Early Cherenkov Light Studies at Uni Sydney → Towards CTA...

Gavin Rowell (Uni. Adelaide)

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EVIDENCE FOR THE DETECTION OF GAMMA RAYS FROM CENTAURUS A AT $E_\gamma \geq 3 \times 10^{11}$ eV

J. E. GRINDLAY AND H. F. HELMKEN
Center for Astrophysics, Harvard College Observatory and Smithsonian Astrophysical Observatory

AND

R. HANBURY BROWN, J. DAVIS, AND L. R. ALLEN
School of Physics, University of Sydney, Australia
Received 1974 November 27

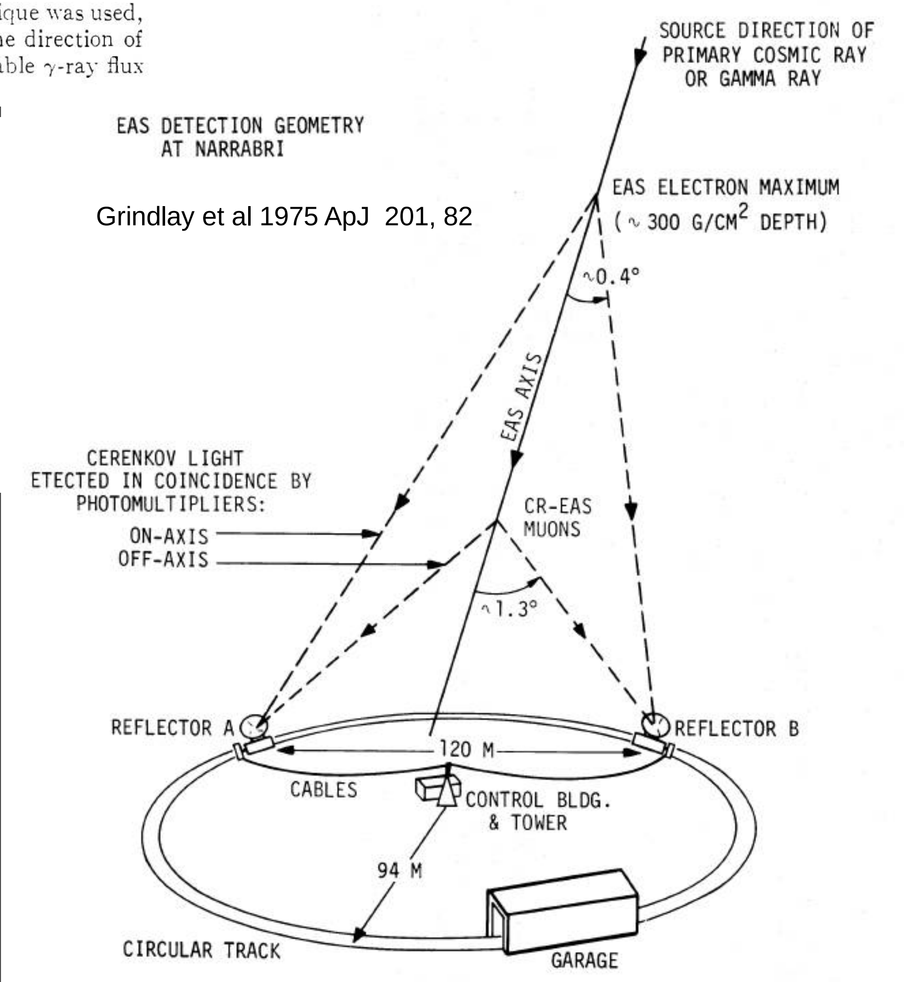
ABSTRACT

Results of extended observations of the active galaxy NGC 5128 (Cen A) at energies $> 10^{11}$ eV are presented. Data were recorded from three observing pericds (1972–1974) in Australia. The atmospheric Cerenkov technique was used, together with partial cosmic-ray rejection, to search for γ-ray–initiated extensive air showers from the direction of Cen A. A 4.5 σ (time-averaged) excess over background was detected. Some implications of this probable γ-ray flux are discussed.

