

2002年12月2-3日

東京大学宇宙線研究所 共同利用研究発表会

Report of the CANGAROO Experiment



F. Kajino (Konan Univ.)

CANGAROO Collaboration

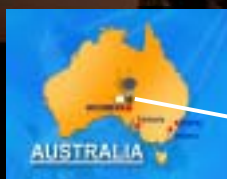


◆ Collaboration of Australia and Nippon for a Gamma Ray Observatory in the Outback

- ◆ University of Adelaide
- ◆ Australian National University
- ◆ Ibaraki University
- ◆ Ibaraki Prefectural University
- ◆ Kanagawa University
- ◆ Konan University
- ◆ Kyoto University
- ◆ Nagoya University
- ◆ National Astronomical
Observatory of Japan
- ◆ Osaka city University

18 Institutes

- ◆ Institute of Physical and
Chemical Research
- ◆ Shinshu University
- ◆ Institute for Space and
Aeronautical Science
- ◆ Tokai University
- ◆ University of Tokyo
- ◆ Tokyo Institute of Technology
- ◆ Yamagata University
- ◆ Yamanashi Gakuin University



Site : South Australia, Woomera

31 ° 06' S, 136 ° 47' E, 160m a.s.l.

CANGAROO Collaboration

50 Japanese members

浅原明広^(A)、土井康博^(C)、P.G.Edwards^(B)、榎本良治、郡司修一^(C)、
服部敬裕^(D)、原敏、原忠生^(F)、林清一^(G)、伊藤千枝^(H)、株木重人、
梶野文義^(G)、片桐秀明、河内明子、木舟正^(I)、L.Ksenofontov、
窪秀利^(A)、榎田淳子^(E,A)、栗原工^(D)、黒坂亮治、松原豊^(J)、
宮下靖史^(D)、水本好彦^(K)、森正樹、茂呂寿子^(D)、村石浩^(L)、
村木綴^(J)、内藤統也^(F)、中瀬友和^(D)、西田大輔^(A)、西嶋恭司^(D)、
荻尾彰一^(E)、大石理子、奥村公宏、折戸玲子^(A)、坂本直樹^(C)、
櫻澤幸司^(E)、薄田竜太郎^(M)、田村忠久^(N)、谷森達^(A)、谷村英樹^(A)、
土屋兼一、津野尾肇、門叶冬樹^(C)、内田直志、渡部至緒^(A)、
山岡知隆^(G)、柳田昭平^(H)、吉田龍生^(H)、吉越貴紀^(O)

東大宇宙線研、京都大理^(A)、
宇宙研^(B)、山形大理^(C)、
東海大理^(D)、東工大理^(E)、
山梨学院大情報^(F)、
甲南大理工^(G)、茨城大理^(H)、
信州大工^(I)、名大STE研^(J)、
国立天文台^(K)、
茨城県立医療大^(L)、理研^(M)、
神奈川大工^(N)、大阪市立大理^(O)

Contribution of Universities

JAPAN

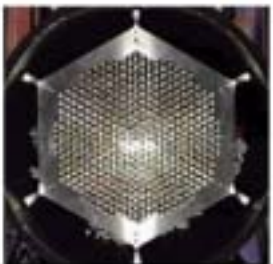

- Science section: **Yamanashi-Gakuin, Ibaraki, ++**
- Front-end Elec.: **Yamagata**
- Online Elec.: **Kyoto**
- Trigger: **Tokai**
- LG, LED Calib., Telescope Cntrl: **Konan**
- Mirror: **ICRR**
- Camera: **ICRR, Ibaraki**
- etc.: **ICRR and other Universities/Institutes**

AUSTRALIA

- Infra structures
- Science section,
- Cloud monitor etc.
- Budget from ARC

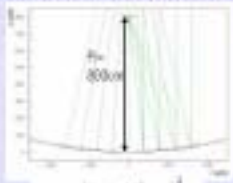
**Adelaide
ANU**

Camera and Mirrors by ICRR

Requirements for the mirror:
 - $\sim 4''$ - 35 FWHM (circular size)
 - High reflectance at 300-400nm

