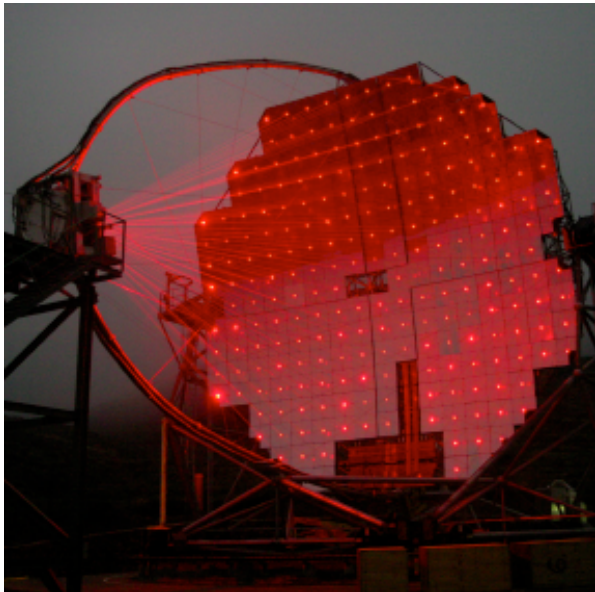


# *The MAGIC observatory: Project Review (MPI 2005)*

**David Paneque on behalf of the MPI MAGIC group**

*Winter 2003/2004*



*(Courtesy of R. Wagner)  
Astronomical picture of  
the day (16/10/04)*

## *OUTLINE*

- 1- IACTs for doing gamma-ray astronomy**
- 2- The MAGIC project: what is it ? Who are we?**
- 3- Status of MAGIC I**
- 4- Construction of MAGIC II**
- 5 - Conclusions**

**Imaging Atmospheric Cherenkov Telescopes  
(*IACT*) as ground-based instruments for making  
gamma-ray astronomy**

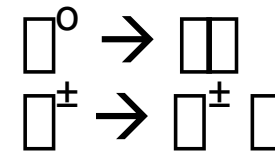
# 1.1 - Introduction to IACTs and Gamma-Ray astronomy

➤ **Imaging Atmospheric Cherenkov Telescopes (IACTs) are instruments for performing gamma-ray astronomy**

***IACTs aim to provide experimental basis for the understanding of the *Non-thermal Universe****

Acceleration, propagation and interaction of high energy particles can produce gamma rays

Hadronic high-energy particles



Leptonic high-energy particles

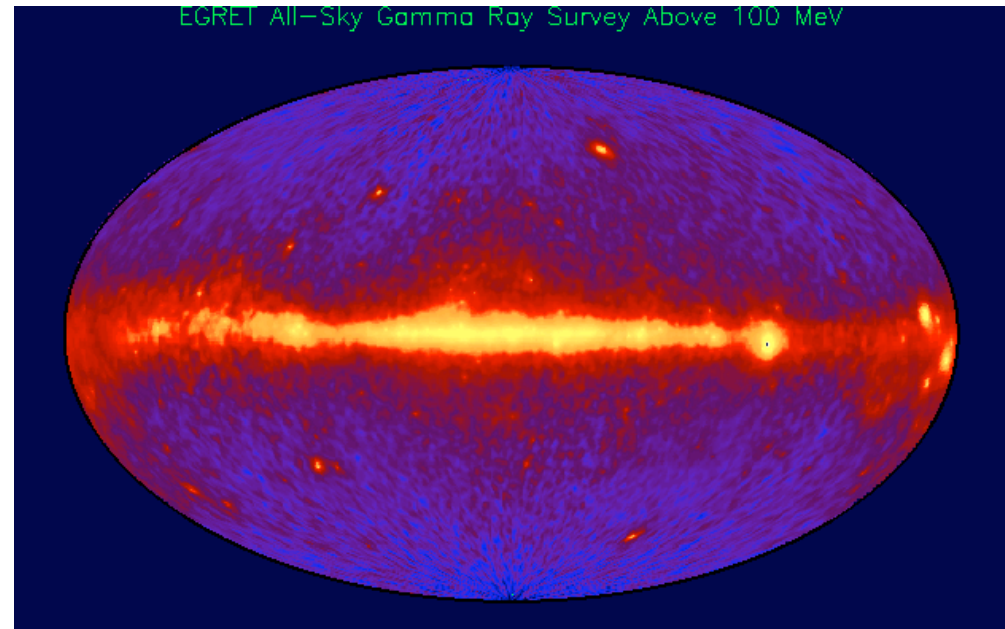


*Bremsstrahlung*  
*Synchrotron*  
*Inverse Compton*

## Gamma rays are secondary products of the cosmic accelerators

### EGRET All-Sky Gamma-Ray Survey $E > 100 \text{ MeV}$

*Gamma rays* are mostly produced by the interaction of *cosmic rays* with the interstellar gas of the *Milky Way*