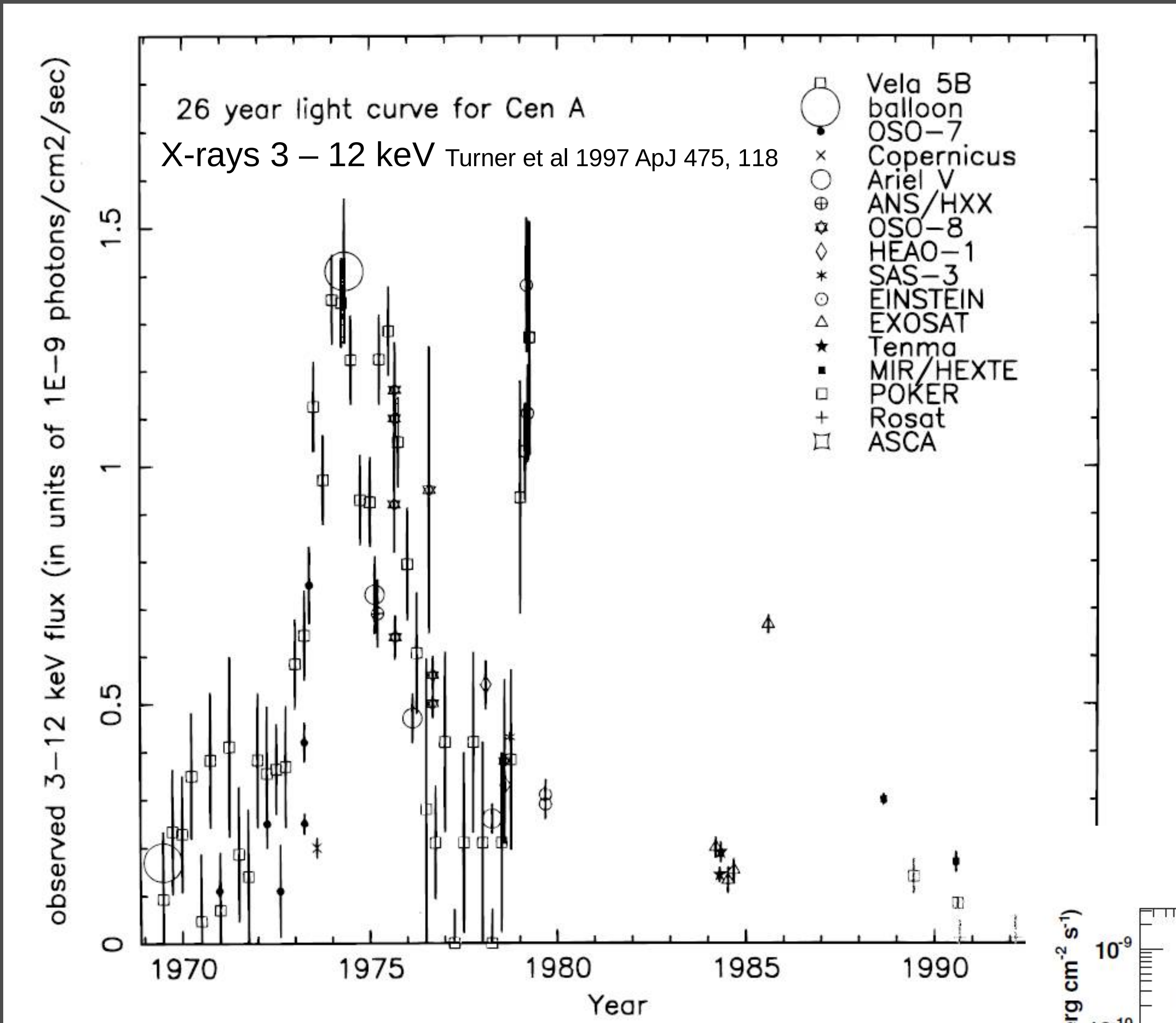
TABLE 1

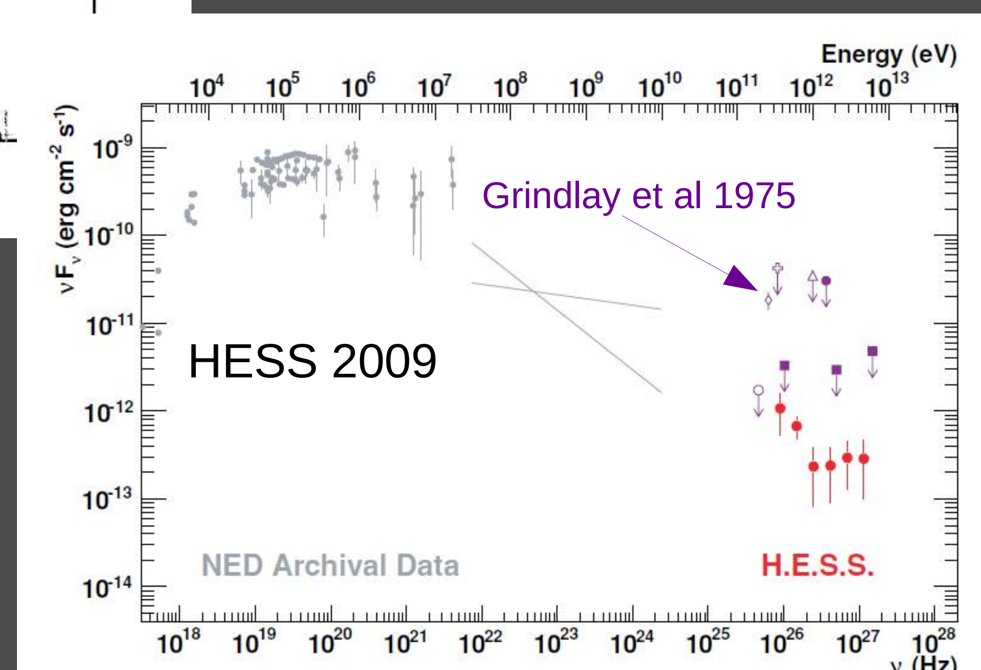
SUMMARY OF CENTAURUS A RESULTS

	Total EAS					Nonrejected EAS				
Year	On	Off	Time (min)	On minus Off Rate (min⁻¹)	No. of σ	On	Off	Time (min)	On minus Off Rate (min⁻¹)	No. of σ
1972...	76660	75601	1289	0.82 ± 0.30	2.7	56471	55167	1240	1.05 ± 0.27	3.9
1973...	35773	35726	782	0.06 ± 0.34	0.2	15463	15297	662	0.25 ± 0.26	1.0
1974...	64759	63757	975	1.03 ± 0.37	2.8	39853	39139	975	0.73 ± 0.29	2.5
Sum	177192	175084	3046	0.69 ± 0.19	3.6	111787	109603	2877	0.76 ± 0.16	4.6
Mean of rates weighted by σ^{-2}				0.63 ± 0.19	3.3				0.66 ± 0.16	4.2



Grindlay et al 1975 ApJ 201, 82


26 year light curve for Cen A
X-rays 3 – 12 keV Turner et al 1997 ApJ 475, 118
Vela 5B
balloon
OSO−7
Copernicus
Ariel V
ANS/HXX
OSO−8
HEAO−1
SAS−3
EINSTEIN
EXOSAT
Tenma
MIR/HEXTE
POKER
Rosat
ASCA
observed 3−12 keV flux (in units of 1E−9 photons/cm2/sec)
0
0.5
1
1.5
1970
1975
1980
1985
1990
Year


Energy (eV)
10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13}
νF_ν (erg cm^{-2} s^{-1})
10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14}
Grindlay et al 1975
HESS 2009
NED Archival Data
H.E.S.S.
10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23} 10^{24} 10^{25} 10^{26} 10^{27} 10^{28}
ν (Hz)

SUPPLEMENTO AL VOLUME VIII, SERIE X
DEL NUOVO CIMENTO
N. 2, 1958
2º Trimestre

Čerenkov Light from Air Showers.

M. H. BRENNAN, J. MALOS, D. D. MILLAR and C. S. WALLACE
The F.B.S. Falkiner Nuclear Research and Adolph Basser Computing Laboratories, School of Physics (*), The University of Sydney - Sydney, N.S.W.

