

# 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

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

# 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

## The Universe viewed in Gamma-Rays

- Univ. Tokyo Workshop 2002 -

25-28 Sept. 2002      Kashiwa, Chiba, Japan

(Towards a Major Atmospheric  
Cherenkov Detector VII)

<http://icrhp9.icrr.u-tokyo.ac.jp>

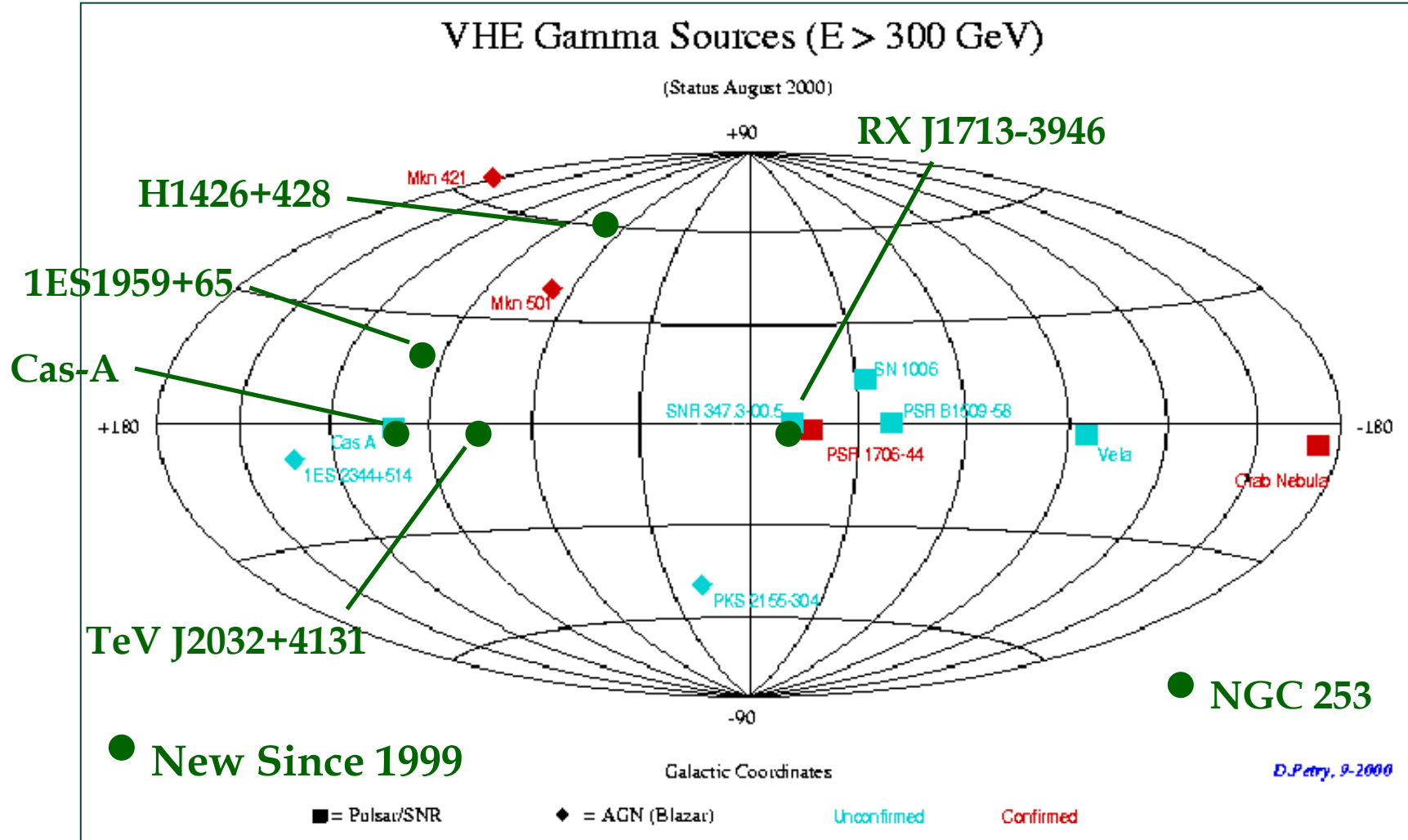
**Not really this !**

# Big Themes

- **Source Count increasing steadily.**



# VHE Sky Map



# Source List

## 1990-1999

## 1999-2002

**Solid (6)**

**Crab  
Mrk 421  
Mrk 501  
PSR 1706**

**H1426  
1ES1959**

**Likely (6)**

**Vela  
1ES2344  
SN1006**

**Cas-A  
RXJ 1713  
TeV J2032**

**??**

**PKS 2155  
Cen X-3  
3C 66A**

**NGC 253**

# 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.

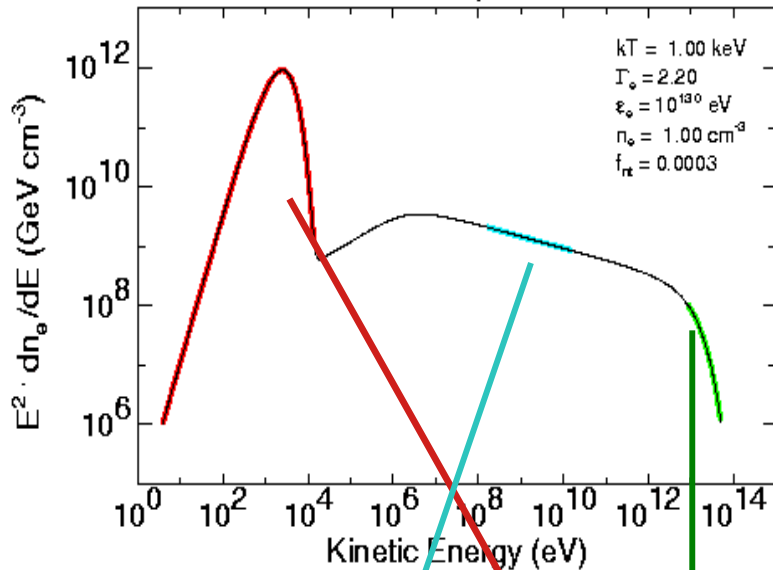
**AGN: Coppi (07), Mukherjee (08):**

- 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.

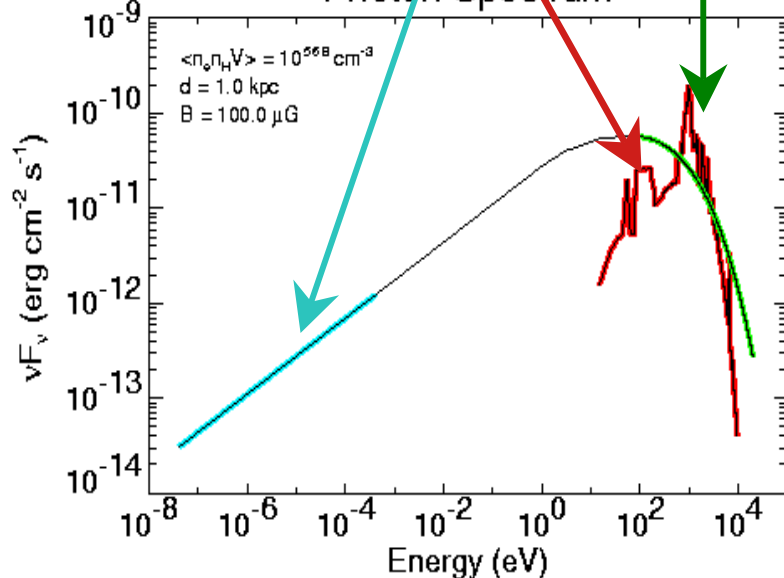
**Good time for X-ray work:**

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

## Electron Spectrum



## Photon Spectrum

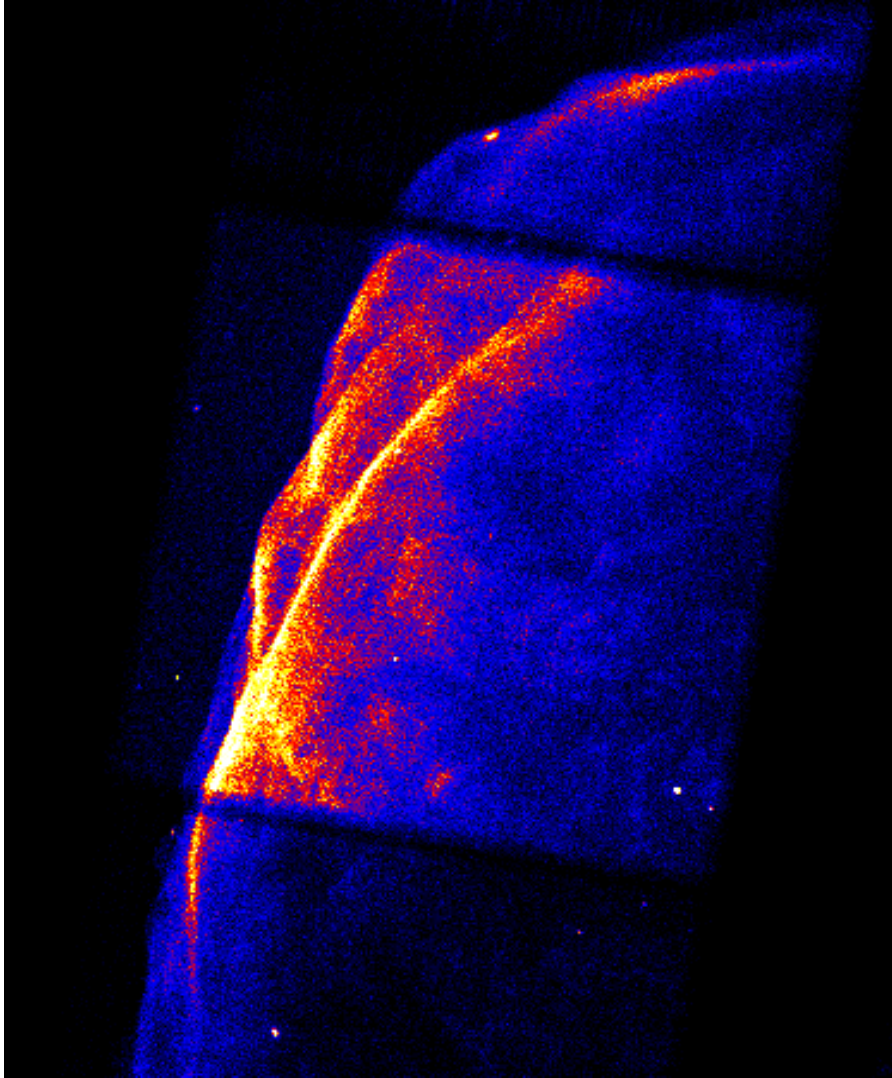


- Thermal electrons produce line-dominated x-ray spectrum with bremsstrahlung continuum
- nonthermal electrons produce synchrotron radiation over broad energy range
- high energy tail of nonthermal electrons yields x-ray synchrotron radiation
- nonthermal X-rays indicate presence of synchrotron nebula or high energy particles accelerated in shock
  - either may be indicative of potential  $\gamma$ -ray emission

