

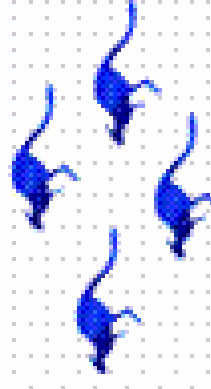
CANGAROO

超高エネルギー ガンマ線望遠鏡

Supported by

COE科研費
宇宙線研共同利用
ARC(オーストラリア)












CANGAROO collaboration



CANGAROO III

Collaboration of Australia and Nippon for a

Gamma Ray Observatory in the Outback

- | | | |
|---|---|--|
| <input type="checkbox"/> University of Adelaide |  | <input type="checkbox"/> Institute of Physical and |
| <input type="checkbox"/> Australian National University |  | <input type="checkbox"/> Chemical Research |
| <input type="checkbox"/> Ibaraki University |  | <input type="checkbox"/> Shimshu University |
| <input type="checkbox"/> Ibaraki Prefectural University |  | <input type="checkbox"/> Institute for Space and |
| <input type="checkbox"/> Kanagawa University |  | <input type="checkbox"/> Aeronautical Science |
| <input type="checkbox"/> Kansai University |  | <input type="checkbox"/> Toai University |
| <input type="checkbox"/> Kyoto University |  | <input type="checkbox"/> University of Tokyo |
| <input type="checkbox"/> Nagoya University |  | <input type="checkbox"/> Tokyo Institute of Technology |
| <input type="checkbox"/> National Astronomical |  | <input type="checkbox"/> Yamagata University |
| <input type="checkbox"/> Observatory of Japan |  | <input type="checkbox"/> Yamaguchi Gakuin University |
| <input type="checkbox"/> Osaka City University |  | |

東大 Adelaide大 協定

AGREEMENT ON ACADEMIC EXCHANGE
BETWEEN
THE UNIVERSITY OF TOKYO
AND
THE UNIVERSITY OF ADELAIDE

This Agreement is entered into between the University of Tokyo, Japan, of the one party and the University of Adelaide, Australia, of the other party, both universities being convinced that academic exchange and cooperation will promote the development of research and other academic activities in each university.

Article 1.

The parties hereto agree to promote cooperation in academic fields of mutual interest through the following:

1. Exchange of faculty members and researchers
2. Exchange of students
3. Conducting joint research
4. Holding lectures and symposia
5. Exchange of information and academic publications

Article 2.

Matters pertaining to the implementation of the exchange based on the preceding Article 1 shall be negotiated and agreed upon between the institutes or organizations of the parties which carry out the specific project(s) hereunder.

Article 3.

This Agreement remains effective for a period of five years starting from the latter date of the signing indicated below by the parties hereto. Its period of validity may be extended by mutual agreement. Either party may, by giving six months written notice to the other party, terminate this Agreement during its period of validity.

Article 4.

This Agreement is executed in duplicate, both in Japanese and in English versions respectively, both of which shall be deemed as originals.

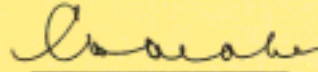
The parties hereto establish this Agreement by duly signing it as of the respective dates written below.

The University of Tokyo

The University of Adelaide



Takechi Sasaki, President



Cliff Blake, Vice Chancellor

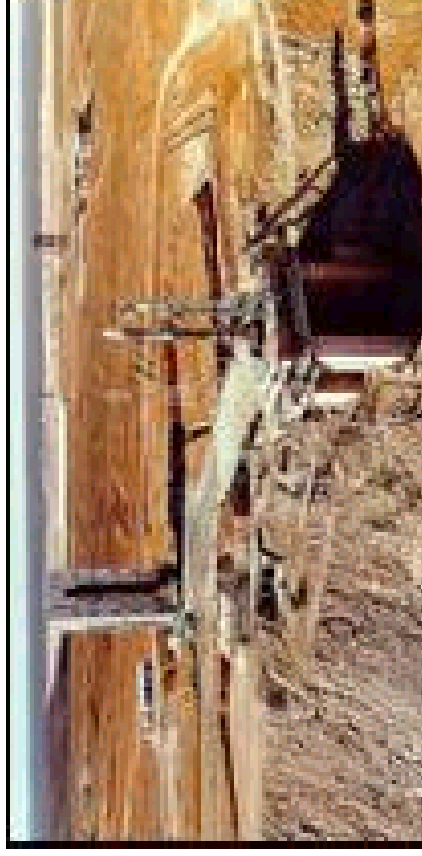
Oct. 2 2001

19th October 2001

Cherenkov observation at Woomera

- Southern sky - good for galactic objects
- Observation only on moonless, clear nights
- Less humidity and rain
- Infrastructure (electricity, access road, people)
- Protection (prohibited area)

Latitude: 21°08' S.
Longitude: 138°47' E.
180 m a.s.l.



Imaging Cherenkov technique

- Differentiate gamma-rays from cosmic-ray nuclei by utilizing difference in Cherenkov light image

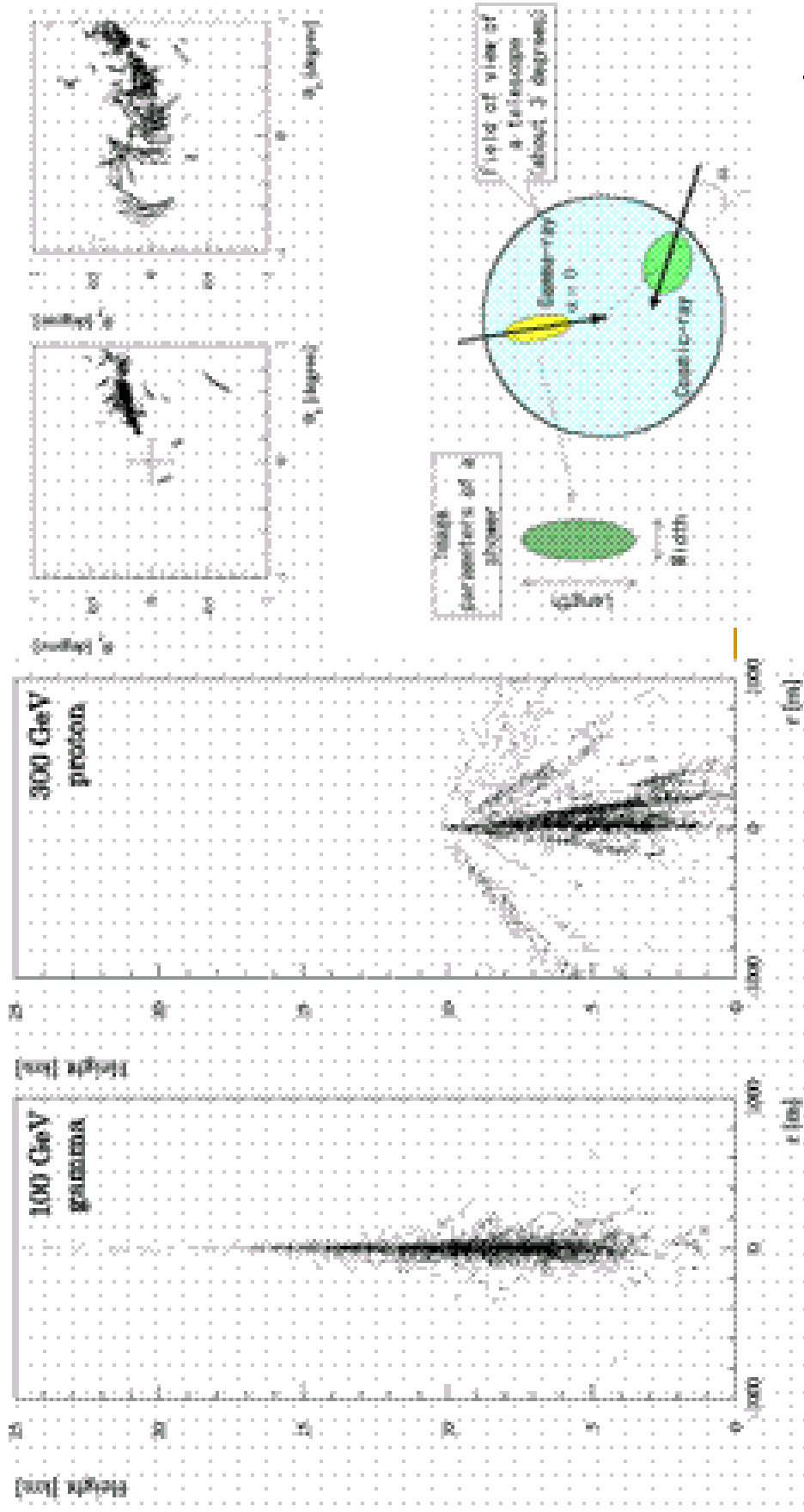
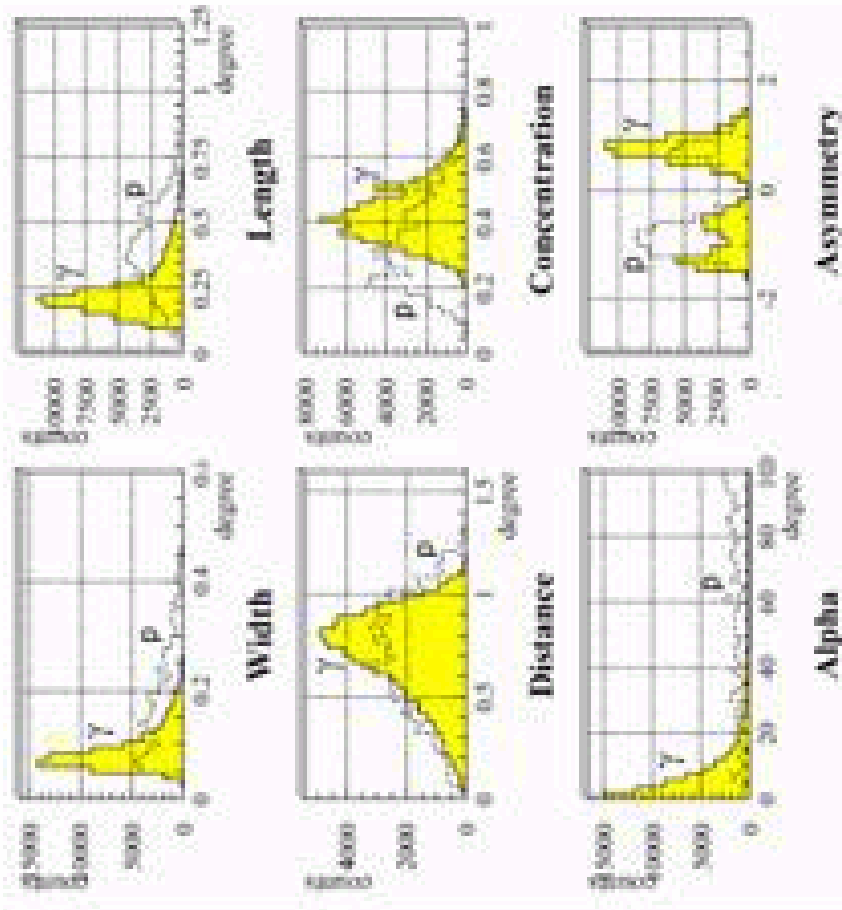
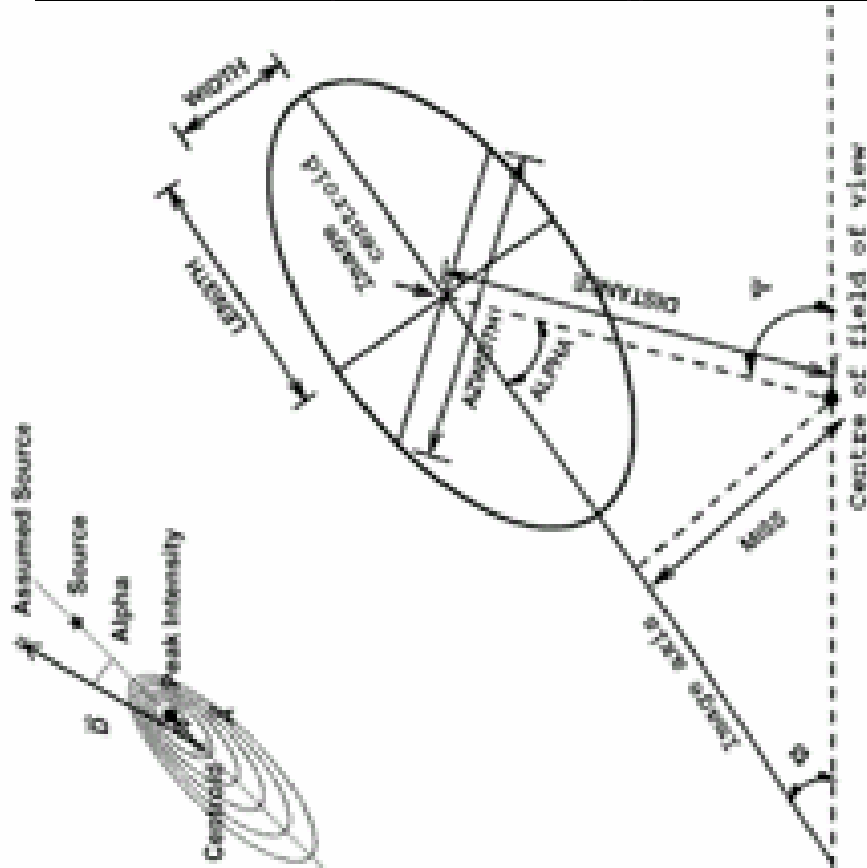


Image parameters

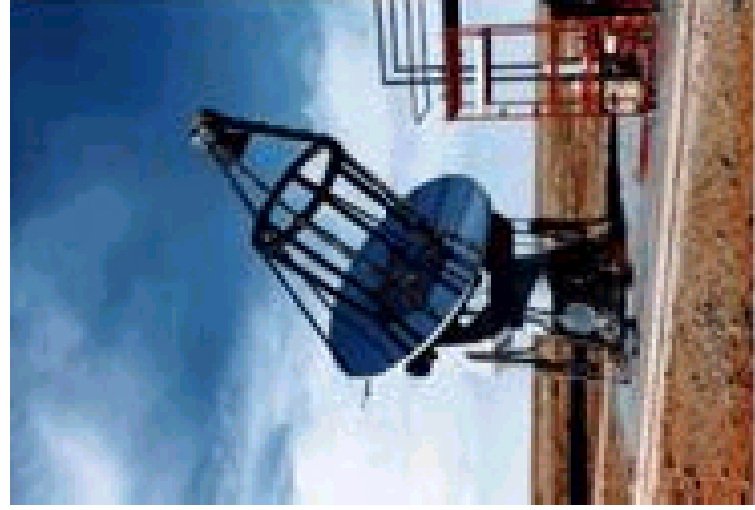
Hillas 1985 ICRC



D.J. Fegan, J.Phys. G, 1997

(Simulation)

