppo-Sax & Oriented Scintillation Spectrometer Experiment on the CGRO), and TeV emission corrected for EBL on two different infrared models (Bednarek & Protheroe (1997) [28]). The 100 MeV upper limit shown is from [43]. 36

2.11 The *Left* figure is the "average" EBL spectrum as shown by Dwek & Krennrich (2005) [54], and where the shaded bar at the top indicates the different wavelength regions depicted in the *Right* panel figure. The *Right* figure is the γ-ray opacity (equation 2.27), located at redshift $z = 0.03$, shown as a thin black line. The shaded curves under this thin line represent the contributions to the different wavelength regions (depicted in the *Left* panel), to the total opacity, [54]. 40

2.12 Template spectra representing different realizations of the EBL, from Fig. 2 of Dwek & Krennrich (2005) [54], where the realization templates are also discussed. This figure shows data points from a large number of authors showing theoretical EBL modeling and from experimental results (see Dwek & Krennrich (2005) [54], to ascertain data reference). 41

2.13 From Figure 1 of Aharonian *et al.* (2005), [5]. Differential energy spectrum of Mkn 421 taken by HESS in April-May 2004. The curve can be described by a power law, $\Gamma = 2.1 \pm 0.1_{\rm stat} \pm 0.3_{\rm sys}$, with an exponential cutoff at, $E_{\rm c} = 3.1(+0.5 - 0,4)_{\rm stat} \pm 0.9_{\rm sys}$ TeV shown by the solid line, or alternatively by a "super exponential" cutoff ($\exp(-(E/E_{\rm c})^{1.6\pm0.3})$, at $E_{\rm c} = (6.25 \pm 0.4_{\rm stat} \pm 0.9_{\rm sys})$ TeV (dashed line). The lower right hand line shows an upper limit at 30-50 TeV with 99% confidence level. . . . 43

2.14 Differential energy spectrum of Mkn 421 from MAGIC, Fig. 10 of Albert *et al.* (2006) [12]. The observed (grey points) of the spectrum, and de-absorbed (black) points are multiplied by E^2. Solid line shows power law fit, and dot-dashed line the curved power law fit both to the intrinsic spectrum (without absorption), the results shown in inlays to this figure. Dotted line shows absorbed (observed) power law with cutoff. 44

3.1 Photograph of the CANGAROO-II IACT, 10 metre diameter T1 telescope, from Mori (2000) [120]. The camera access tower in front of T1 is approximately 9 metres high. The hut at the ground level is the electronics, T1 data acquisition control, and telescope array control (observer's) hut. 48

3.2 A diagram of the CANGAROO-III telescope mirror array, from Gunji (2006) [73]. There are six equally sized steel plate radial sections which each hold 19 × 80 cm, diameter mirrors. The black numbering of each 114 mirrors is indicated, as seen by the camera's point-of-view. The red numbering, e.g. D1, is a radially positioned mirror clustering indicator, and is extraneous. 49

3.3 A sketch of the CANGAROO-II individual 80 cm mirror stepper motor adjustment, from Kawachi *et al.* (2001) [94]. 50

3.4 The *Hamamatsu* R4124 spectral efficiency characteristics, from Hamamatsu (1998) [74], showing both quantum efficiency and cathode radiant sensitivity curves. The cathode radiant sensitivity is defined as the ratio of the cathode current, I_k, (less the dark current) to the incident photon flux, Φ, i.e. $S_k(A/W) = \frac{I_k(A)}{\Phi_e}$, where I_k is in milliamperes (mA), and Φ_e is in Watts", Flyckt & Marmonier (2002) [61]. The cathode radiant sensitivity is expressed in radiometric units; mA per Watt. 51

3.5 Sketch of the dimensional outline of the R4124 PMT (*left*) in millimetres, from Hamamatsu (1998) [74], and the positions of the cathode, anode and 10 dynodes pins in the socket, where **K** shown in the *middle* diagram is the cathode, **P** is the anode, **DY1** and **DY10** is the first and tenth dynodes respectively, and **IC** is the internal circuit. These PMT elements map to the *right* diagram positions, showing the 13 pins of each element and the short pin in the E678-13A socket of the R4124 PMT. The short pin, which is used to guide the PMT into the socket insertion, is shown in the *right* diagram as; ⊙ 52

3.6 A photograph of the front end of the CANGAROO-II camera, receiving light from the primary mirror, from Mori (2000) [121]. There are spaces for 576 $\frac{1}{2}$ inch PMTs, behind the Winston cone light guides shown. See Section 3.2.4 for a discussion on Winston cones. 55