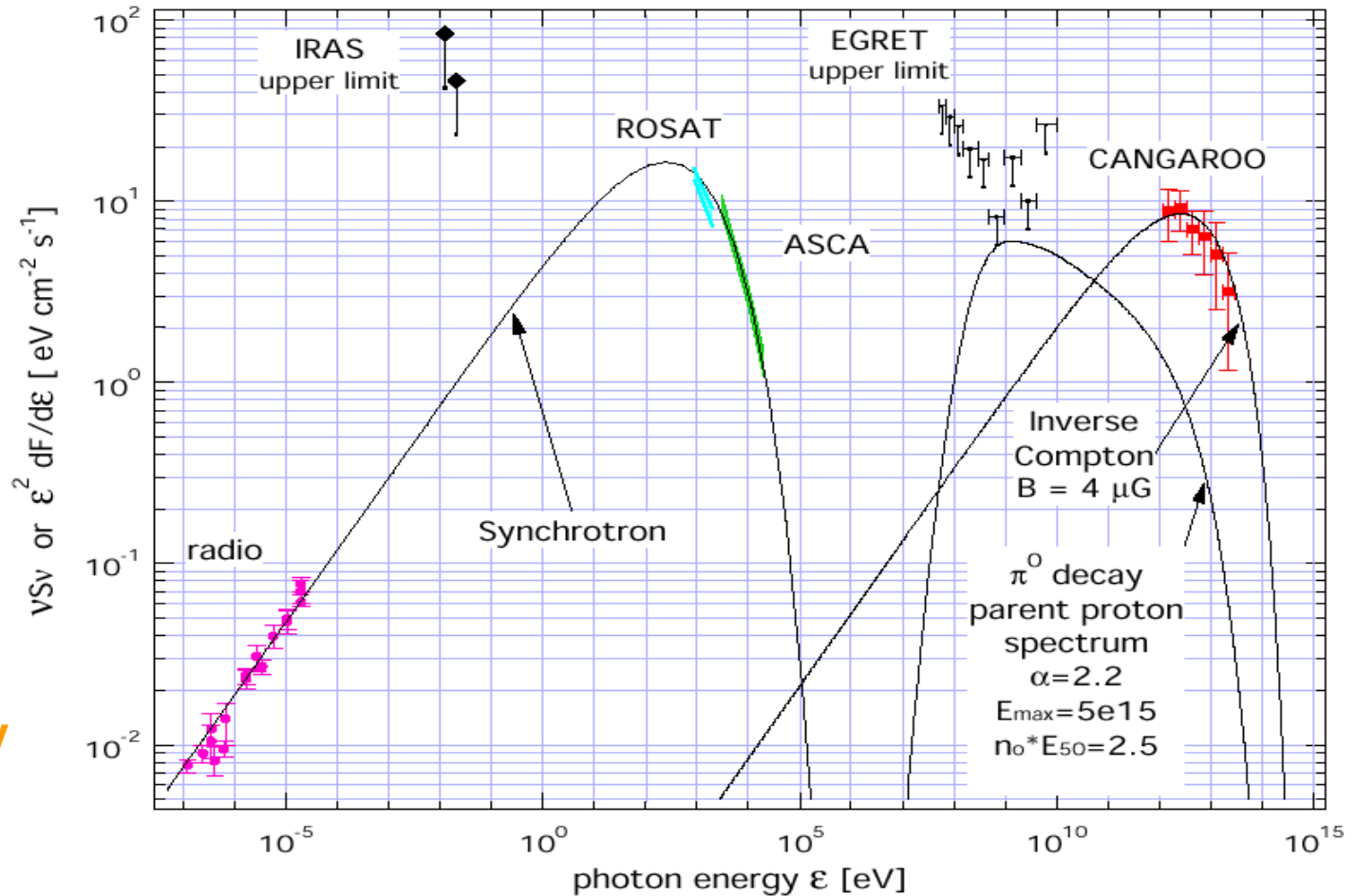


## SN 1006

- 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  $\mu$ G**  
**E<sub>max</sub> ~ 50 TeV**

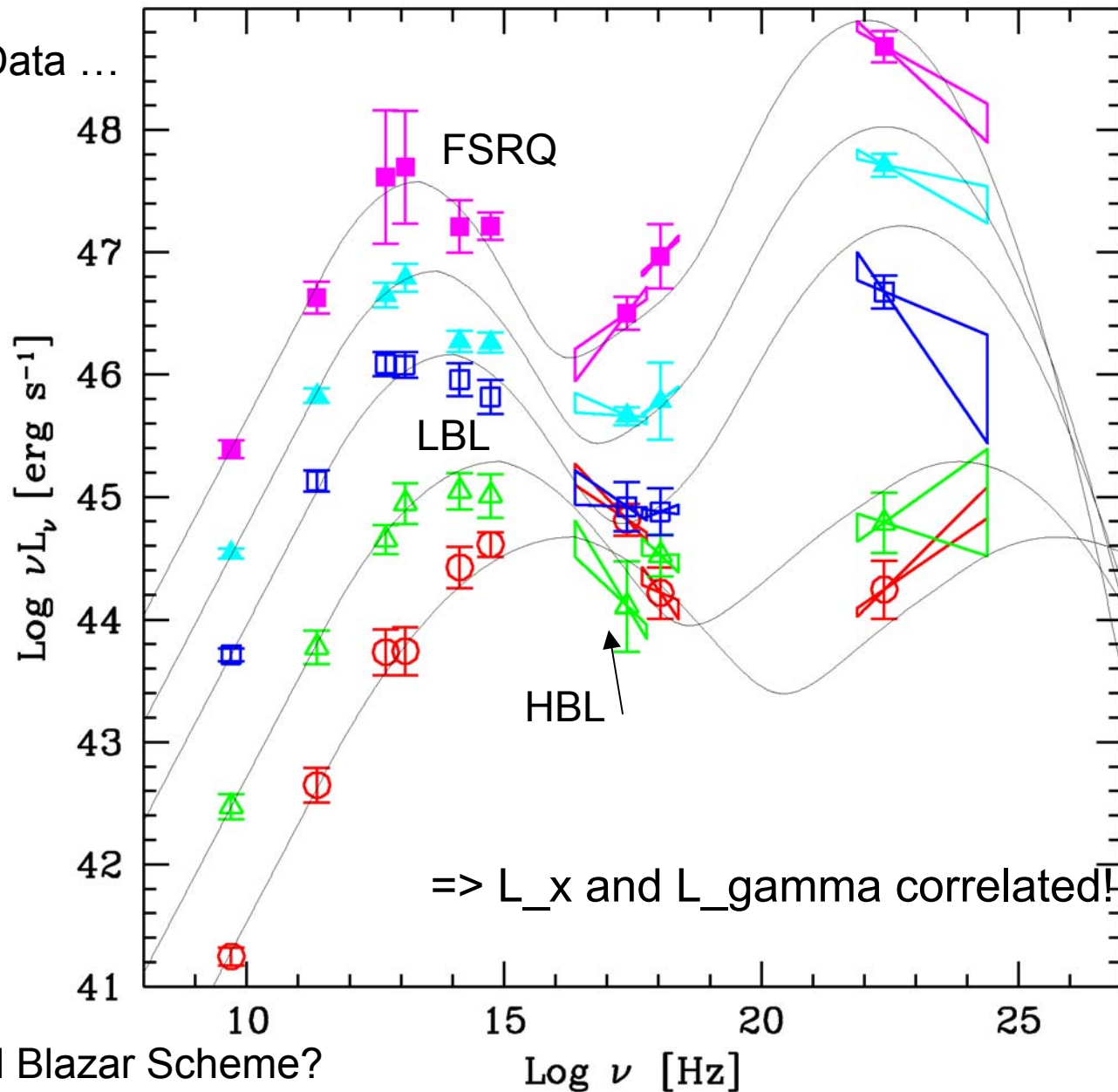


**IC Modeling works!**

*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)

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?

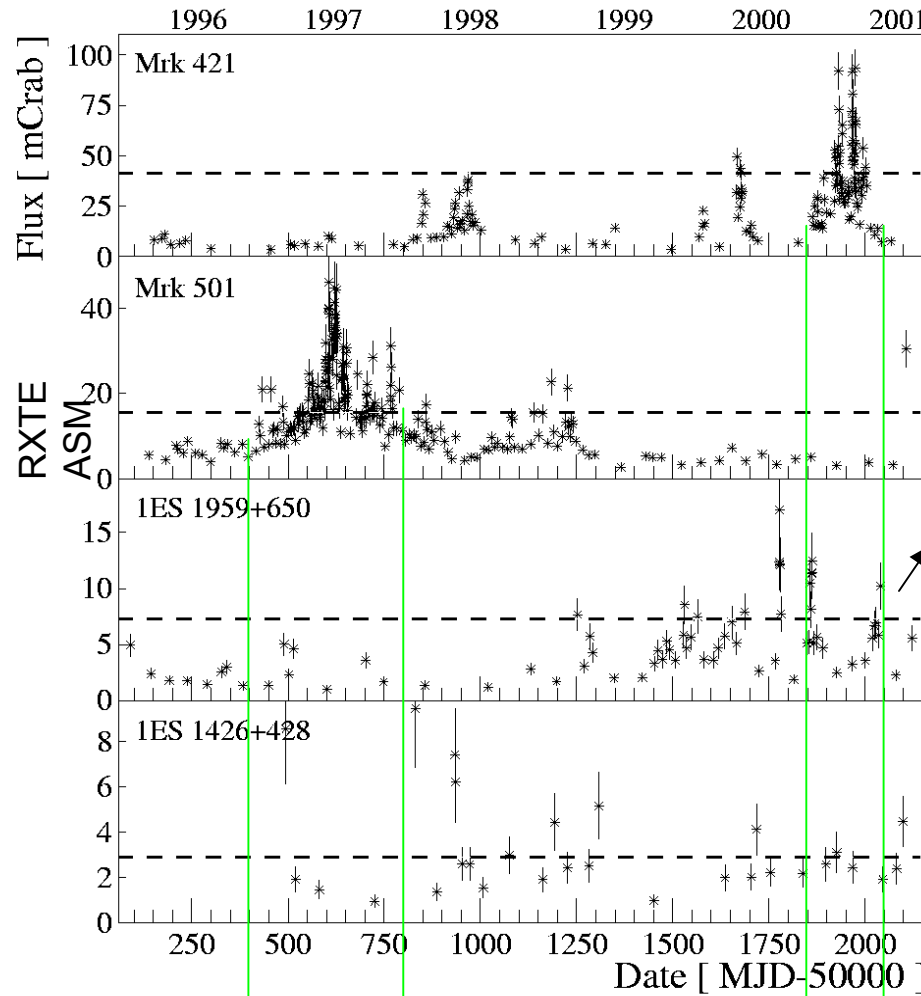
What are seed photons for Compton upscattering??

- 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- distribution!

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

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



vs.

May-June 2002

1959 flares!  
(RXTE TOO)

Problem: In "standard model,"  
single blob would be at  
 $R : \delta^2 c \Delta t : 5 \times 10^{19} \delta_{25}^2 \Delta t_{\text{month}} \text{ cm!}$   
Unlikely....

$\Delta t$ : months??