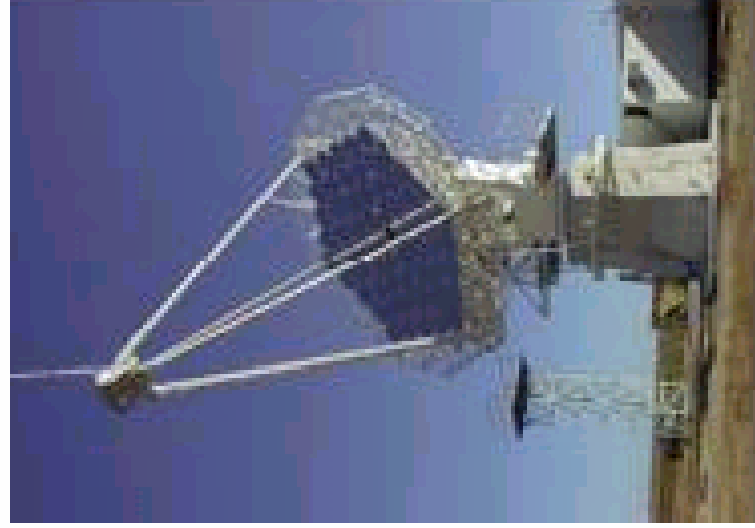
History of CANGAROO telescopes



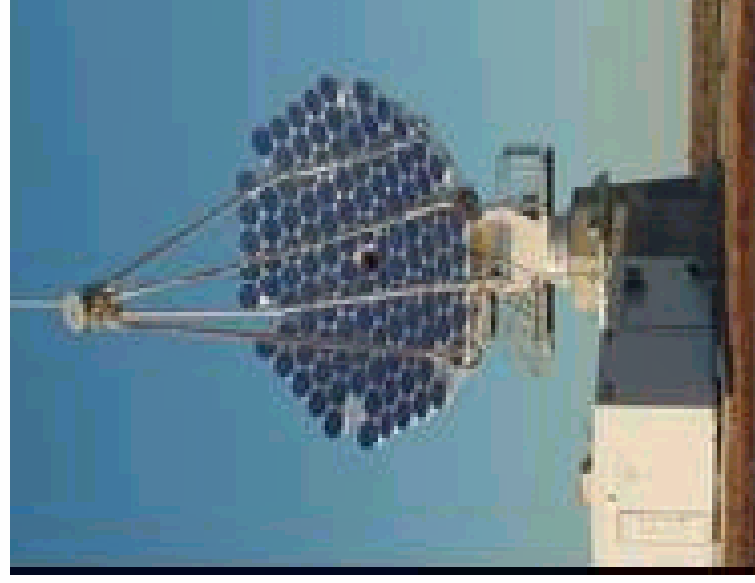
Aperture 0.8m
Focal length 3.0m
Number of pixels 288
Point image size 0.1'

(FWHM)

Generation



Aperture 7m
Focal length 8m
Number of pixels 512
Point image size 0.15'



Aperture 10m
Focal length 8m
Number of pixels 552
Point image size 0.20'

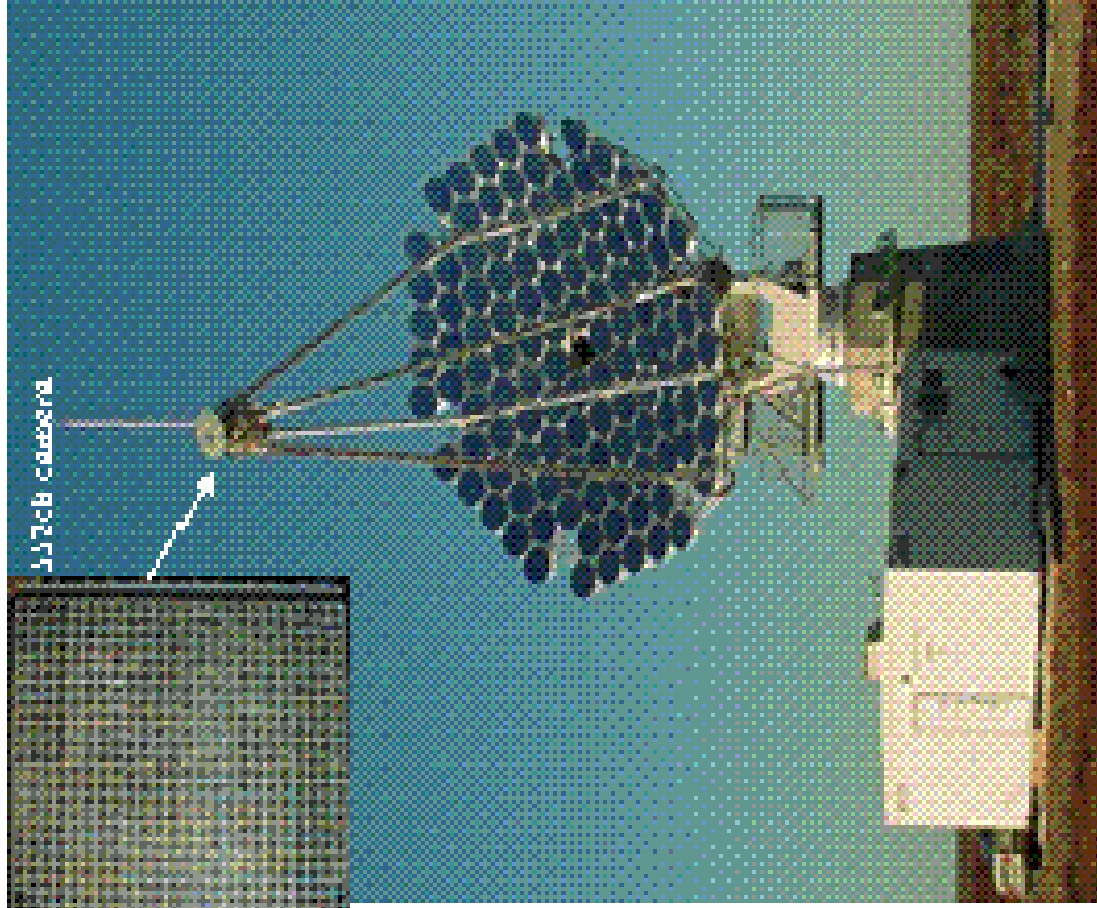
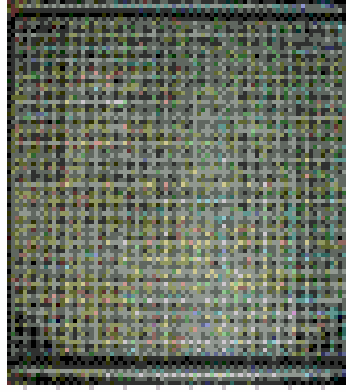
1992-1998

May 1999 - Feb 2000

Mar 2000-

CANGAROO-II 10m telescope

- Alt-azimuth mount
- Reflector
 - tessellated parabol with
 - 114 spherical mirror facets
 - (made of CFRP, 0.8 m in diameter)
 - light collection area: 57 m^2
 - focal length: 8m
- Camera (prime focus)
 - field of view: $\sim 3^\circ$
 - PMT pixel size: $0.115^\circ \times 0.115^\circ$
 - number of pixels: 552

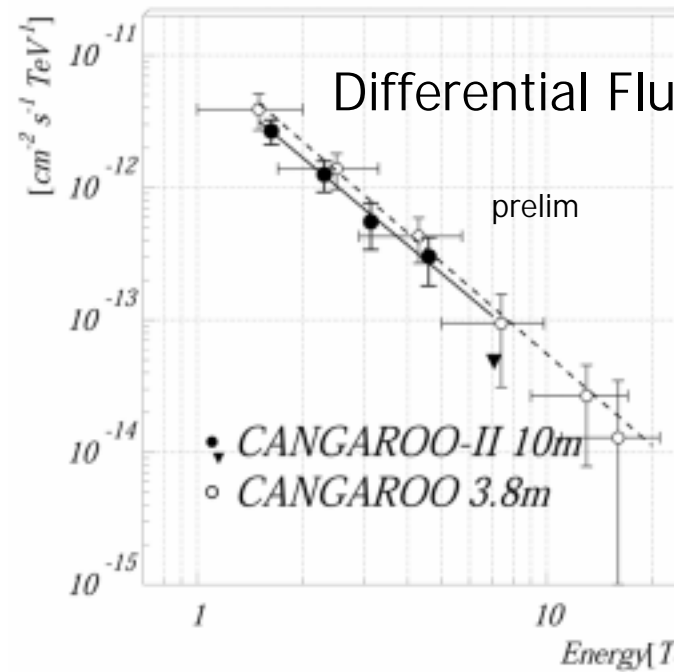
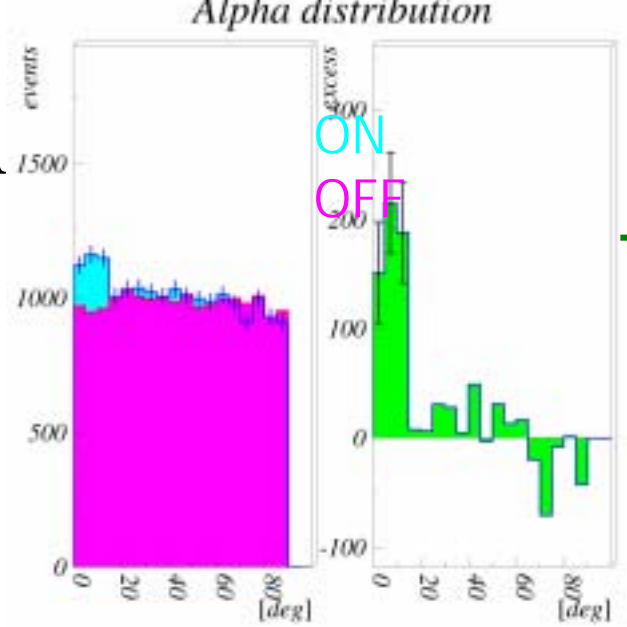
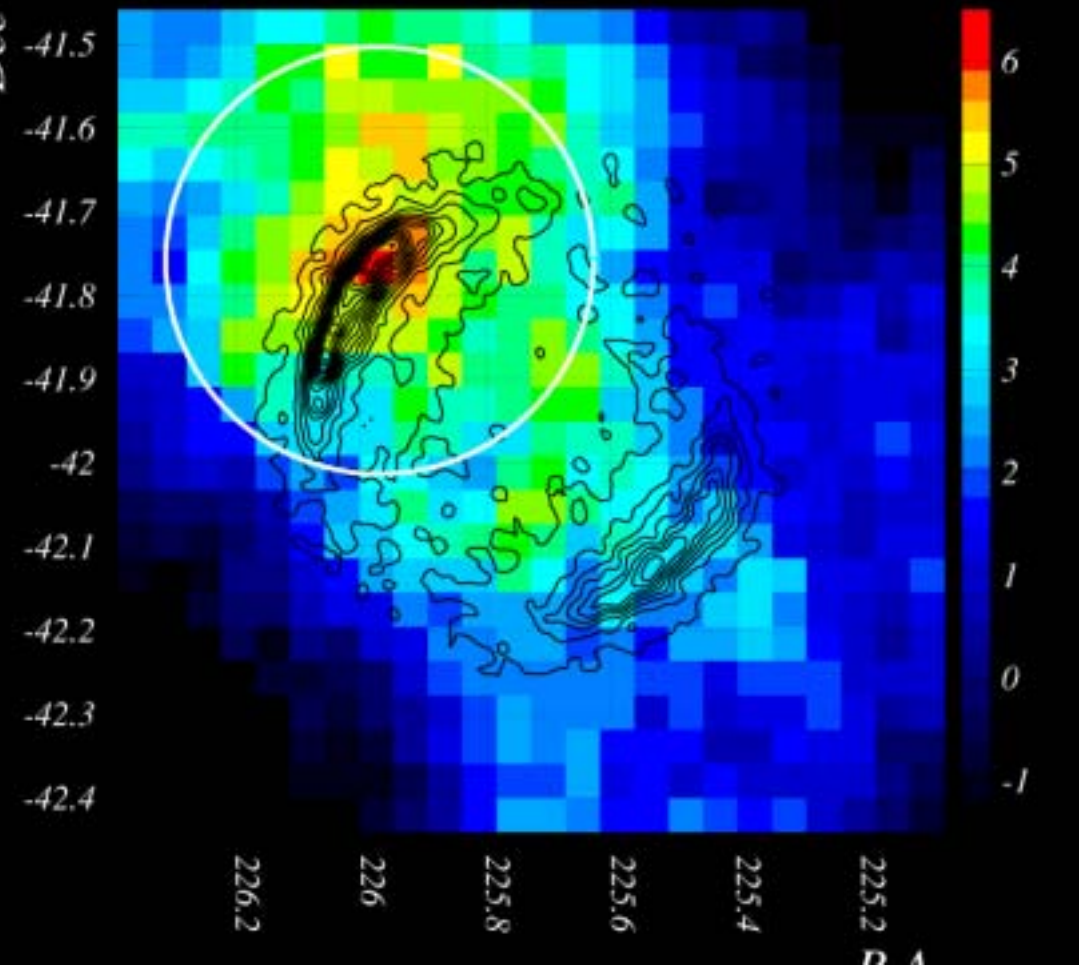


Observations with CANGAROO-II this year.

