

## Summary (2)

### **The Universe Viewed in Gamma-Rays Univ. of Tokyo Workshop 2002**

**Rene A. Ong  
Univ. of California, Los Angeles**

## Thanks

**LOC, Mori, Yanagita, for inviting me.**

**All speakers and contributing authors.**

**Modern Computing ... ?**

## Apologies, etc.

Reviewing is not an easy business, so this talk will be far from perfect:

- Mostly obs/exp - see also Summary(1).
- Not comprehensive.
- Subjective !
- Concentrates on results presented here.

Note: As many review talks as contributed papers.  
Will not redo all those nice presentations.  
But will try to go beyond a simple recap of meeting.

## Outline

- Historical Perspective  
How has the field changed recently?
- Big Themes  
Where is the field going?
- Selected New Results
- Summary - Future
- Comments

## Historical Perspective

1990		1 <sup>st</sup> solid detection (Crab)
1992	TMACD I	1 <sup>st</sup> extragalactic (Mrk 421) Palaiseau Suggestion – large TAs
1993	TMACD II	Calgary
1994	TMACD III	Tokyo (Kifune)
1995	TMACD IV	Padova
1997	TMACD V	Mrk 501 Flares Kruger Park “Big Four” 3 <sup>rd</sup> Gen. Detectors

## Historical Perspective

1999 TMACD VI Snowbird

2002 Kashiwa

TMACD Conferences were important:

- Marked separation of  $\gamma$ -rays from ICRC
- Evolved - mix of reviews, theory/obs/detectors

It would be nice to have a VHE  $\gamma$ -ray meeting every two years, whatever the name.

Kashiwa Meeting has been in the spirit of this tradition. Consider trends since Snowbird.  
Also – see summary by Pohl at 27<sup>th</sup> ICRC (Hamburg).

## Workshop Sub-Title I

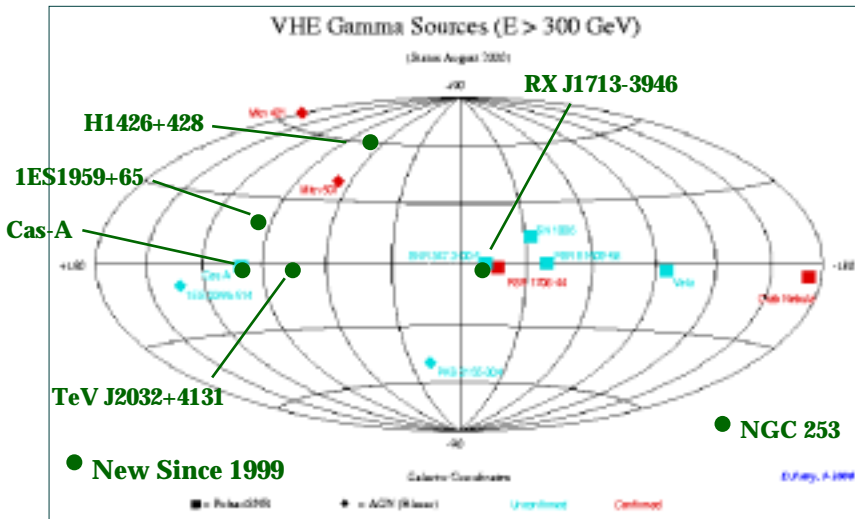


Not really this !

## Big Themes

- Source Count increasing steadily.

# VHE Sky Map



Rene A. Ong (UCLA)

The Universe Viewed in Gamma-Rays – Summary (2)

## Source List

	<u>1990-1999</u>	<u>1999-2002</u>
<b>Solid (6)</b>	Crab Mrk 421 Mrk 501 PSR 1706	H1426 1ES1959
<b>Likely (6)</b>	Vela 1ES2344 SN1006	Cas-A RXJ 1713 TeV J2032
<b>??</b>	PKS 2155 Cen X-3 3C 66A	NGC 253

Rene A. Ong (UCLA)

The Universe Viewed in Gamma-Rays – Summary (2)

10

## Source Notes

- At this meeting, CANGAROO reported a new source:  
NGC 253 (Starburst) – Itoh (S26)
- And showed early evidence for possible sources:  
RCW 86 (SNR) – Watanabe (S32)  
RX J0852-4622 (SNR) – Katagiri (S19)  
Galactic Center – Tsuchiya (S17)
- No confirmed detection of any SNR.
- (Solid + Likely) = 12 Total VHE Sources.

## Hemisphere Counting

Q: How does the S compare with the N?

Hemisphere	AGN	Galactic	Unknown
N	5	2	1
S	0	4	0

- At present, statistics are still limited.
- Future picture will look different:
  1. SNR detections will be confirmed.
  2. S Detectors improving dramatically.
  3. # of N Detectors is reducing.  
(TA, HEGRA, CAT...)