# 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  $\rightarrow$  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)

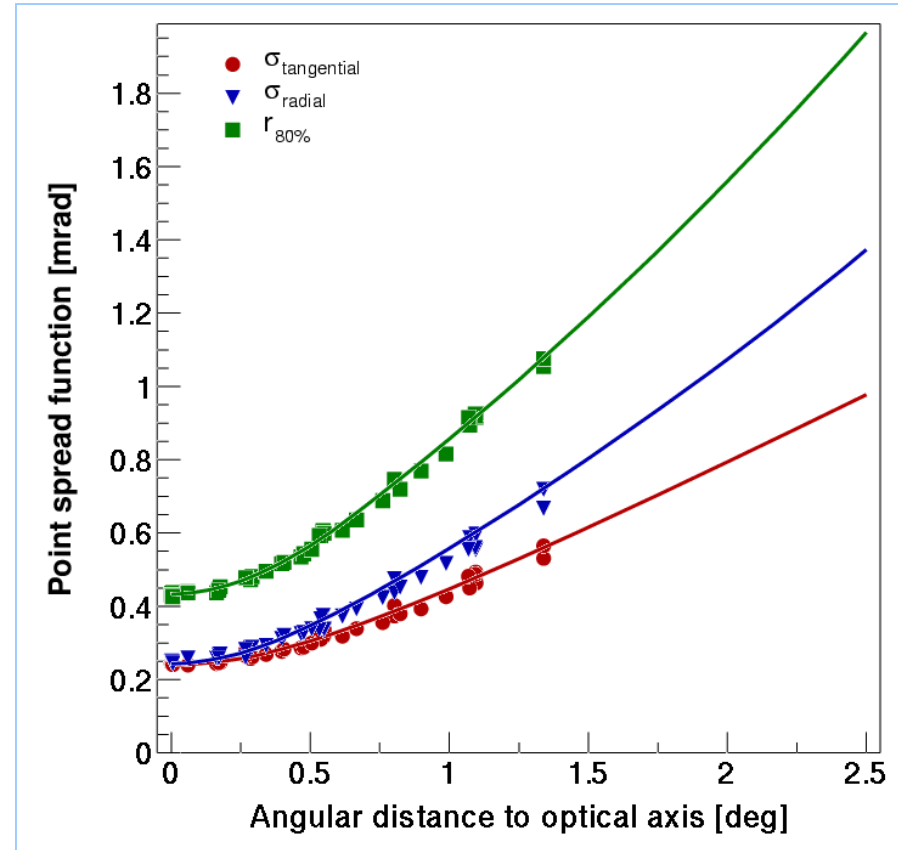




# New Technology is Here: Mirrors



Al Mirrors (MAGIC)



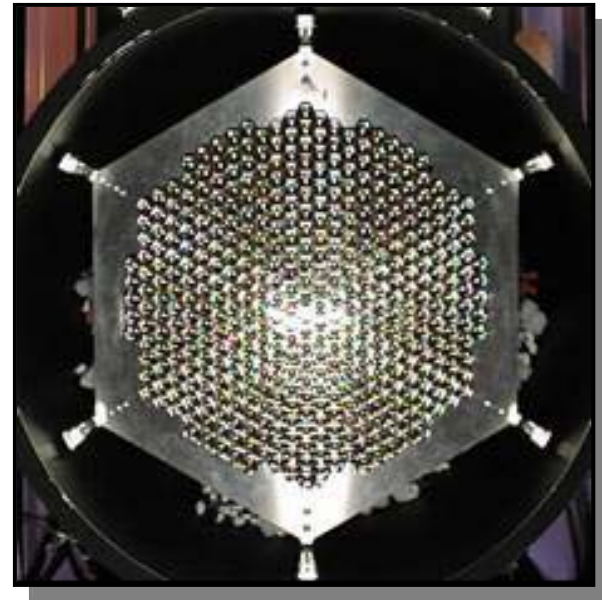
PSF After Alignment (HESS)

# New Technology is Here: Cameras



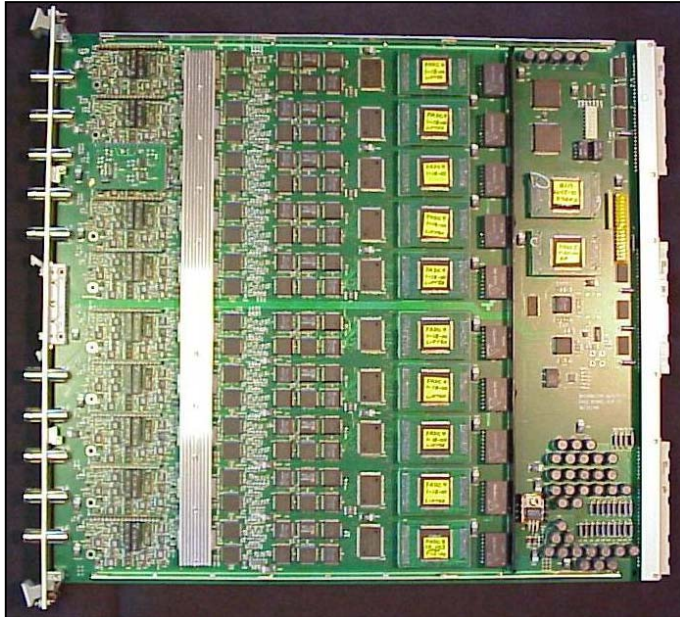
Modular Construction (HESS)

Single, lightweight (CANGAROO)



# New Technology is Here: Electronics

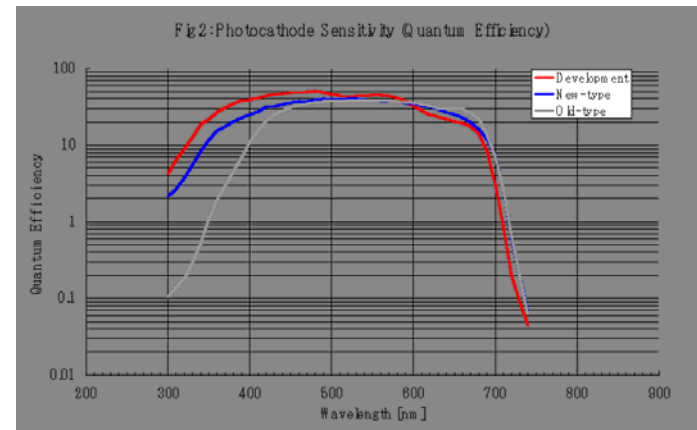
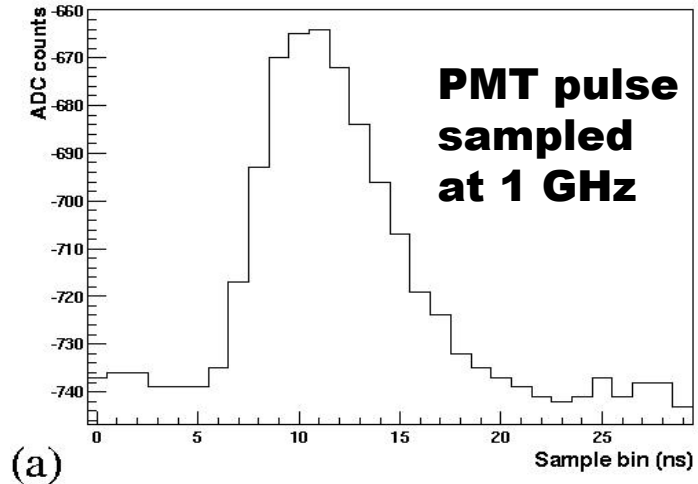
## 500 MHz FADCs (VERITAS)



Analog Fiber Signal  
Transmission (MAGIC)

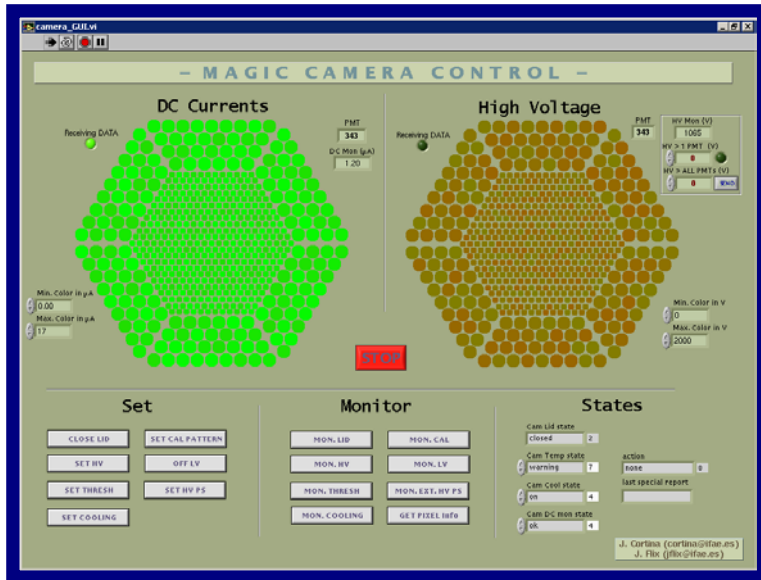
1 ns rise time  
Dyn range of 60 dB

## Fast Sampling (HESS)

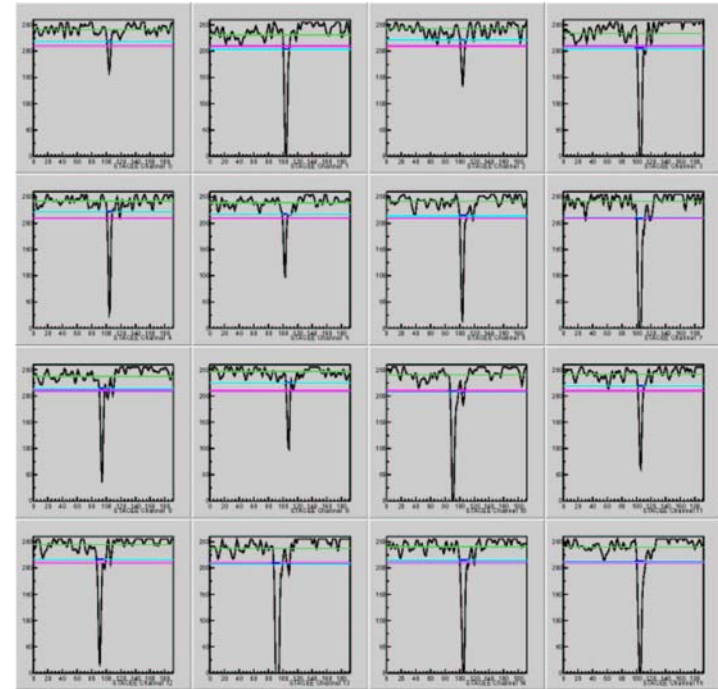


Hi QE HPD ... still 2 yrs off?

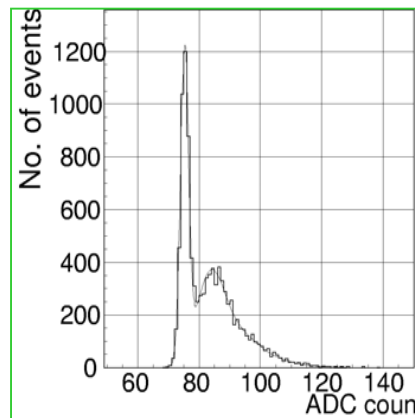
# Posters - Instrumentation



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

## The Universe viewed in Gamma-Rays

- Univ. Tokyo Workshop 2002 -

25-28 Sept. 2002      Kashiwa, Chiba, Japan

(Reaching a Major Atmospheric  
Cherenkov Detector)