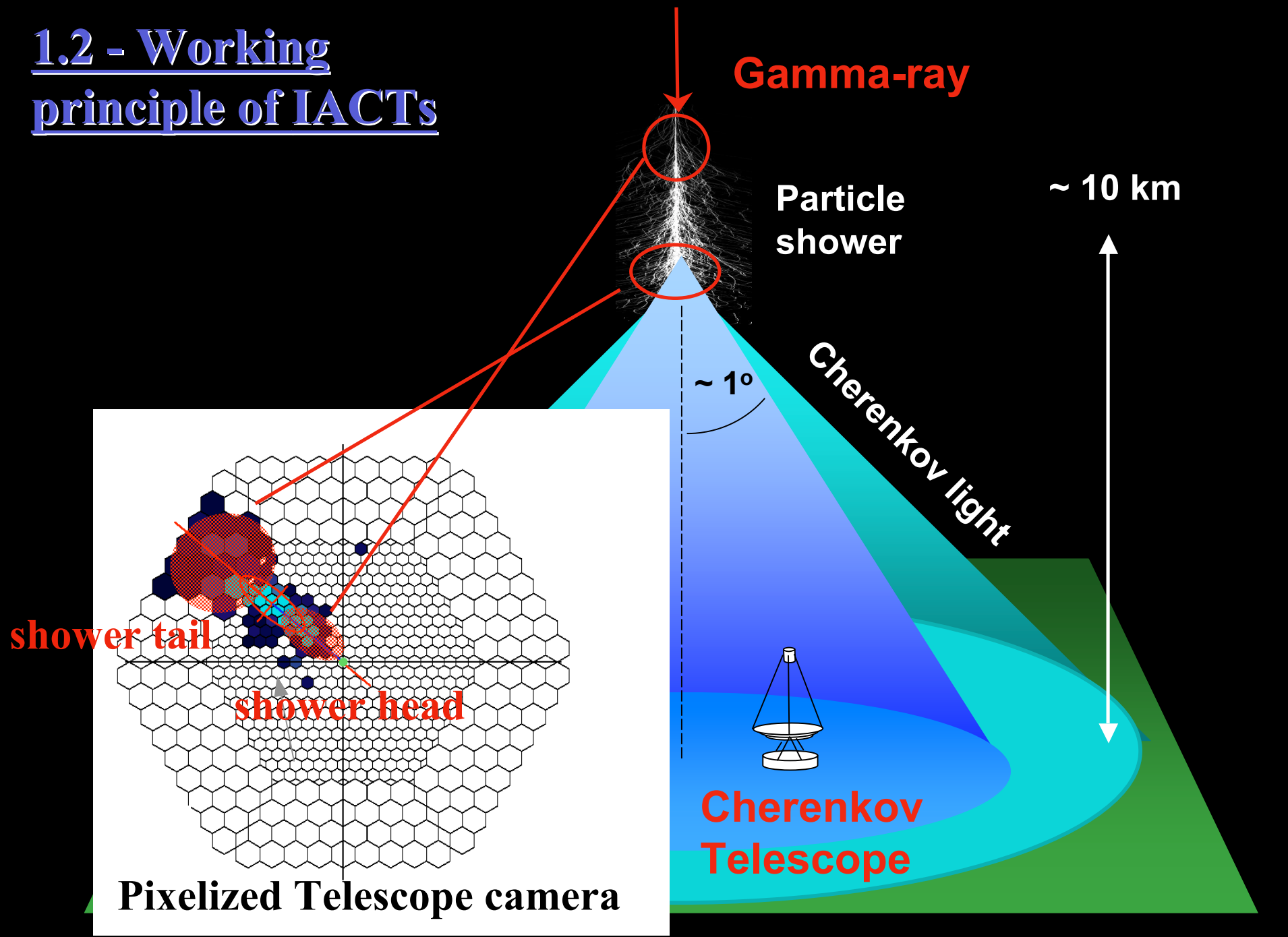


### Information brought by the gamma quanta:

- 1 - Location of the high energy particles
- 2 - Lower limit to the energy of the high energy particles
- 3 - Time information