3.7 Sketch of the CANGAROO-II camera 36 boxes array with numbers shown, from Mori (2000) [122]. Each box holds 16 (4×4) $\frac{1}{2}$ inch PMTs. The corner boxes 33 to 36, hold only 10 PMTs. 56

3.8 An overview sketch of the CANGAROO-III telescope array site at G-range, Woomera. Distances between telescopes are included in metres. Also shown are access roads, the direction of the rifle club mound where the flasher experiment was conducted, and nearby buildings; CANGAROO-I and BIGRAT (from previous IACT experiments), and the rifle club sheds. 57

3.9 A photograph of the CANGAROO-III T2 telescope, from Mori (2002) [123]. This telescope has a 10m dish with the same compound mirror system as T1, but uses a different camera. The scale of T2 is very similar to T1, see Figure 3.1. The hut at ground level is the dish steering control hut, with the data acquisition hut sited on the left of the dish platform, above the dish pedestal. 58

3.10 A schematic view of the CANGAROO-III camera, taken from Ito (2000) [88]. . . . 60

3.11 The *left* figure (figure(a)), shows the single electron peak from Flyckt & Marmonier (2002) [61], as it may appear when measured by a multi-channel analyzer. The relative scale of the horizontal axis represents increasing energy and the vertical axis represents the frequency count of each channel. Each dot in figure(a) represents a single channel. The *right* figure (figure (b)), represents the relative variation of the secondary emission coefficient, δ (vertical axis), as a function of primary electron energy, E_p (horizontal axis), [61]. The secondary emission coefficient ratio first increases to a maximum (when the initial energy of the primary electrons is, E'_p), then gradually decreases with primary electron energy, as the proportion of the electrons excited at greater depth in the material increases. 63

3.12 Schematic side view of a Winston cone light guide, from Winston (1970) [170]. The *left* figure shows that the entrance and exit apertures are of radii, a, and a', respectively. F, is the focus of the upper parabola section and, f, its focal length. The *right* figure shows the origins and orientations of the focus-centred and symmetry axis-centred coordinate systems. 65

3.13 "The angular acceptance as a function of the angle of incidence light rays at the entrance aperture for an ideal three-dimensional Winston cone", from Winston (1970) [170]. The angular acceptance measures the degree of transmission from the exit aperture for rays entering the Winston cone at angles, where 1.0 is 100% and 0.5 is 50% transmission. Note that "the angular acceptance cuts off over a narrow region, $\Delta\theta$ (approximately 1° centred about $\theta_{\max}$). In this example, $\theta_{\max} = 16°$", [170]. . . 66

3.14 Sketch of how forward and backward crosstalk effects can occur in parallel wires, from Brooks (2003) [40]. The lower wire carries the AC aggressor current, which has stepped down at point X and is moving to the right. The arrows indicate the flow directions of the crosstalk currents from point X, in the top victim line. 68

3.15 Network diagram of the overall data acquisition system electronics modules, data buses, and controlling & recording computers for T1. From Kubo *et al.* (2001), [105]. 69

3.16 Network diagram of the overall data acquisition system electronics modules, data buses, and controlling & recording computers for T2. From Kubo *et al.* (2003) [104]. 70

3.17 This diagram shows the data bus and discriminators for the Discriminator and Summing Module, (DSM) (or TKO module), taken from the CANGAROO observation manual, Gunji (2006) [73]. The box labeled, "AC", in the diagram is the (Digital) to Analogue Converter, DAC. 71

3.18 Left diagram: The LSUM and NHIT discriminator data bus; threshold control for **nhit_disc** discriminator. Right diagram: The ASUM data bus to the CAMAC C285 & *LeCroy* 4413 NIM crates; threshold control for the **CAMAC** and **nbox_disc** discriminators, [73]. 72

3.19 The left diagram is the data bus for the TKO DSM, (*Hoshin* 2548, [127]). Circuitry within the dashed line boxes are not included in T1. The right diagram shows the data bus acquisition trigger, which is an extension of the LSUM and ASUM discriminator logic gates shown in the left diagram, from Kubo (2001) [105]. 73

4.1 Photograph of the flasher apparatus above (top figure), including a design sketch of Unit 1 (bottom figure), from Patterson, Swaby & Wild (2001) [136]. 80

4.2 Circuit diagram of the *Nichia* blue LED flasher calibration apparatus. For clarity, this figure is shown enlarged in Appendix A, Figure A.1. 83