<http://icrhp9.icrr.u-tokyo.ac.jp>

**Not this either !**

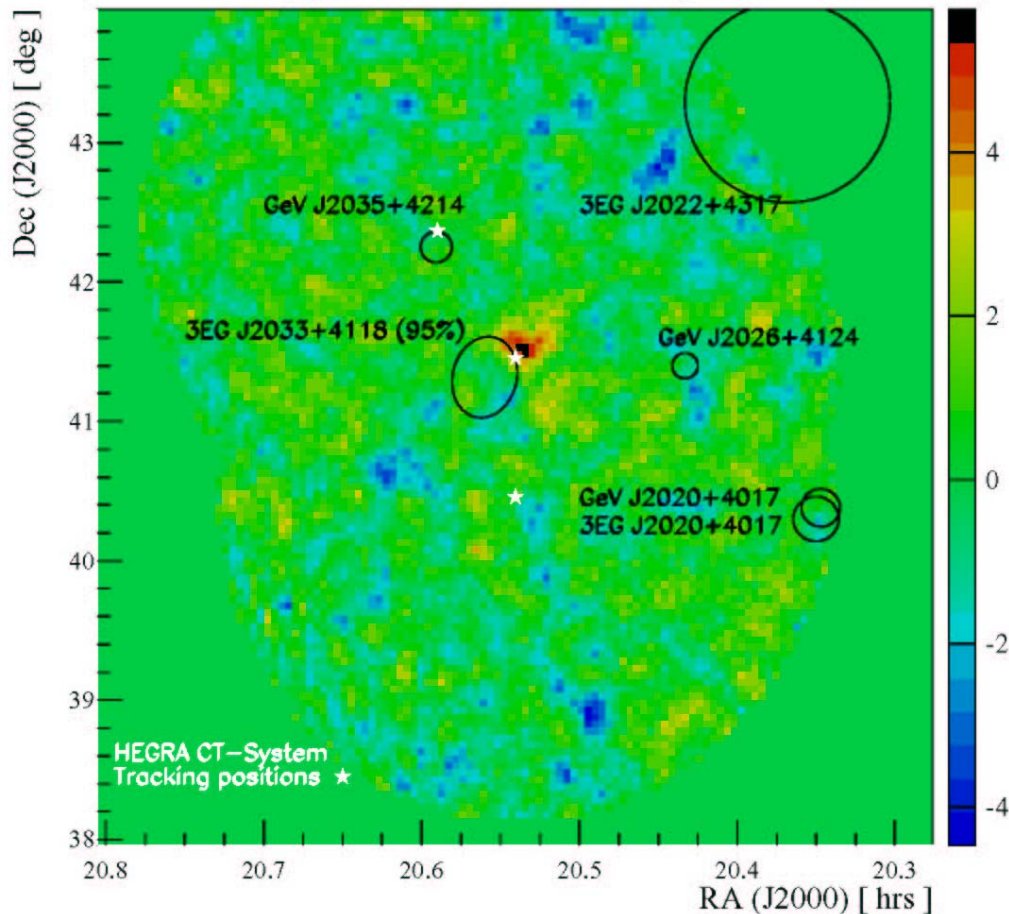
# Selected New Results

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)

Cygnus Field: HEGRA CT-System



- $4.6 \sigma$  (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

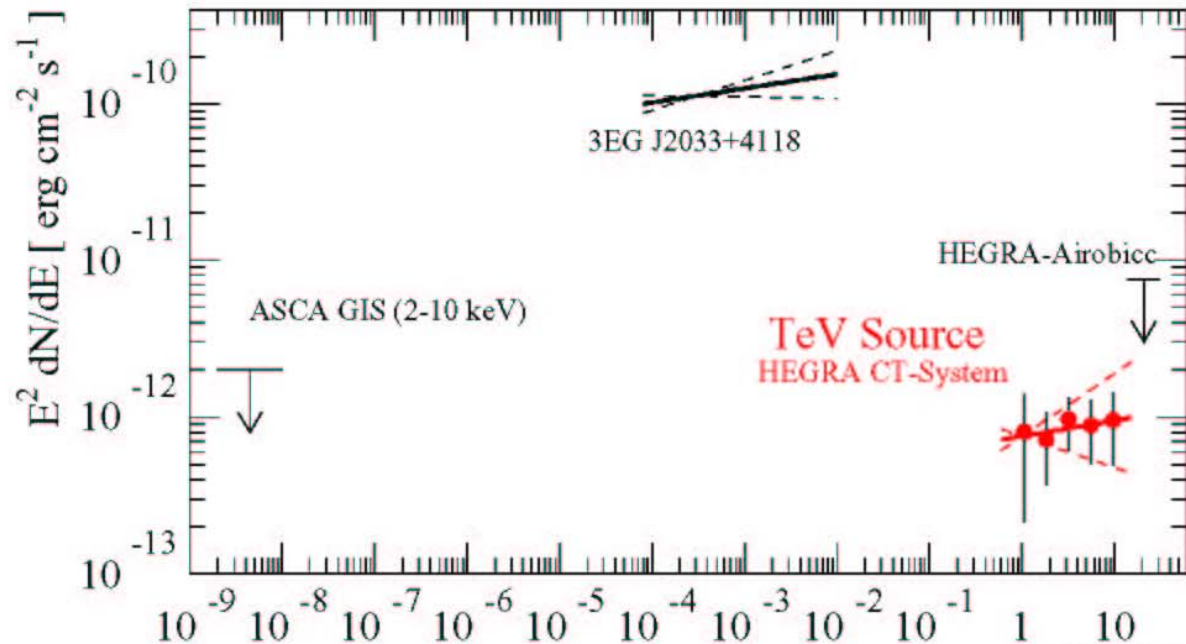
Spectrum/Flux  $\theta < 0.224^\circ$ ,  $\bar{w} < 1.1$ ,  $n_{\text{tel}} \geq 3$ : (for other spectral cuts see Aharonian et al. 1999 A&A, 349, 11)

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

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

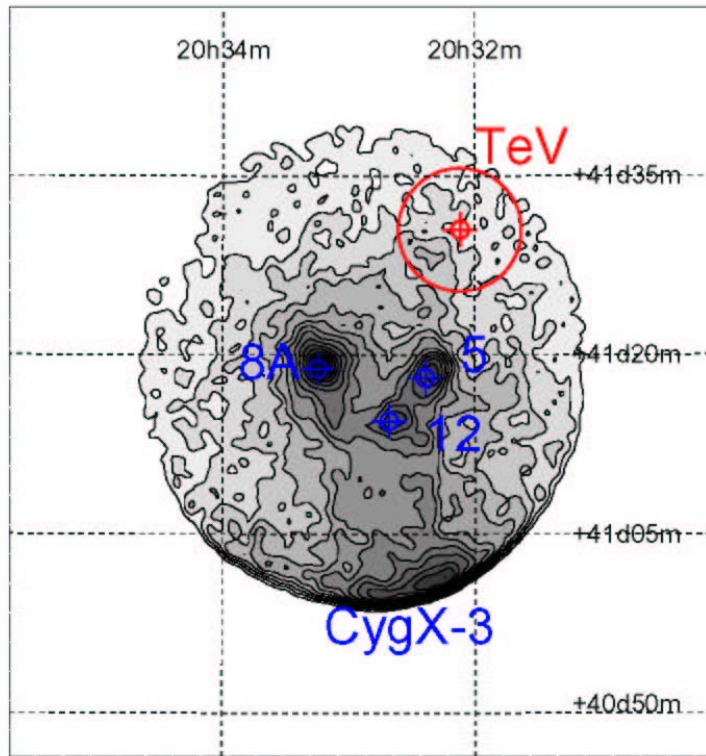
$$\gamma = -1.9 (\pm 0.3_{\text{stat}} \pm 0.3_{\text{sys}})$$

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



- **Detection and Spectrum Confirmed in 2002 Data (preliminary)**

# 1. TeV J2032+4131



ASCA GIS (0.7-3 keV)

Most consistent with  
Cyg OB2 complex, but

**No apparent counterpart at TeV  
position.**

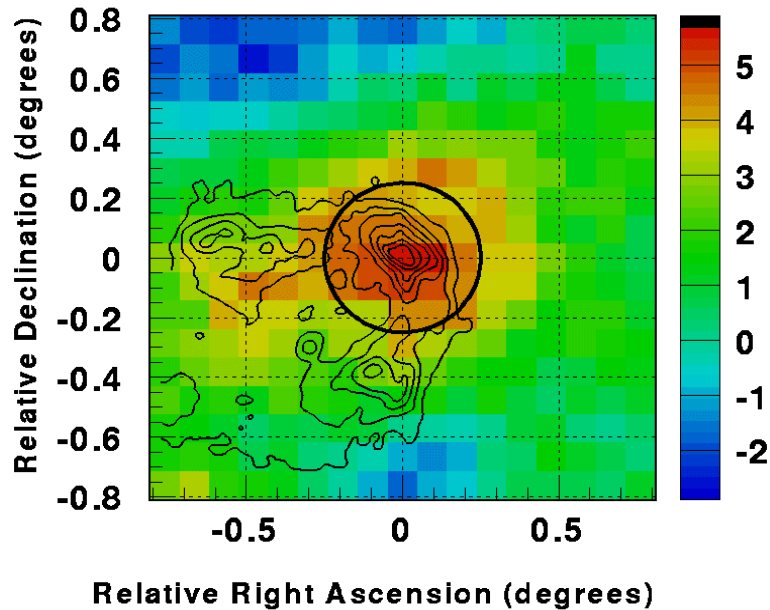
What is this object?

... we don't know.

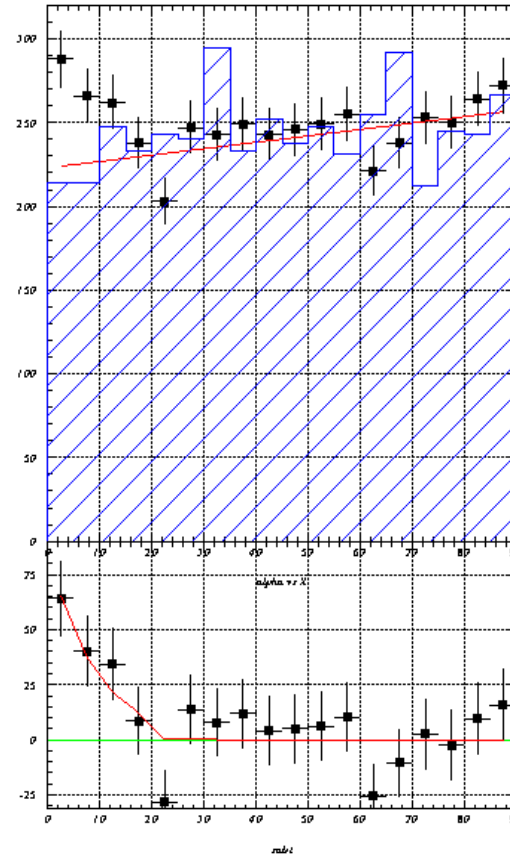
**Catalog of UnID TeV Sources is started.**

## 2. RX J1713-3946 Mystery

Tanimori (02)  
Kawachi (S06)



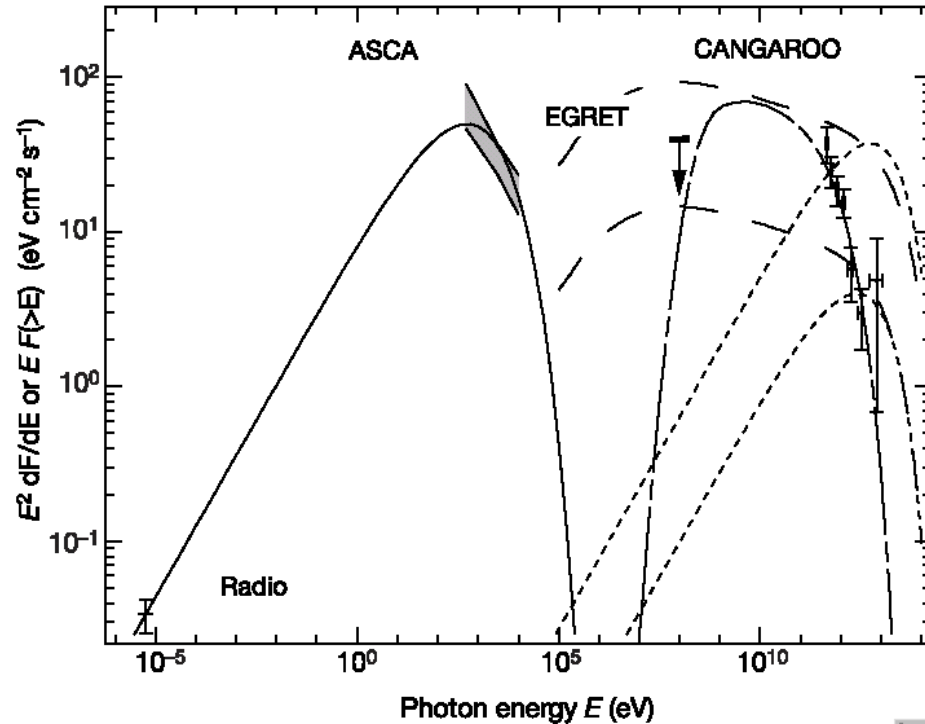
TeV-Gamma  
3.8m Tele.