## Hemisphere Counting

**Galactic studies will gain in importance.  
SNRs, pulsars, EUIDs ...**

## Big Themes

- **Source Count increasing steadily.**
- **S hemisphere will be increasingly important for field.**
- **Multi- $\lambda$  Approaches are essential.  
Spectral, temporal, spatial correlations.**

# The X-ray - TeV $\gamma$ Connection

**SNRs: Slane (01), Tanimori (02), Berezhko (03):**

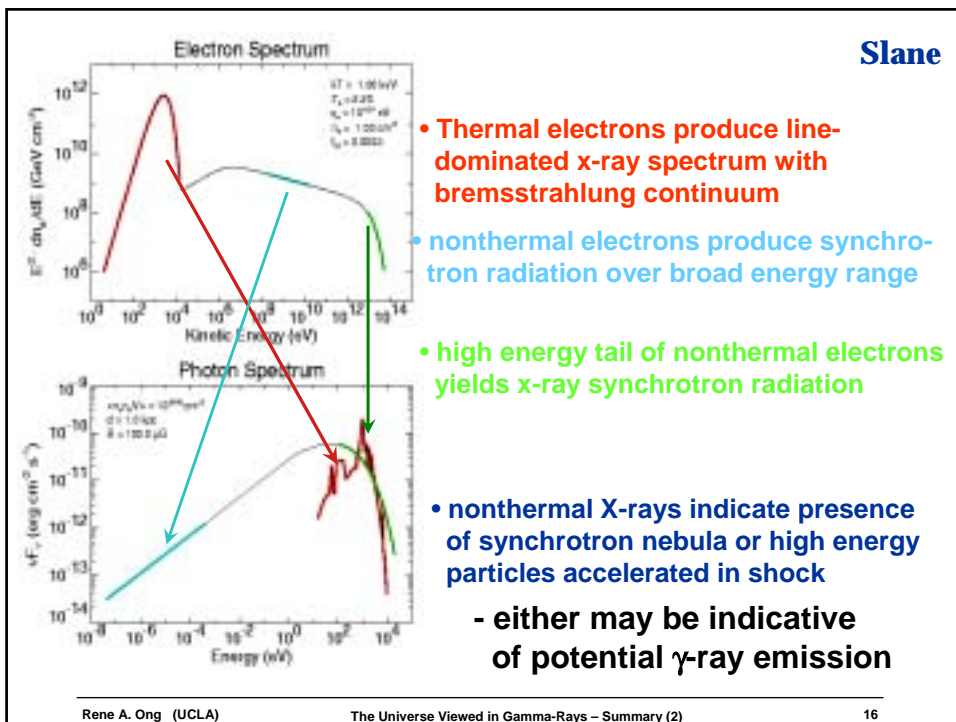
- Importance of understanding the broadband SED in SNRs and plerions.
- SN 1006 – IC models look satisfactory.
- In RX J1713 the situation is not clear at all.

**AGN: Coppi (07), Mukherjee (08):**

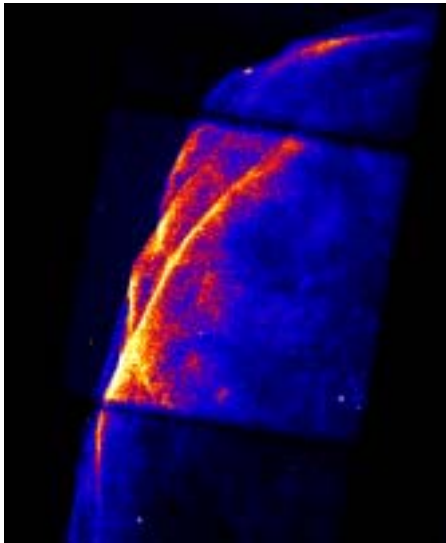
- In broad terms: x-ray and TeV data are correlated. Double-peaked SEDs, temporal relations.
- Evidence for unified picture.
- Look in detail: many complications. TeV blazars may be more tractable, interesting.

**Good time for X-ray work:**

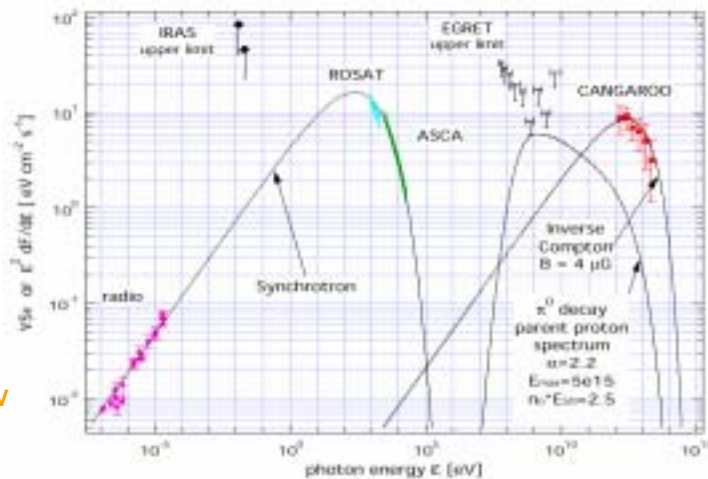
**Chandra, XMM/Newton, RXTE, (Astro 2E), etc.**







- Spectrum of limb dominated by nonthermal emission  
- keV photons imply  $E_e \approx 100 \text{ TeV}$
- *Chandra* observations show distinct shock structure in shell
- Same region as TeV emission



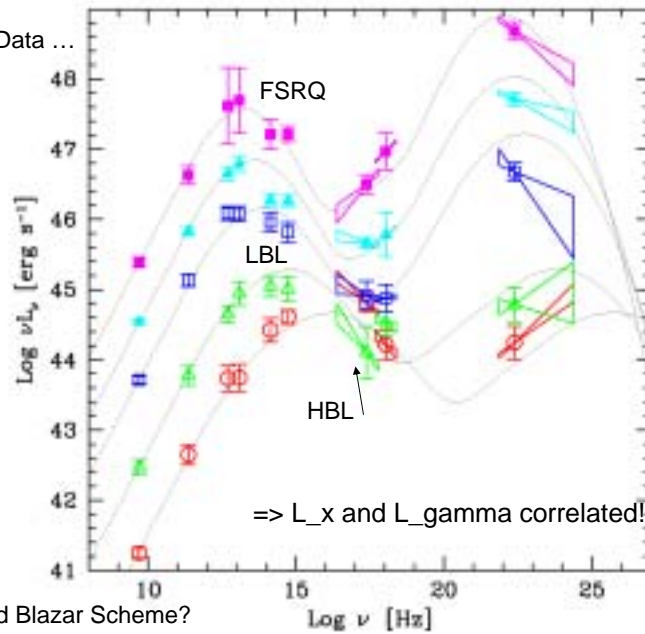
S = -2.2  
B ~ 4 μG  
E<sub>max</sub> ~ 50TeV

IC Modeling works!