4.3 Sketch of the PIN diode flasher monitor apparatus. The circuit is held in a die cast metal box; 11.3 cm × 3 cm × 6.2 cm shown. The PIN diode monitor circuit is shown in Figure 4.4. 87

4.4 Circuit diagram of PIN diode monitor apparatus to measure the flasher output. For clarity, this figure is enlarged in Appendix A, Figure A.2. 88

4.5 PIN diode monitor output voltages, testing the linearity of the light intensity output of the flasher using neutral density filters. 90

4.6 PIN Diode monitor output voltage measurements of the flasher, taken at the 10 ns & 20 ns setting, using the unit 2 emitter. Weighted means of the voltage were calculated, usually because two or more readings were taken at the time of calibration (see equation 4.2, for weighted mean definition). The open symbols indicate where the sticky tape (semi-opaque film), on unit 2 was not changed immediately before taking PIN diode readings. 92

5.1 Background light peak (left peak on both histograms) with added flasher signal (right peak both histograms), taken in 1999 from the airport tower. *Left*: Histogram plot of raw ADC count values for all 256 pixels in the inner T1 camera, for all events. The number of event triggers in this run (99071204), is 5719. The flasher unit triggers at 33 Hz, interspersed with many background light event triggers without the flasher signal present. *Right*: Histogram of; $\sum_{i=1}^{256}$ (sum of raw ADC counts of the inner T1 camera pixels for each event), for all events (number of events is 5719). The data file is the same as the *left* histogram. The sum ADC (flasher signal) histogram peak at $\sim$ 20000 counts, is explained in Section 5.1.3. 101

5.2 Gaussian or Normal distribution; $f(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]$, where σ is the Population Standard Deviation and the mean is, μ, Bevington (1992) [32]. These three curves are based on this statistical function only and not flasher data, for illustrative purposes. Typically, while $\mu \neq 0$ for a signal, these three curves show flattening when the FWHM, Γ, widens with increasing background noise level, where Γ_1 has the lowest background noise level (smallest FWHM), to Γ_3, which has the highest (largest FHWM). All three curves have the same mean or maximum "signal amplitude", $\mu = 0$. 103

5.3 A LED calibration (or scan) plot result for a single PMT pixel (number 1), produced by *calib10*, Okumura (2000) [132]. The mean ADC (the average summed ADC counts of every camera pixel shown on the x-axis), is plotted against their individual ADC count value on the y-axis. The two circle points on each graph is a LED run; the slightly higher value pixels is a LED data file set to 0 dB, and the lower value is LED 1 dB. These points are closely spaced due to the standard output of flat-fielding calibration. The equation; $y = P2x + P1$, describes the fitted line through these two points, results shown in the upper right box. 107

5.4 LED scan result for 16 PMTs (pixels) in Box number 1, produced by *calib10*, [132]. PMT 1 is shown larger in Figure 5.3. Each graph is a LED scan in ADC counts for the i^{th} pixel number (ADC pixel numbers 1 to 16 in this case). 108

5.5 **Calib10** bad channels as represented by the T1 camera. Crossed pixels are flagged as bad channels, square ([ ]) pixels are accepted (not bad channel) pixels and the asterisks are printing padding. PMT boxes information for T1 camera is found in Figure 3.7. The left figure is from July 2001 (data file no. 1071712), and the right figure from Feb. 2002 (data file no. 2020705). 113

5.6 A sketch of the Neutral Density (ND) holder for the flasher. The arrows show where the aluminium sheet is folded over at the edges to enable the ND filter film to be held in place when slotted in. 118

5.7 Geometry of the knife-edge diffraction, acting as an interferometer. From Kumar *et al.* (2007) [106]. 119

5.8 Two dimensional cross-correlation results for T1 flasher calibration by the calibration month, shown in the cross-correlation transform space of x-shift (delta, δ), y-shift (epsilon, ϵ). Flasher calibration month shown as the first month above each slide with the slide number on the top left, e.g. slide 1 is the April 2001 calibration. The concentric rings centre position in these slides (numbers 1 to 8), is the position of the cross-correlation maximum. This maximum position is shown in δ and ϵ, in Table 5.4. Slide no. 8 shows the autocorrelation function (cross-correlating October 2003 with itself). For clarity, this figure is enlarged in Figure E.4, Appendix E. 124

5.9 Mean ADC over all calibration months. The eight selected inner camera linear pixels used are (by ADC ID-number); 60, 64, 73, 74, 154, 227, 228, 236. Flasher settings are 10ns (solid lines), and 10ns ND 0.4 filter (dotted lines), recorded in **calib10a** data format. Each point and line, pertinent to its particular pixel, is indicated by the table on the right of the graph. Each monthly mean ADC value is corrected using the PDM derived ratio values, shown in Table 4.3. For clarity, this figure is also shown enlarged in Figure F.1, Appendix F. 127