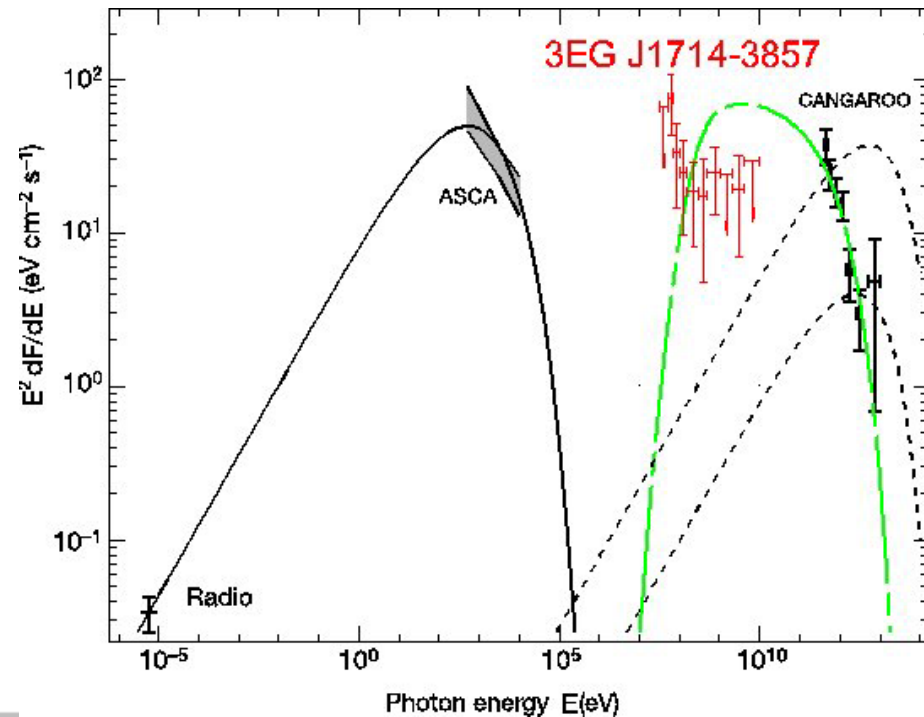
7m Tele. 1999 (16hours))

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

## 2. Mystery I

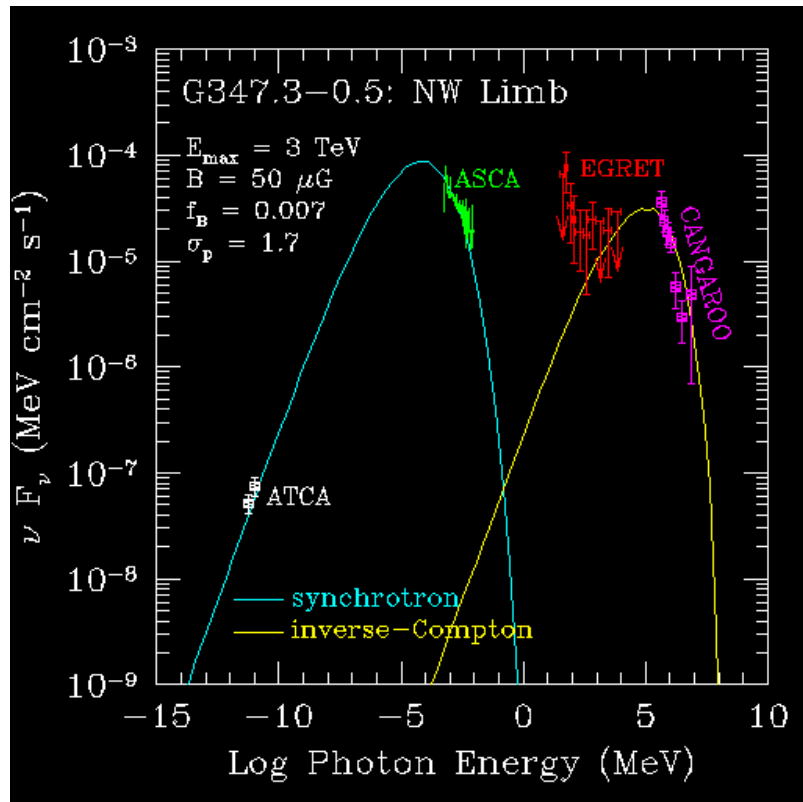


**Enomoto et al 2002**  
**Hard to explain with IC.**



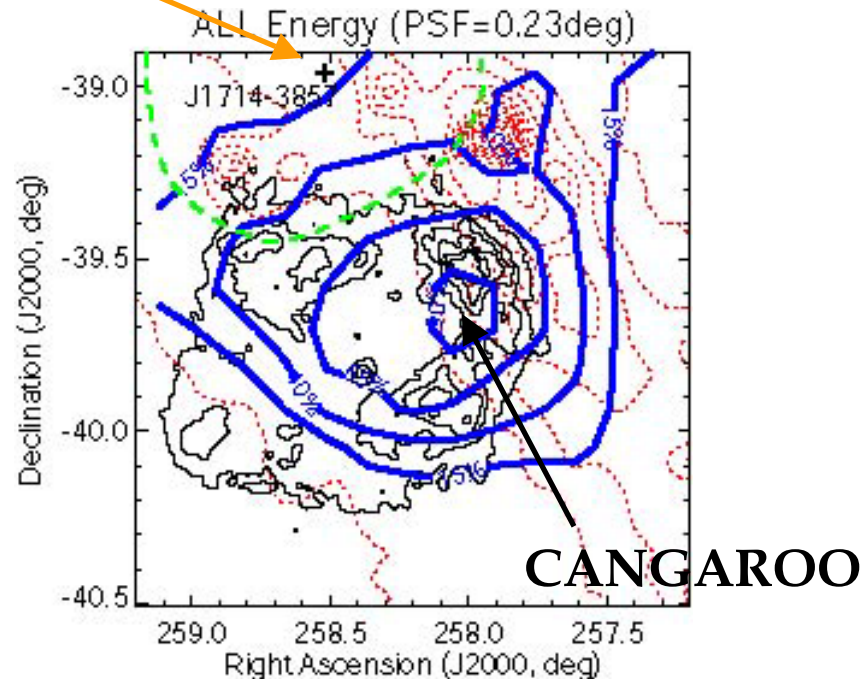
**Reimer & Pohl 2002**  
**Proton fit inconsistent with actual EGRET limit.**

## 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

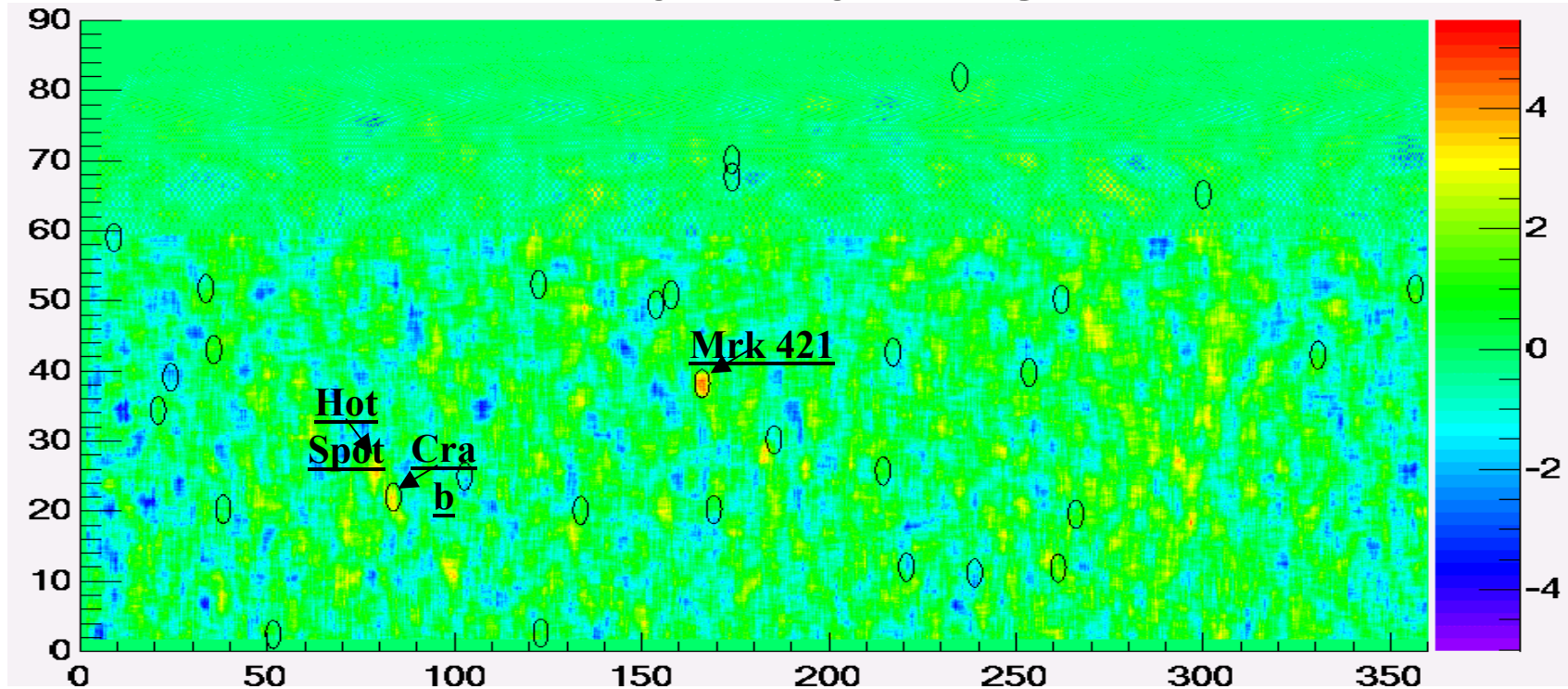
- RX J1713 picture is not clear – one cannot claim from this source that there is evidence for VHE proton acceleration.
- In general, SNRs will have both an  $e^-$  – IC component and a proton –  $\pi^0$  component, but separating the two is challenging.  
“Smoking Gun” is not so smoking!