*Naito et al. Astron. Nach. 320, 1999*

Add EGRET  
Gamma-Ray Data ...

Coppi



Grand Unified Blazar Scheme?

(synchrotron & Compton from SAME e<sup>+</sup>/e<sup>-</sup>?;  $\gamma_{peak} \propto Lum^{-1}$ ?)

Donati et al. 2001  
(cf. Fossati et al. 1998)

Coppi

If electrons/pairs are primary particles, what is acceleration energy spectrum?

Is the observed high energy cutoff in some objects intrinsic or simply due to photon-photon pair production (inside source or intergalactic)?

What is the origin of the spectral breaks seen in X-rays/gamma-rays?

What are seed photons for Compton upscattering??

- Synchrotron Photons (SSC)
- Accretion Disk Photons (ERC)
- BLR Photons (reprocessed accretion disk photons) ..
- IR photons from hot dust in central region ..
- [Microwave background, probably not relevant, but always there ] ..

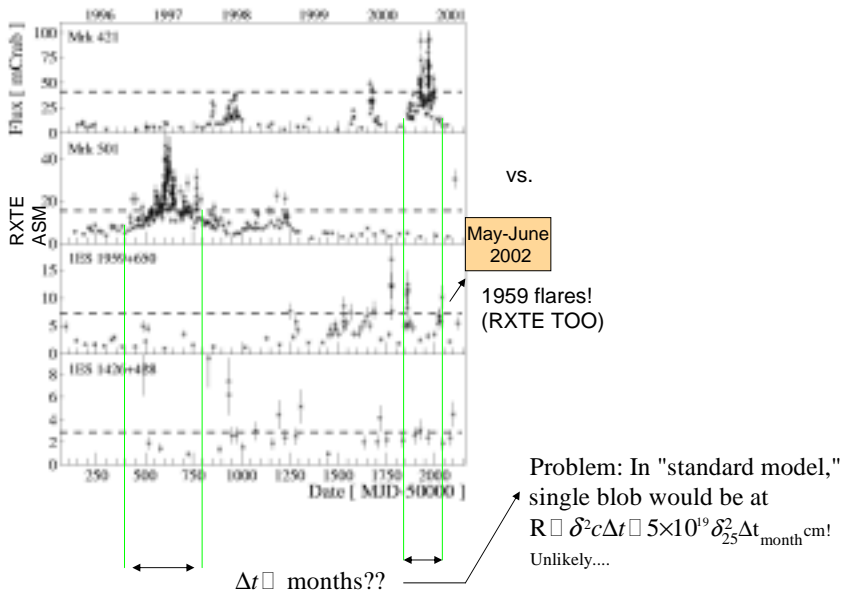
All possible => **different** gamma-ray spectra for **same** e<sup>-</sup> distribution!

**∴ Lots of uncertainty for generic blazar!!**

TIMESCALES (II):

TeV (and GeV) blazars appear to have discrete "flare" states...

Coppi



## The GeV - TeV $\gamma$ Connection

Main Questions left from EGRET: Pohl (05)  
Prospects for Diffuse Bkgnd: Pavlidou (G07)

GeV excess is highly significant, present at high latitudes, and not understood.

Large number of unid sources. Probably > 100 are galactic in origin, but minor fraction are SNR or pulsars → New source class.

- Are the two problems (GeV Excess & UnID) related?
- What is relevant at TeV energies?

**Not a great time for GeV  $\gamma$ -ray work: (... GLAST).**

## Big Themes

- Source Count increasing steadily.
- S hemisphere will be increasingly important for field.
- Multi- $\lambda$  Approaches are essential.
- Experimentation & Technology march on.

## New Telescopes are Here

Hofmann (T03)



Ohishi (T04)

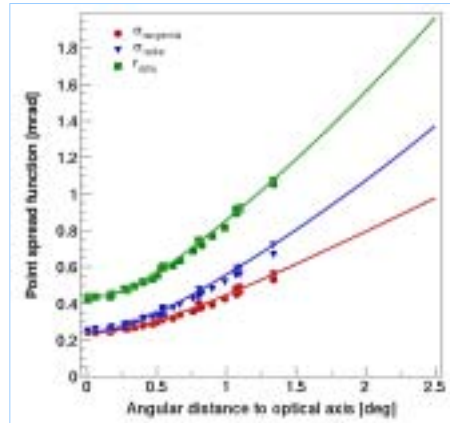
Lorenz (T02)