Vela	Analyzing	Tokai+OCU+ICRR
Mkn421 High State TOO	Final Draft	ICRR+Tokai+ANU
PSR1259-63	Writing Draft	ICRR+Adelaide+Sydney
RCW86 SW rim	Analyzing	Kyoto
SN1006 NE rim	Writing Draft	Kyoto
PSR1706-44	1 st -Draft	Kyoto
RX J1713-39 NW rim	Submitted	ICRR+all
GC	Analyzing	ICRR+Ibaraki(3.8m)
PKS2155-304	Analyzing	Tokai
SS433 w1	Analyzing	YamanashiG+Konan+?
NGC253	Finalizing Ana	Ibaraki+ICRR
SN1987A	Analyzing	ICRR
(RXJ0852)	observing	ICRR

SN1006 NE-rim

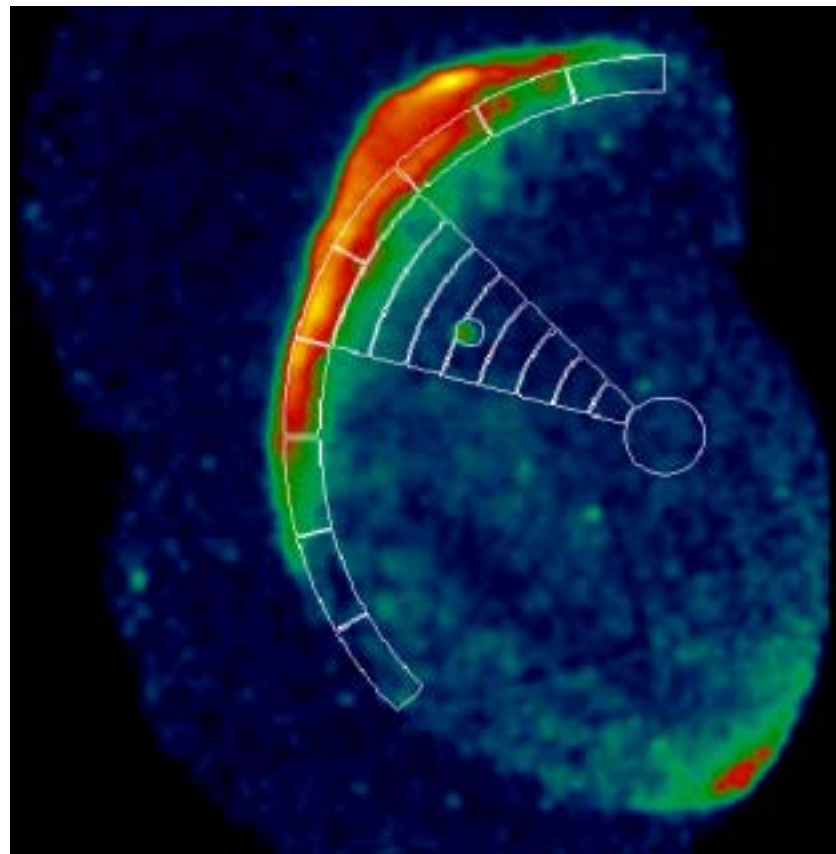
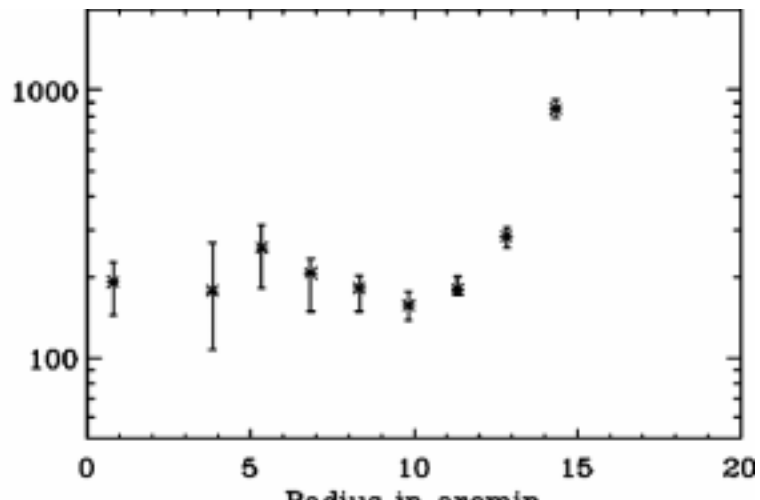
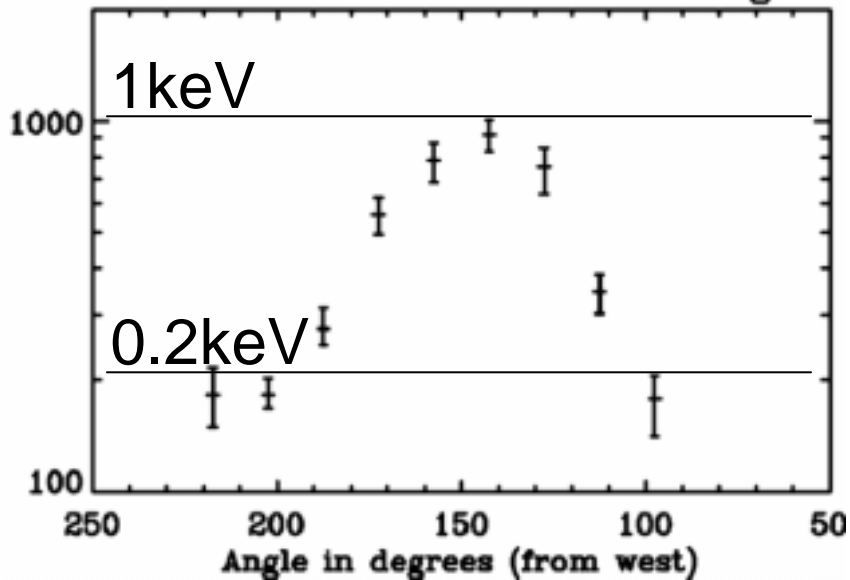
Significance Map



Observation by XMM

- Synchrotron breakdown energy varies in the NE-rim

Break variation with azimuth angles

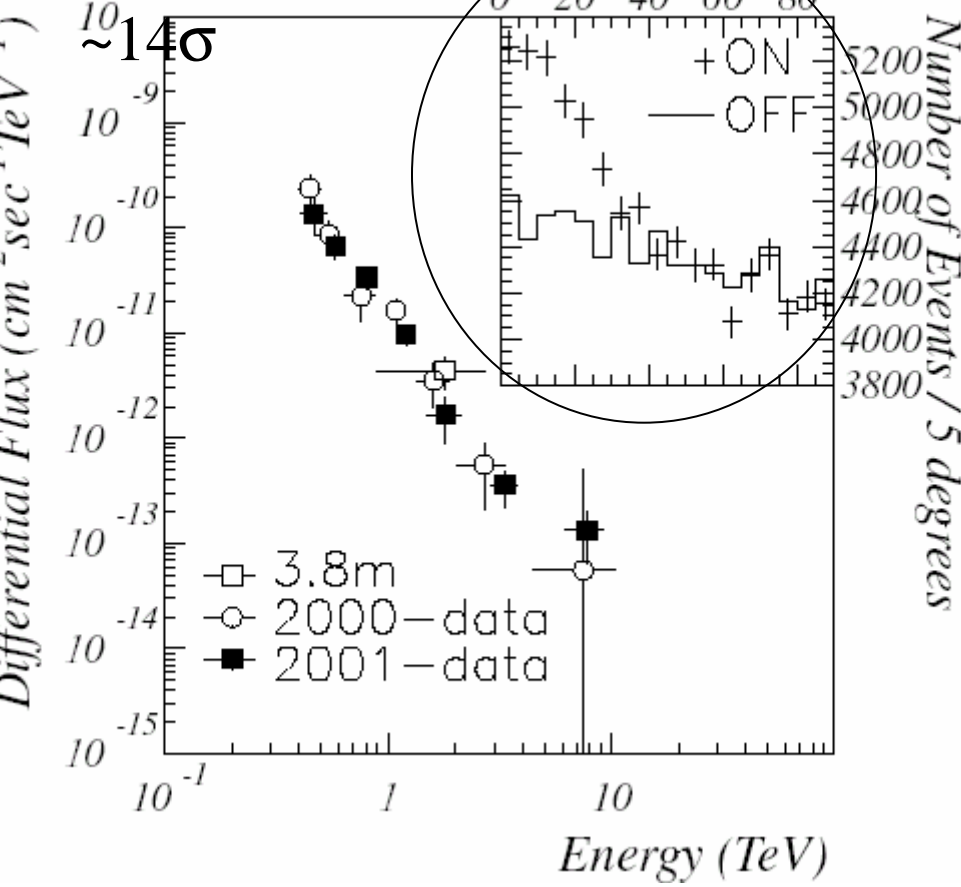


2-10keV

To be a lighthouse in southern hemisphere!

(we can live as lighthouse-keepers).

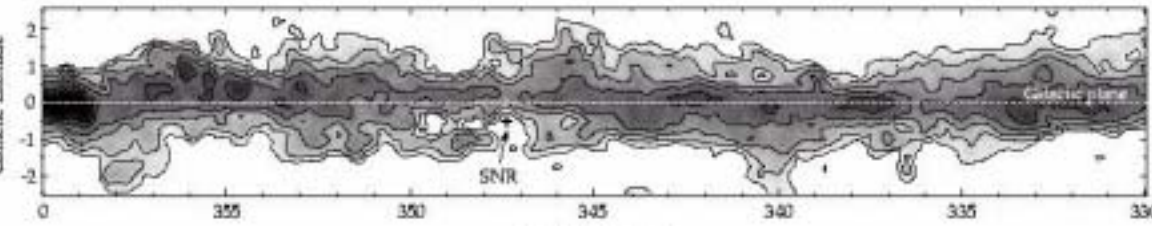
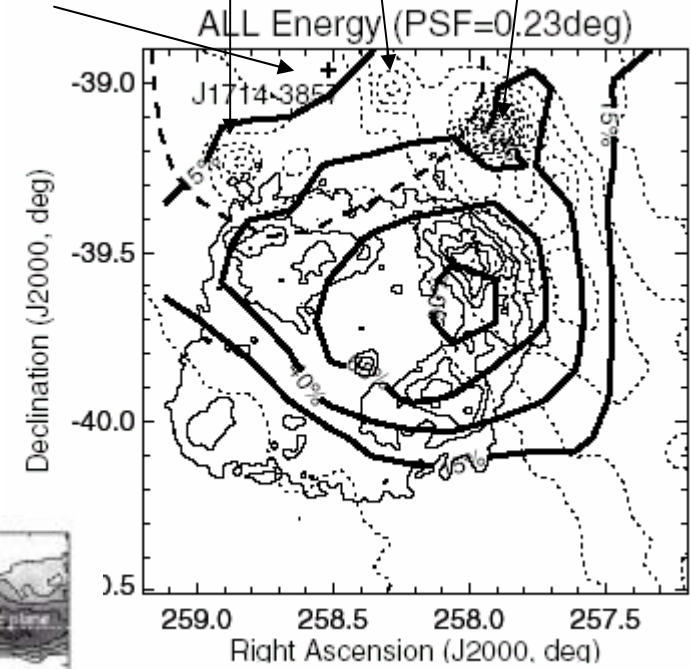
Really nice peak



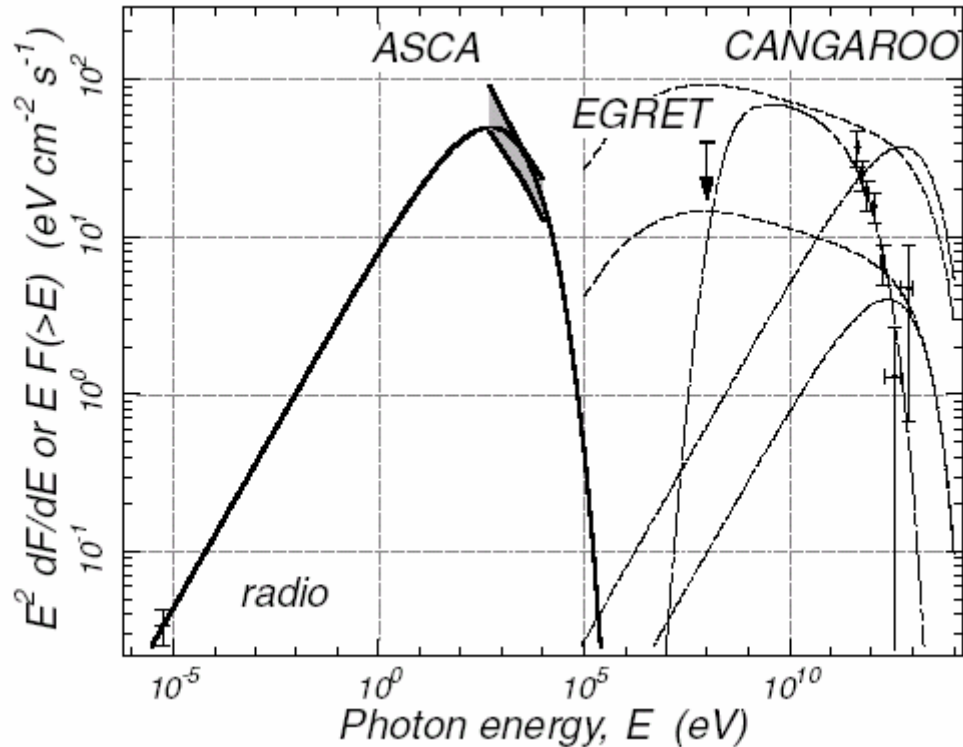
“beam dump experiment”

Molecular clouds

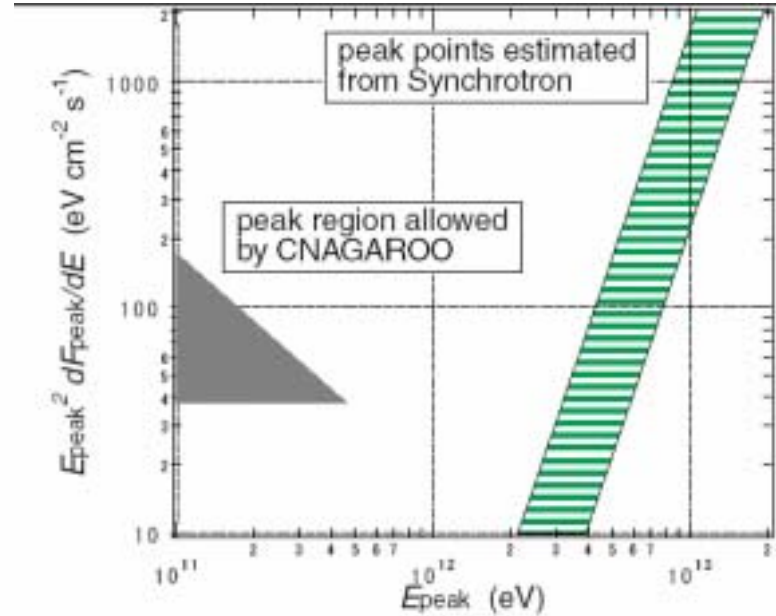
EGRET source



Multi-band spectrum



IC impossible!



Other possibility? No!
Proton acceleration natural!!!!

SN1006 → evidence for electron acceleration! (Tanimori et al.)
Same electron?

Evidence for Proton Acceleration!!