**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



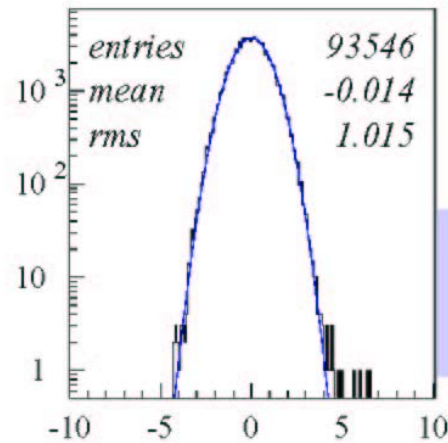
$E \sim 4 \text{ TeV}$

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)

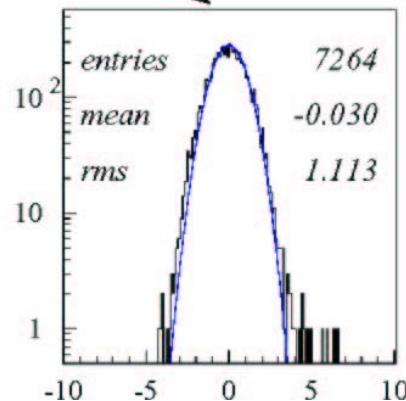
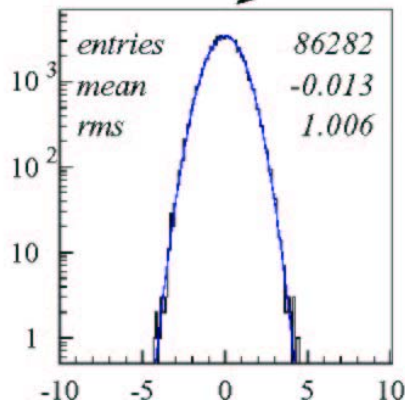


**Puelhohofer (S09)**  
**Survey using archival HEGRA**

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

less than 50 hrs

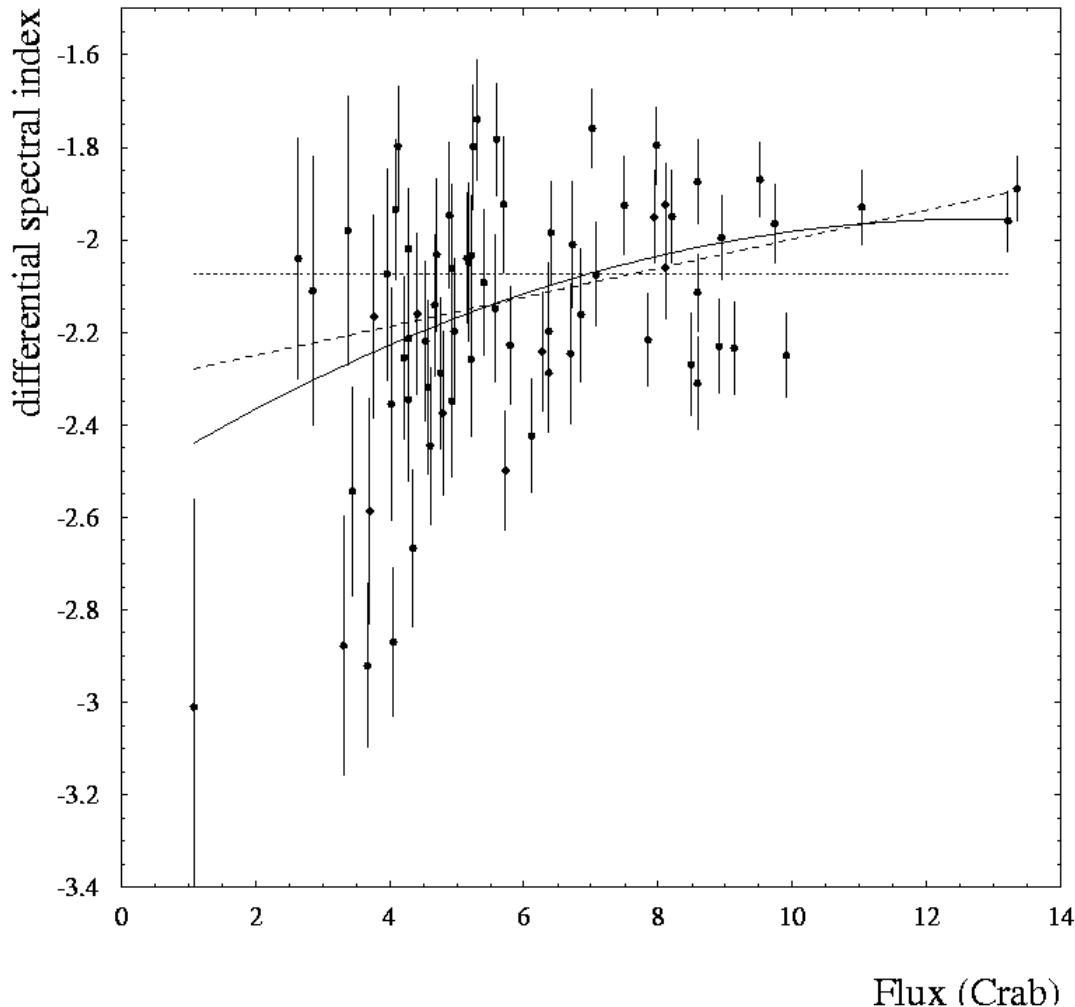
more than 50 hrs



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



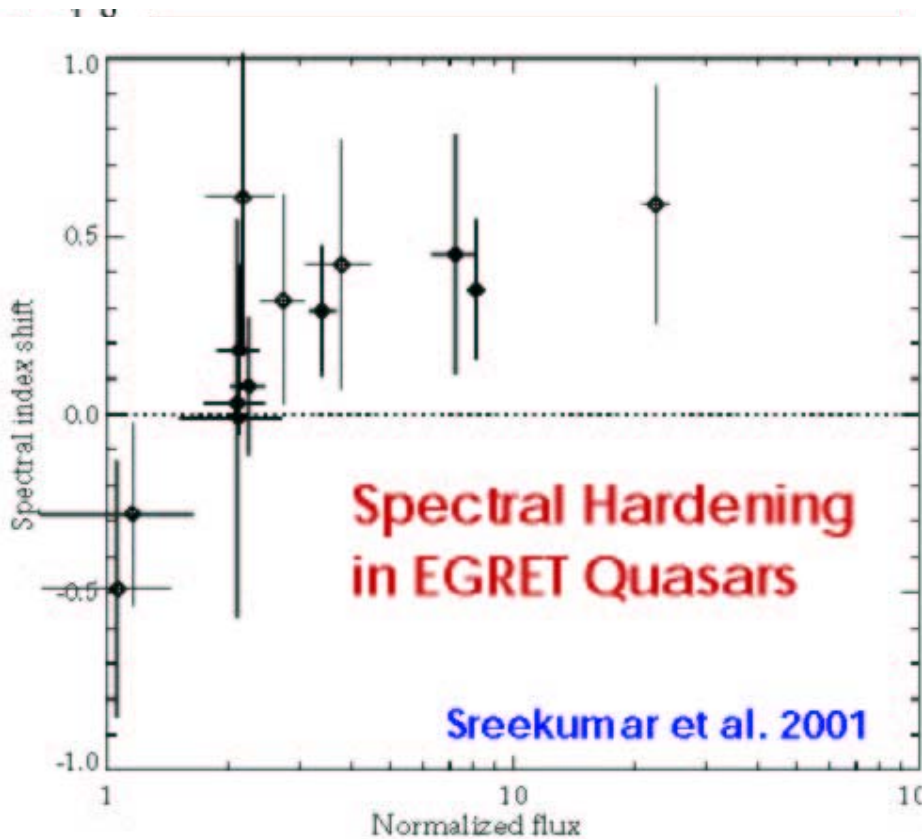
# 4. Spectral Variability of AGN



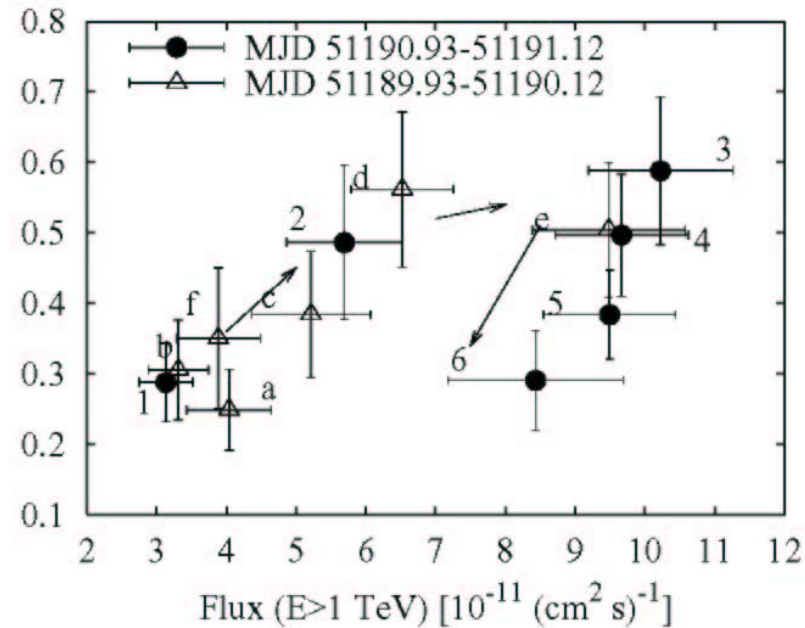
**General trend is shown on short (30 min) time scales as well, but with lots of scatter.**