## New Technology is Here: Mirrors



**AI Mirrors (MAGIC)**

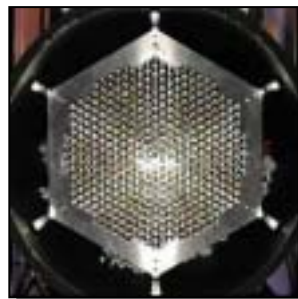


**PSF After Alignment (HESS)**

## New Technology is Here: Cameras



**Modular Construction (HESS)**



**Single, lightweight (CANGAROO)**

# New Technology is Here: Electronics

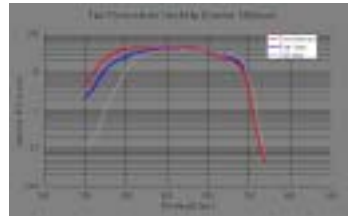
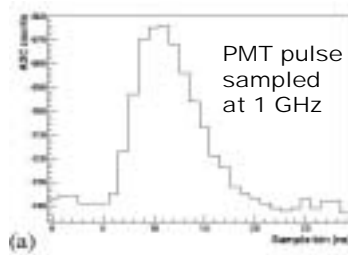
## 500 MHz FADCs (VERITAS)



### Analog Fiber Signal Transmission (MAGIC)

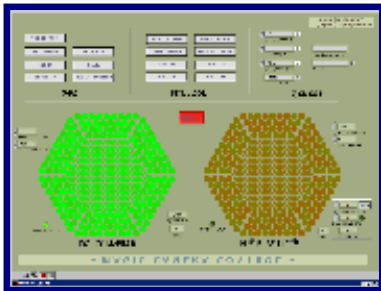
1 ns rise time  
Dyn range of 60 dB

## Fast Sampling (HESS)

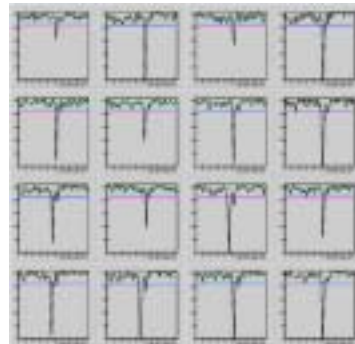


Hi QE HPD ... still 2 yrs off?

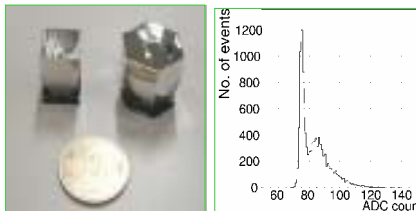
# Posters - Instrumentation



Cortina (T10) – MAGIC Control



Covault (T15) – STACEE FADCs



Kabuki (T09) – CANGAROO Camera

## Posters - Instrumentation

**Additional contributions that I did not have time to discuss:**

<b>Achara</b>	<b>(S16) - Pachmari Array of Cherenkov Telescopes</b>
<b>Cowsik</b>	<b>(T06) - High Altitude Observatory at Hanle</b>
<b>Sinitsyna</b>	<b>(T07) - Selection of Gammas from Protons - SHALON</b>
<b>Puelhofer</b>	<b>(T11) - Technical performance of HEGRA IACT</b>
<b>Cornils</b>	<b>(T12) - Mirror Alignment of HESS Telescopes</b>
<b>Cortina</b>	<b>(T13) - Absolute Flux Calibration for MAGIC</b>
	<b>(T14) - Data Acquisition of MAGIC</b>
<b>Kajino</b>	<b>(T16) - High Resolution Cherenkov Telescopes</b>
<b>Nishida</b>	<b>(T17) - Development of DAQ of CANGAROO-III</b>
<b>Nishijima</b>	<b>(T18) - Trigger module for CANGAROO-III</b>
<b>Ohishi</b>	<b>(T19) - Plastic Spherical Mirrors of CANGAROO-III</b>
<b>Oson</b>	<b>(T20) - New Gamma-Ray Detector Concept</b>
<b>Asahara</b>	<b>(T21) - Performance of 10-100 GeV "CheSS"</b>
<b>F. Krennrich</b>	<b>(T22) - SGARFACE - PBH Burst Experiment</b>
<b>S. LeBohec</b>	<b>(T23) - Cosmic Ray Calibration of ACTs</b>

## Workshop Sub-Title II



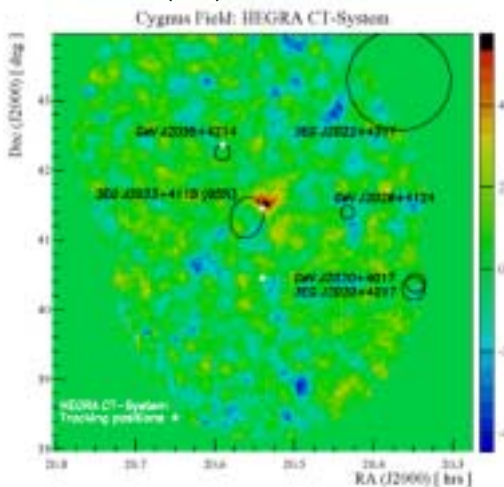
**Not this either !**

## Selected New Results

1. First UnID TeV Source
2. RX J1713 Mystery
3. Sky surveys are here !
4. AGN have spectral variability
5. New AGN (H1426, 1ES1959)  
New source type (NGC 253)?
6. AGN Cutoffs – what do we make of them?
7. Spectral measurements 50-250 GeV

## 1. First UnID Source at TeV

### Rowell (T08)



- $4.6 \sigma$  (post-trial)
- Weak  $\sim 30$  mCrab  
But steady.
- Not clearly identified  
with any EGRET source.
- Proximity of Cyg OB2.
- Finite Size?  $\sim 6'$
- Hard Spectrum.