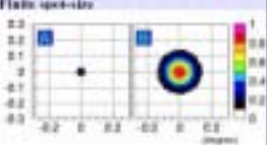
Spherical mirrors on paraboloid



$$C(R) = \left[\left(R - \frac{R^2}{4f} \right)^2 + f^2 \right]^{-1/2}$$

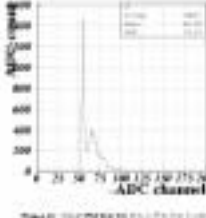
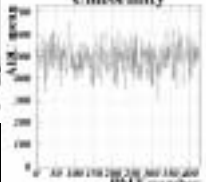
CR: 16.0-17.2m
 (15.0m as average)

Flats spot-size



segment: ideal sphere total RMS: 0.027 deg
 segment: spot-size total RMS: 0.088 deg
 -0.13 deg (FWHM) PWHM: 0.15 deg

Material: CFRP GFRP
 (Glass Fiber Reinforced Plastic)
 Reflectivity: 80% @ 400nm
 Weight: 5.6kg + 1.1kg(back base)

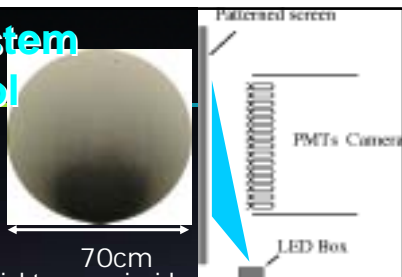
Uniformity

Light guide, LED Calib. system and Multi-Telescope control system by Konan Univ.

New light guide for the CANGAROO-III 2nd telescope



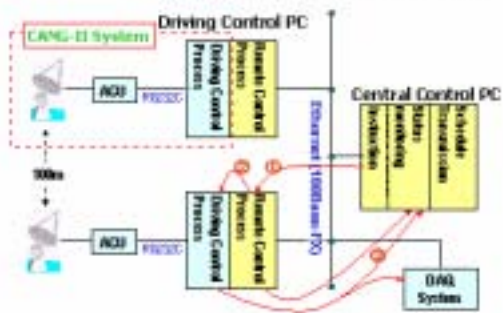
Collection eff. +70%



Calibration Light source inside CAMERA-BOX, without NSB

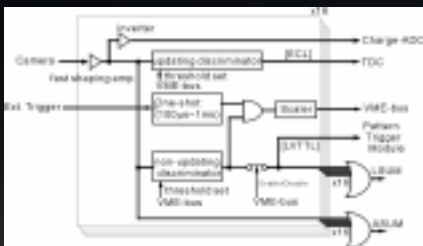
Multi-Telescope Control System

(Konan U + Osaka City U + ICRR)

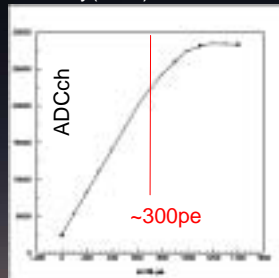


Electronics by Kyoto / Yamagata Univ.

- ◆ Front-end : DSM (Kyoto / Yamagata)
(Discriminator and Summing Module)



Linearity(ADC)

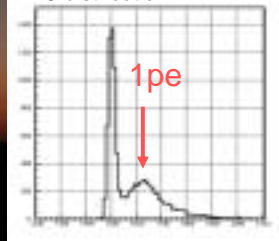


- ◆ Charge-ADC (Kyoto)

- HOSHIN V008HS
- VME 9U size, A24D16/D32 access
- 16ch × 2/board × 14 boards
- Readout 1ch(T1)
- 2ch(T2)(readout time <math>< 20\mu\text{s}/\text{board}</math>)
- 0.1pC/ADCch
- VME J1,J2,Jaux(CERN V430) required
- Linearity from 0pe to ~300pe
- Internal 150ns delay-line chip for each channel