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

# 4. Spectral Variability of AGN



**Mukherjee:  
Evidence with EGRET.**

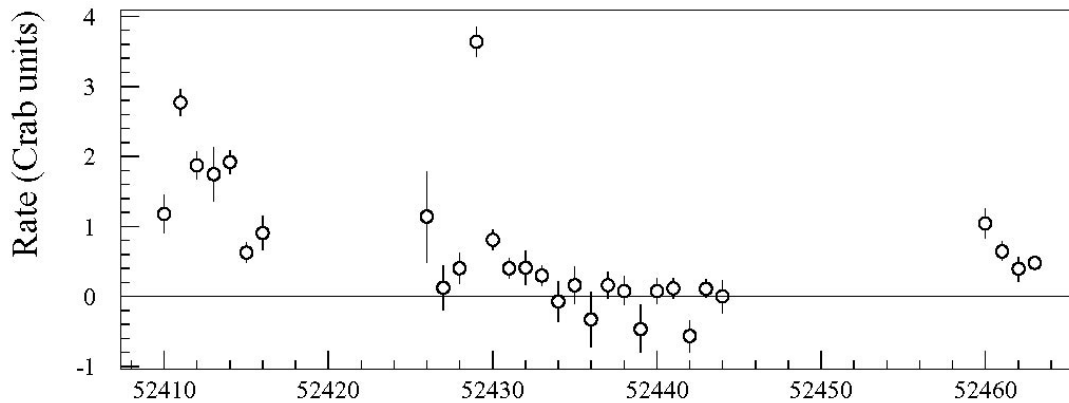


**Diurnal variation –  
"hysteresis" effect.**

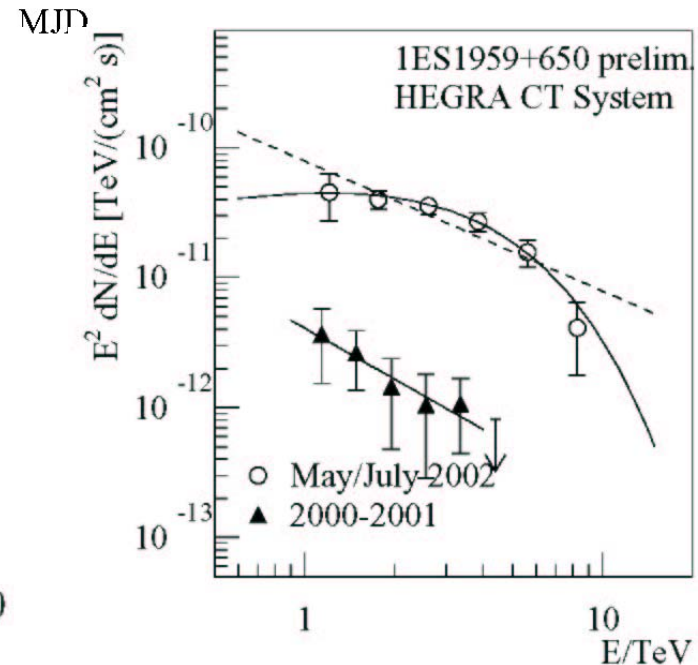
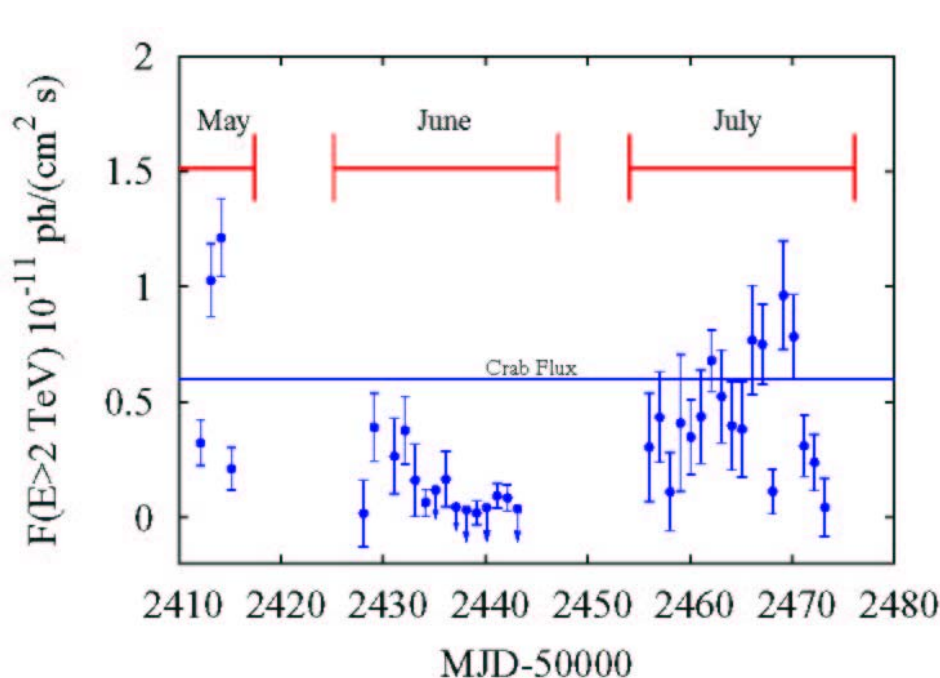
**Implications were discussed  
by Mukherjee, Coppi.**

**Shift of synch peak to higher E.**

# 5. New AGN 1ES1959+650



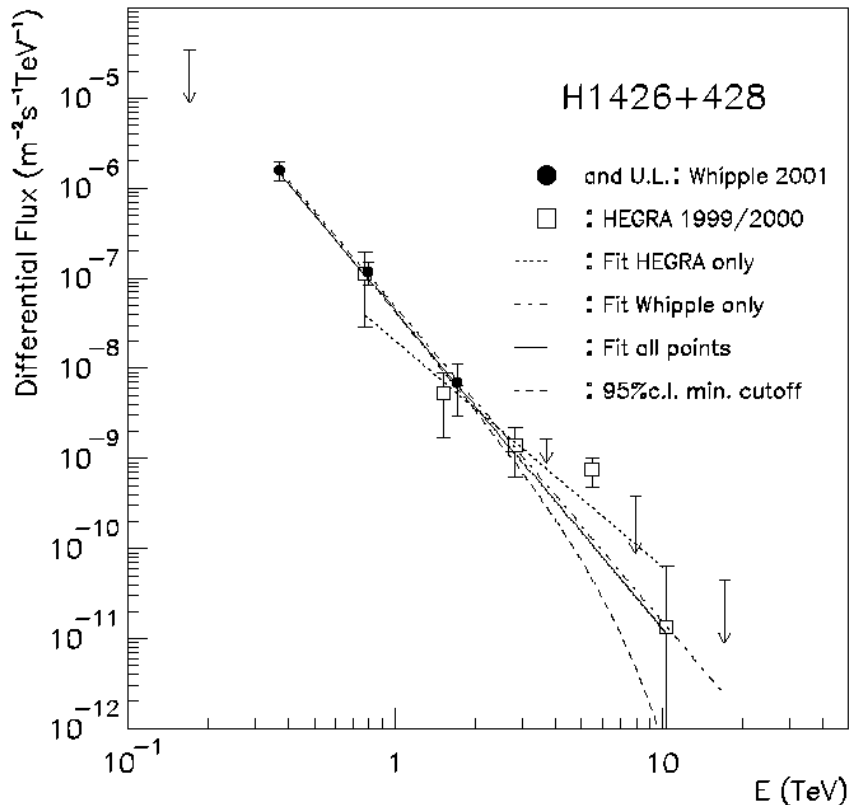
Holder (S07) - VERITAS  
 2002 Light Curve  
 Krennrich – prel. Spectrum.  
 Schroedter (S21) – Multi- $\lambda$



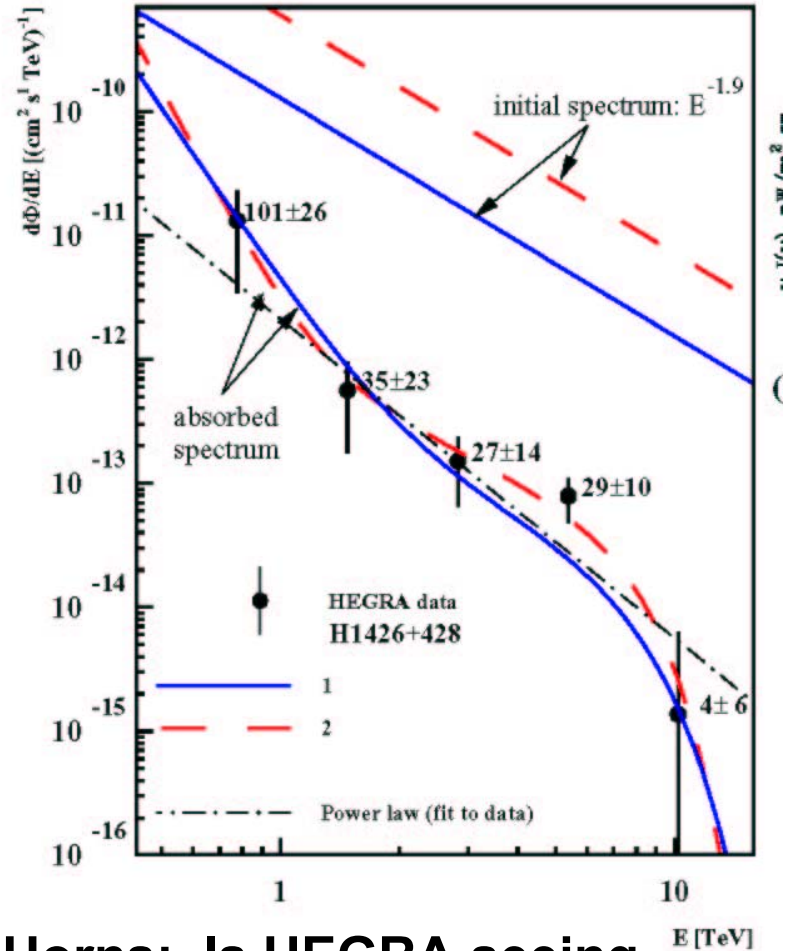
**Horns: HEGRA 2002 data Evidence for Spectral Var.**

# 5. AGN H1426+428

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

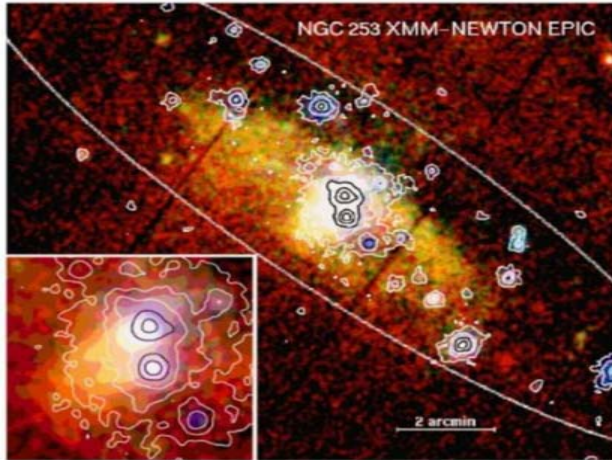


Krennrich: VERITAS & HEGRA data



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

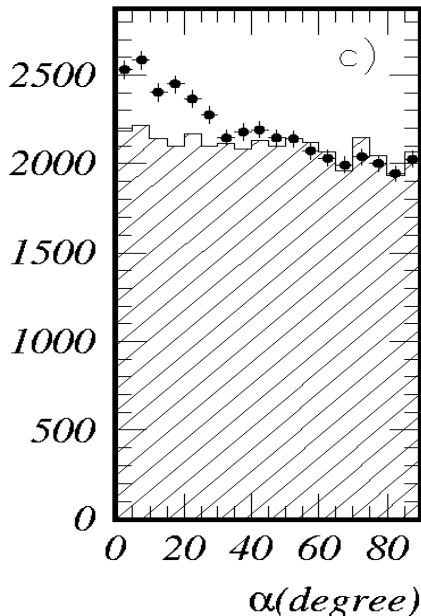
# 5. New Source? NGC 253



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

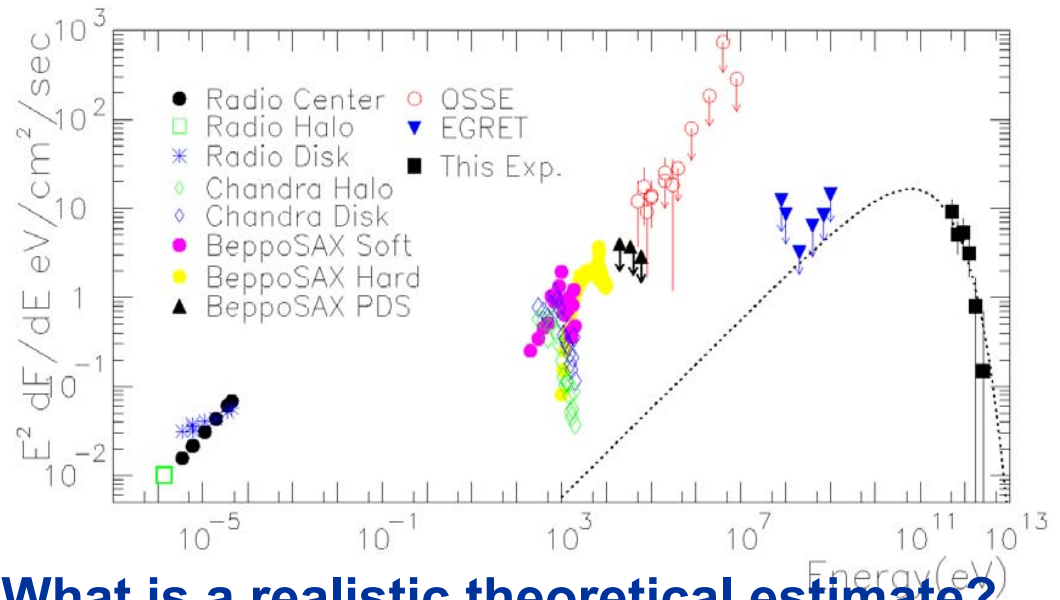
Voelk: Enhanced SFR, 0.1-0.3 SN/yr  
Higher CR prod by factor 10-100