# 1. Spectrum of UnID TeV Source

**Spectrum/Flux**  $\theta < 0.224^\circ$ ,  $\bar{w} < 1.1$ ,  $n_{\text{rel}} \geq 3$ : (for other spectral cuts see Aharonian et al. 1999 A&A, 219, 11)

$$dN/dE = N(E/\text{TeV})^{-\gamma}$$

$$N = 4.7(\pm 2.1_{\text{stat}} \pm 1.3_{\text{sys}}) \times 10^{-13} \text{ ph cm}^{-2} \text{ s}^{-1} \text{ TeV}^{-1}$$

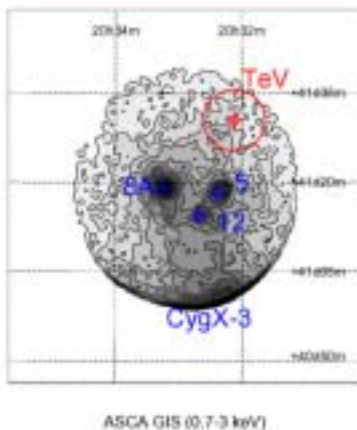
$$\gamma = -1.9(\pm 0.3_{\text{stat}} \pm 0.3_{\text{sys}})$$

$$\text{Int. flux } (E > 1 \text{ TeV}) \sim 3\% \text{ Crab} \\ \rightarrow \sim 10^{31} \text{ erg s}^{-1} (d \sim 1.7 \text{ kpc})$$



- Detection and Spectrum Confirmed in 2002 Data (preliminary)

# 1. TeV J2032+4131



Most consistent with  
Cyg OB2 complex, but

**No apparent counterpart at TeV  
position.**

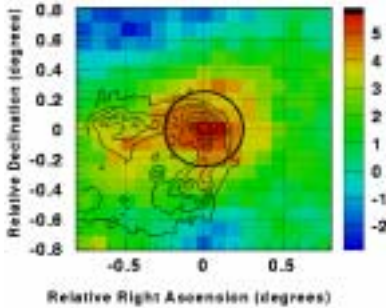
What is this object?

... we don't know.

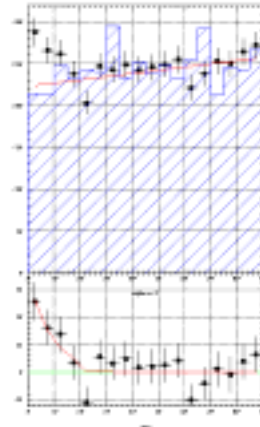
**Catalog of UnID TeV Sources is started.**

## 2. RX J1713-3946 Mystery

Tanimori (02)  
Kawachi (S06)



TeV-Gamma  
3.8m Tele.



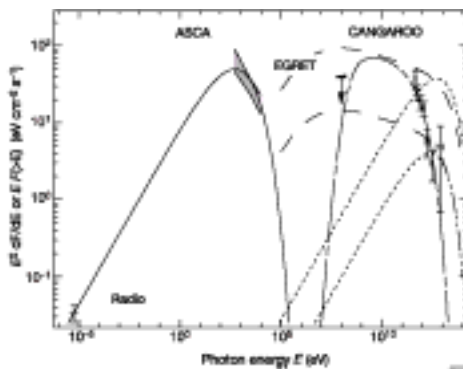
7m Tele. 1999 (16hours))

$E_\gamma > \sim 1\text{TeV} (E^{-2.5})$

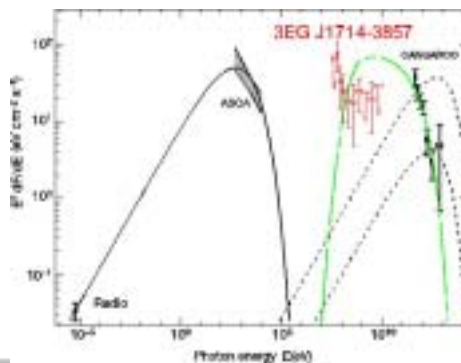
Rene A. Ong (UCLA)

The Universe View

## 2. Mystery I



Enomoto et al 2002  
Hard to explain with IC.



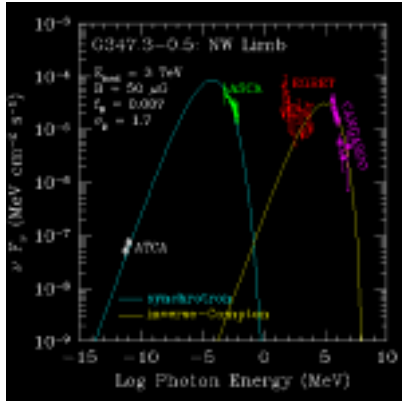
Reimer & Pohl 2002  
Proton fit inconsistent with  
actual EGRET limit.

Rene A. Ong (UCLA)

The Universe Viewed in Gamma-Rays – Summary (2)

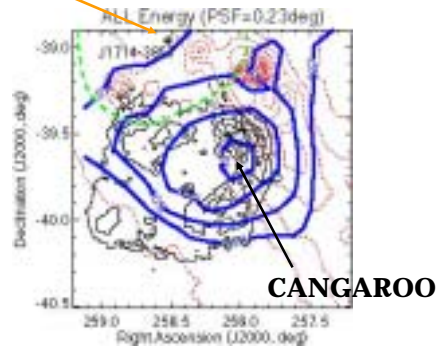
36

## 2. Mystery II



Slane  
Showed IC fit in agreement  
with CANGAROO, EGRET.  
Large B, small filling factor.

3EG J1714-3857



Tanimori  
EGRET Source is  $0.8^\circ$  away

Doesn't seem exp. valid!