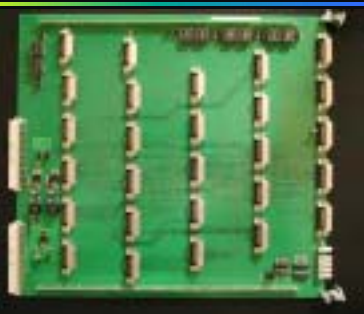


ADC distribution

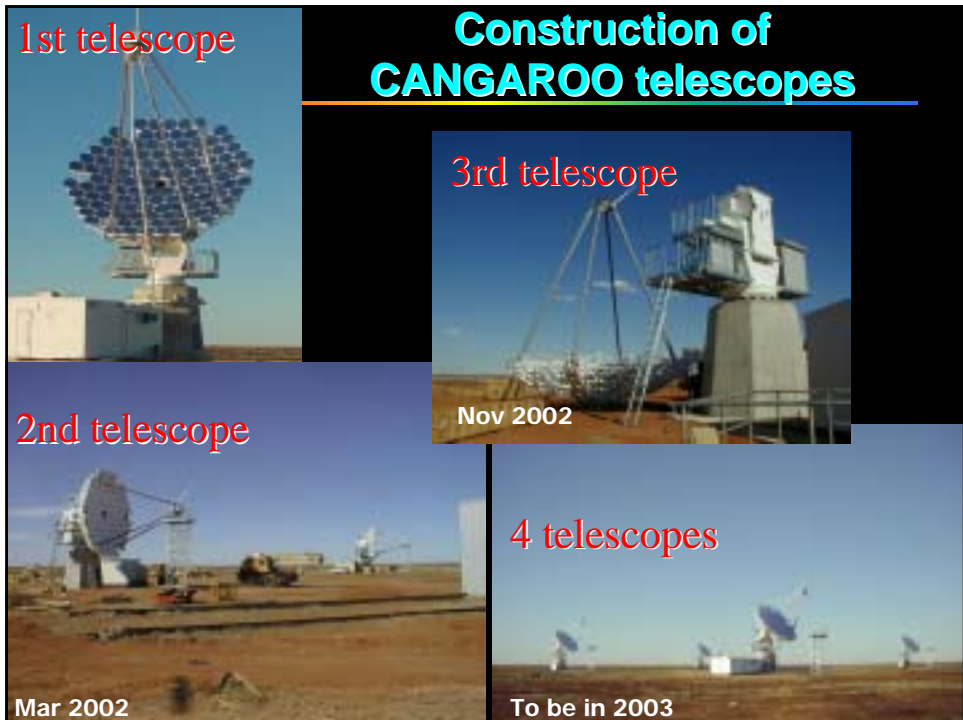
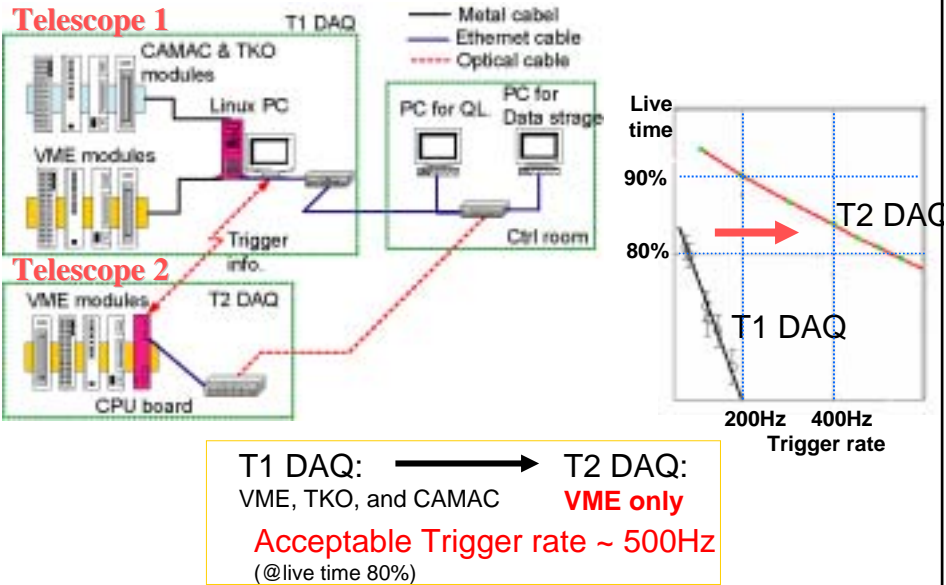


Trigger Module by Tokai Univ.

- 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



Networking and DAQ by Kyoto Univ.