5.10 Normalized ratio of average mean ADC of the eight selected T1 camera pixels over all calibration months for the 10ns setting with T1 cross-correlation maximum position distance (where 1.0 indicates the camera centre position and a lower value, further away from it). See Table 5.5. Both these quantities plotted together are unit-less. The average mean ADC datum point from June 2003 has been left out due to mirror dewing. This figure is enlarged in Figure F.2 (Appendix F), for clarity. 128

5.11 Plot of cross-correlation maximum position distance from 1.0 (see Figure 5.10), versus ratio of average mean ADC of the eight selected T1 camera pixels over all calibration months for 10ns setting to test the hypothesis, that of correlation, between these two variables. The least linear squares fit result equation is shown in the lower right of the figure. 130

5.12 Comparison of 10ns flasher hit-map contour images with the calibration in Feb. 2002, compared to July 2001 . Slide A is July 2001 (unit 2), slide B is Feb. 2002 (unit 2), slide C is July 2001 (unit 1), slide D is Feb. 2002 (unit 1). The number of equidistant contour lines are fixed at 10. Contour colours are false and not set to any level. Contour levels are determined from the maximum pixel value to zero. This figure is enlarged in Appendix E, Figure E.2. 132

5.13 T1 flasher mean ADC two dimensional pixel map (top two slides), and mean sum ADC (bottom two histograms). The data for all four figures is 20ns (no ND filters) from T1 in June 2003. The colour scale on the right hand side of the top slides is mean ADC count where, e.g. yellow indicates a mean ADC pixel count between 1000 to 1999. The isolated bright (> 7000 mean ADC counts) pixel in the lower right hand corner of the pixel maps is a scaling reference pixel only, and is not a real data point. "Flashercut" and "saturated" were an early attempt at pixel correction, where "saturated" are uncorrected pixels, see Section 5.2.5. This figure is also shown (enlarged) in Figure E.3, Appendix E. 133

5.14 ADC count histograms per pixel (in T1) from box number 10. The ADC pixel number is shown above each histogram (i.e. 145 to 160). These histograms are used to show examples of malfunctioning PMTs. 136

5.15 Sketch showing any T1 camera pixel (except edge pixels). The central pixel is grey shaded, with eight adjacent pixels. The two crossed pixels are "bad" pixels. 139

5.16 Box numbering PMT pixels in the T2 camera. 141

5.17 Two dimensional cross-correlation results for the T2 flasher calibration by calibration month, shown in the cross-correlation transform space of x-shift (delta, δ), y-shift (epsilon, ϵ). The centre of the concentric rings in these slides (numbers 1 to 6), is the position of the cross-correlation maximum. This maximum position is shown in δ and ϵ, in Table 5.7. Slides 1 to 3 are the 10 ns flasher setting and slides 4 to 6 are 10 ns ND 0.4 flasher setting. The cross-correlation months (shown above each slide) as January and June 2003 with slides 3 and 6 showing the auto-correlation function (cross-correlating October 2003 with itself). For clarity, this figure has been enlarged in Appendix E, Figure E.5. 144

5.18 Showing: 1. Normalized ratio of average mean ADC of the 192 inner T2 camera pixels for the calibration months, January, June & October 2003, for 10 ns & 10 ns settings. 2. Normalized T2 cross-correlation maximum position distance from 1.0°, for 10 ns & 10 ns ND 0.4 settings. All results from other months are normalized to the sum ADC and cross-correlation maximum values from October 2003. Error bar size is explained in the main body of the text. This figure is enlarged in Figure F.3 (Appendix F), for clarity. 148

5.19 Plot of cross-correlation maximum position distance from 1.0°, versus ratio of average mean ADC of the 192 inner T2 camera pixels over January & October 2003 for 10 ns and 10 ns ND 0.4 settings, to test the hypothesis (that of correlation), between these two variables. The least linear squares fit result equation is shown in the centre left of the figure. The data from June 2003 has been left out due to mirror dewing on this month. 150

6.1 Zenith cosmic ray shower run from July 2001 from **calib10**. The abscissa range is 10000 to 150000 sum ADC counts. 152

6.2 Zenith cosmic ray shower run from Feb. 2002, uncalibrated. The abscissa range is 60000 to 150000 sum ADC counts. 153

7.1 T1 dish tracking plot of the zenith angle of one Mkn 421 on-source data file (number 01012619) as an example. The zenith angle is 90° minus the dish degree elevation angle. The **ievents** number is the number of the telescope triggered events, proportional to the exposure time. 160

