



# Observations of PSR 1706-44 with CANGAROO-II Telescope



Junko Kushida  
and CANGAROO collaboration  
Dept. of Phys,  
Tokyo Institute of Technology

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## CANGAROO

Collaboration of **A**ustralia and **N**ippon  
for a **G**amma **R**ay **O**bservatory in the **O**utback



Site: South Australia,  
Woomera

31° 06' S  
136° 47' E  
160m a.s.l.



# CANGAROO Collaboration

## Japanese Institutes : 16

- ◆Tokyo Institute of Technology
- ◆University of Adelaide
- ◆Australian National University
- ◆Ibaraki University
- ◆Ibaraki Prefectural University of Health Science
- ◆Institute for Cosmic Ray Research, U. Tokyo
- ◆Institute of Space and Astronautical Science
- ◆Institute of Physical and Chemical Research (RIKEN)

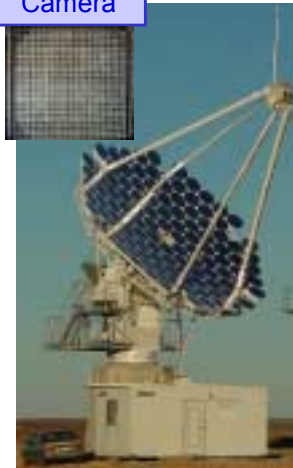
## Australian Institutes: 2

- ◆Kanagawa University
- ◆Konan University
- ◆Kyoto University
- ◆National Astronomical Observatory of Japan
- ◆Osaka City University
- ◆Shinshu University
- ◆STE Laboratory, Nagoya University
- ◆Tokai University
- ◆Yamagata University
- ◆Yamanashi Gakuin University



# CANGAROO-II 10m Telescope

Camera



2000 10m  $\phi$

	10m telescope
Focal length	8m <b>Parabola</b>
80cm mirrors	114 (57m <sup>2</sup> ) <b>CFRP</b>
Number of PMTs	552 (1/2") <b>FOV ~ 3°</b>
Electronics	TDC(0.5ns) & ADC (All PMTs)
Point image size	~0° . 20 (FWHM)



# PSR 1706-44 Basic Data

- Age :  $1.7 \times 10^4$  y
- Distance : 1.8 kpc
- Period : 102 ms
- Period derivative :  $93 \times 10^{-15}$  s/s
- Magnetic field :  $3.1 \times 10^{12}$  G
- Spin-down energy loss :  $3.4 \times 10^{36}$  erg/s



# Multi-wavelength Observations

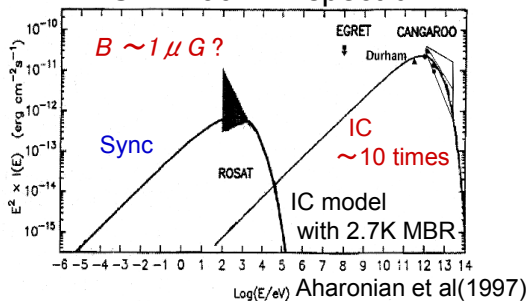
## • Pulsed

Radio : VLA  
GeV -  $\gamma$  : EGRET

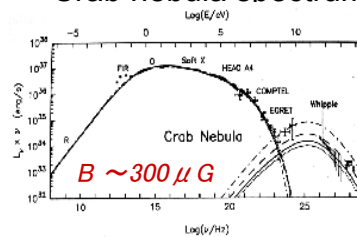
## • Unpulsed

X ray : ROSAT, ASCA, RXTE  
TeV -  $\gamma$  : CANGAROO, Durham

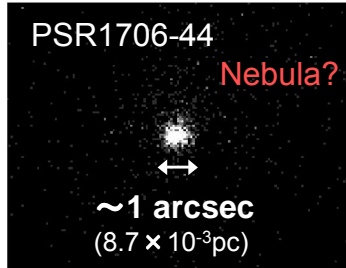
### PSR 1706 -44 spectrum



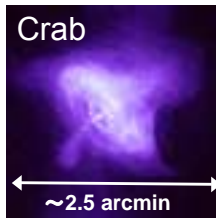
### Crab nebula spectrum



# Nebula



Chandra HRC from Archive Data



$$B_{\mu\text{G}} L_{\text{pc}} > \frac{E}{10^{15} \text{ eV}} \frac{1}{Z\beta}$$