AGN

TeV gamma-ray absorption by IR

background



Summary of extragalactic background light measurements

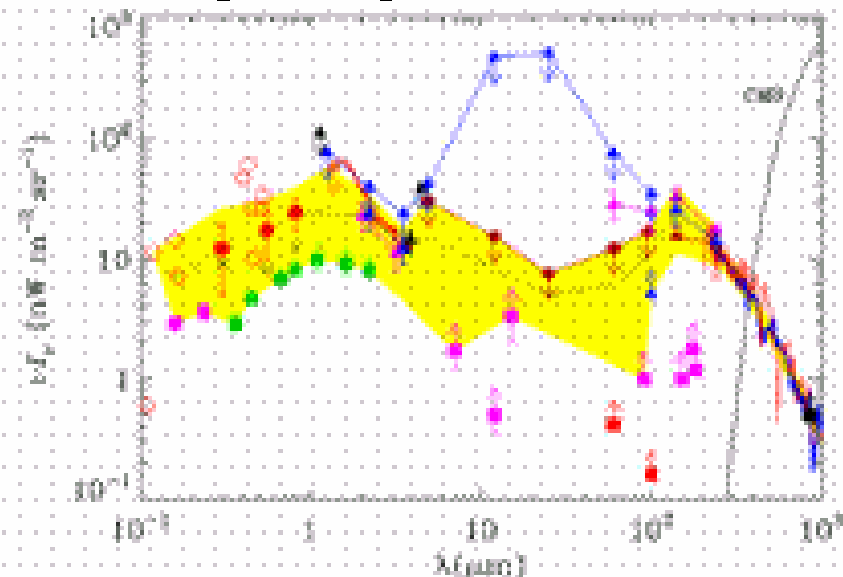


Figure 5. Summary of extragalactic background light (EBL) measurements and limits. Error bars for detections are 1σ . Square symbols show lower limits obtained by integrating the light of detected sources. X's above 2σ lower limits on integrated resolved sources from Hearnshaw (1999). Diamonds show upper limits from fluctuation measurements. All other symbols show absolute background measurements (for error bars) or limits (2σ). The shaded region represents current observational limits for the EBL spectrum, and the dotted line shows scaled values (see § 3.10 for discussion). The black line (CMB) shows the cosmic microwave background radiation.

Mean free path for e^+e^- pair production

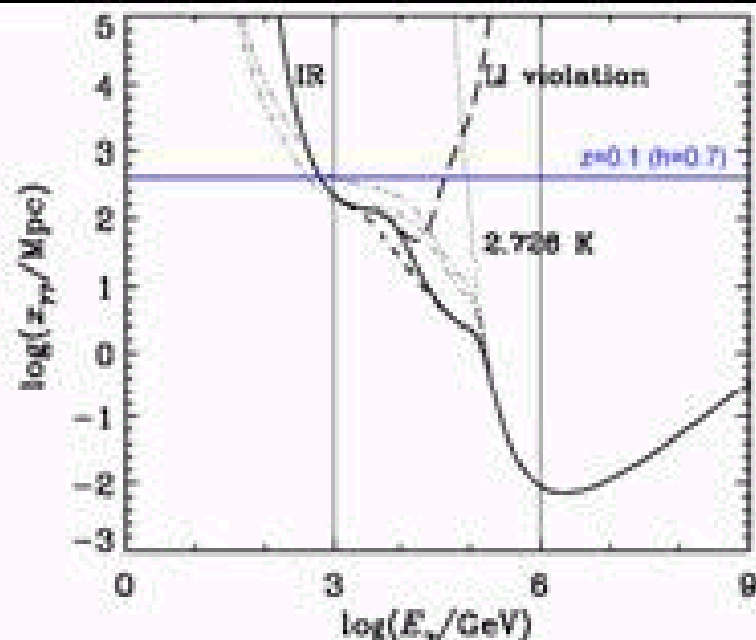
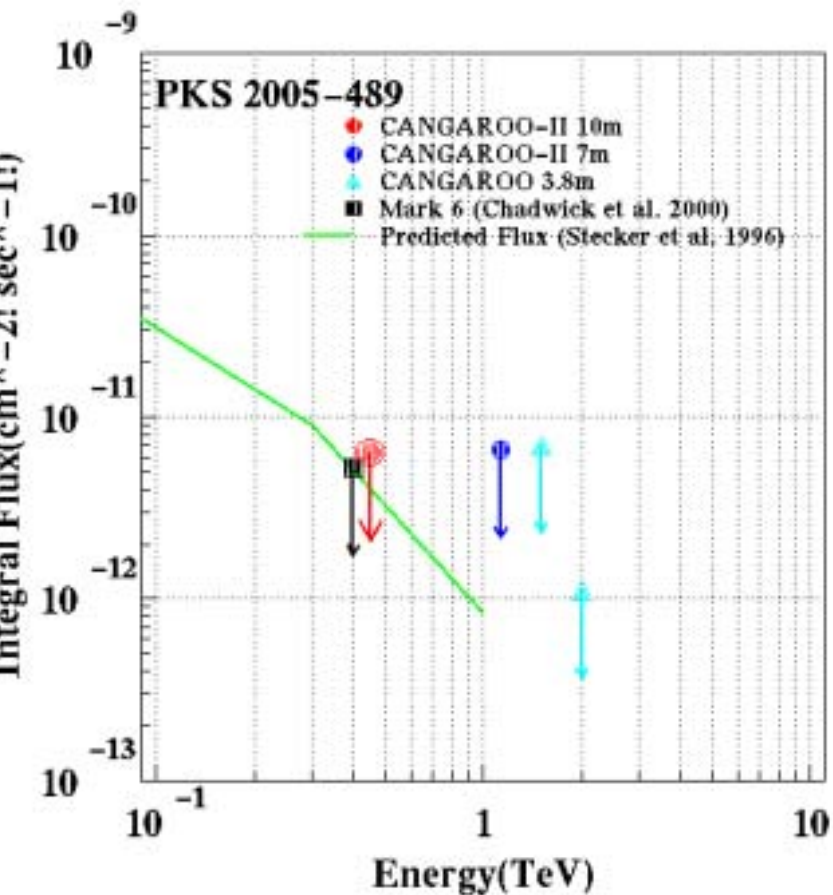


Figure 7. Mean free path for photon-photon pair production in the infrared-microwave background radiation. The curves correspond to those in Fig. 1 except that the effect of Lorentz invariance violation discussed in Section 4 is shown by the long dashed curve.

PKS2005-489(2000)

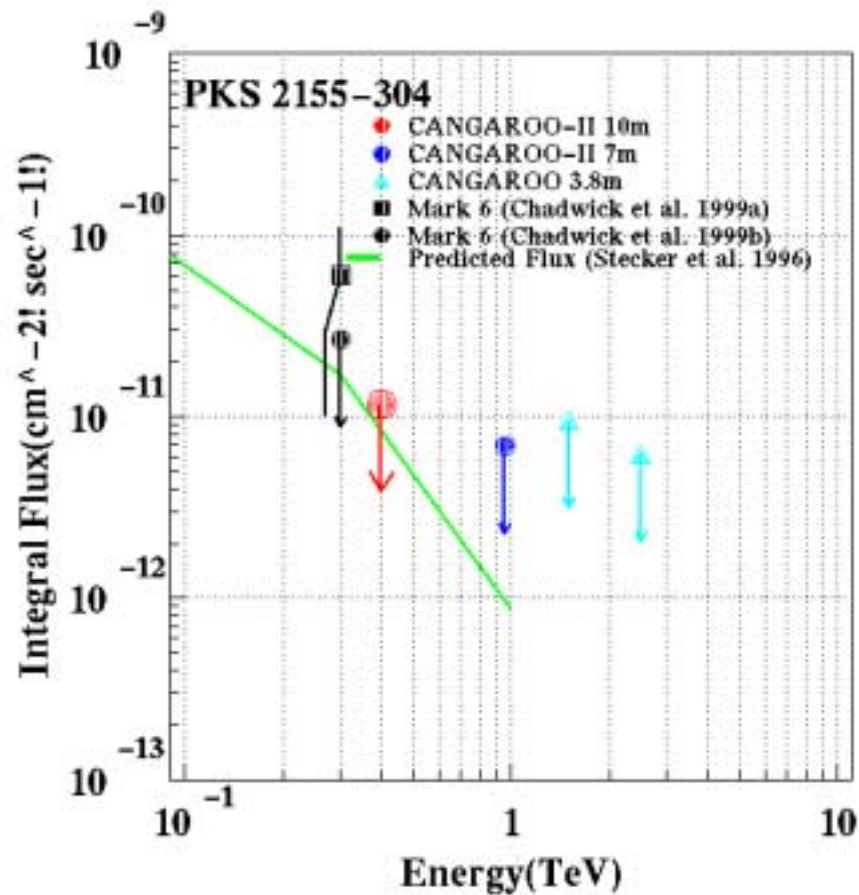
33h(ON)



PKS2155-304(2000)

36h(ON)

2001-data analyzing



N.B. : Results from epoch 2000 only

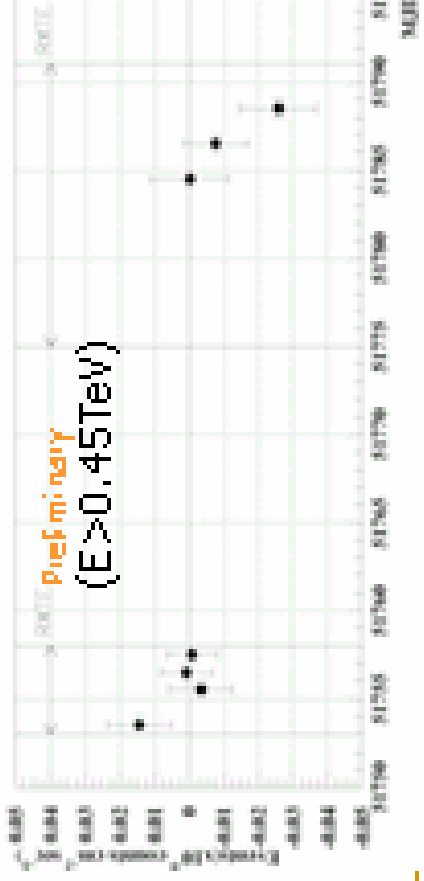
PKS 2005-489: light curve

■ No evidence for gamma-ray flare emission

- CANGAROO-I 3.8 m
 - Aug 1993, 1994
(Roberts, M.D. et al.(1998)
A&A 337, 25)

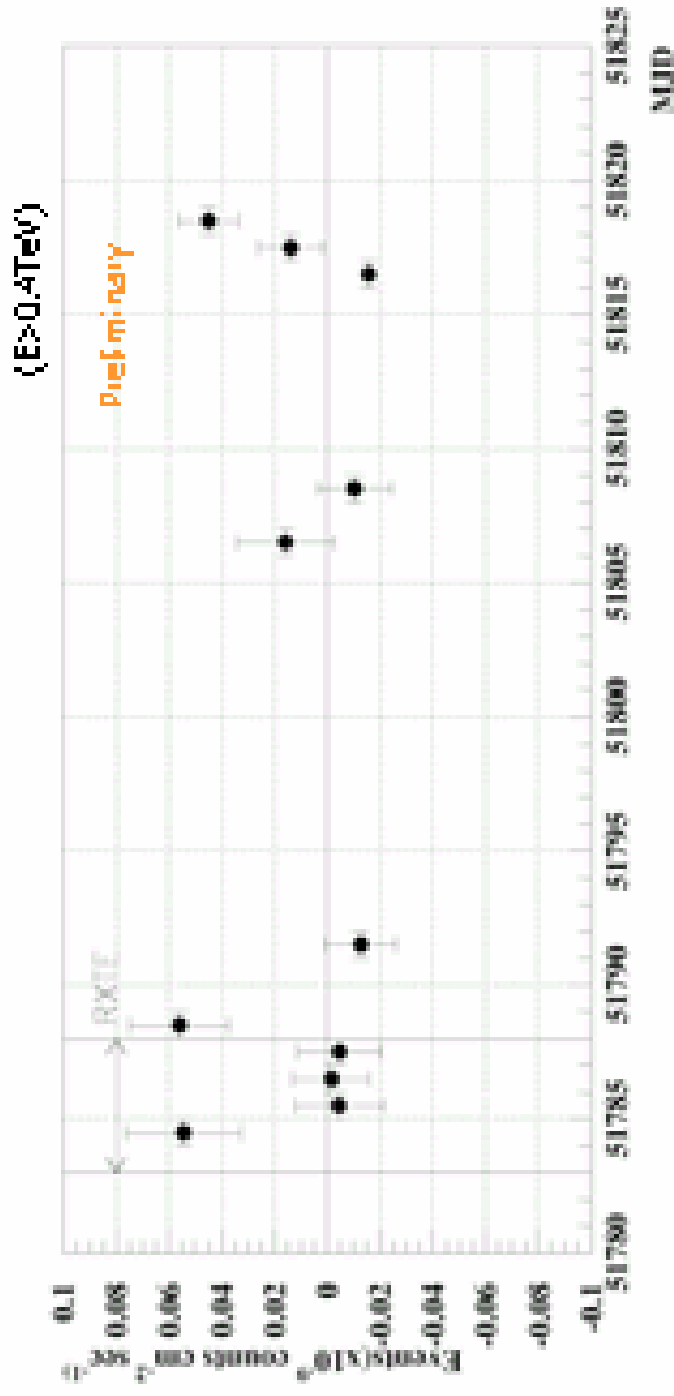


- CANGAROO-II 10 m
 - July/Aug/Sep 2000
(preliminary)