## RX J1713+4131 is Unsolved

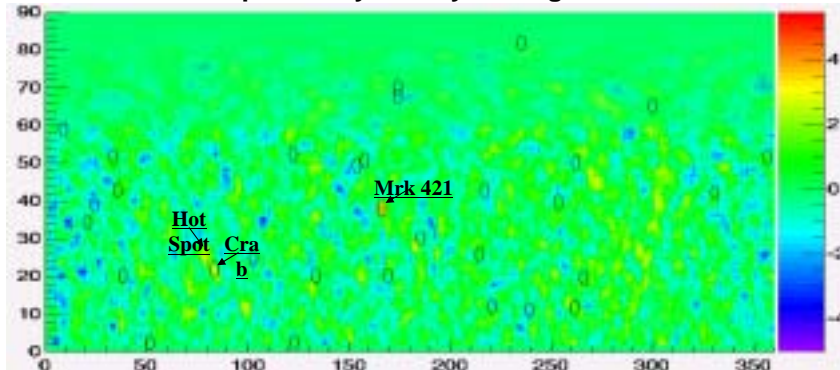
- RX J1713 picture is not clear – one cannot claim from this source that there is evidence for VHE proton acceleration.
- In general, SNRs will have both an e – IC component and a proton –  $\pi^0$  component, but separating the two is challenging. “Smoking Gun” is not so smoking!

Q: Is there good, direct evidence for VHE proton acceleration in any SNR?  
Cas-A is possible (Berezhko, Voelk)  
Relies on large B field reported for remnant.  
Resolved in future (HESS, CANGAROO-III).

### 3. Sky Surveys are Here !

Sinnis (S13)

Northern Hemisphere Sky Survey – Milagro



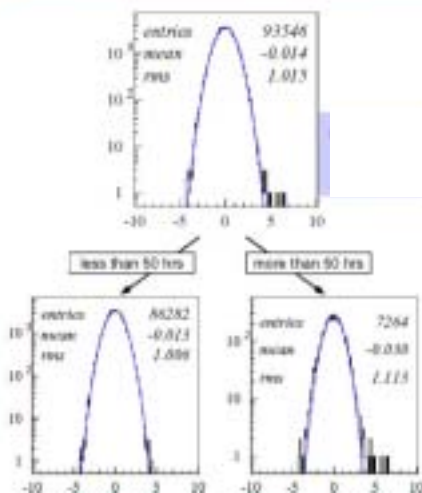
$E \sim 4 \text{ TeV}$

3 locations in sky ~ Crab  
Crab, Mrk 421, “Hot Spot”

Sakata (S30) Tibet As- $\gamma$   
Similar, Crab only source

### 3. Sky Surveys – Cherenkov

FOV background (ring model)

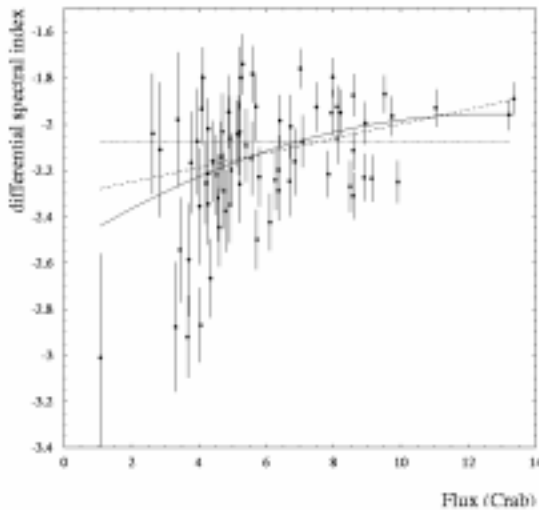


Puelhofer (S09)  
Survey using archival HEGRA

0.4 sr covered – 3.5% of sky.  
No strong new sources seen  
(except TeV J2032+4131)

**TeV  $\gamma$ -ray Sky is  
not bright  
(Northern Hemisphere)**

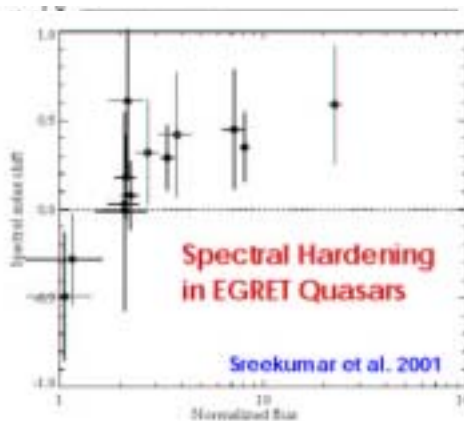
## 4. Spectral Variability of AGN



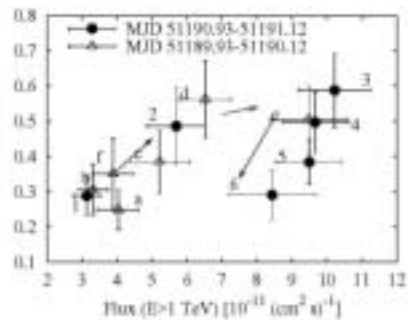
General trend is shown on short (30 min) time scales as well, but with lots of scatter.

Complicated system.  
Is spectral variability a general trend of blazars?

## 4. Spectral Variability of AGN



Mukherjee:  
Evidence with EGRET.

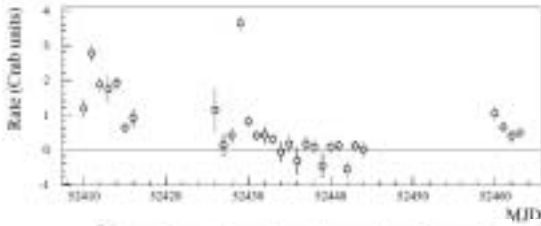


Diurnal variation –  
“hysteresis” effect.