(Hillas, 1984)

$B_{\mu\text{G}}$  : magnetic field ( $\mu\text{G}$ )  
 $L_{\text{pc}}$  : accelerating region size  
 $Z$  : relativistic particle of charge  
 $E_{\text{eV}}$  : particle's energy

$$B_{\mu\text{G}} \sim 1 \mu\text{G}, Z \sim 1, \beta \sim 1, E_{\text{eV}} \sim 10 \text{ TeV}$$

$$\Rightarrow L_{\text{pc}} > 1.0 \times 10^{-2} \text{ pc} \sim 10 \text{ arcsec}$$

# Observation History

## 3.8m telescope



year	time(hour)	Excess( $\sigma$ )	Threshold(TeV)
1992+1993	84	10.0	>1.2
1994+1995	14.8	3.4	>2
1997	27.8	5.1	>1.2
1998	23.2	4.3	>1.2

(1996, mirror recoating)

## 7m telescope



year	time(hour)	Excess( $\sigma$ )	Threshold(TeV)
1999	16.4	4.2	>0.9



## Observation with 10m Telescope

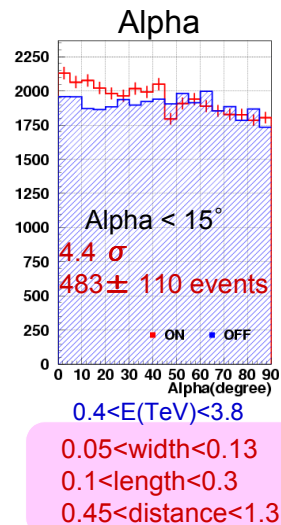
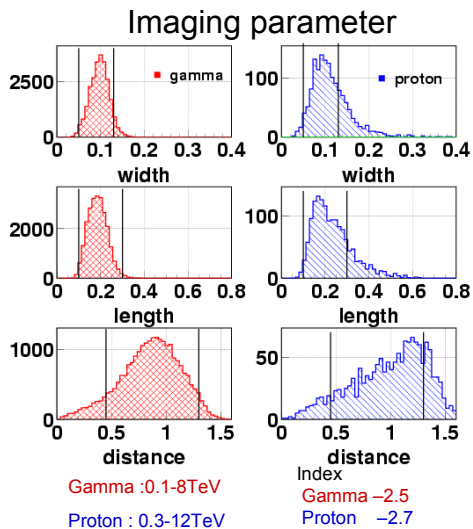
Observation time

2000	ON source		OFF source	
	Obs time	Selected	Obs time	Selected
June	24h49m	16h32m	19h10m	11h50m
July	25h37m	16h56m	28h59m	16h52m
Total	50h26m	33h28m	48h9m	28h42m

High humidity → Effect of dew



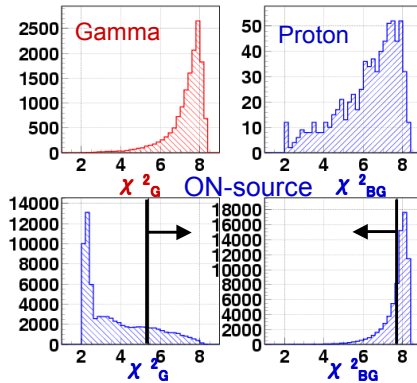
## Imaging Method



# Maximum Likelihood Method

- The logarithm of the likelihood function
- $\chi^2 = \log(P(\text{distance}) \times P(\text{width}) \times P(\text{length}))$

## Simulation



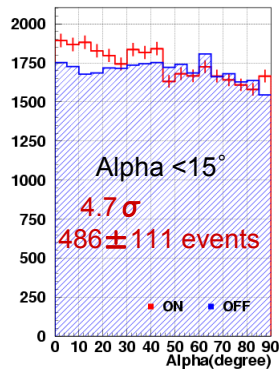
P: probability density function obtained from Image parameter