# 1.2 - Working principle of IACTs



## 1.2 - Working principle of IACTs

**Large Collection Area**  
 $\sim 10^5 \text{ m}^2$

**High Energy threshold**  
 $\sim 10 \text{ GeV} - 1 \text{ TeV}$

**Future**

**Past**

**Larger Collector Mirrors**  
**Higher photon sensitivity**

**Gamma-ray**

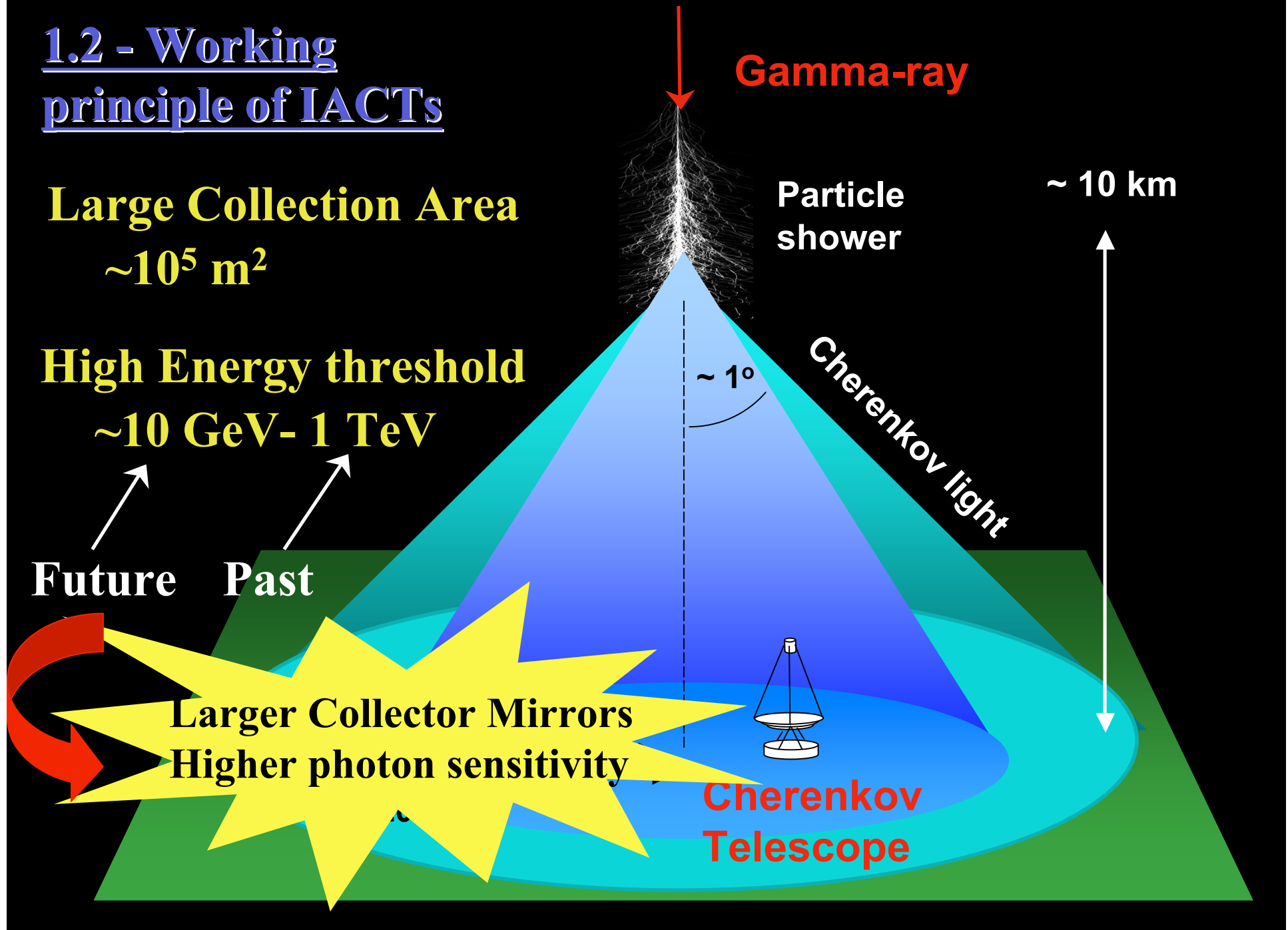
**Particle shower**

$\sim 10 \text{ km}$

$\sim 1^\circ$

**Cherenkov light**

**Cherenkov Telescope**

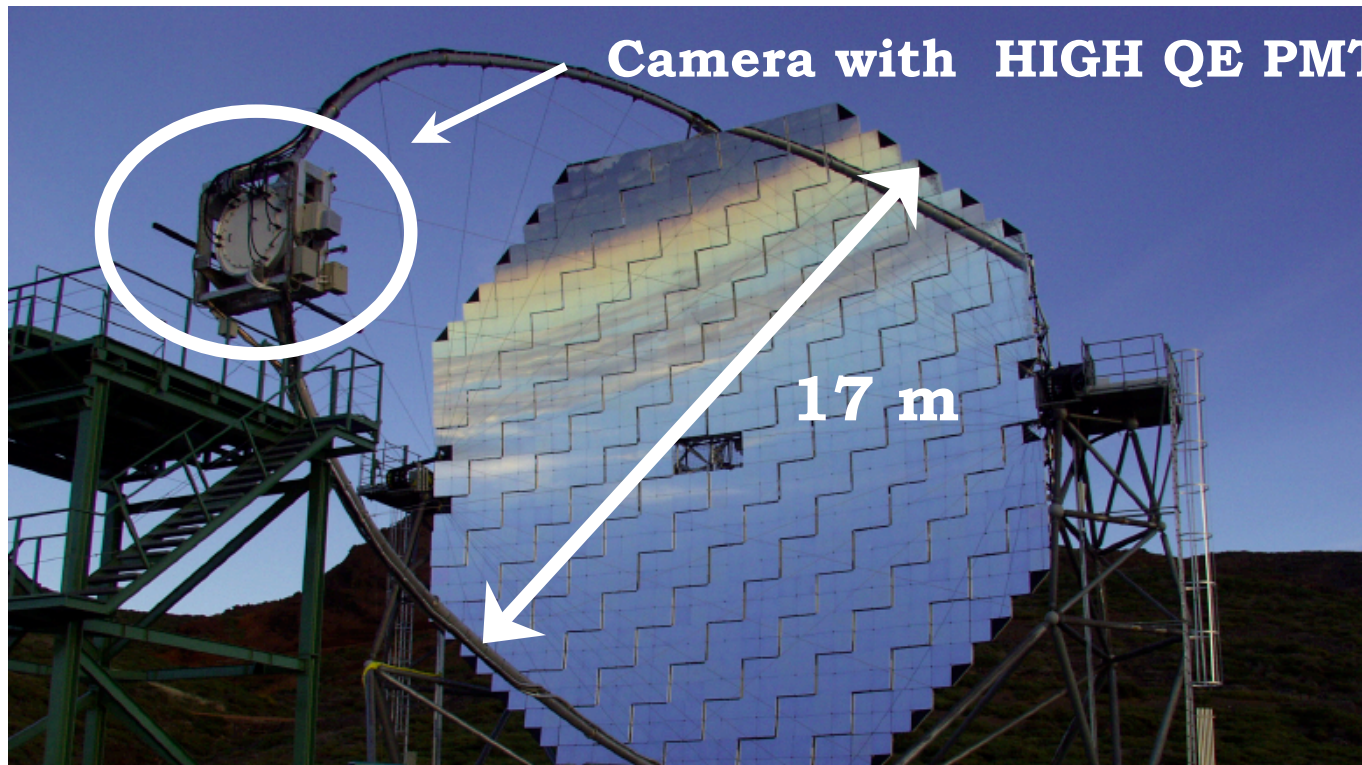


# **The MAGIC project**

## 2.1 - The MAGIC Telescope

- **Largest** Imaging Air Cherenkov Telescope (*IACT*) world-wide
- **Lowest analysis energy threshold**; Currently 100 GeV (trigger  $\sim 50$  GeV)

**100-300 GeV was unexplored before MAGIC and HESS**  
**10-100 GeV is still unexplored**



**Collaboration:  $\sim 150$  physicists & technicians, 16 institutes, 9 countries:**  
Barcelona IFAE, Barcelona UAB, HU Berlin, U.C. Davis, U. Dortmund, U. Lodz,  
UCM Madrid, MPI München, INFN/ U. Padua, INFN/ U. Siena, INRNE Sofia,  
Tuorla Obs., Yerevan Phys. Institute, INFN/ U. Udine, U. Würzburg, ETH Zürich

## 2.3 - The MPI MAGIC group

### 27 Physicists

- 1 Director :** M. Teshima (**Spokesperson of MAGIC**),
- 5 Senior scientists:** R. Mirzoyan (**Chair Collab. board**), F. Goebel (**NT project manager**),  
R. Bock, E. Lorenz, W. Wittek
- 7 Postdocs:** E. Carmona, T. Coarasa, P. Liebing, P. Majumdar, J. Ninkovic,  
D. Paneque, K. Shinozaki
- 11 PhD students:** H. Bartko, M. Garczarczyk, M. Hayashida, C. Hsu, G. Isar, D. Mazin,  
C. Merck, S. Mizobuchi, N. Otte, N. Tonello, R. Wagner
- 3 Diplom students:** M. Fuchs, R. Kosyra, A. Romaszekiewicz

### 14 Engineers/Technicians

J. Hose T. Haubold, R. Maier, O. Reimann, A. Rudert, A.L. Stipp, A. Wassatsch ,  
S. Tran, P. Sawallisch, W. Pimpl, Toni, S. Schmidl, J. Schlammer, S. Vogt

### 2 Secretaries

S. Rodriguez, I. Wacker

**The MPI MAGIC group is ~30% of the people  
from the MAGIC collaboration**

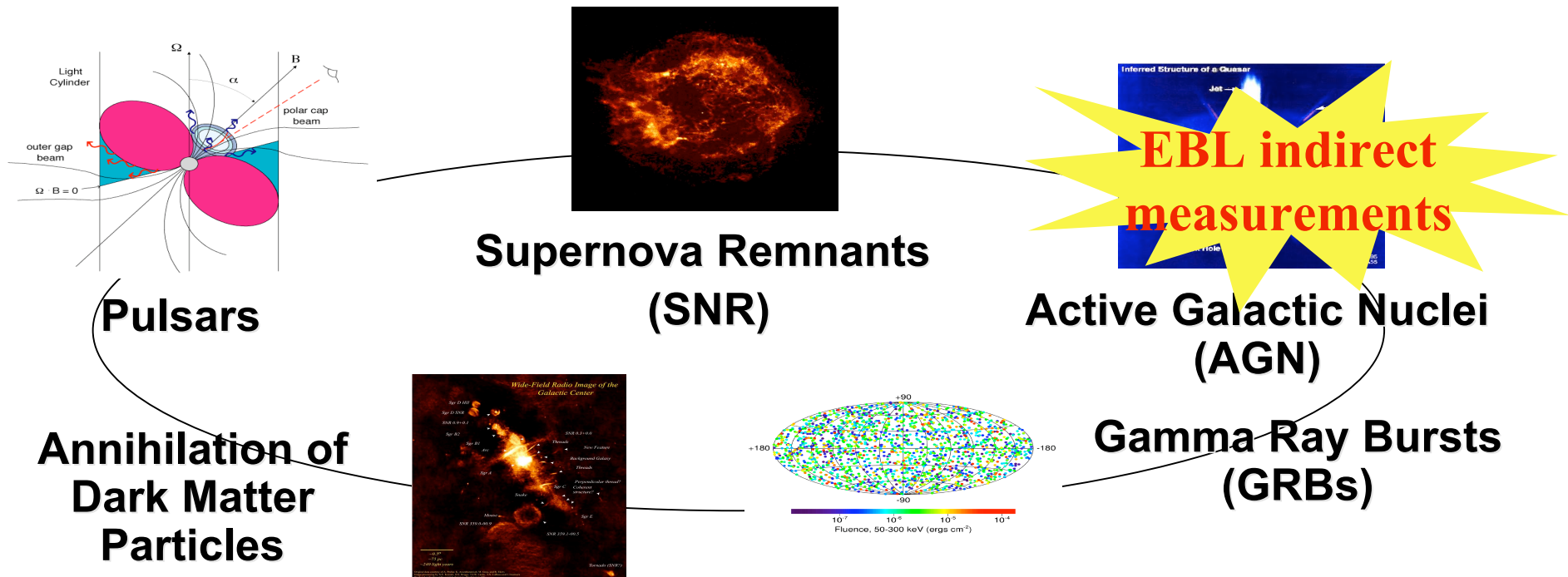
## 2.4 - Motivation for building MAGIC

- **Largest** Imaging Air Cherenkov Telescope (*IACT*) world-wide
- **Lowest analysis energy threshold**; Currently 100 GeV (trigger ~50GeV)

**100-300 GeV was unexplored before MAGIC and HESS**

**10-100 GeV is still unexplored**

### Main astrophysical targets for the MAGIC Telescope



**Aim to perform ASTROPHYSICS with VHE radiation emitting objects  
... also contribute to COSMOLOGY and PARTICLE PHYSICS**

# **The MAGIC Telescope, status and source observations**



## 3.1 - Operation during 2005: environmental occurrences

January 2005: **SNOW STORM**



21/12/2005

David Paneque

12



## 3.1 - Operation during 2005: environmental occurrences

February 2005: ... **EVEN MORE SNOW**



## 3.1 - Operation during 2005: environmental occurrences

September 2005: **FIRE**



**FIRE !!!!!**

Fire reached the observatory... 300 m from MAGIC !!