No. 4640 October 4, 1958 NATURE 905

AIR SHOWERS OF SIZE GREATER THAN 10^5 PARTICLES

(1) CORE LOCATION AND SHOWER SIZE DETERMINATION

By M. H. BRENNAN*, D. D. MILLAR and C. S. WALLACE
The F.B.S. Falkiner Nuclear Research and Adolph Basser Computing Laboratories, School of Physics†, University of Sydney

No. 4641 October 11, 1958 NATURE 973

AIR SHOWERS OF SIZE GREATER THAN 10^5 PARTICLES*

(2) ČERENKOV RADIATION ACCOMPANYING THE SHOWERS

By M. H. BRENNAN†, J. MALOS, DR. D. D. MILLAR and C. S. WALLACE
The F.B.S. Falkiner Nuclear Research and Adolph Basser Computing Laboratories, School of Physics‡, University of Sydney

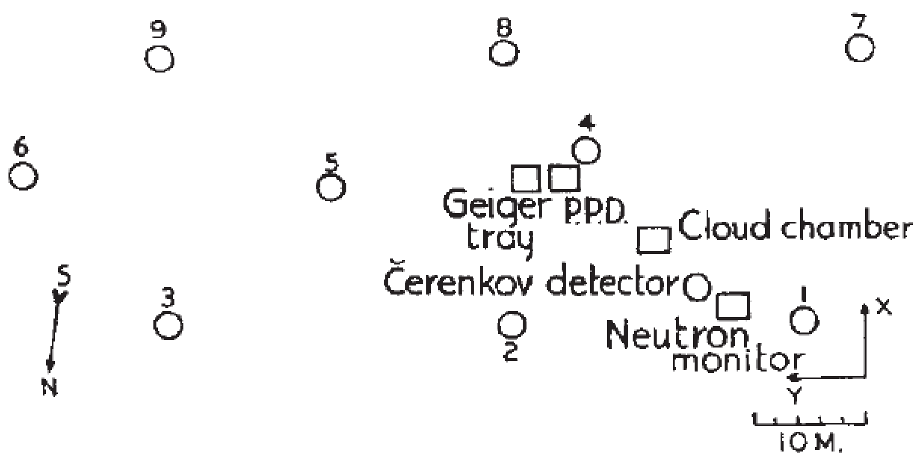


Fig. 1. Plan view of air-shower array. The circles numbered 1-9 represent the liquid scintillation counters. The triggering Geiger trays (not shown) are grouped around the cloud chamber

Seven-PMT array at focus of 44in parabolic mirror (3 deg / PMT)

→ Two/three-PMT coincidences
→ Cherenkov 'image' extends over several degrees

<u>Following first Cherenkov light detection</u>
- W. Galbraith and J.V. Jelley, J. Atmos. Terr. Physics 6 (1955) 250
- J.V. Jelley and W. Galbraith, J. Atmos. Terr. Physics 6 (1955) 304

<u>Russia/USSR Group</u>
-N.M. Nesterova and A.E. Chudakov, JETP 28 (1955) 384
- Chudakov, A.E. and Nesterova, N.M, 1958. Nuovo Cimento, 8, Ser. X, Suppl. No. 2, 606

LETTERS TO THE EDITORS

PHYSICS

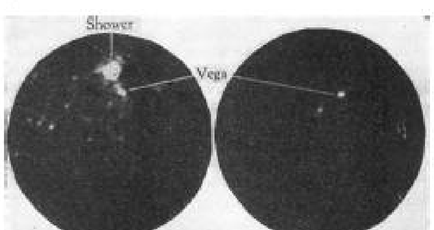
Photography of Čerenkov Light from Extensive Air Showers in the Atmosphere

SEVERAL authors[1-4] have shown that Čerenkov light from extensive air showers in the atmosphere can be detected above the background light of the night sky, and that a single photomultiplier can be used for detecting showers of about 10^{15}-eV. primary energy at distances up to 600 m. from the shower axis.

We have used an image intensifier system, triggered by amplified pulses from a 5-in. photomultiplier, in an attempt to photograph the showers. The system consists of a Schmidt mirror 30 cm. in diameter, and nominal aperture of f0·5, but with usable area only 300 cm.^{2}. It has an acceptance cone of half-angle 17° about the zenith and is focused for infinity on the 5-in. diameter cathode of an image intensifier (Westinghouse *WX*4171). This is run continuously and integrates night-sky light over the decay time of the *P*15 phosphor, nominally 1 µsec. It is coupled optically to a three-stage cascaded intensifier (R.C.A. *C*73491) which is normally gated off, and which is followed by an intensifier orthicon, with kinescope display. The intensifier system has previously been used with a scintillation chamber and is described elsewhere[5]. Under present conditions we are limited by night-sky background, and operate the system well below full gain.