Presentations at 2002-Fall JPS Meeting

- 1) CANGAROO-II望遠鏡による**銀河中心**の観測と解析結果(I)
東大宇宙線研 他CANGAROOチーム 土屋兼一 他CANGAROOチーム
- 2) CANGAROO-II望遠鏡による**RXJ0852.0-4622**の解析報告(I)
東大宇宙線研, 他 片桐秀明, 他CANGAROOチーム
- 3) CANGAROO-II望遠鏡による**超新星残骸RCW86**の観測 III
京大理, 東工大理A 渡部至緒, 谷森達, 窪秀利, 櫛田淳子A, 他CANGAROOチーム
- 4) CANGAROO-II 望遠鏡による**ガンマ線銀河団**の探索
東海大理, 国立天文台A, 他 服部敬裕, 西嶋恭司, 戸谷友則A, 他CANGAROOチーム
- 5) CANGAROO-II望遠鏡による**SS433/W50**の観測と解析結果(I)
甲南大理工, 山梨学院大情報A, 他 林清一, 梶野文義, 内藤統也A, 他 CANGAROOチーム
- 6) カンガルーIII望遠鏡の**カメラ**の改良及び性能テスト
東大宇宙線研究所 内田直志
- 7) **PSR1706-44**のTeVガンマ線観測および多波長スペクトル
東工大理, 京大理A他 櫛田淳子, 谷森達A, 窪秀利A, 他 CANGAROOチーム

International Symposium

"The Universe Viewed in Gamma-rays "

--- Univ. Tokyo Workshop 2002 ---"

September 25-28, 2002, Kashiwa, Chiba, Japan

Plenary Talks from CANGAROO group

- 1) T. Tanimori : TeV gamma rays from synchrotron X-ray SNRs
- 2) K. Okumura : Results from CANGAROO (Extragalactic objects)
- 3) A. Kawachi : Results from CANGAROO (Galactic objects)
- 4) M. Ohishi : Status of CANGAROO-III

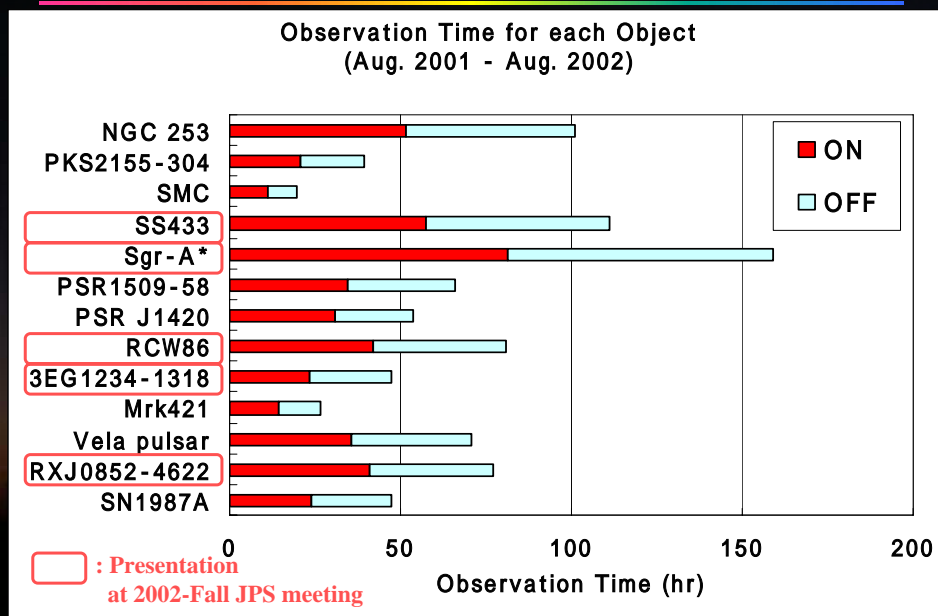
Contributed papers

- 1) K. Tsuchiya : Galactic Center
- 2) H. Katagiri : RX J0852.0-4622
- 3) K. Okumura: Mrk421
- 4) S. Hayashi : SS433/W50
- 5) C. Itoh : NGC253 starburst Galaxy
- 6) A. Kawachi : PSR B1259-63/SS2883
- 7) J. Kushida : PSR 1706-44
- 8) S. Watanabe : RCW86 SNR
- 9) T. Nakase : PKS 2155-304 BL Lac
- 10) T. Hattori : gamma-ray clusters of galaxies
- 11) S. Kabuki : IACT camera system
- 12) D. Nishida : data acquisition system
- 13) K. Nishijima : Trigger module