It was close... fire was controlled; MAGIC was saved

## 3.1 - Operation during 2005: environmental occurrences

November 2005: **WIND STORM (*Delta*)**



**Wind speed up to 152 km/h**

Telescope should stand up to *170 km/h*

**MAGIC survived all these incidences (with only minor problems)  
... Yet we all hope next year is an easier one ...**

## 3.2 - First year operation (Sep04-Sep05): observed sources

*Obs. sources and obs. time (in hours)*

<b>Crab Nebula</b>	102
<b>Mrk 421</b>	73
<b>Mrk 501</b>	58
PSR1957+20	26
<b>HESS 1813-178</b>	28
<b>HESS 1834-08</b>	11
<b>Sgr A*</b>	26
<b>GRBs</b>	12
3C66A	22
0317+18	14
1553+11	9
1ES0120+34	11

<b>1ES1218+304</b>	10
<b>1ES1959+650</b>	34
1ES1440+122	7
<b>1ES2344+51</b>	11
2E-1415+2557	20
3EG0520+2626	8
3EG0853+19	13
3EG1605+15	10
3EG1727+04	7
3EG2033+41	23
Arp-220	17
3C279	16

4C15.05	7
GRS1915+105	11
PSRJ2229+61	7
Sadr	18
M87	13
IC 443	8
TeV2032+42	9
W44	15
1ES1426+428	33
W Comae	8
<b>Total ON</b>	<b>740</b>
<b>Total OFF</b>	<b>190</b>

**1 Year = 365 x 24 h. = 8760 h.**  
**Observation time = 930 h.**



**11% duty cycle**



## 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

### CRAB NEBULA

➤ ONLY steady (VHE) source in the Northern sky. Very powerful object. Located only 2 kpc away.



Test case for developing methods of ENERGY and FLUX calibration

➤ Remnant of the SN 1054. Plerion type...

➤ FIRST significant VHE gamma ray detection; 1989 (WHIPPLE)

**50 h. of ON observation to get a 9 sigma detection**

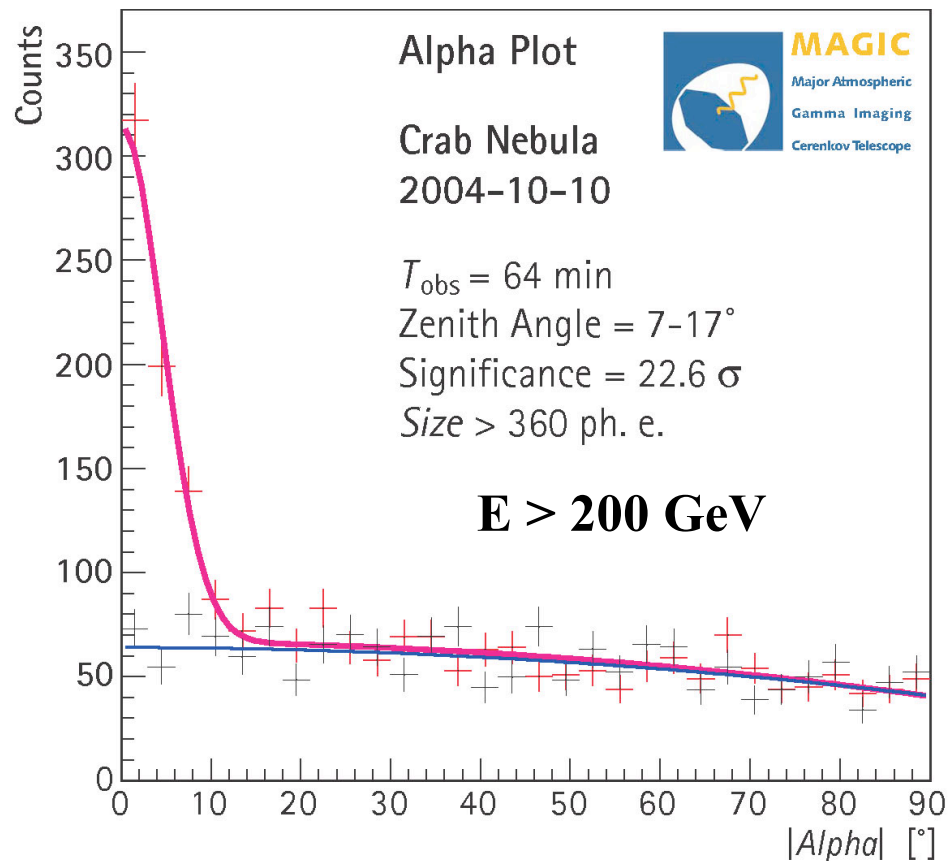
**Very young astronomic discipline**



## 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

### CRAB NEBULA

*Wagner et al, 29th ICRC,  
August 2005*



**CRAB** detected in relatively short time with high significance

With this analysis



$$22\sigma \cdot \sqrt{time(h)}$$

***(5 sigmas for Crab in 3 minutes)***

(Only statistical errors are considered)