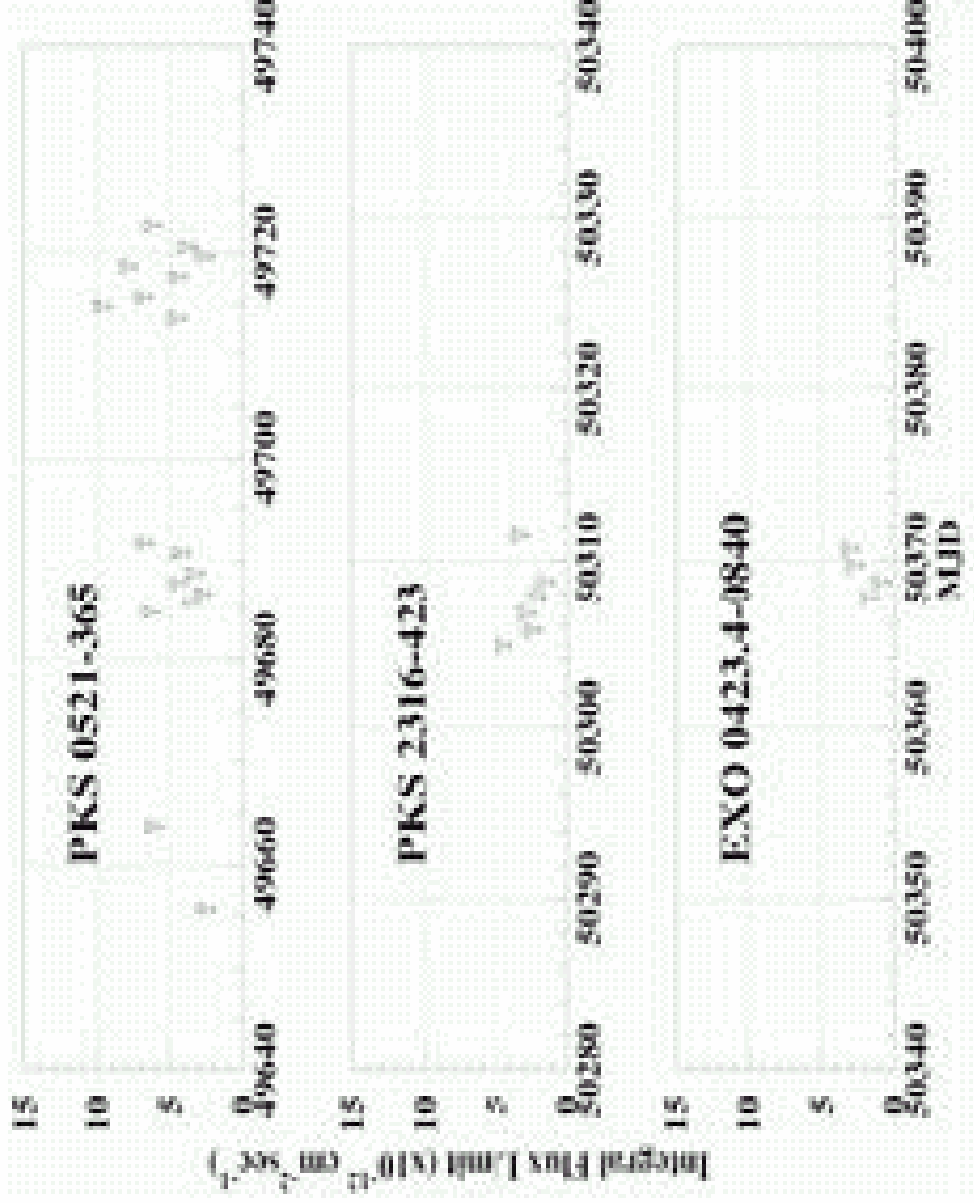
PKS 2155-304: light curve

- No evidence for short-term emission



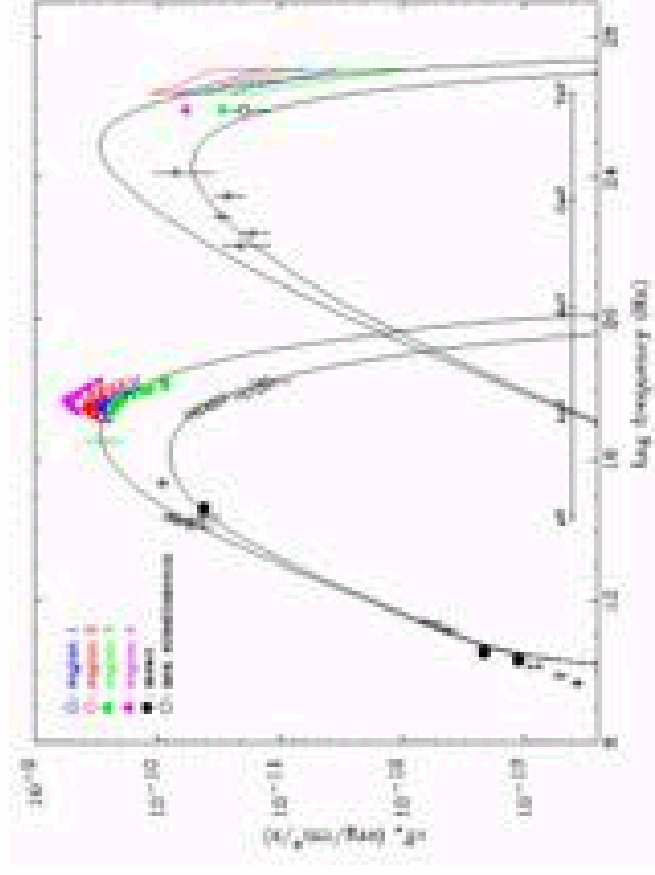
Other AGNs: light curve

- Night by night flux upper limits



Mrk 421

- Nearby XBL ($z=0.031$)
- The first extragalactic source at TeV energies reported by Whipple group in 1992
- Extensive measurements in the TeV region
- Several multiwavelength campaigns
- TeV gamma radiation can be explained by SSC (synchrotron self-Compton) mechanism



Takahashi et al. *ApJ*, 542, 200

CANGAROO observation of Mrk 421 in Feb/Mar 2001

□ Jan.24 – Feb.1, Mar.1 – 4, 2001

■ 10 nights, 14.4 hours (on)

□ Average zenith angle :

69.8 degree

(large zenith angle

observation – higher

threshold but larger

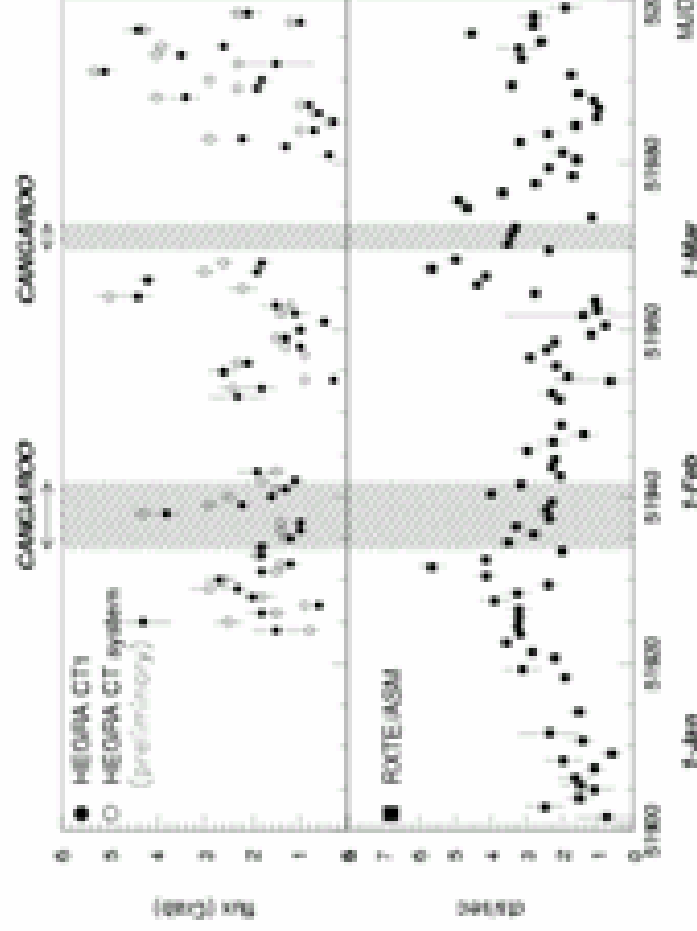
effective area)

□ Energy threshold :

~10 TeV

□ Average effective area :

~8 × 10⁹cm²



Large zenith angle observations

Simulation: spectral index $\gamma = -2.5$

effective area

detection rate



Figure 1. A detector which accepts light within a cone of half-angle ϕ can be pointed vertically or at large zenith angle. The shaded regions represent the effective detection area in the two cases.

Sommers and Robert, *J.Phys.G13* (1987)

Markarian 421

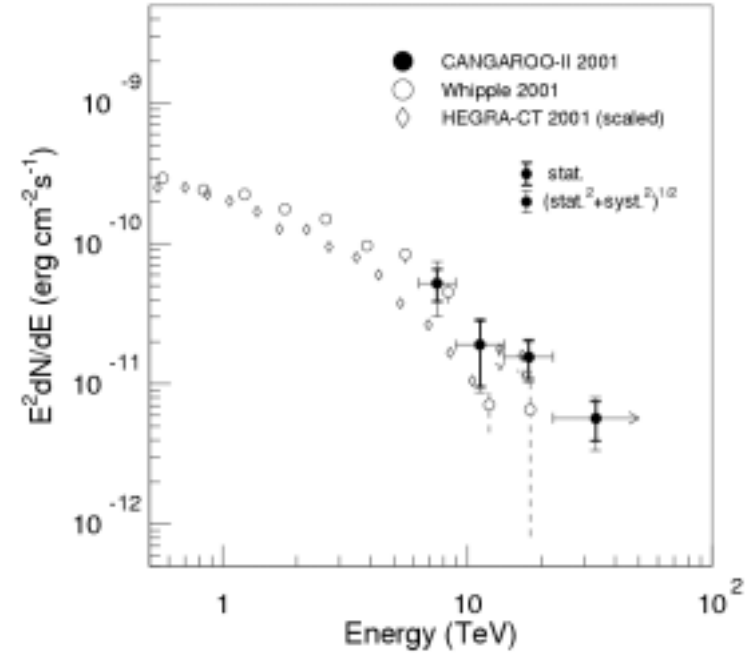
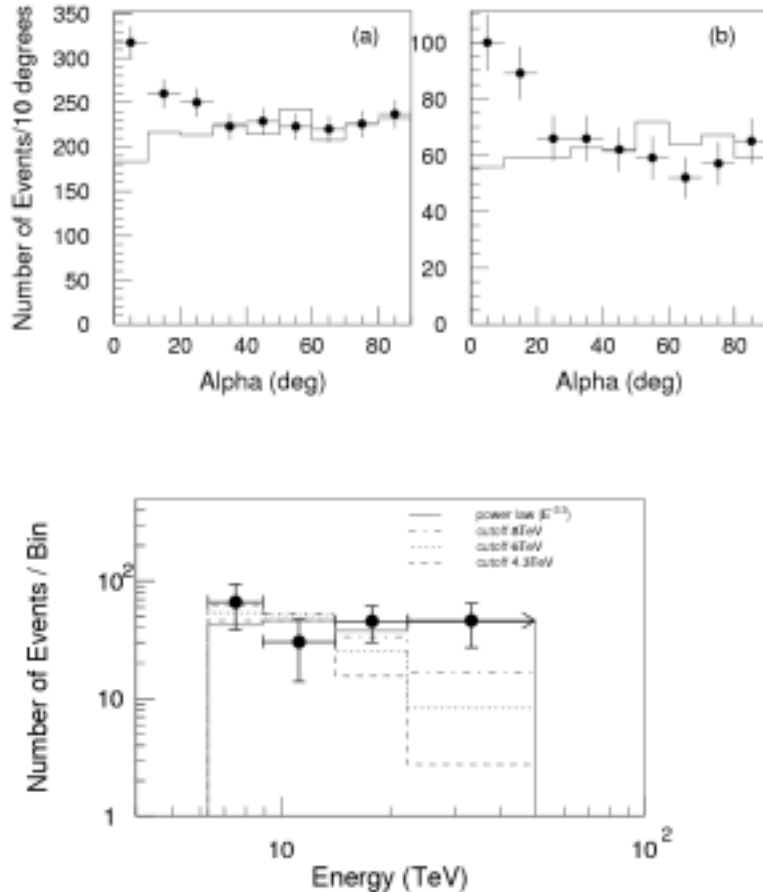


Fig. 2.— Time-averaged spectral energy distribution of Markarian 421 observed by CANGAROO-II telescope, during the strong flare of 2001 (filled circles with error bar). The thick error bar shows the statistical error and the thin shows the statistical and systematic uncertainty, added in quadratic. The cutoff spectrum reported by Whipple (Krennrich et al. 2001) and HEGRA-CT group (Kohale et al. 2001) were also shown with open circles and diamonds.

Summary of AGN observations

Table 1: AGN observation summary. Present work including preliminary results with the CANGAROO-II 7/10 m telescope is indicated by c in the last column. Other data are taken from a; Roberts et al. 1998a, bc Roberts et al. 1998b and d; Rowell et al. 1999 which are all obtained with 3.8 m telescope

Target	z	Year	Time (hr)	E (TeV)	Flux ($\text{cm}^{-2}\text{s}^{-1}$)	Ref
EXO 0423-0849	0.039	1996	20	2.0	$< 1.1 \times 10^{-12}$	a
PKS 0521-365	0.055	1995-96	89	2.0	$< 1.0 \times 10^{-12}$	a
PKS 0548-322	0.069	1997	26	1.5	$< 4.3 \times 10^{-12}$	b
		1999	16.6	1.0	$< 1.0 \times 10^{-11}$	c
		2000	2.6			
PKS 2005-489	0.071	1993-94	41	2.0	$< 1.1 \times 10^{-12}$	a
		1997	17	1.5	$< 7.0 \times 10^{-12}$	b
		1999	26.2	1.1	$< 6.6 \times 10^{-12}$	c
		2000	32.6	0.45	$< 6.4 \times 10^{-12}$	c
PKS 2155-304	0.116	1997	18	1.5	$< 3.5 \times 10^{-12}$	b
		1999	58.5	0.96	$< 6.9 \times 10^{-12}$	c
		2000	35.6	0.40	$< 1.2 \times 10^{-11}$	c
PKS 2316-423	0.055	1996	26	2.0	$< 1.2 \times 10^{-12}$	a
Gen A	3.5 Mpc	1995	23	1.5	$< 5.5 \times 10^{-12}$	d
Mck 421	0.031	2001	14.4	0.3		c

RX J1713-39: peculiar SNR?

can be explained by the same picture
as **SN1006**.

MKN421: something ? To extra-galactic cosmic-ray?