Publication in Refereed Journals

- 1) **Detection of diffuse TeV gamma-ray emission from the nearby starburst galaxy NGC253**
C. Itoh et al., **A&A** 396(2002)L1-4
- 2) **Development of an atmospheric Cherenkov imaging camera for the CANGAROO-III experiment**
Kabuki, S. *et al.*, accepted by **Nucl. Instr. & Meth. A**
- 3) **Observation of gamma-rays greater than 10 TeV from Markarian 421**
Okumura, K. *et al.*, **Astrophys. J. Lett.** 579, L9-L12
- 4) **The Acceleration of Cosmic-ray Protons in the Supernova Remnant RX J1713.7-3946**
Enomoto, R. *et al.*, **Nature**, 416, 823-826 (2002)
- 5) **Design Study of CANGAROO-III, Stereoscopic Imaging Atmospheric Cherenkov Telescopes for Sub-TeV Gamma-ray Detection**
Enomoto, R. *et al.*, **Astropart. Phys.** 16, 235-244 (2002)

Observation Targets and Time



Observation Target & Status (Aug 2001-Aug 2002)

Obs. Period	Target	Description	Anal Inst	Gamma Signal
Aug 2001				
- Sept	SS433 w1	Jet objects	Konan	---
	PKS2155-304	AGN z=0.116	Tokai	---
Sep - Nov	NGC253	Star burst galaxy	Ibaragi/ICRR	Positive
Nov -				published in AA
Jan 2002	SN1987A	SNR	ICRR	---
Dec -				
Feb, Apr	Vela pulsar	Pulsar		---
Dec - Feb	RXJ0852-4622	SNR	ICRR	Positive
Feb	Mrk421	AGN	ICRR	Positive(2001)
				Published in ApJ
Mar	3EGJ1234-1318	Cluster of galaxy	Tokai	
Mar - Apr	RCW 86 SW shell	SNR	Kyoto	Positive
Apr - Jun	PSR J1420-6048	Radio Pulsar	Kyoto	---
May - Jul	PSR1509-58	Pulsar	Yamagata	---
May - Aug	Sgr-A*	Galactic Center	ICRR	Positive
Jul	SS433 w1			---
Aug	SMC			---

Nearby galaxy NGC253

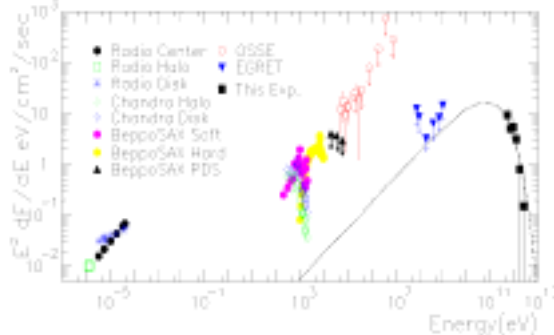
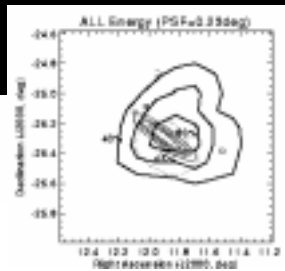
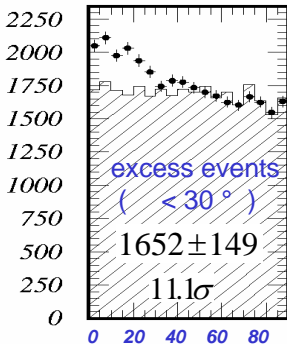
C. Itoh (Ibaraki) et al., *A&A* 396(2002)L1-4

CANGAROO II telescope detected an extended TeV -ray emission.