7.2 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas parameter *distance* (*dis*, bottom left histogram and given in units of degrees), amongst other results. The assumed spectral index for this source is 3.0, the zenith angle is 70° and the number of events simulated is 1×10^5. 162

7.3 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas parameter *length* (*len*) and *width* (*wid*), all given in units of degrees, amongst other results. The assumed spectral index for this source is 3.0, the zenith angle is 70° and the number of events simulated is 1×10^5. 163

7.4 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas parameter *alpha* (top left histogram, given in units of degrees), amongst other results. The spectral index for this source is 3.0, the zenith angle is 70° and the number of events simulated are 1×10^5. 164

7.5 Plot of elapsed data acquisition seconds from the start, versus trigger rate for the **calib10a** data file; 01012809 (Mkn 421, see Table H.1, Appendix H). Trigger rate is the number event triggers per second (rate per sec.). 168

7.6 Camera image pixels as they appear for each event trigger in the the T1 telescope. The pixels are TDC data, where the light grey pixels are un-triggered low value pixels, while coloured pixels are detected EAS Čerenkov photons or random background noise photons. The relative scale of TDC pixel amplitudes is shown on the right of each camera image box. The *left* figure shows what NSB noise may typically appear like, i.e. a few randomly scattered pixels. The *right* figure is an example of an EAS shower caused by a cosmic ray EAS in this case. In EAS events, the camera pixels are usually clustered around the shower core image. 173

7.7 The *alpha* image plot for all Markarian 421 T1 observation data from 2001 to 2003 (data files; see Tables H.1 and H.2, Appendix H). The solid line is the *alpha* plot from on-source data and the overlaid dotted line is the *alpha* plot from off-source data. These on- and off-source *alpha* plots in the above figure, can be viewed separately in Figure J.1 (on-source) and Figure J.2 (off-source) in Appendix J. 175

7.8 The *alpha* image plot for Markarian 421 T1 observation data from 2001 only (data files; see Table H.1, Appendix H). The solid line is the *alpha* plot from on-source data and the overlaid dotted line is the *alpha* plot from off-source data. These on- and off-source *alpha* plots in the above figure, can be viewed separately in Figure J.3 (on-source) and Figure J.4 (off-source) in Appendix J. 176

7.9 The *alpha* image plot for Markarian 421 T1 observation data from 2002 to 2003 only (data files; see Table H.2, Appendix H). The solid line is the *alpha* plot from on-source data and the overlaid dotted line is the *alpha* plot from off-source data. These on- and off-source *alpha* plots in the above figure, can be viewed separately in Figure J.5 (on-source) and Figure J.6 (off-source) in Appendix J. 177

7.10 T1 dish tracking plot of the zenith angle of one EXO 055625 on-source data file (number 02110806) as an example. The zenith angle is 90° minus the dish degree elevation angle. The **ievents** number is the number of telescope triggered events, proportional to the exposure time. 185

7.11 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas parameter *distance* (*dis*, bottom left histogram and given in units of degrees), amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. 187

7.12 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas parameter *length* (*len*) and *width* (*wid*), all given in units of degrees, amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. . . . 188

7.13 Histograms of primary gamma ray EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas parameter *alpha* (top left histogram, given in units of degrees), amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. . . . 189

7.14 The *alpha* image plot for EXO 055625-3838.6 T1 observation data from 2002 to 2003 (data files; see Table H.3, Appendix H). The solid line is the *alpha* plot from on-source data and the overlaid dotted line is the *alpha* plot from off-source data. These on- and off-source *alpha* plots in the above figure, can be viewed separately in Figure J.7 (on-source) and Figure J.8 (off-source) in Appendix J. 191

8.1 Plot of cross-correlation maximum position distance from 1.0 (see Figure 5.10), versus ratio of average mean ADC of the eight selected T1 camera pixels over all calibration months for 10ns setting to test the hypothesis, that of correlation, between these two variables. The least linear squares fit result equation is shown in the lower right of the figure. 196

8.2 From Okumura *et al.* (2002) [133]: Differential energy spectra from CANGAROO shown from Okumura *et al.* (2002) [133], Whipple and HEGRA (shown separately) derived from the Mkn 421 TeV gamma ray observation dataset, during a flaring state in late 2000/early 2001. The differential energy spectra is described by equation 8.2 (Whipple [103]), equation 8.3 (HEGRA [8]), and equation 8.4 (CANGAROO [133]) in this section. The inset; "with the filled circles was used for the spectral shape fitting. The fluxes plotted for the HEGRA group have been scaled in order to normalize it to the Whipple flux at 1 TeV", [133]. 205