More SNRs such as RCW86 and RXJ0852
(analysing) (observing)

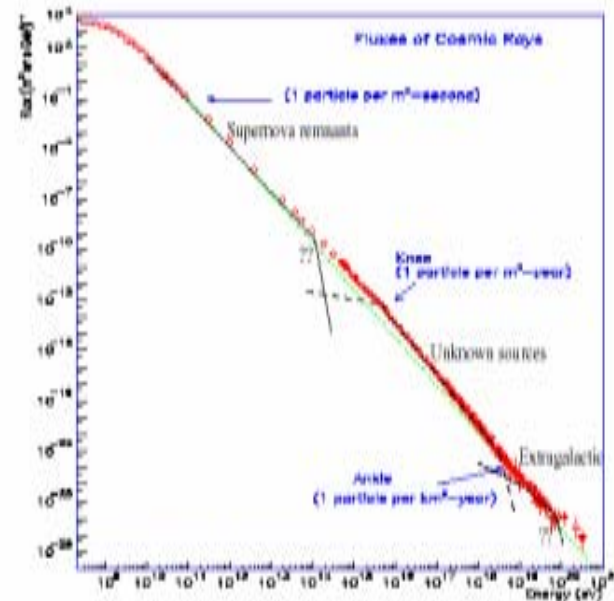
Other possibility ?

Consideration on scale dependence!

SNR → GC → GALAXY → extra galaxy

Coming soon

NGC253



Might be a key to enigma of Cosmic-ray origin?

NGC253: a whole galaxy inside FOV

(including halo)

galactic cosmic-ray?

high star burst rate

one of closest(2.4Mpc).

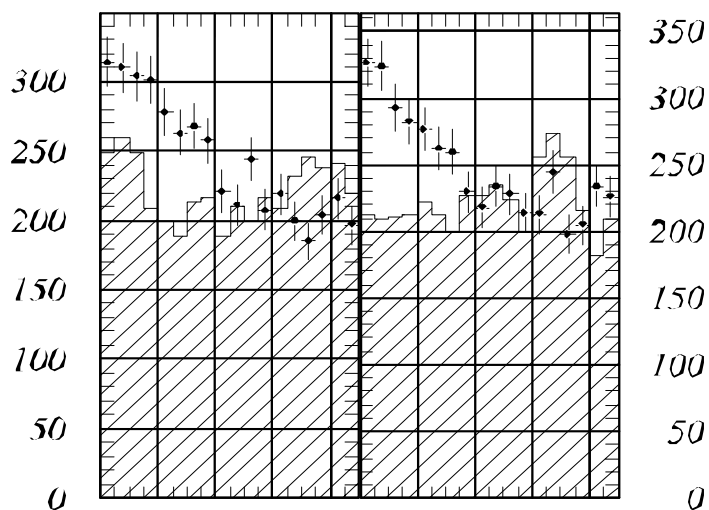


0.45degree

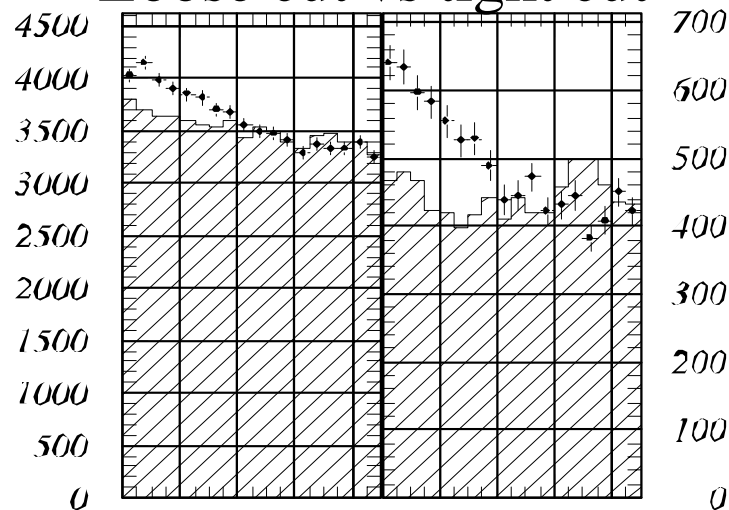
Combined

Loose cut vs tight cut

2000 vs 2001



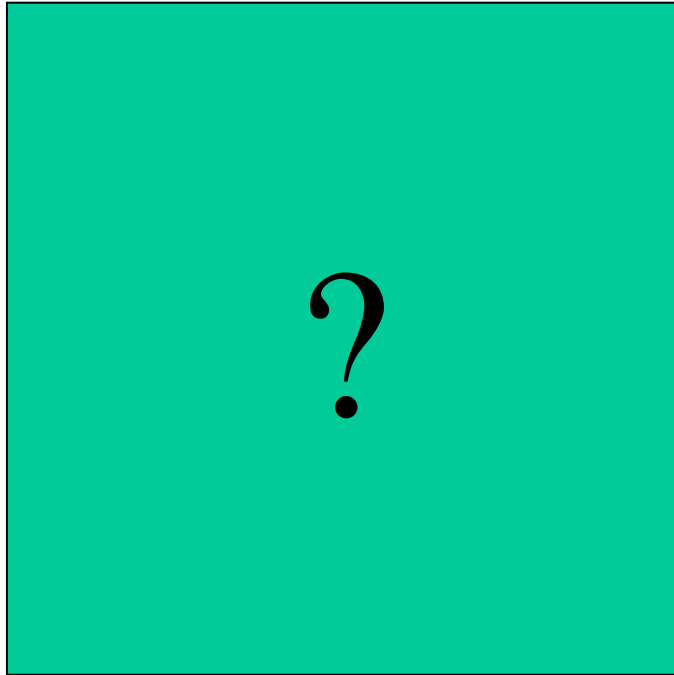
alpha vs like2d *alpha vs like2d*



alpha vs like2d *alpha vs like2d*

Galactic Center

Obs. @ July 2001

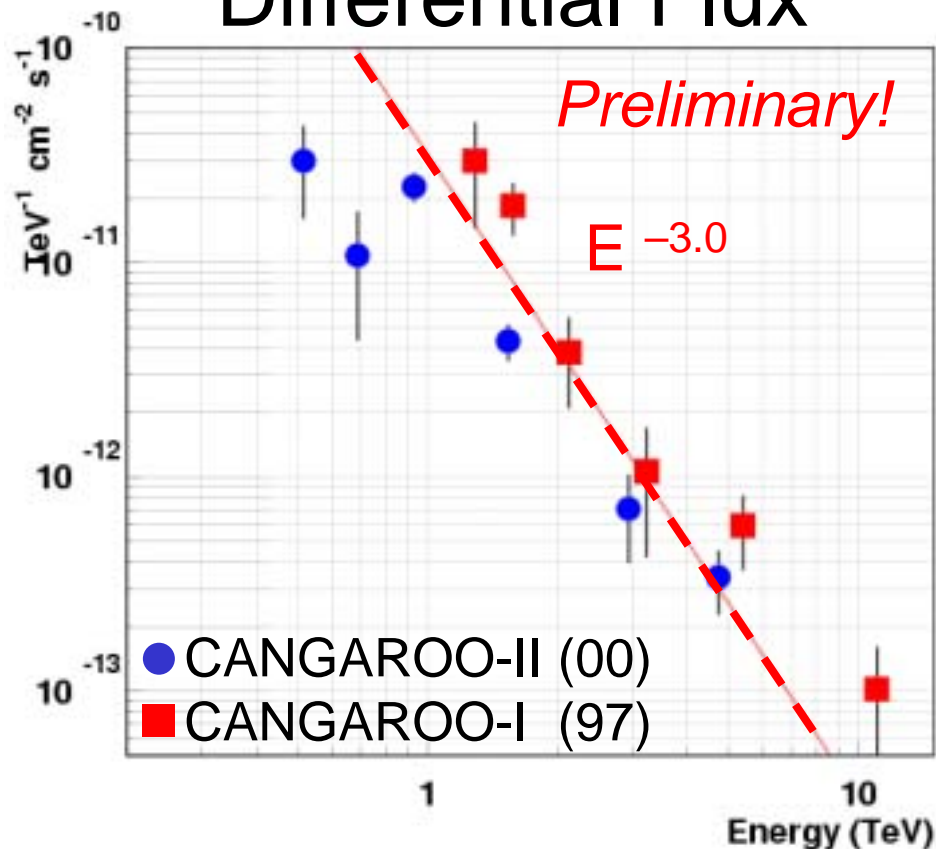


Very promising result.

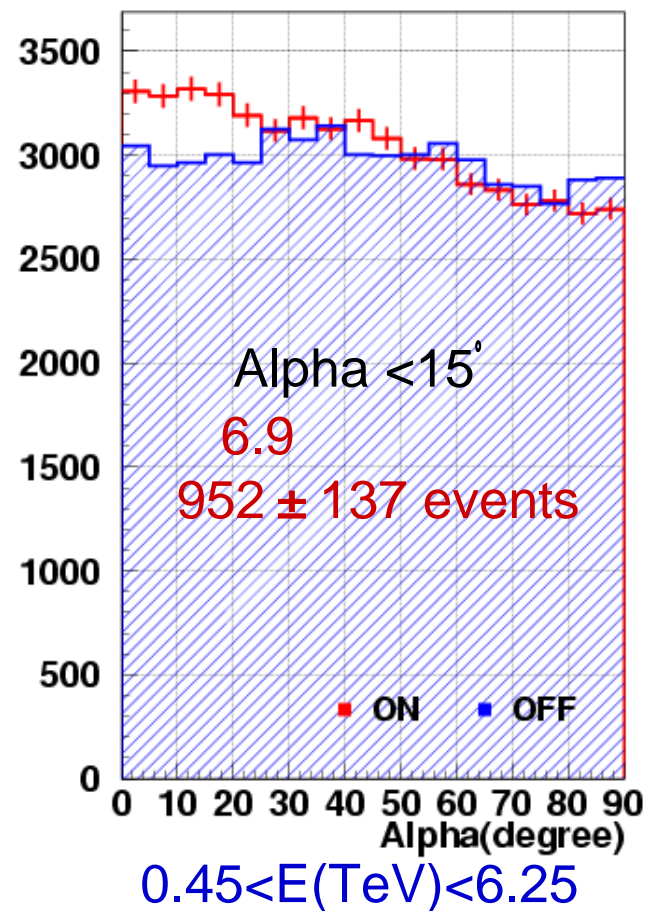
See again in this summer.

PSR 1706 - 44

Differential Flux

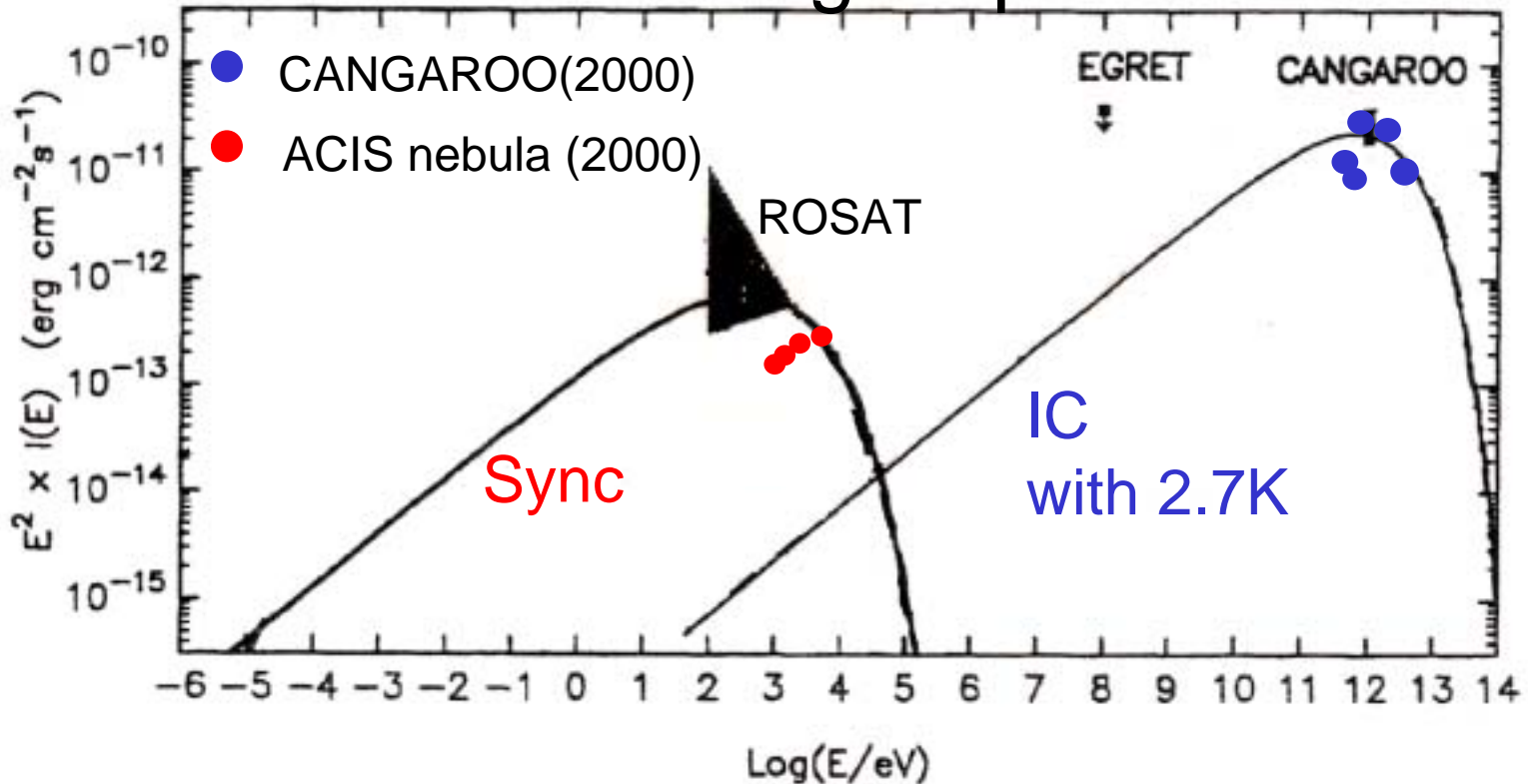


Alpha distribution



Multi-wavelength spectrum

Multi-wavelength spectrum



Aharonian , Atoyan & Kifune (1997)