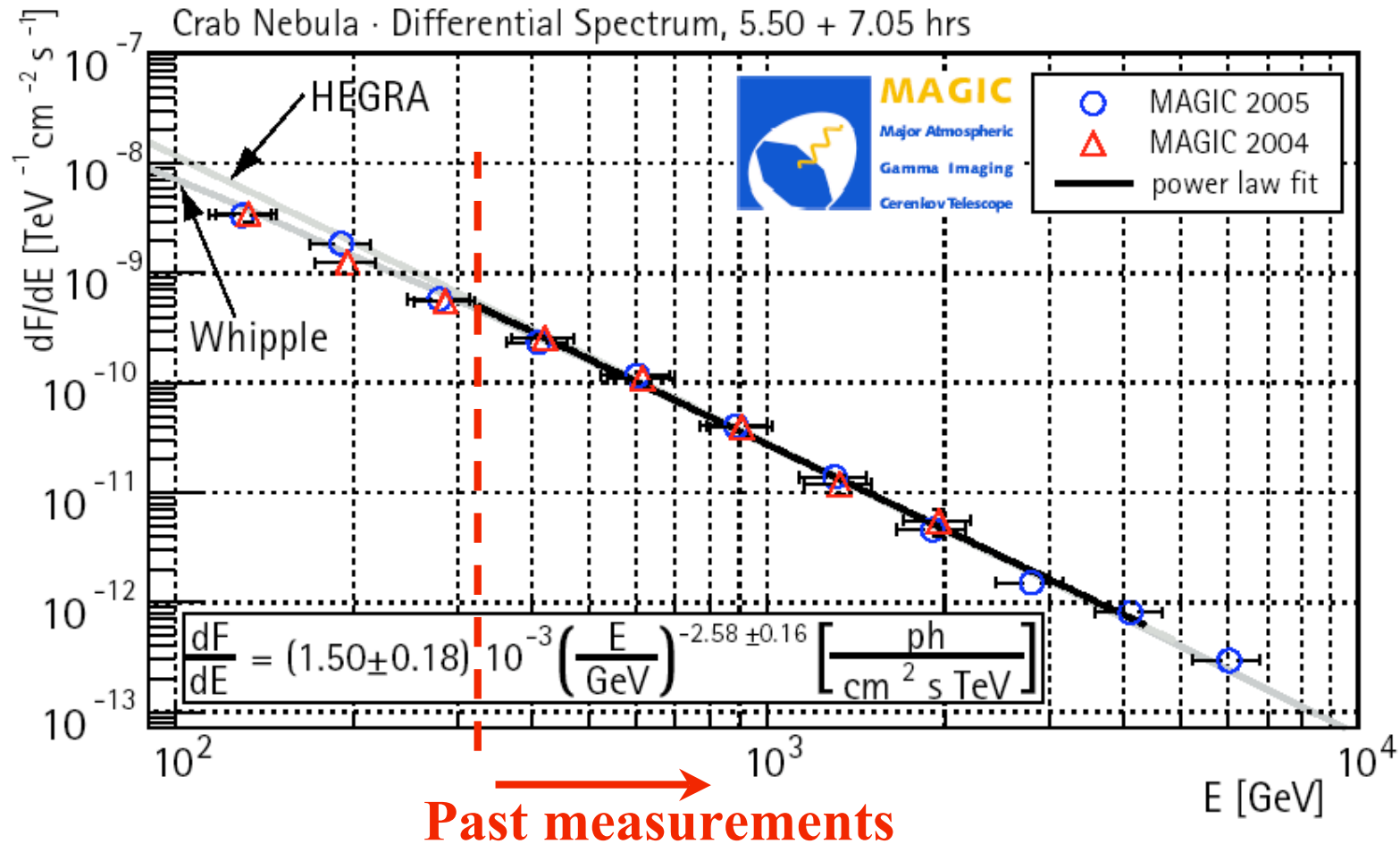
Observation time: 1 h.

Mean Zenith Angle: 12°

### 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

Differential photon flux

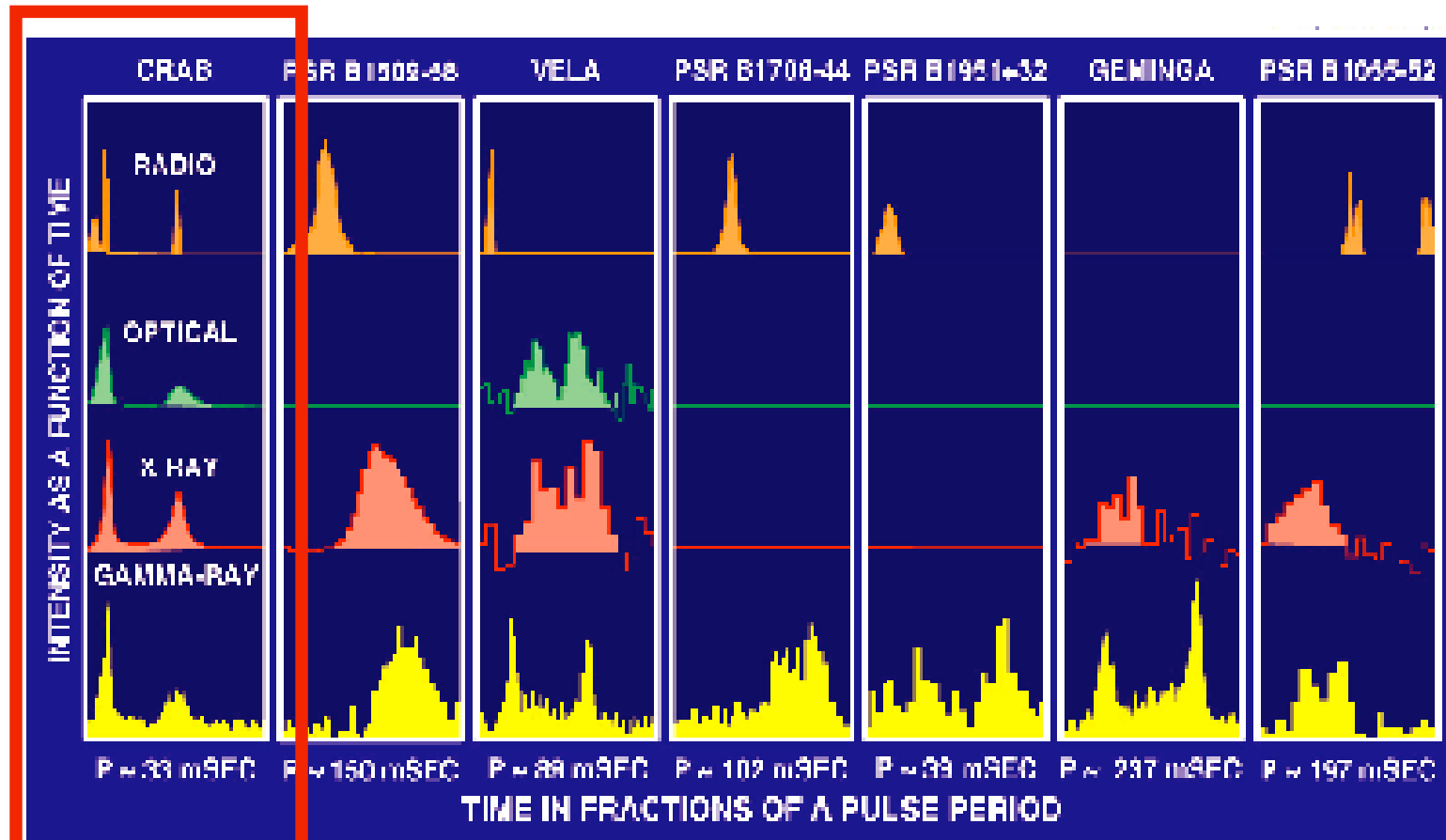
*No SSC peak down to 100 GeV*



## 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

### CRAB PULSAR

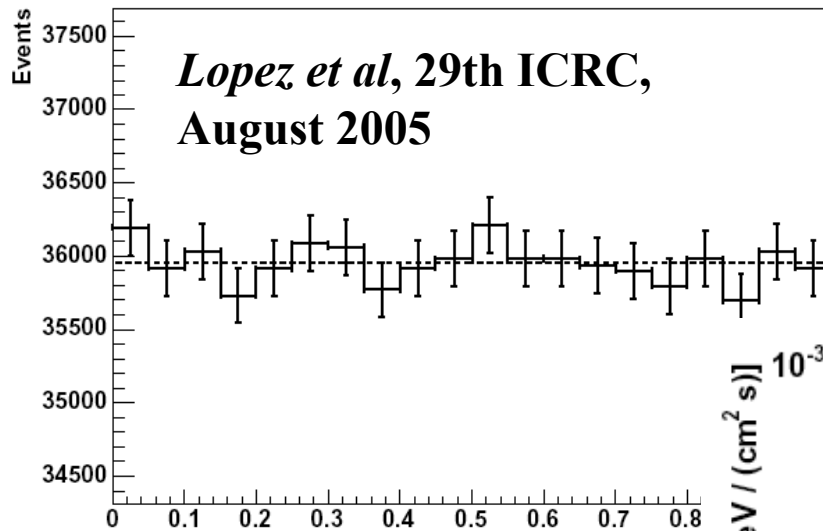
- Most energetic pulsar ( $L_m = 5 \cdot 10^{38} \text{ erg s}^{-1}$ )
- Only pulsar whose pulsed emission phase is the same in all wavelengths.