A.1 Circuit diagram (rotated 90°) of the *Nichia* blue LED flasher calibration apparatus. 209

A.2 Circuit diagram (rotated 90°) of pin diode monitor apparatus to measure the flasher output. 210

C.1 ADC pedestals over 15 months. Box 1. Each figure shows 1-16 boxes of the T1 inner camera (16 pixels per box). ADC pixel number is shown below each histogram. . . 216

C.2 Box 2. ADC pixel number is shown below each histogram. 217

C.3 Box 3. ADC pixel number is shown below each histogram. 218

C.4 Box 4. ADC pixel number is shown below each histogram. 219

C.5 Box 5. ADC pixel number is shown below each histogram. 220

C.6 Box 6. ADC pixel number is shown below each histogram. 221

C.7 Box 7. ADC pixel number is shown below each histogram. 222

C.8 Box 8. ADC pixel number is shown below each histogram. 223

C.9 Box 9. ADC pixel number is shown below each histogram. 224

C.10 Box 10. ADC pixel number is shown below each histogram. 225

C.11 Box 11. ADC pixel number is shown below each histogram. 226

C.12 Box 12. ADC pixel number is shown below each histogram. 227

C.13 Box 13. ADC pixel number is shown below each histogram. 228

C.14 Box 14. ADC pixel number is shown below each histogram. 229

C.15 Box 15. ADC pixel number is shown below each histogram. 230

C.16 Box 16. ADC pixel number is shown below each histogram. 231

D.1 ADC pedestals differences over 15 months. Box 1. Each figure shows a box of the T1 inner camera, (16 pixels per box). "Pedestal difference" is the difference between the sample mean ADC, see equation 5.4 (Section 5.1.6), and the mean ADC generated by *PAW*, from the ADC histogram. 233

D.2 Box 2. ADC pixel number is shown below each histogram. 234

D.3 Box 3. ADC pixel number is shown below each histogram. 235

D.4 Box 4. ADC pixel number is shown below each histogram. 236

D.5 Box 5. ADC pixel number is shown below each histogram. 237

D.6 Box 6. ADC pixel number is shown below each histogram. 238

D.7 Box 7. ADC pixel number is shown below each histogram. 239

D.8 Box 8. ADC pixel number is shown below each histogram. 240

D.9 Box 9. ADC pixel number is shown below each histogram. 241

D.10 Box 10. ADC pixel number is shown below each histogram. 242

D.11 Box 11. ADC pixel number is shown below each histogram. 243

D.12 Box 12. ADC pixel number is shown below each histogram. 244

D.13 Box 13. ADC pixel number is shown below each histogram. 245

D.14 Box 14. ADC pixel number is shown below each histogram. 246

D.15 Box 15. ADC pixel number is shown below each histogram. 247

D.16 Box 16. ADC pixel number is shown below each histogram. 248

E.1 Hit-map of T1 flasher images from Feb 7th 2002. This "hit-map" is a two dimensional image map (of the T1 camera), where any PMT pixel recorded a "hit" during the data acquisition run (see Section 3.2.6), hence hit pixels. The colour scale on the two right hand side slides (slides B and D) is hit pixel count where, e.g. yellow indicates a hit pixel count between 2000 to 3999. The number of equidistant contour lines are fixed at 10. Contour line colours are false and not set to any level. Contour line levels are determined from the maximum pixel value to zero. Slides A and B are unit 2 at 20ns. Slides C and D are unit 2 at 10 ns. The FOV of the camera shown in each slide is about 3 degrees by 3 degrees. 250

E.2 Comparison of 10ns flasher T1 hit-map contour images with the calibration in Feb. 2002, compared to July 2001. The number of equidistant contour lines are fixed at 10. Contour colours are false and not set to any level. Contour levels are determined from the maximum pixel value to zero. Slide A is July 2001 (unit 2), slide B is Feb. 2002 (unit 2), slide C is July 2001 (unit 1), slide D is Feb. 2002 (unit 1). 251

E.3 T1 flasher mean ADC two dimensional pixel map (top two slides), and mean sum ADC (bottom two histograms). The data for all four figures is 20ns (no ND filters) from T1 in June 2003. The colour scale on the right hand side of the top slides is mean ADC count where, e.g. yellow indicates a mean ADC pixel count between 1000 to 1999. The isolated bright ($>$ 7000 mean ADC counts) pixel in the lower right hand corner of the pixel maps is a scaling reference pixel only, and is not a real data point. "Flashercut" and "saturated" were an early attempt at pixel correction, where "saturated" are uncorrected pixels, see Section 5.2.5. 252