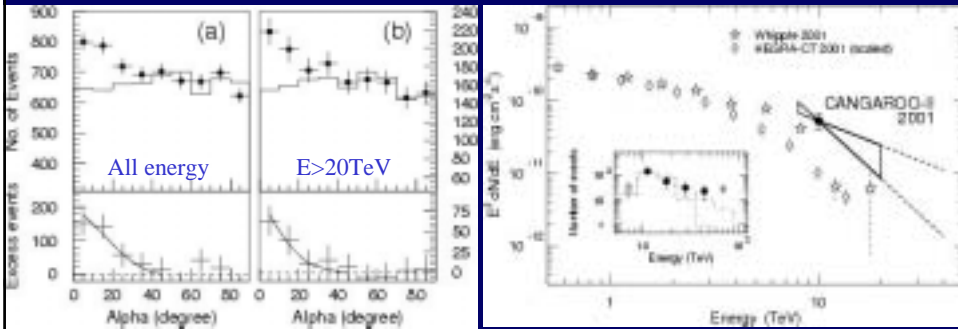
observation : 2000,2001y

~ 55h good data



Markarian 421

by K. Okumura (ICRR) et al. **ApJ** 579, L9-12, 2002



- ◆ Large zenith angle observation ($\theta_{zen} \sim 70\text{deg}$)
 - ~ 10 times increased sensitivity at $E > 10\text{TeV}$
- ◆ 298 ± 52 events observed with 14h obs. time during its flaring state in 2001
- ◆ Step spectrum ($E^{-4.0}$) supports the cutoff feature
- ◆ 4σ excess at $E > 20\text{TeV}$ indicates a larger cutoff energy of $\sim 8\text{TeV}$

RX J1713-39

R. Enomoto et al., **NATURE** 416(2002)813-816

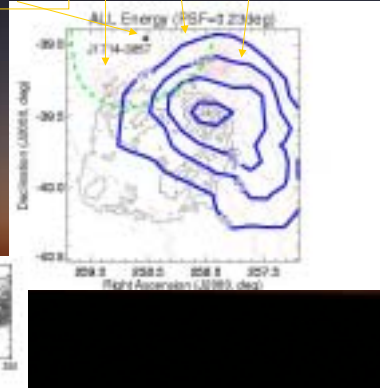
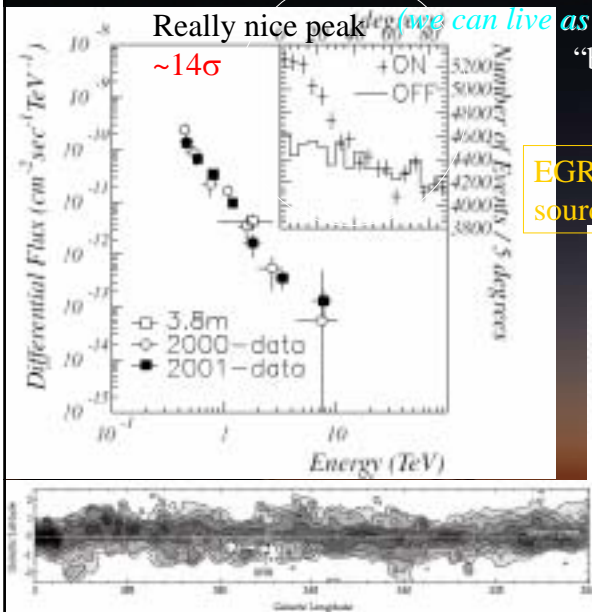
To be a lighthouse in southern hemisphere!

(we can live as lighthouse-keepers).

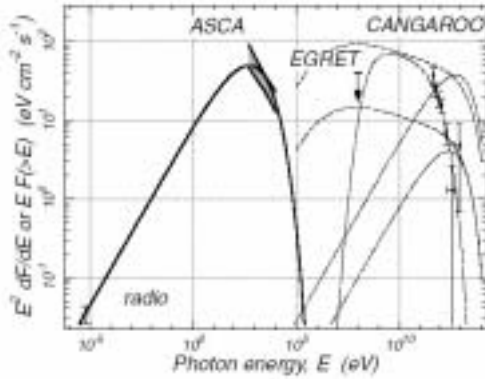
“beam dump experiment”

Molecular clouds

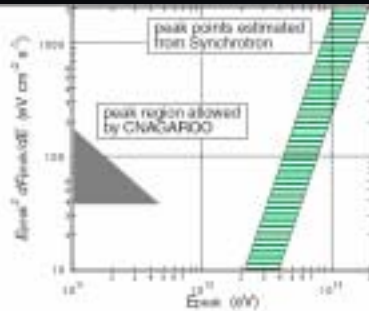
EGRET source



Multi-band spectrum



IC impossible!



Other possibility? No!
Proton acceleration natural !!

SN1006 \rightarrow evidence for electron acceleration! (Tanimori et al.)
Samely electron?

Evidence for Proton Acceleration ?