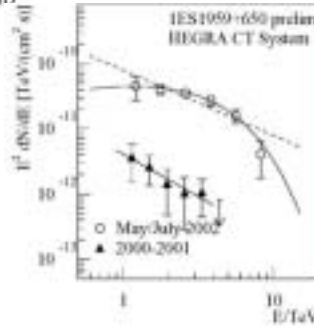
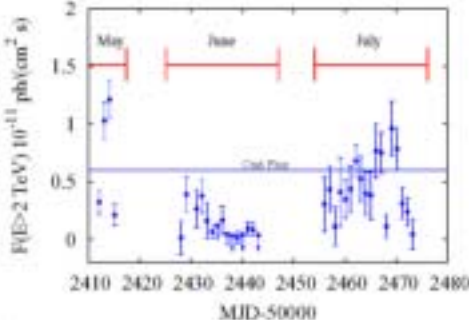
Implications were discussed  
by Mukherjee, Coppi.

Shift of synch peak to higher E.

## 5. New AGN 1ES1959+650



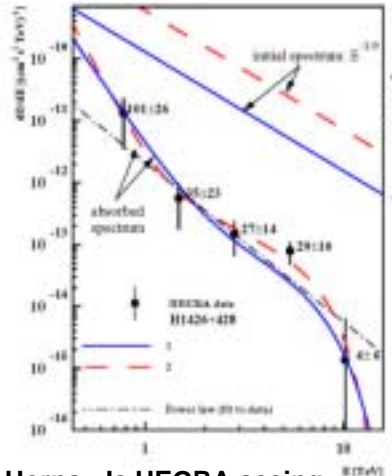
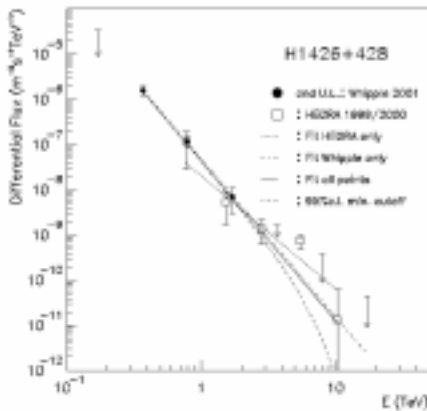
Holder (S07) - VERITAS  
2002 Light Curve  
Krennrich – prel. Spectrum.  
Schroedter (S21) – Multi- $\lambda$



Horns: HEGRA 2002 data Evidence for Spectral Var.

## 5. AGN H1426+428

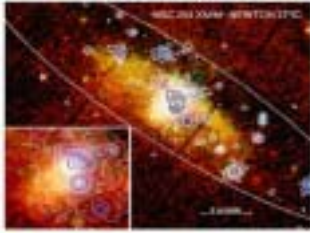
Seen by Whipple, HEGRA, CAT.  
Weak source,  $z=0.129$   
Very soft spectrum,  $\alpha \sim -3.0$



Horns: Is HEGRA seeing  
Pile-up near 5 TeV – absorption ?

Krennrich: VERITAS & HEGRA data

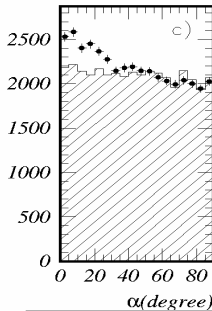
## 5. New Source? NGC 253



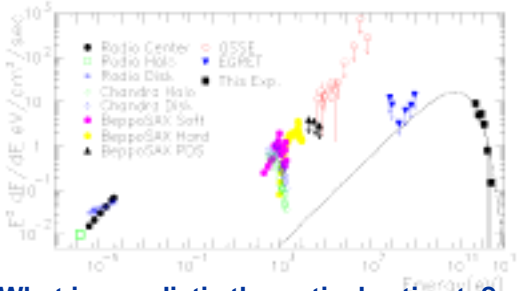
NGC 253 in X-rays, EGRET UL  
Starburst galaxy, near by

Voelk: Enhanced SFR, 0.1-0.3 SN/yr  
Higher CR prod by factor 10-100

Itoh (S26) CANGAROO

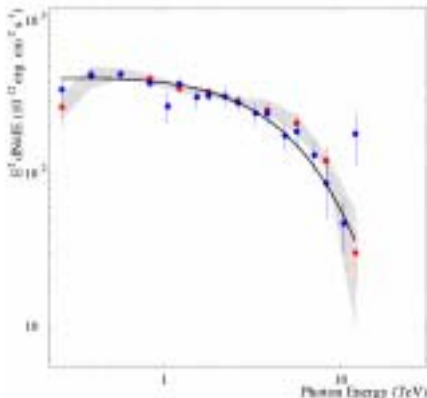


~ 50 hr  
0.5 TeV  
10.2  $\sigma$



Q: What is a realistic theoretical estimate?  
Voelk: M82 weak, HEGRA < 0.02 Crab.

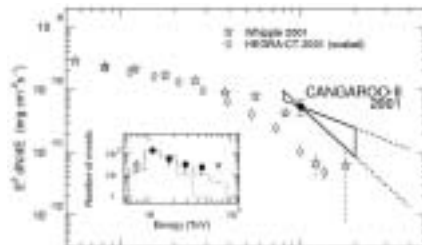
## 6. AGN Spectra Cutoffs



VERITAS data show similar  
Cutoff for Mrk 421/501 ~ 4 TeV

HEGRA did not show new results  
here – get somewhat different  
values for Mrk 421 & 501.