E.4 Two dimensional cross-correlation results for the T1 flasher calibration by the calibration month, shown in the cross-correlation transform space of x-shift (delta, δ), y-shift (epsilon, ϵ). The flasher calibration month is shown as the first month above each slide with the slide number on the top left, e.g. slide no. 1 is the April 2001 calibration. The centre of the concentric rings in these slides (numbers 1 to 8), is the position of the cross-correlation maximum. This maximum position is shown in δ and ϵ, in Table 5.4. Slide no. 8 shows the autocorrelation function, (cross-correlating October 2003 with itself). 253

E.5 Two dimensional cross-correlation results for the T2 flasher calibration by calibration month, shown in the cross-correlation transform space of x-shift (delta, δ), y-shift (epsilon, ϵ). The centre of the concentric rings in these slides (numbers 1 to 6), is the position of the cross-correlation maximum. This maximum position is shown in δ and ϵ, in Table 5.7. Slides 1 to 3 are the 10 ns flasher setting and slides 4 to 6 are 10 ns ND 0.4 flasher setting. The cross-correlation months (shown above each slide) as January and June 2003 with slides 3 and 6 showing the autocorrelation function, (cross-correlating October 2003 with itself). 254

F.1 Mean ADC over all calibration months, per pixel (rotated 90° to fit page). The eight selected inner camera linear pixels used are (by ADC ID-number); 60, 64, 73, 74, 154, 227, 228, 236. Flasher settings are 10ns (solid lines), and 10ns ND 0.4 filter (dotted lines), recorded in **calib10a** data format. Each point and line, pertinent to its particular pixel, is indicated by the table on the right of the graph. Each monthly mean ADC value is corrected using the PDM derived ratio values, shown in Table 4.3. 256

F.2 Normalized ratio of average mean ADC of the eight selected T1 camera pixels over all calibration months for the 10ns setting with T1 cross-correlation maximum position distance (where 1.0 indicates the camera centre position and a lower value, further away from it). Both these quantities plotted together are unit-less. The average mean ADC datum point from June 2003 has been left out due to mirror dewing. . . 257

F.3 (Rotated to fit page). Showing: 1. Normalized ratio of average mean ADC of the 192 inner T2 camera pixels for the calibration months, January, June & October 2003, for 10 ns & 10 ns settings. 2. Normalized T2 cross-correlation maximum position distance from 1.0, for 10 ns & 10 ns ND 0.4 settings. All results from other months are normalized to the sum ADC and cross-correlation maximum values from October 2003. 258

F.4 (Rotated to fit page). Monthly data of Outside Temperature, Dew Point and Humidity from the Davis Weather Station at the T1 telescope. 259

G.1 **Page 1** logbook entry detailing flasher image analysis from 24/2/01 and 25/2/01 showing consistent dark bands through different flasher data files 261

G.2 **Page 2** logbook entry, detailing flasher image analysis from 25/2/01 (and previous month's data on the 2nd January 2001), showing consistent dark bands through different flasher data files. 262

I.1 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas Parameter *distance* (*dis*), amongst other results. The spectral index for this source is 2.7, the zenith angle is 70° and the number of events simulated are 1×10^5. 268

I.2 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas Parameter *length* (*len*) and *width* (*wid*), amongst other results. The spectral index for this source is 2.7, the zenith angle is 70° and the number of events simulated are 1×10^5. 269

I.3 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for Markarian 421: Showing the Hillas Parameter *alpha* (top left histogram), amongst other results. The spectral index for this source is 2.7, the zenith angle is 70° and the number of events simulated are 1×10^5. 270

I.4 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas Parameter *distance* (*dis*), amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. 271

I.5 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas Parameter *length* (*len*) and *width* (*wid*), amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. 272

I.6 Histograms of primary proton EAS Monte Carlo *GEANT 3.21* simulation results for EXO 055625-3838.6: Showing the Hillas Parameter *alpha* (top left histogram), amongst other results. The spectral index for this source is 2.7, the zenith angle is 10° and the number of events simulated are 1×10^5. 273

J.1 The *alpha* image plot for all Markarian 421 T1 observation data from 2001 to 2003 (data files; see Tables H.1 and H.2, Appendix H). On-source *alpha* plot only. See Figure 7.7 for comparison. 275