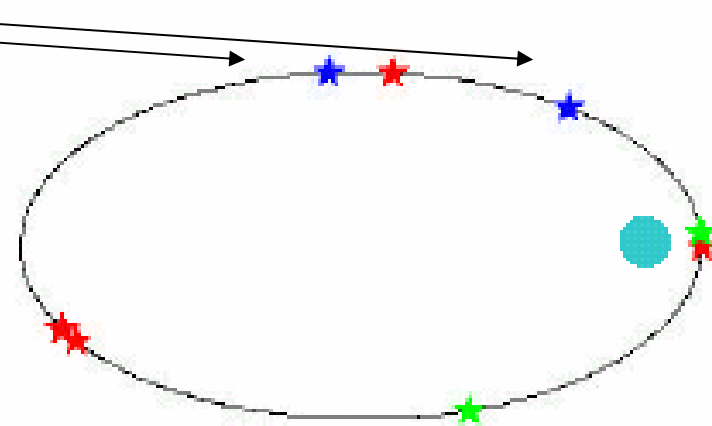
CANGAROO-I Observations

& II

Sako et al. (1997) proc.ICRC,

Dazley et al. (1997) proc. NSPWS,

Yuki (2000) Mthesis, Nagoya University



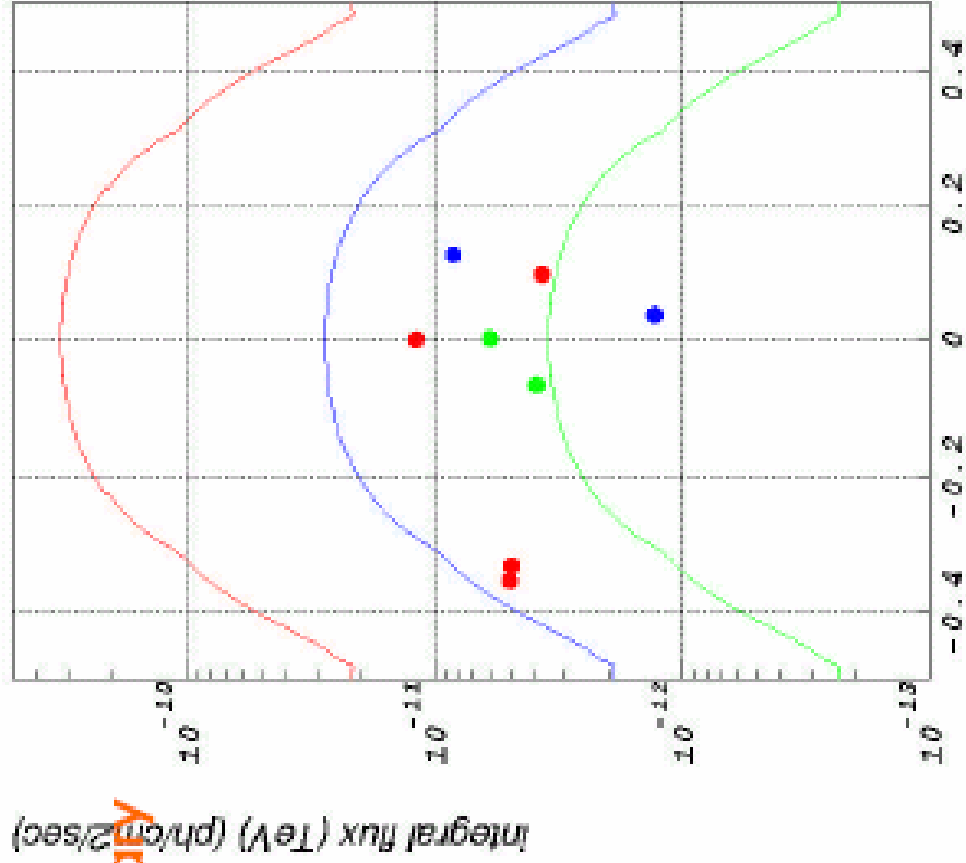
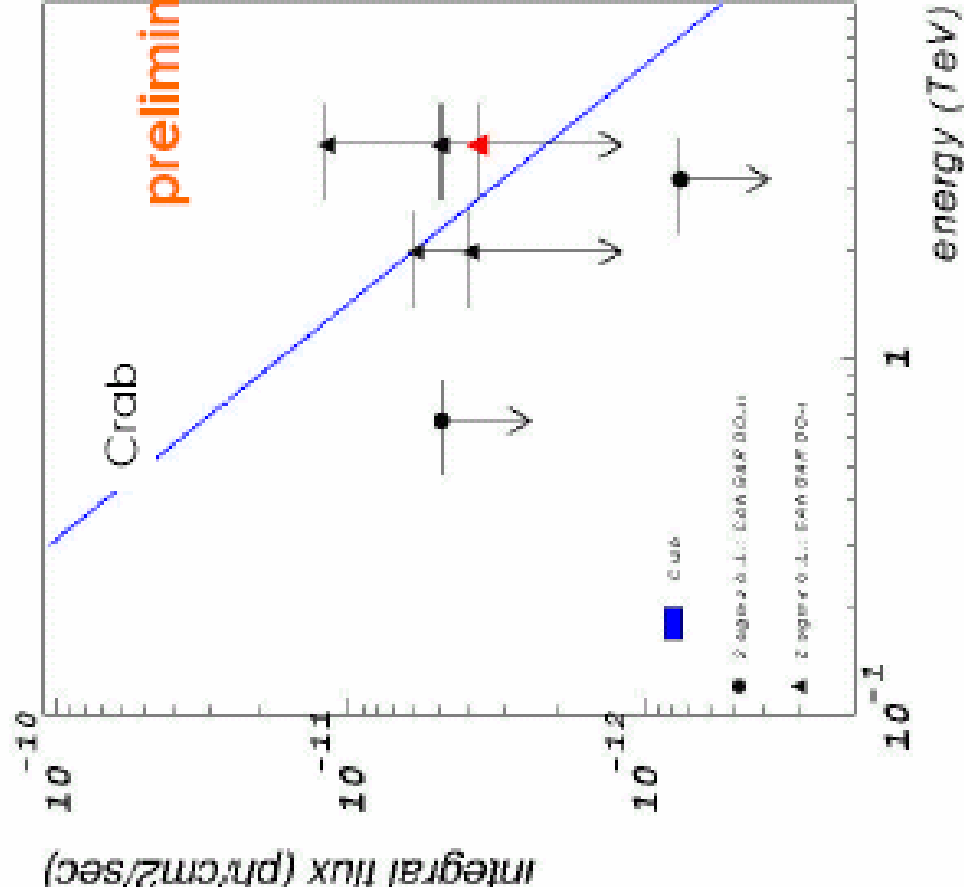
Obs-1	1994 Jan. 8—10	245 min.	0.9 sigma
Obs-2	1994 May 3—12	1119 min.	3.5 sigma
Obs-3	1996 Mar. 16—22	585 min.	2.0 sigma
Obs-4	1996 Apr. 13—23	720 min.	0. sigma
	<i>recoating</i>		
Obs-5	1997 Mar. 6—11	890 min.	0.8 sigma
Obs-6	1997 May 28—Jun. 6	610 min.	1.8 sigma

Zen.: ~40 deg.

All data summary

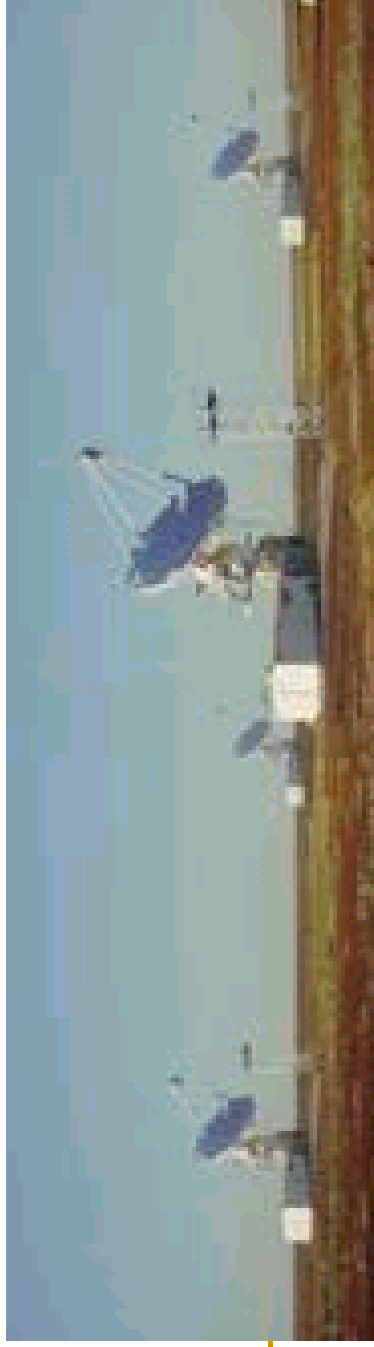
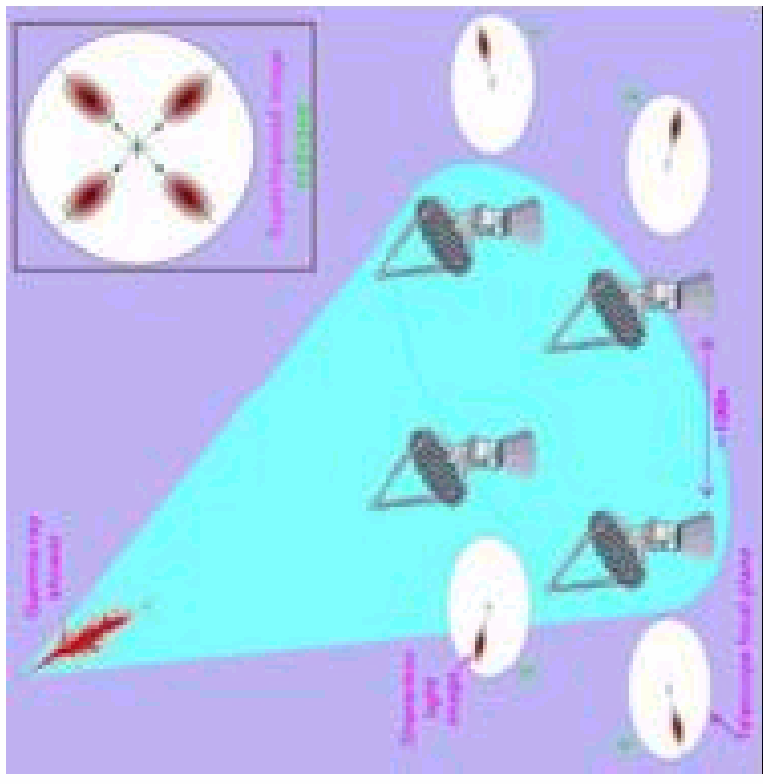
Theoretical estimation:

pion decay emission



CANGAROO-III project

- Stereoscopic observation of Cherenkov images
 - Better ??, better ?E
- An array of four 10 m imaging Cherenkov telescopes will be completed in early 2004



JAPAN

Science section: Yamanashi-Gakuin, Ibaraki, ++
Frontend Elec.: Yamagata
Online Elec.: Kyoto
Trigger: Tokai
LG, Calib.,
Telescope Cntrl: Konan
Mirror: ICRR
Camera: ICRR, Ibaraki
Etc.: ICRR

AUSTRALIA

New members from Adelaide:

R.Clay, R.Prothro, B.Dawson

A stronger backup from Faculty and University.

+ Sydney Univ.

Infra structures, Science section, etc.

Budget from ARC!

New PosDoc in near future

Contribution from Yamagata Univ.

Development of electronics (Frontend Module)

- **Speed-up**

VME standard is employed.

- **Multi purpose**

It issues signals to ADC, TDC, Trigger module, and etc.

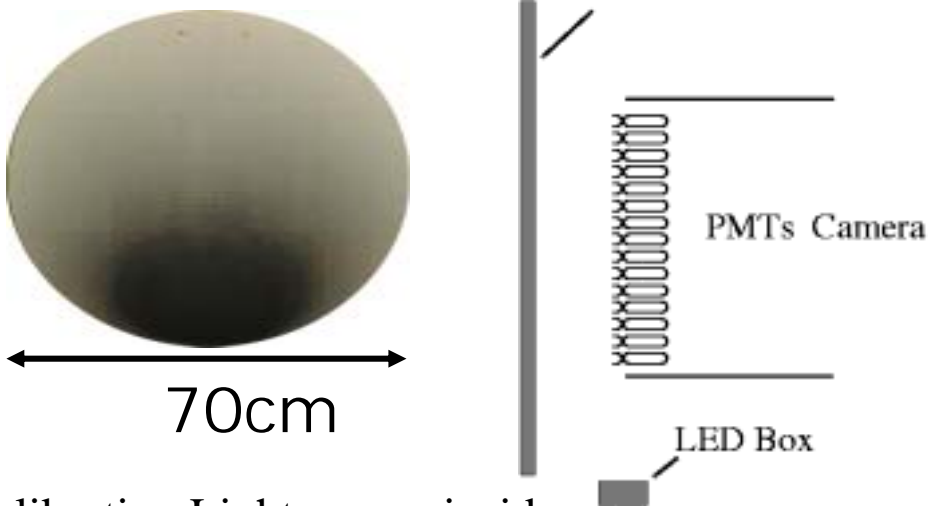
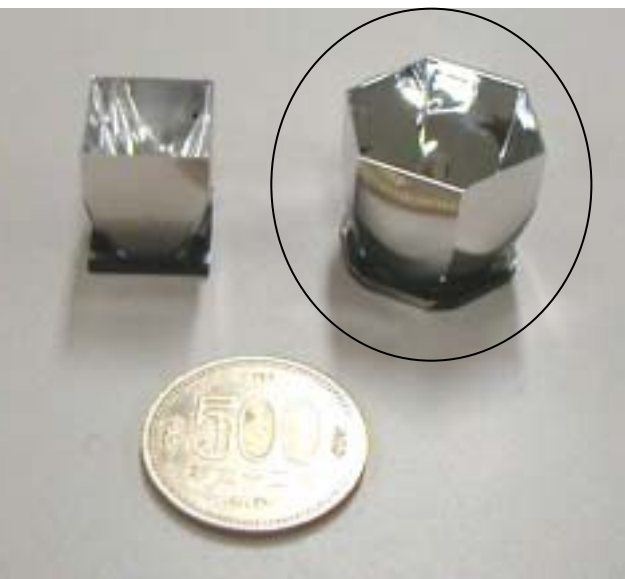
Present status

29 modules has been fabricated and the test has been almost finished.