RX J0852.0-4622 (G266.2-1.2) by H. Katagiri (ICRR)

- Shell type SNR along the line of sight to the Vela SNR.
- Very near and young
Distance < 500pc, age ~ 1000yr
- Non-thermal X-rays (Fig.1)
X-ray spectrum is well described by power law
 \Rightarrow Indication of the presence of the high energy electrons
- Sub-TeV gamma-rays
Observation from 2001 Dec to 2002 Feb by CANGAROO-II (ON 41h OFF 36h) \Rightarrow analysis is underway (Fig.2)

The detection would be further evidence for the acceleration of cosmic rays, as observed for SN1006 and RX J1713.7-3946

- Further observation
During 2003 Jan. to confirm it.

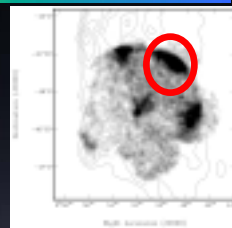


Fig.1 X-ray images taken by ASCA

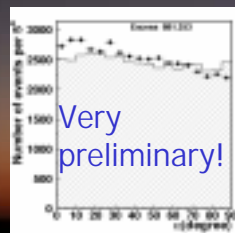
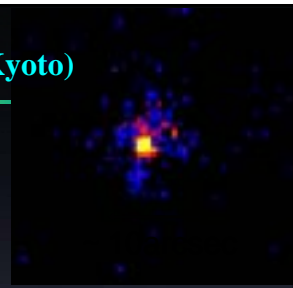


Fig.2 Alpha distribution

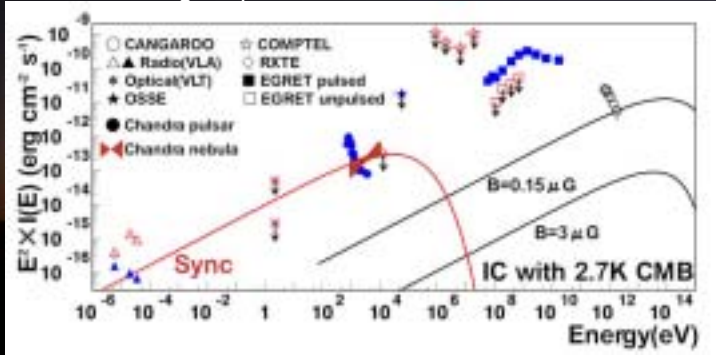
PSR B1706-44 by J. Kushida (Kyoto)

- ◆ Synchrotron cut off > 10keV
- ◆ TeV flux: $10 \times$ X ray flux
- ◆ difficult to explain
Sync-IC(2.7k CMB) model



Chandra/ACIS Image

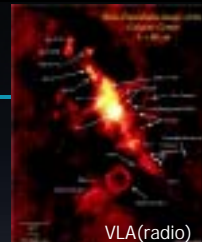
Multi-wavelength Spectrum of PSR 1706-44



The Galactic Center by Tsuchiya (ICRR)

by Tsuchiya (ICRR)

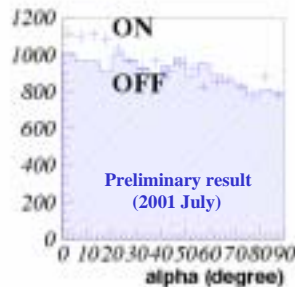
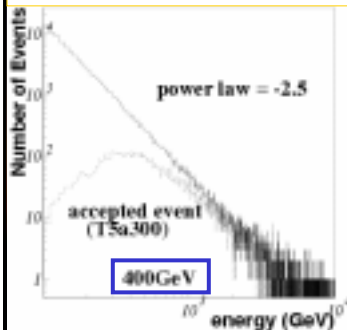
Observation time (good condition)	2001 July	2002 July	2002 August
ON source	20.8h	32.0h	20.1h
OFF source	22.1h	17.9h	14.9h



VLA(radio)

CANGAROO-II telescope in the southern hemisphere
 → Advantage of decreased energy threshold for observations of the galactic center (Energy threshold : ~ 400GeV)

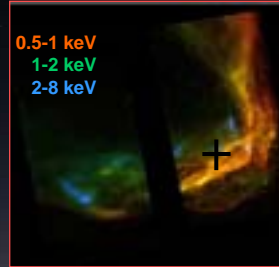
Past result
 Whipple : upper limit at ~2TeV (1997)
 HEGRA : upper limit at ~4.5TeV (2002)