## Chi-square cut condition

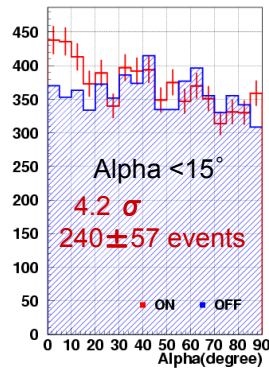
$$\chi_G > 5.8$$

$$\chi_{BG} < 7.7$$

# Alpha Distribution



$$0.4 < E(\text{TeV}) < 3.8$$

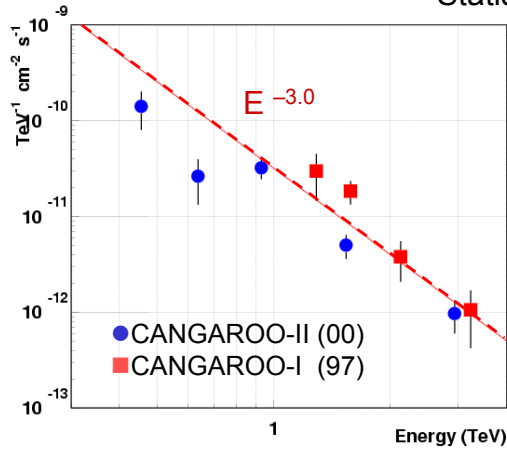


$$0.8 < E(\text{TeV}) < 1.1$$

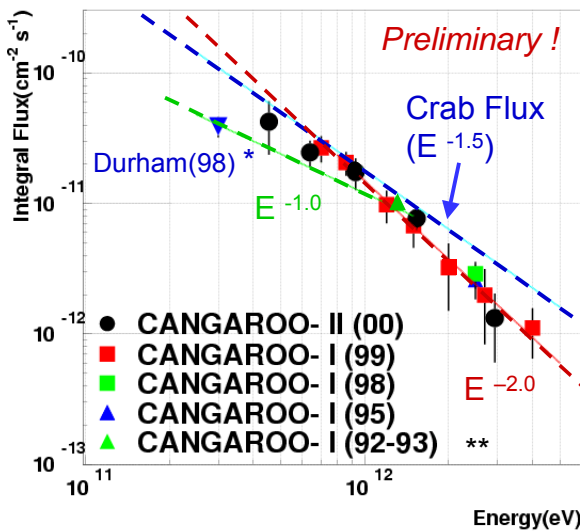
# Differential Flux

*Preliminary !*

Statistic error only



# Compilation of Observed Integral Flux



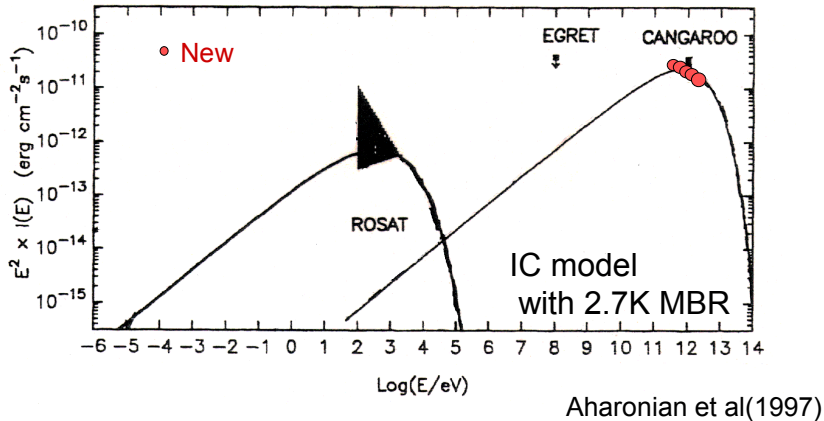
Statistic error only

Spectrum break near 1 TeV

\*Chadwick et al(1998)

\*\*Kifune et al (1995)

## Multi-wavelength Spectrum



These results support IC model with 2.7K MBR

## Summary

- PSR1706-44 has been observed continuously
- The integral flux is consistent with the previous results
- It seems to have a spectrum break near 1 TeV
  - Our results support IC model with 2.7K MBR
- In 2001, We took additional data with 10m telescope