### 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

#### CRAB PULSAR



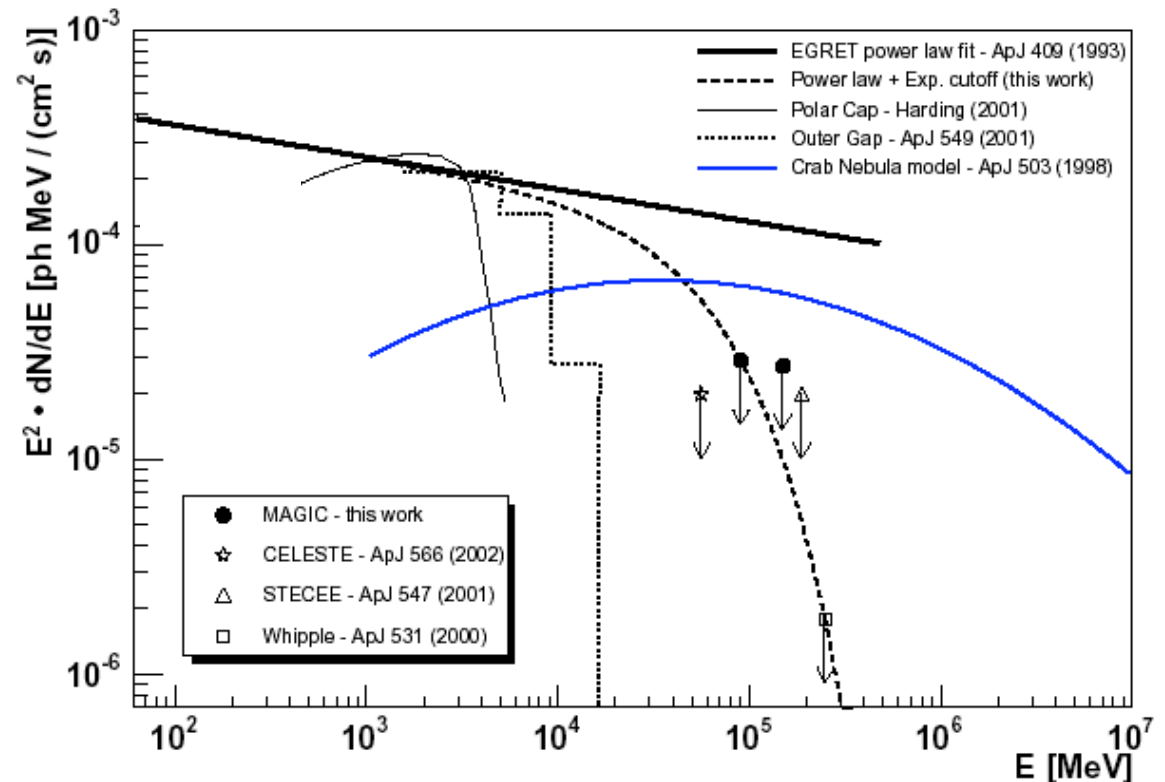
***NO PULSATION DETECTED  
AT ENERGIES > 100 GeV***



Limit to Exponential cut-off

$$E_{cut} < 60 \text{ GeV}$$

Agreement with CELESTE



## 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

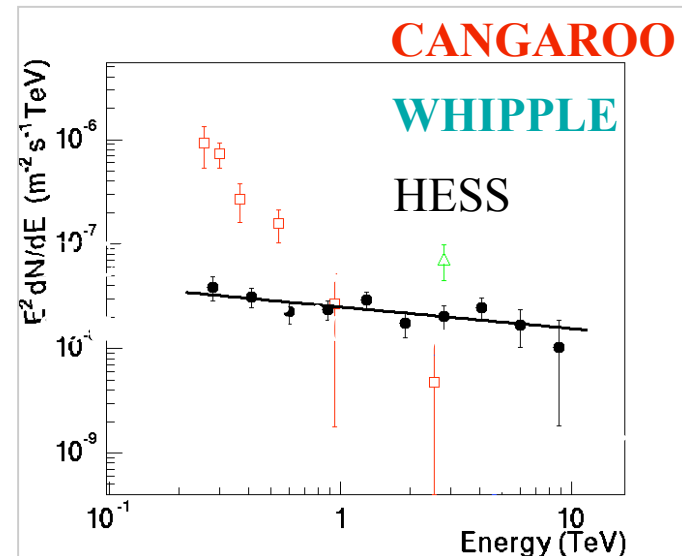
### GALACTIC CENTER

Quite some excitement due to the latest detections in this region

CANGAROO II, Jul 2001, Jul-Aug 2003, *(Tsuchiya et al,2004)*  
**67 h, about 9 sigma**

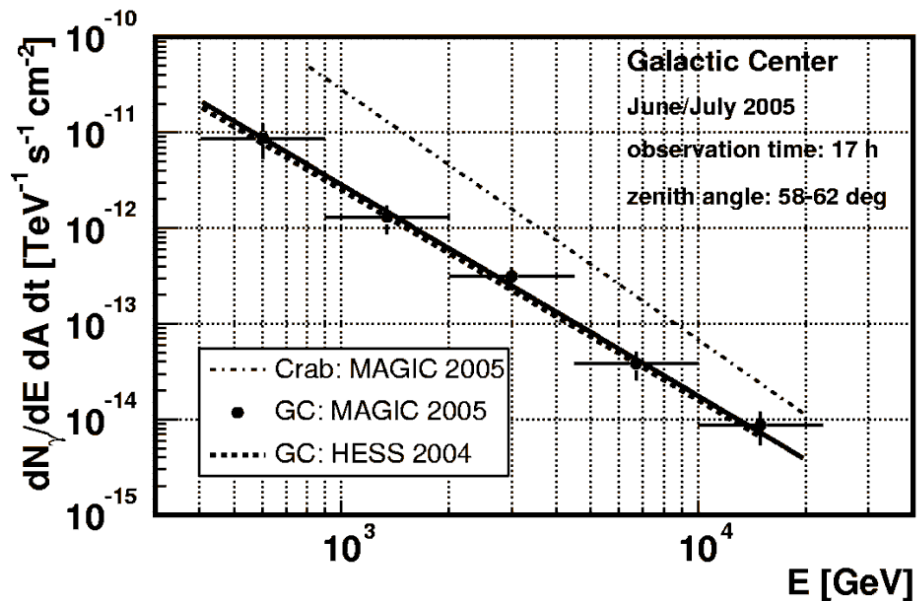
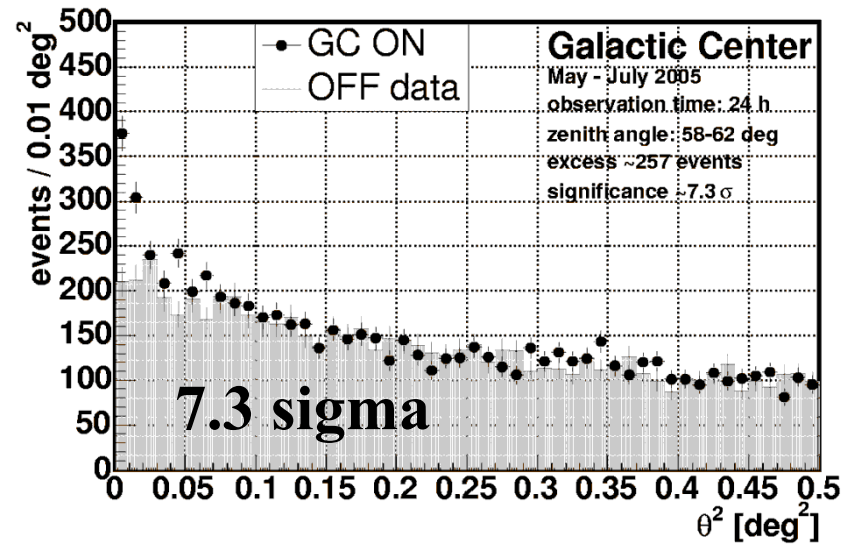
WHIPPLE/VERITAS, 1995-2003, *(Koshack et al,2004)*  
**26 h, about 4 sigma, (Large Zenith Angle)**