RCW86 (G315.4-2.3)

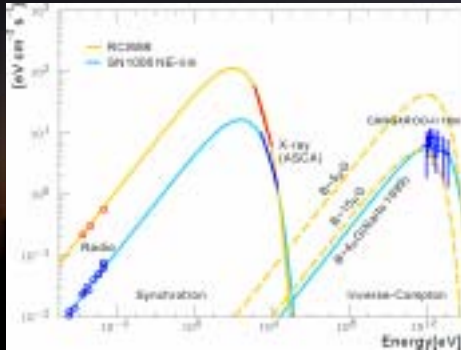
by S. Watanabe (Kyoto)

- Observation :
The strongest X-ray point in SW shell
79 hours for ON-source
- We can detect TeV γ -ray, if $B < 15 \mu\text{G}$.
- Possibility of TeV γ -ray emission,
now analyzing.

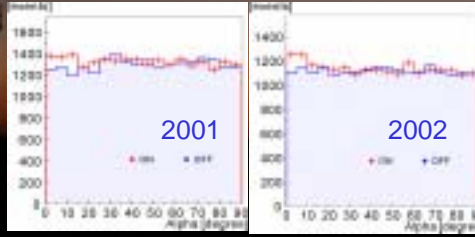


Chandra Image
(Rho et al. 2002)

Multi-wavelength Spectrum of RCW86



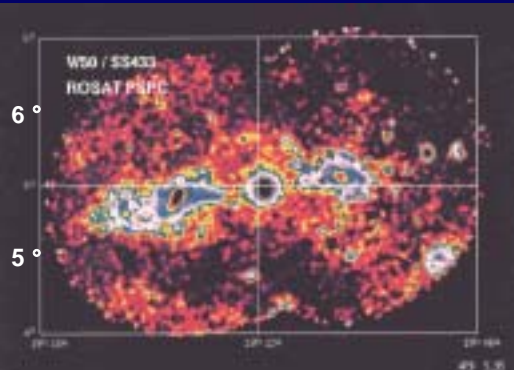
Alpha distribution (preliminary)



SS433/W50

by S. Hayashi (Konan)

Namiki et al. 2000



19h18m 19h12m 19h06m

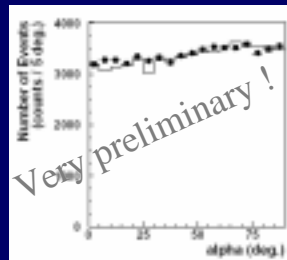
(Brinkmann et al. 1995)

W50

- Galactic SNR ($2 \times 1 \text{ deg}$)
- Distance: 5 kpc
- Age: ~ 10000 year

SS433

- Center of W50
- Magnitude 14.2
- Parsec-scale jet ($v = 0.26c$)
- Binary system (13.1 day)
- X-ray lobes



PSR B1509-58

Yamagata Univ.(N.Sakamoto, Y.Do, S.Gunji, F.Tokanai)
Tokai Univ.(Y.Miyashita, K.Nishijima)

- ◆ Source Position
(RA,Dec.)=(228.48 ° , -59.14 °)
- ◆ Observation Time
2002 May, June, July
OFF: ~32hr, On: ~34hr
- ◆ Elevation
~60 ° (Min.: 49 ° Max.: 62 °)

Analysis

- ◆ Cloud cut and rate cut criteria
elevation angle > 50 °
adjacent: T5a
shower rate > 0.8Hz
- ◆ Square cut
0.60 ° < Distance < 1.30 °
0.14 ° < Length < 0.40 °
0.04 ° < Width < 0.09 °

Analysis in progress

Summary

- ◆ **CANGAROO 1st telescope is working steady.**
- ◆ **2nd telescope has been constructed.**
- ◆ **3rd and 4th telescope will be constructed until 2003FY.**
- ◆ **Observation has been continued for various types of objects.**
- ◆ **Data analysis has been performed by many Universities and Institutes.**
- ◆ **We are going to get many good results.**

Acknowledgements

We greatly appreciate the ICRR Collaboration Research Program for supporting the CANGAROO experiment and collaborating Universities.



カンガルー実験関係 補助金

件数	8件
校費	310万円
旅費	169万円