Itoh (S26) CANGAROO



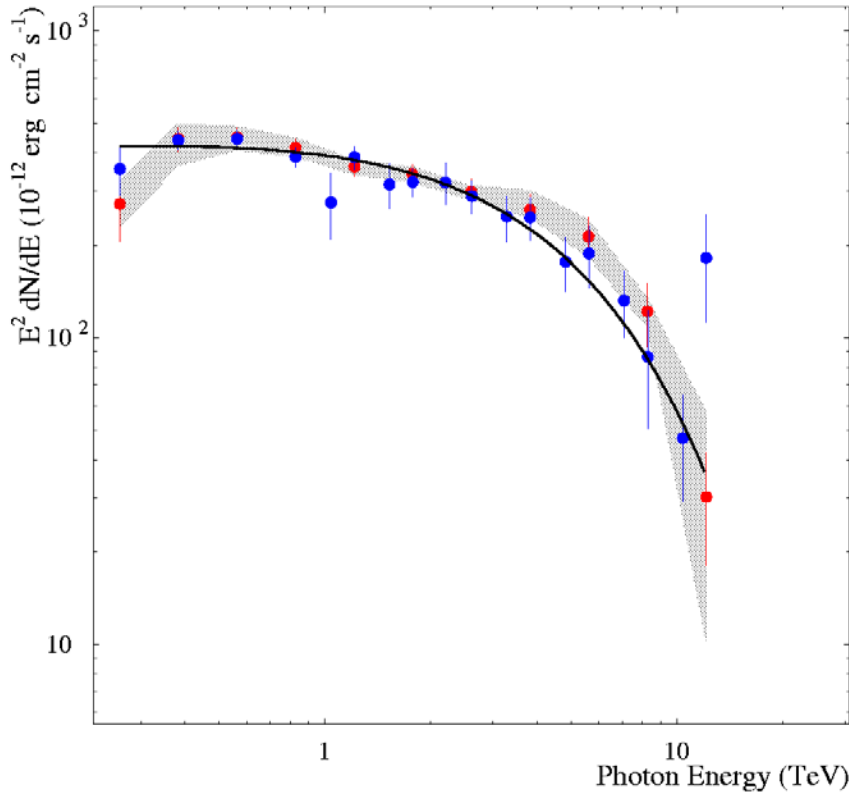
~ 50 hr  
0.5 TeV

10.2  $\sigma$



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

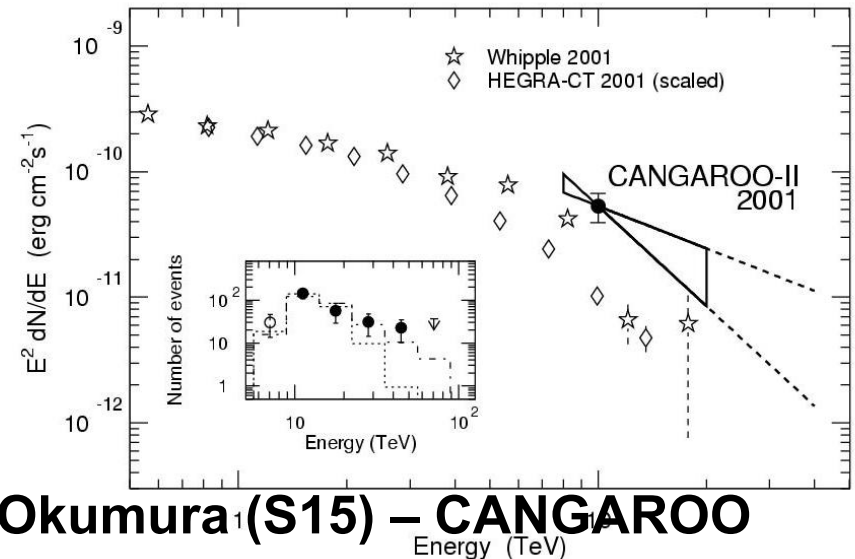
# 6. AGN Spectra Cutoffs



**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.**

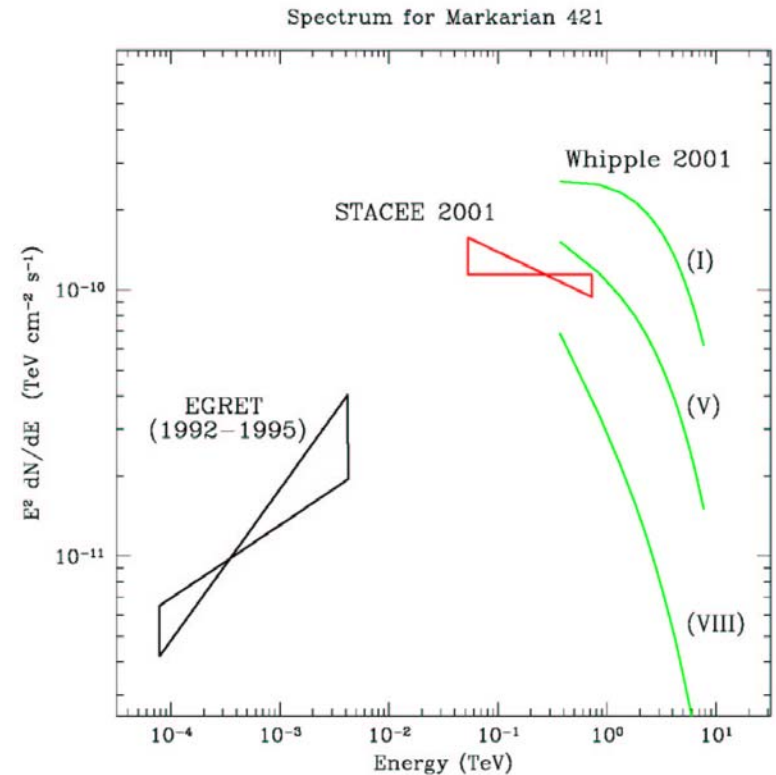
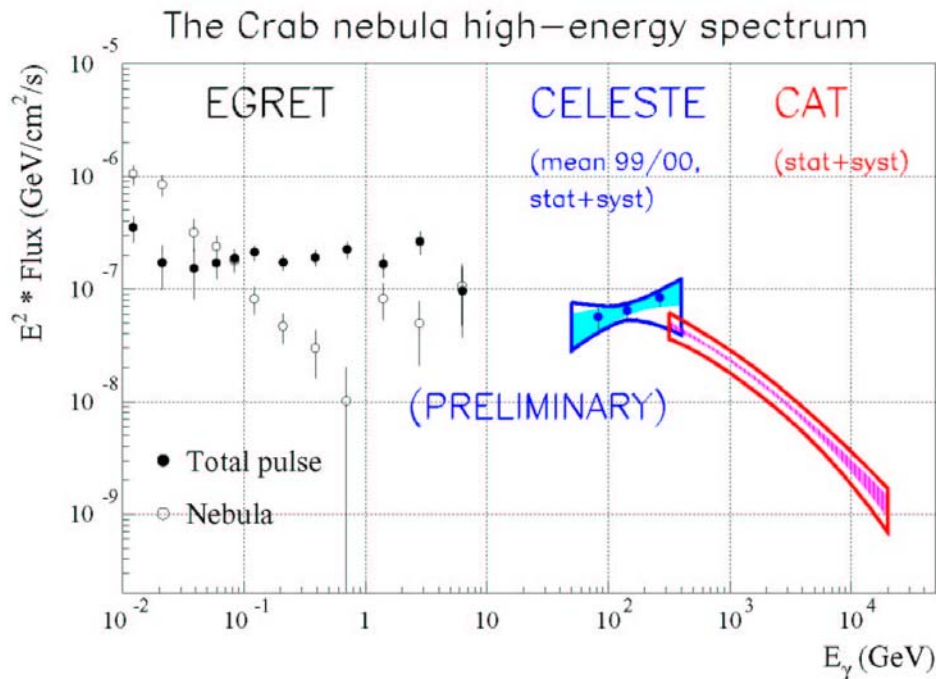
**Possibly not intrinsic?**



**Okumura<sub>1</sub>(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:**

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



# 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.**

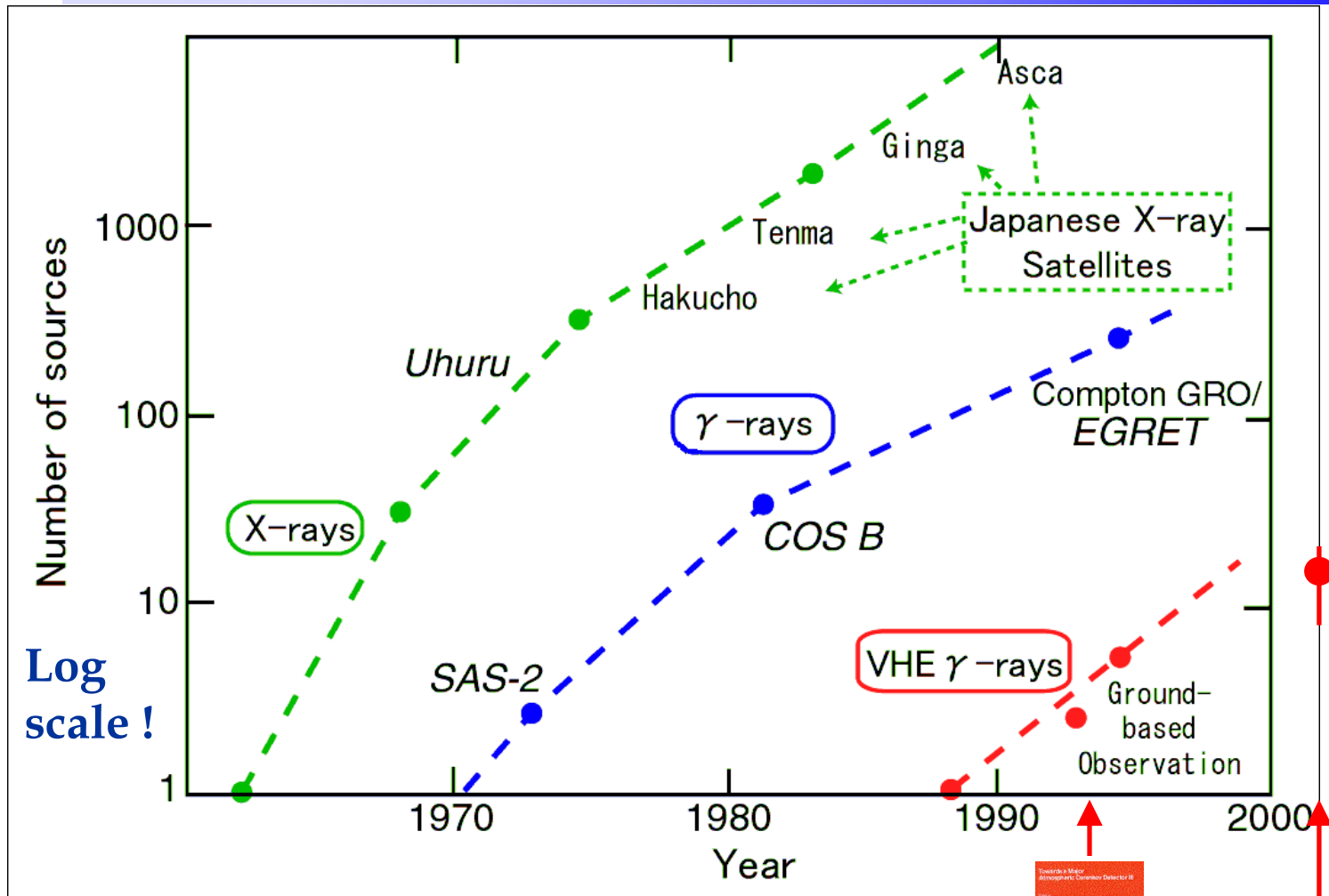
# Kifune Pictures



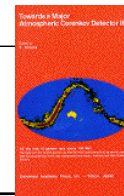
# Kifune-san “Retirement”



# “Kifune Plot”



Tokyo



Kashiwa

# Workshop Sub-Title IIO

## The Universe viewed in Gamma-Rays

- Univ. Tokyo Workshop 2002 -

25-28 Sept. 2002

Kashiwa, Chiba, Japan

**Thank you Tadashi !!**

<http://icrhp9.icrr.u-tokyo.ac.jp>