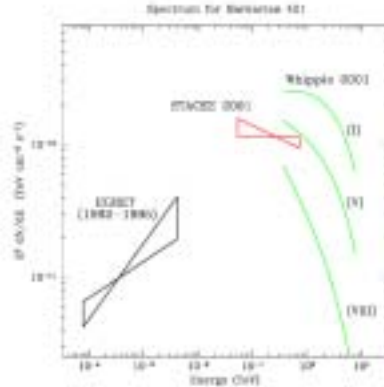
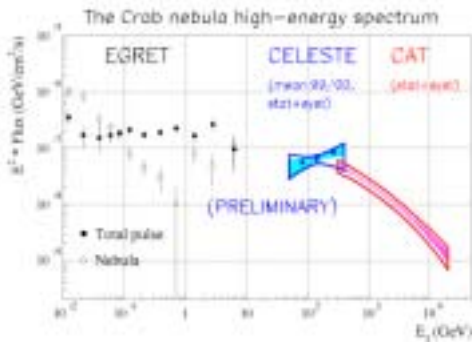
Possibly not intrinsic?



Okumura (S15) – CANGAROO  
Data has 4 $\sigma$  excess above 20 TeV

Dwek (2): Full review of IR measurement & implications.

## 7. Spectral Measurements 50-250 GeV



Piron (S02)  
CELESTE has measured diff.  
spectrum for Crab, Mrk 421.

de Jager discussed the Crab  
pulsar search – getting close!

Hanna (S01)  
STACEE data on Mrk 421  
2001 flare, light curve and  
flux comparison.  
See also Boone (S22).

## Observations - Additional

Additional contributions that I did not have time to discuss:

Edwards	(G07)	VLBI Observations of $\gamma$ -ray sources
Tamagawa	(G04)	Properties of GRBs localized by HETE-2
Sinitsyna	(S14)	Detection of AGN with Shalun
Borisov	(S18)	TeV emission from SNRs and Cyg X-3
Cortina	(S23)	HEGRA CT1 spectrum of Mrk 421
Hayashi	(S24)	CANGAROO obs. of SS433/W50
Kawachi	(S27)	CANGAROO obs. of PSR B1259-63
Kushida	(S28)	Multi- $\lambda$ study of PSR B1706-44
Osone	(S29)	Periodicity studies of blazars
Ueno	(S31)	Non-thermal emission near 30 Dor
Yamamoto	(S33)	Diffuse gamma-rays search with Tibet
Nakase	(S34)	CANGAROO obs. of PKS 2155-304
Hattori	(S35)	CANGAROO search for clusters of galaxies



## Big Themes - Recap

- Source Count increasing steadily.
- S hemisphere will be increasingly important for field.
- Multi- $\lambda$  Approaches are essential.
- Experimentation & Technology march on.
  
- First UnID TeV source.
- VHE Proton acceleration in SNRs still open.
- AGN are complicated beasts, but VHE data may be the most interesting.
- $\gamma$ -ray sky is not bright at VHE (same as UHE).
- There are prospects for exotica  
e.g. Bergstrom (10) talk on dark matter.

## Summary – Future

With the advent of HESS, MAGIC, CANGAROO, (VERITAS) – we are entering a new era for observations. Field has always been observationally driven (lack of sources!), but now telescopes will provide lots of results for theorists.

VHE astrophysics is changing, and it will continue to change. Sources we would like to study include:

- GRBs (SWIFT era)
- Diffuse emission (Galactic, Isotropic)
- Something completely new!

## Summary – Future

**Experimentally, great progress has been made – but, it has taken 10 years to reach the Major Atm. Cherekov Detector!**

**People are looking ahead:**

- **High altitude arrays (5@5, etc.)**
- **High precision optical systems (see T16)**
- **Advanced technologies (see T05)**
- **Wide FOV instruments – several groups across the world (e.g. Kifune)**

## Comments

**Last year – we had hoped to have this meeting.**

**Coincide with the “retirement” of Tadashi Kifune.**

**The field of VHE g-ray Astrophysics owes a great deal to Tadashi –**

**One of the pioneers of the field, of the AC technique, and of observations in the Southern Hemisphere.**

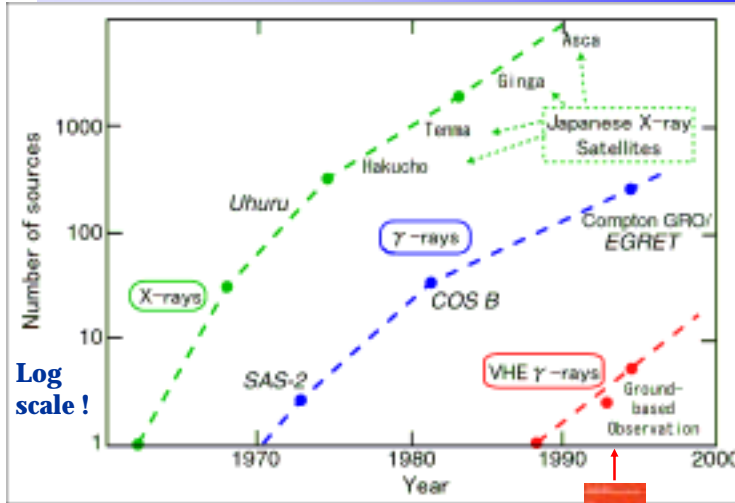
## Kifune Pictures



## Kifune-san “Retirement”



# “Kifune Plot”



Tokyo



Kashiwa

# Workshop Sub-Title IIO