HESS, Jun-Jul and Jul-Aug 2003,  
(1 and 2 telescopes)  
**5 h and 12 h, about 6 and 9 sigma**



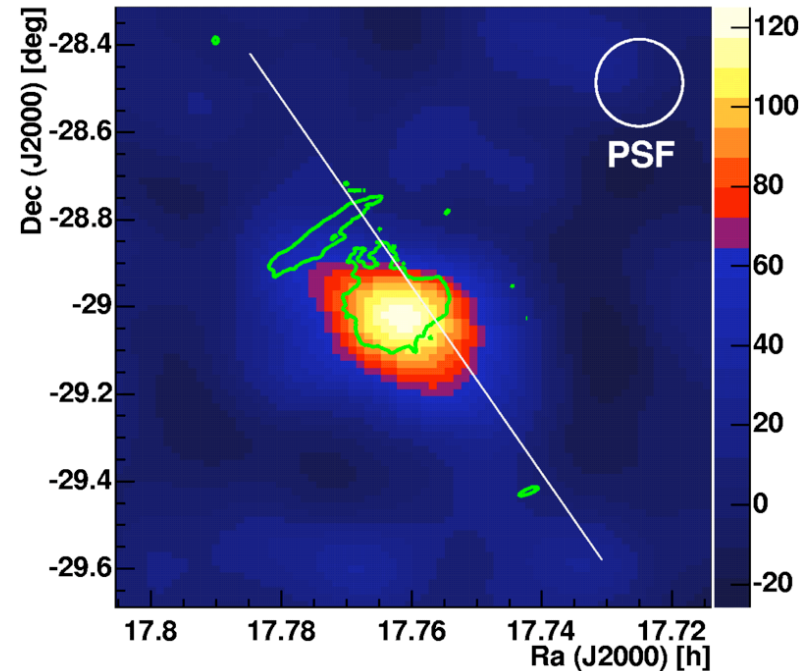
### 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

## GALACTIC CENTER SEEN BY MAGIC



*Bartko et al, 29th ICRC, August 2005*

*Submitted to ApJ Letters*



**MAGIC and HESS detections  
disfavour hypothetical neutralino  
annihilation coming from SgrA\***

**Origin of gammas still unknown**

### 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

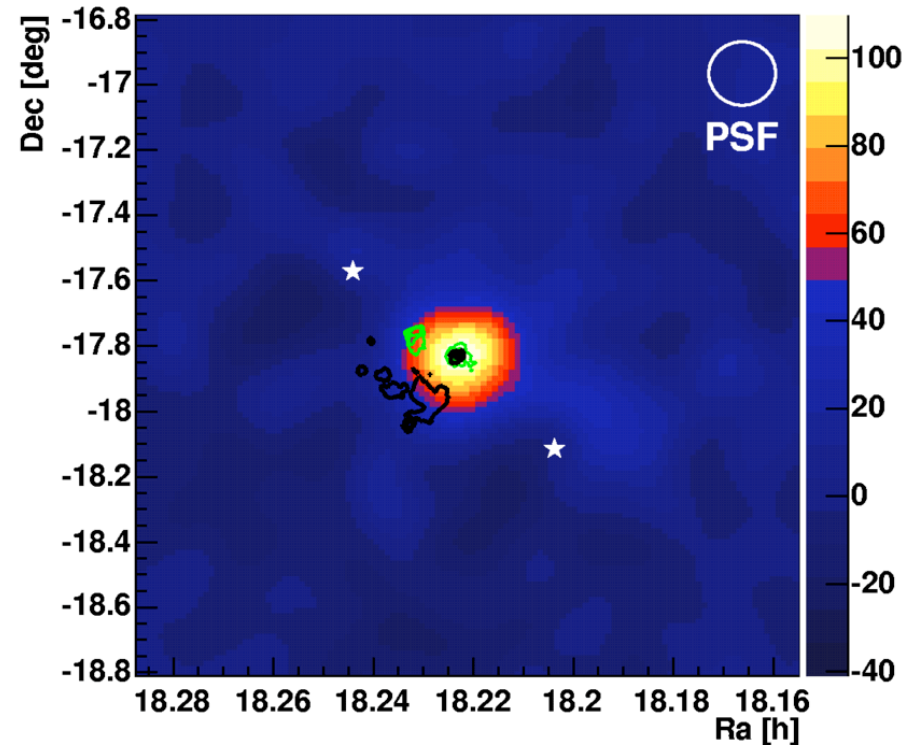
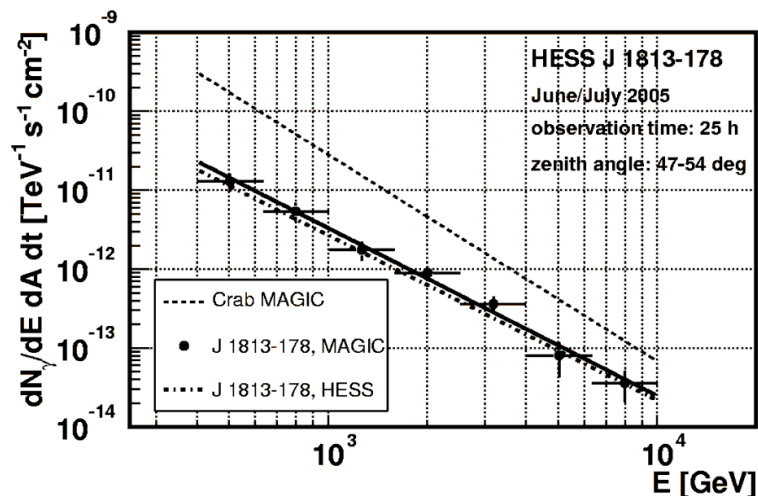
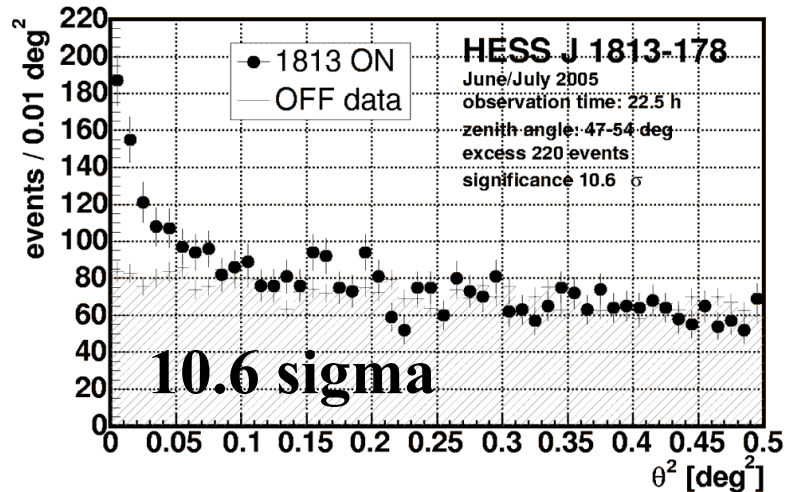
#### HESS 1813 -178