J.2 The *alpha* image plot for all Markarian 421 T1 observation data from 2001 to 2003 (data files; see Tables H.1 and H.2, Appendix H). Off-source *alpha* plot only. See Figure 7.7 for comparison. 276

J.3 The *alpha* image plot for Markarian 421 T1 observation data from 2001 (data files; see Table H.1, Appendix H). On-source *alpha* plot only. See Figure 7.8 for comparison. 277

J.4 The *alpha* image plot for Markarian 421 T1 observation data from 2001 (data files; see Table H.1, Appendix H). Off-source *alpha* plot only. See Figure 7.8 for comparison. 278

J.5 The *alpha* image plot for Markarian 421 T1 observation data from 2002 to 2003 (data files; see Table H.2, Appendix H). On-source *alpha* plot only. See Figure 7.9 for comparison. 279

J.6 The *alpha* image plot for Markarian 421 T1 observation data from 2002 to 2003 (data files; see Table H.2, Appendix H). Off-source *alpha* plot only. See Figure 7.9 for comparison. 280

J.7 The *alpha* image plot for EXO 055625-3838.6, T1 observation data from 2002-2003 (data files; see Table H.3, Appendix H). On-source *alpha* plot only. See Figure 7.14 for comparison. 281

J.8 The *alpha* image plot for EXO 055625-3838.6, T1 observation data from 2002-2003 (data files; see Table H.3, Appendix H). Off-source *alpha* plot only. See Figure 7.14 for comparison. 282

K.1 Data taken directly from Table 7.2: Plot of Mkn 421 2001-2003 incremental significance calculated using equation 7.3 (Li & Ma (1983), [111]) against each 5° (bin width) angle in Figure 7.7 *alpha* cut histogram. The size of the error bars (uncertainty) in this figure are explained in Section 7.1.4 and in Table 7.2 caption. 284

K.2 Data taken directly from Table 7.2: Plot of Mkn 421 2001 incremental significance calculated using equation 7.3 (Li & Ma (1983), [111]) against each 5° (bin width) angle in Figure 7.8 *alpha* cut histogram. The size of the error bars (uncertainty) in this figure are explained in Section 7.1.4 and in Table 7.2 caption. 285

K.3 Data taken directly from Table 7.2: Plot of Mkn 421 2002-2003 incremental significance calculated using equation 7.3 (Li & Ma (1983), [111]) against each 5° (bin width) angle in Figure 7.9 *alpha* cut histogram. The size of the error bars (uncertainty) in this figure are explained in Section 7.1.4 and in Table 7.2 caption. 286

K.4 Data taken directly from Table 7.3: Plot of EXO 055625-3838.6 incremental significance calculated using equation 7.3 (Li & Ma (1983), [111]) against each 5° (bin width) angle in Figure 7.14 *alpha* cut histogram. The size of the error bars (uncertainty) in this figure are explained in Section 7.1.4 and in Table 7.2 caption. 287

List of Tables

2.1 Weighted moment of the ellipse, calculated from camera coordinates 21

2.2 Hillas Parameters of the ellipsoid, based on the shape of a gamma ray shower on the ground 21

4.1 Table of ACU telescope pointing coordinates 85

4.2 Table of flasher time measurements 89

4.3 Table of normalizing ratios for flasher 95

5.1 Table of Discriminator module settings for T1 100

5.2 T1 ADC pedestal file table 111

5.3 Knife-edge interferometer diffraction fringe sizes 121

5.4 T1 cross-correlation maximum position and distance from camera centre. 126

5.5 T1 cross-correlation distance versus mean sum ADC. 129

5.6 Table of Discriminator module settings for T2 140

5.7 T2 cross-correlation maximum position and distance from camera centre. 145

5.8 T2 cross-correlation distance versus mean sum ADC. 147

7.1 The gamma ray signal significance (S), of Markarian 421 *alpha* distributions 180

7.2 Incremental significance (S, Li & Ma (1986)) of Mkn 421 per 5° *alpha* distributions 181

7.3 Incremental significance (S, Li & Ma (1986)) of EXO 055625 per 5° *alpha* distributions 193

B.1 Table (1 of 2) of flasher calibration data files from the T1 telescope 212

B.2 Table (2 of 2) of flasher calibration data files from the T1 telescope 213

B.3 Flasher calibration data files from the T2 telescope 214

H.1 Table (1 of 2) of Mkn 421 observation data files (2001) 264

H.2 Table (2 of 2) of Mkn 421 observation data files (February 2002 and January 2003) 265
H.3 Table of EXO 055625 observation data files 266