Light pulses are accepted by the photomultiplier over a cone of half-angle 50°, so that selection is isotropic over the field of view of the Schmidt system, but not all selected showers will be visible to it. Operation has been possible for 8 hr. under clear sky conditions and 32 shower pulses have been observed. A random pulse is applied a few seconds after each Čerenkov pulse, to obtain a comparison picture. Ten of the Čerenkov photographs have large spots, 3–5° in angular diameter. A typical event is shown in Fig. 1. No spots of comparable size or brightness have been observed in any of the 32 random pictures, though stars appear in both Čerenkov and random pictures. On covering the system, the field becomes dark. The evidence indicates that we are photographing the Čerenkov radiation from extensive air showers.

In the case illustrated, the first-magnitude star α Lyræ (Vega) also appears in both exposures, and this can be used to set a lower limit for the brightness of the shower pulse. It is known from previous work with the system that the effective integration time of the first phosphor is approximately 10 µsec., about ten times the nominal decay-time of the fast component. The total visible flux from the star during this time is roughly 10 photons/cm.^{2}. From the film density we estimate that the intensity of the shower pulse is of the order of 50 photons/cm.^{2}, consistent with a shower size of 10^5 particles. Accurate estimates are difficult because of non-linearities in the kinescope display and film response.



Čerenkov Random

Fig. 1

The centres of the shower spots, which correspond presumably to the directions of the showers, can be determined with accuracy better than 0·5°. This combination of high directional precision with relatively high detection-rate suggests that the technique may be of value in the search for showers initiated by primary γ-rays.

The work was carried out at the Agassiz Observatory of Harvard University (100 m. above sea-level) and we would like to thank the Committee of the Observatory for allowing us the use of an astronomical building as well as Mr. K. Richards for his help in constructing and operating the system. One of us (N. A. P.) thanks the O.E.E.C. for the award of a senior visiting fellowship at the Massachusetts Institute of Technology. The experiment was supported in part through A.E.C. Contract *AT*(30-1)—2098, by funds provided by the U.S. Atomic Energy Commission, the Office of Naval Research, and the Air Force Office of Scientific Research.

D. A. HILL

Massachusetts Institute of Technology,
Cambridge, Mass.

N. A. PORTER

University College,
Dublin.

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3 Brennan, M. H., Malos, J., Millar, D. D., and Wallace, C. S., *Nature*, 182, 973 (1958).
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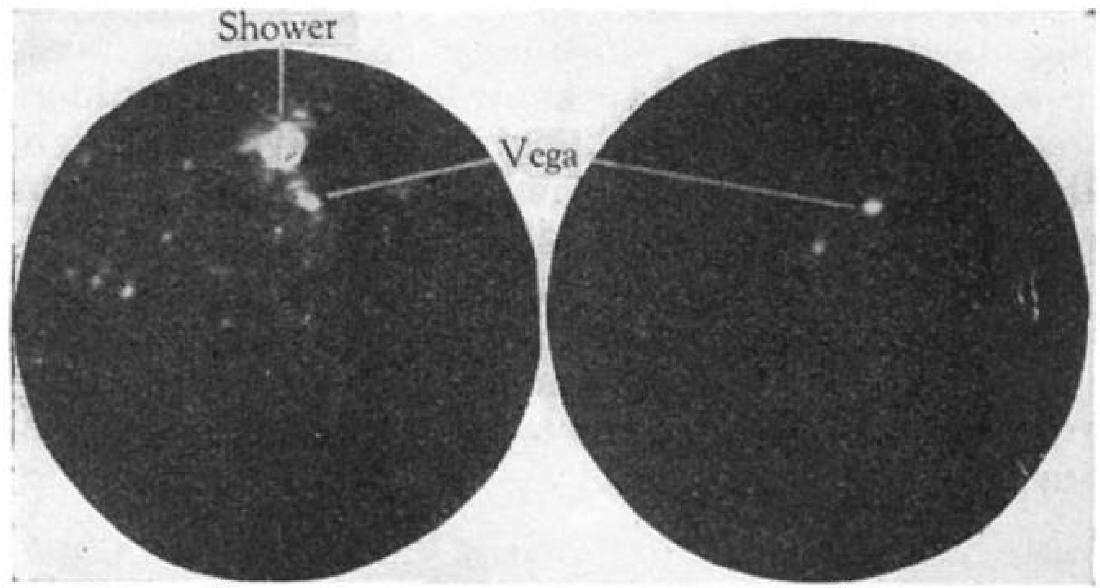
5 Caldwell, D. O., *Rep. Belgrade Conf. Nuclear Instruments* (in preparation).