**Frontend Module
For Cangaroo III**

New light guide for the CANGAROO-III 2nd telescope (Konan U)

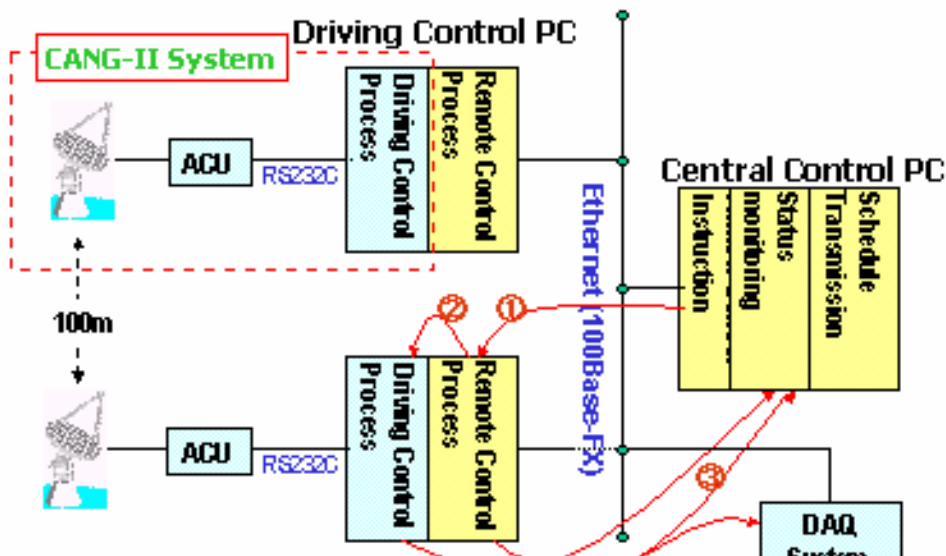


Calibration Light source inside CAMERA-BOX, without NSB
 Uniformity==0.8%

Multi-Telescope Control System

(Konan U + Osaka City U + ICRR)

Collection eff. +70%

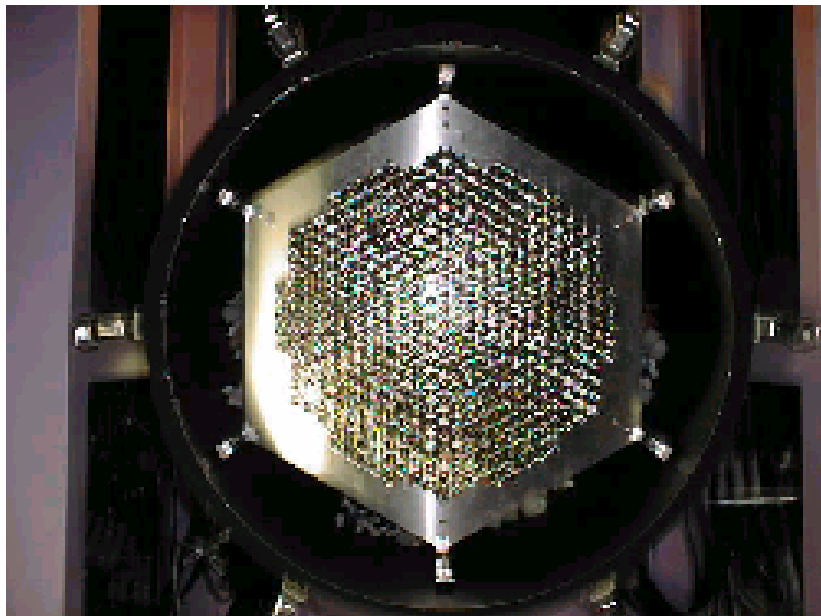


Optical reflector

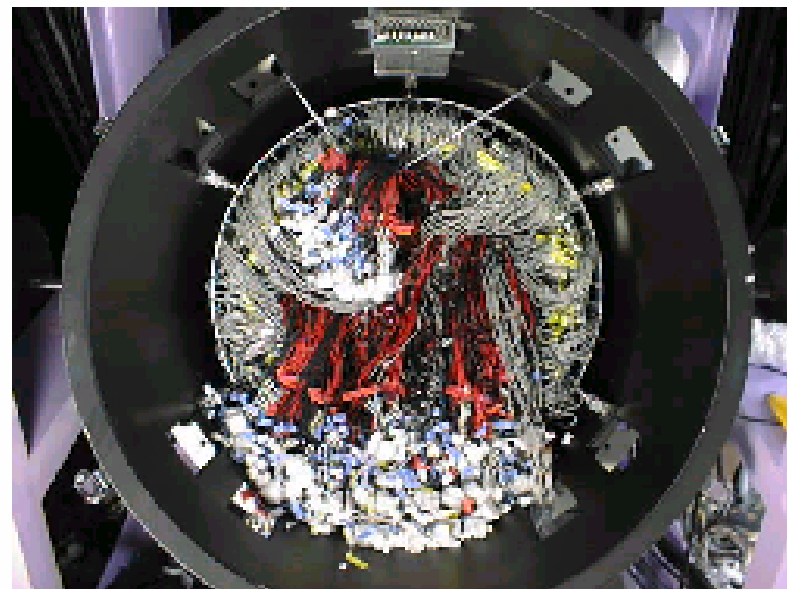
- 114 x 80cm? segmented mirrors (57m²)
- Further development from 1st telescope
 - Carbon Fiber Reinforced Plastic (CFRP)
⇒ CFRP (Glass Fiber)
 - Improved manufacturing accuracy
(mirror surface, curvature radius)
 - Increased yield rate (~80%)
- Light weight (~6.7kg/mirror)
 - gravitational deformations is negligible
- Robust and durable for outdoor usage
 - tested with 1st telescope



CAMERA

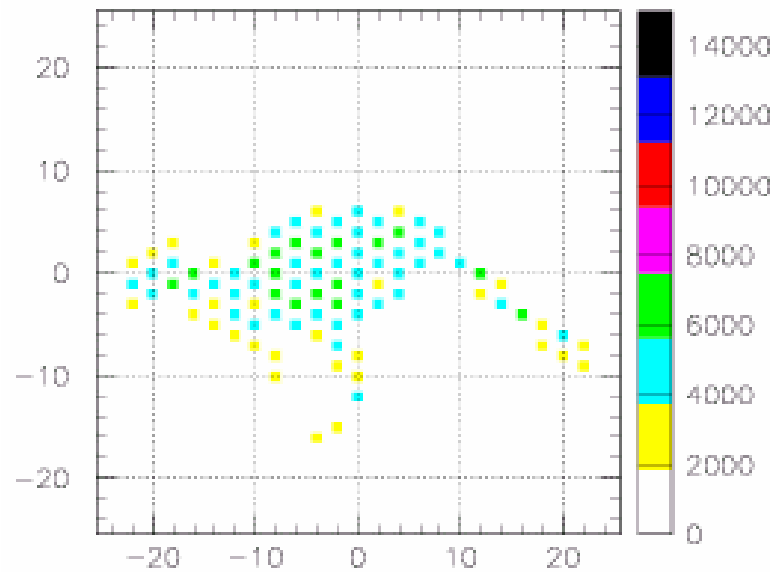


Front view



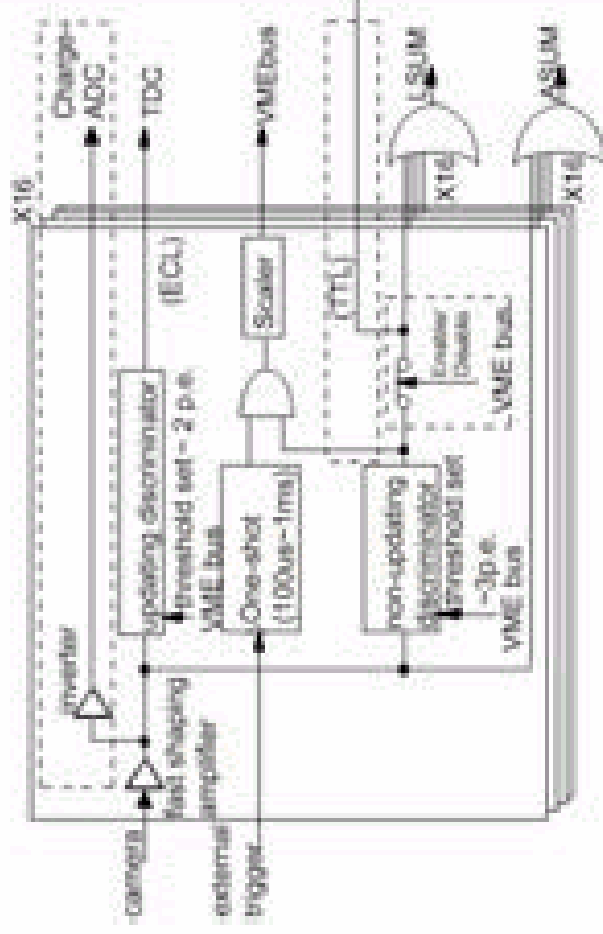
Back view

performance



New electronics

- VME-based module
- Frontend (Discriminator and summing) module
- Charge ADC
 - 16bit ADC chip for each channel
 - 130 ns internal delay
- TDC
 - 1 msec resolution
 - 256 msec window
- Electronics hut on telescope verandah
- remote controllable





KYOTO people are working hard

Compact system

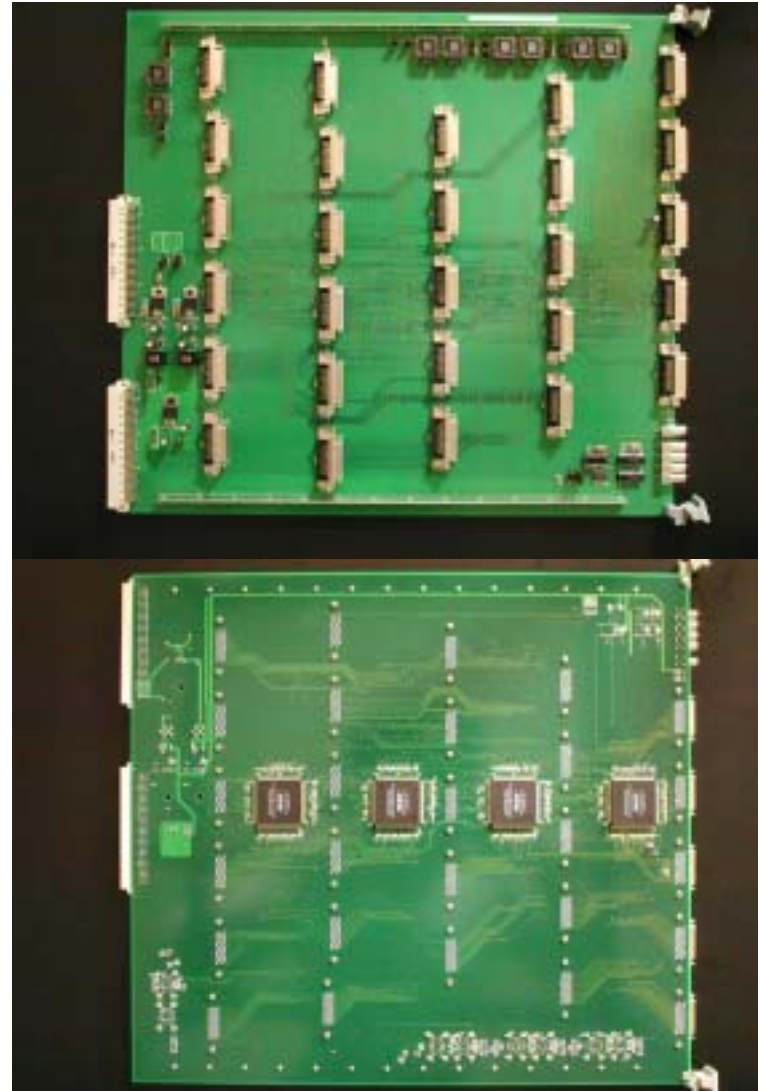
To be mounted on telescope.

ADC developed
For this experiment.



Trigger Module (TOKAI)

- Image pattern recognition
- Programmable Logic Device
 - EPF10K130EQC-1 (Altera) × 4
 - Re-configuration for later logic change
- VME specific (9U size)
 - Input : 526 channel (TTL)
 - Output : 4 channel (NIM)
- Timing simulation
 - Input pulse width : 20 nsec
 - Signal through put : 23 nsec
- Now under final check



CAMGARIOO - III Construction Schedule

As of 2002/2/1

UPS

April, 2002

March, 2002

February, 2002



Schedule

- FY2000: production of the 2nd telescope
- FY2001: installation of the 2nd telescope /
start of stereo observation /
production of the 3rd telescope
- FY2002: installation of the 3rd telescope /
production of the 4th telescope
- FY2003: installation of the 4th telescope /
start of observation by the full array

将来に向けての第一歩

OSG 会員各位

宇宙線研究所共同利用研究会「宇宙線の起源にせまる：高地を利用したガンマ線・宇宙線観測とステレオを用いたガンマ線観測」を、以下の様に12月12日に関きます。宇宙線共同利用研究会12月10日、11日に引き続き、行われますので皆様のご参加をお待ちしております。

尚、時間に若干余裕がございますので、2〜3議度を募集致したいと思います。講演を御希望の方は、筑城大学の吉田(yoshidet@mito.igcc.ibaraki.ac.jp)まで、タイトルと御希望の講演時間を御連絡下さい。

宇宙線研究所共同利用研究会

「宇宙線の起源にせまる

：高地を利用したガンマ線・宇宙線観測とステレオを用いたガンマ線観測」

開催日時：2007年12月12日（水）19:00～19:30

場所：東京大学宇宙線研究所（東大・船橋キャンパス）

6 階大ホール11室

趣旨：4000m 以上の高地での新たなガンマ線、宇宙線観測を継続し、将来の計画について検討する。これまでの成果を踏まえ、更に宇宙線の起源にせまるためには、将来どのような技術を使った観測の可能性があるかを検討し、高地でのガンマ線観測によってサブ100GeV 領域の世界を開くことで、どのような観測が期待できるかを議論する。また、訪がったソースを中心に、今後の超高エネルギーガンマ線のステレオ観測の方向性・可能性を、最近の Chandra・Roentgen による X 線や、なんてんによる電波など他波長域の成果を踏まえて議論する。

プログラム（案）

高地におけるガンマ線観測 谷森 達（京大）

BASE の将来計画 萩原 聡一（東工大）

Tibet の将来計画私見 遠山 正人（東大・宇宙線研）

Solar Neutron の観測 村本 桜（名大）

Galactic Anisotropy 赤塚 一忠（信州大）

高地と全天サーベイ：
超高エネルギーガンマ線観測の多様な実現 超高地でのガンマ線全天サーベイ
木倉 昌（信州大）

ステレオを用いたガンマ線観測 岡村 公宏（東大・宇宙線研）

系外のガンマ線ソース（仮題） 河内 朋子（東大・宇宙線研）

pulsar nebula（仮題） 樋口 雄平（東工大）

Chandra・Roentgen による新時代の X 線 観測 馬場 彰（京大）

「なんてん」サーベイ（仮題） 榎井 康雄（名大）

世話人：谷森 達（京大）、村本 桜（名大）、樋口 雄平（東工大）
坂本 良治（宇宙線研）、内藤 統台（山梨学院大）、吉田 隆生（筑城大）

+ センター化が必要