An Autoradiographic Effect

WHILE using X-ray films in another investigation, autoradiographic effects were obtained from many ordinary substances or mixtures of them. Materials such as zinc metal powder alone or mixtures of metal powders in a medium such as dried 'Glyptal' varnish were used. Such mixtures were put in holes in wooden or plastic blocks and the films attached to the blocks with drawing-pins or tape. A cardboard separator was used around the edges of the blocks to keep the films out of contact with the materials, leaving an air-gap of about 1 mm. Exposures of 48 hr. were generally used.

The combination of materials used in most of these experiments was a mixture of aluminium filings in 'Glyptal' varnish with addition of small amounts of castor oil sometimes. The following experimental



Čerenkov Random

Fig. 1

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Čerenkov Radiation Extensive Air Shower Telescope*

FORREST I. BOLEY† AND NORMAN H. MACOY‡
Scott Laboratory of Physics, Wesleyan University, Middletown, Connecticut

(Received August 21, 1961; and in final form, October 5, 1961)

A telescope is described which has been used to determine the directional characteristics of the Čerenkov radiation accompanying extensive cosmic ray air showers. The reflecting telescope has a 12.5-in. aperture, a 48-in. focal length and is of an off-axis design to permit the use of a 19 photomultiplier tube light detection array. Pulse-height information from each tube is fed to separate, spaced inputs on a delay line which supplies the resulting signal for oscilloscope presentation. The various pulse heights provide the Čerenkov radiation directional information. An average of 75% of the Čerenkov photons arrive at the telescope within a half-angle of 2.3°.

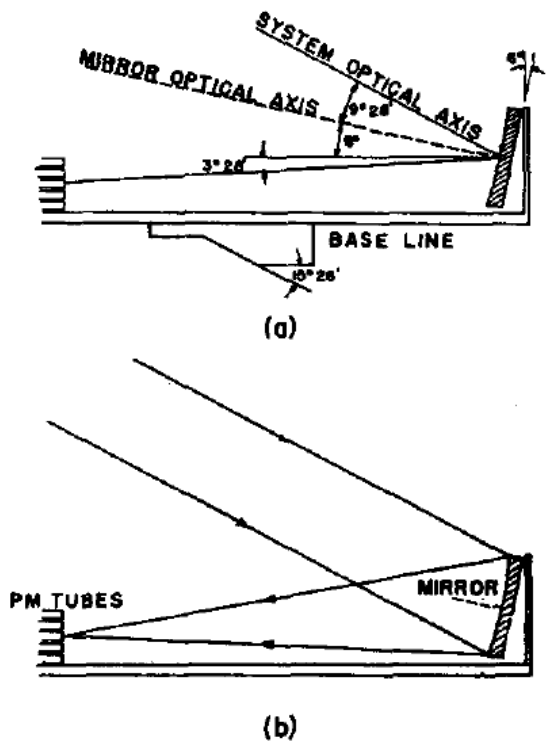
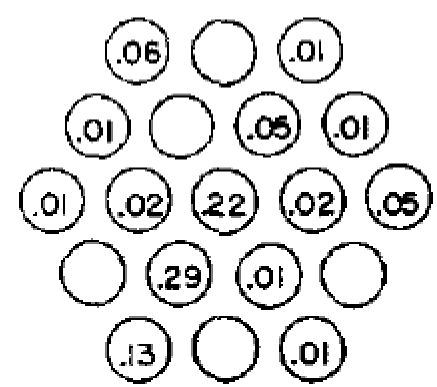
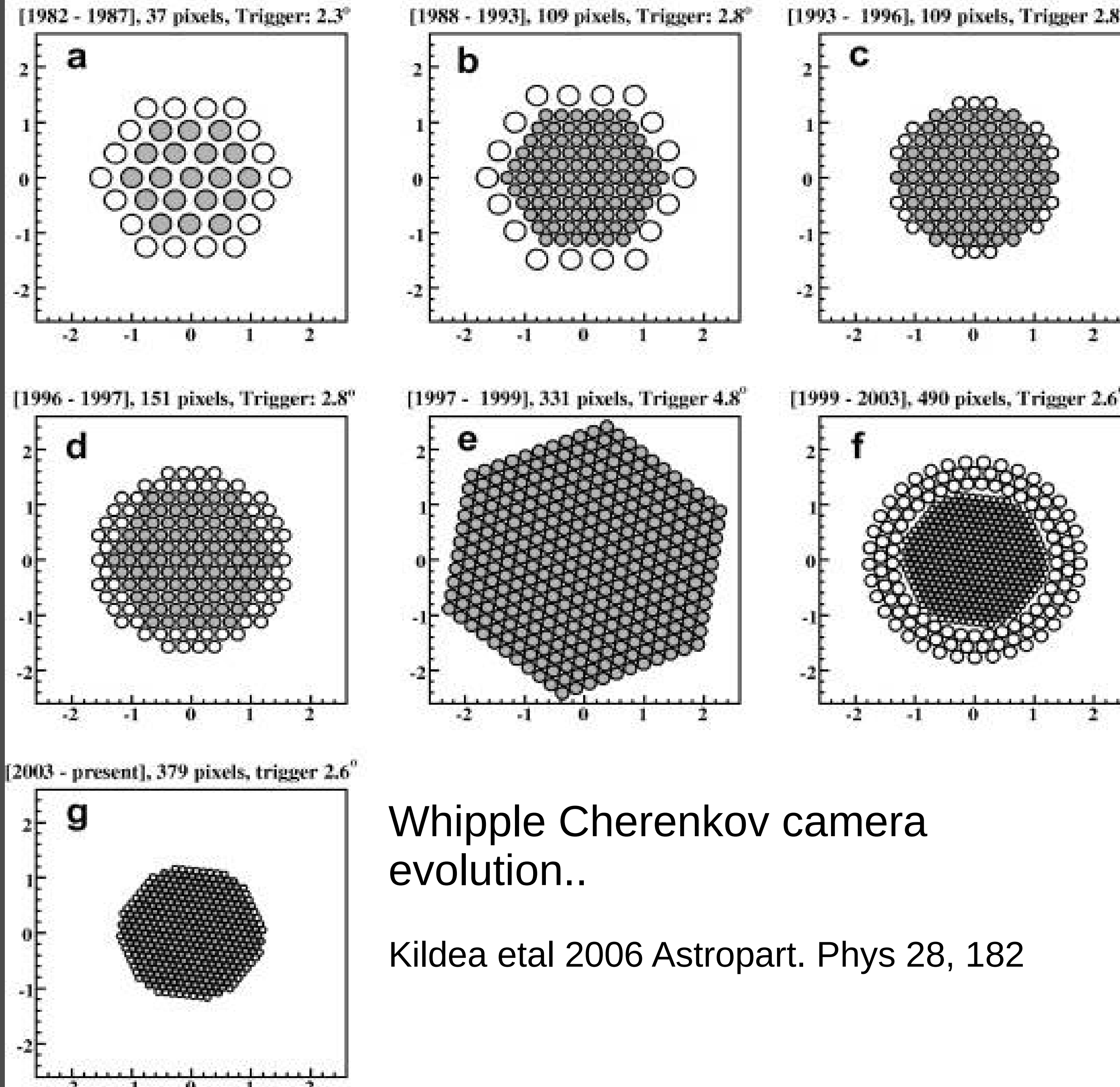


FIG. 1. Schematic diagram of the designed telescope showing (a) the relation between the mirror and system optic axes and (b) a ray diagram for light falling on the center tube.

19 Pixel “Camera”

FIG. 4. Plot plan of photomultiplier tube array showing pulse amplitudes derived from Fig. 3 for each tube.





Whipple Cherenkov camera evolution..

Kildea etal 2006 Astropart. Phys 28, 182

Camera Pixels: >200 pixels to >10,000 pixels...
Camera FoV: 3 to 9 degrees