1<sup>st</sup> independent confirmation

High energy galactic source discovered recently by HESS  
*Aharonian et al, Science 307 (2005) 1938-1942*

astro-ph/0512283

Accepted in ApJ Letters



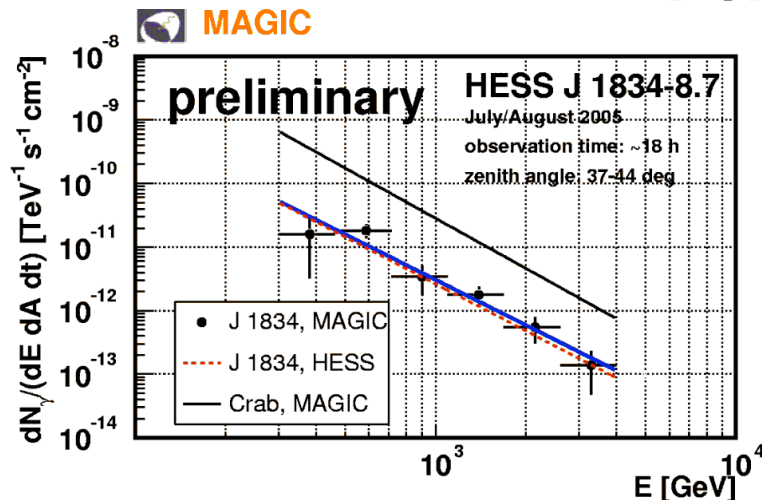
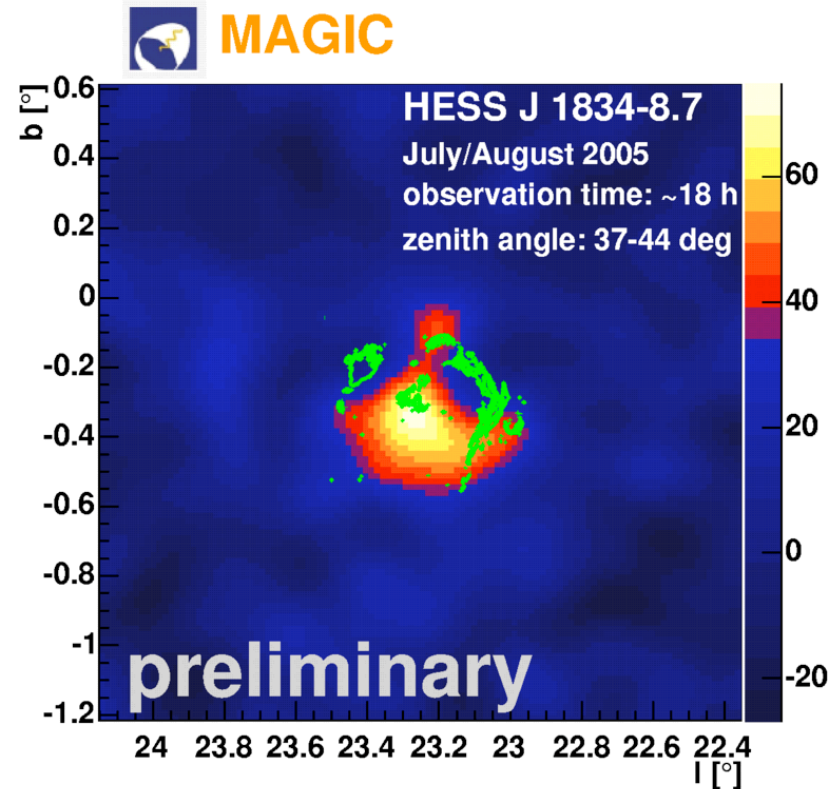
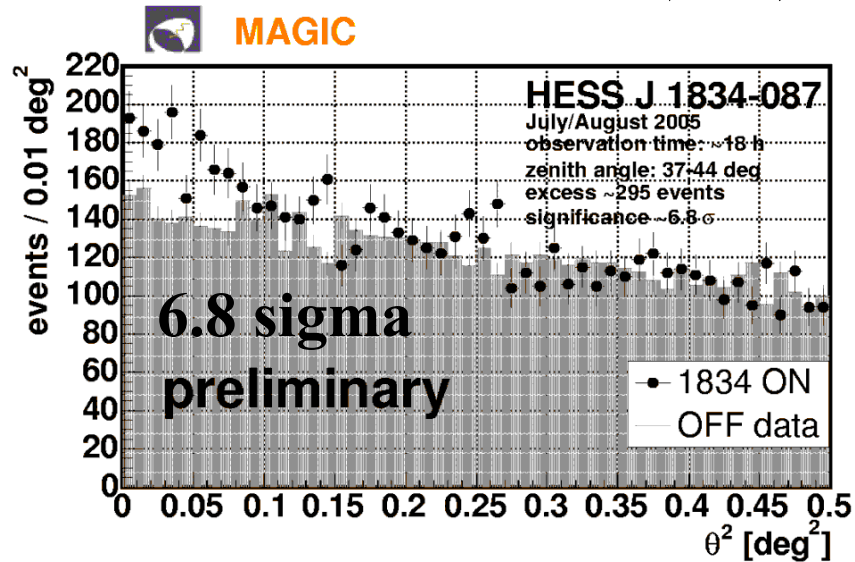
Association with SNR G12.82-0.02

# 3.3 - First year operation (Sep04-Sep05): GALACTIC sources

## HESS 1834 -087

**1<sup>st</sup> independent confirmation**

High energy galactic source discovered recently by HESS  
*Aharonian et al, Science 307 (2005) 1938-1942*



Association with SNR G23.3-0.3

**Data analysis ongoing**



## 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

### **MARKARIAN 421**

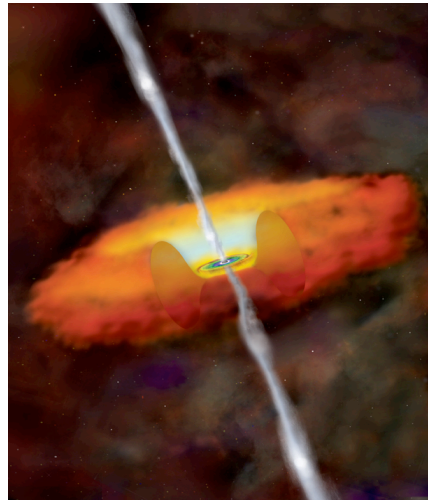
Elliptical galaxy

Active Galactic Nucleus (AGN)

**$z = 0.031$**

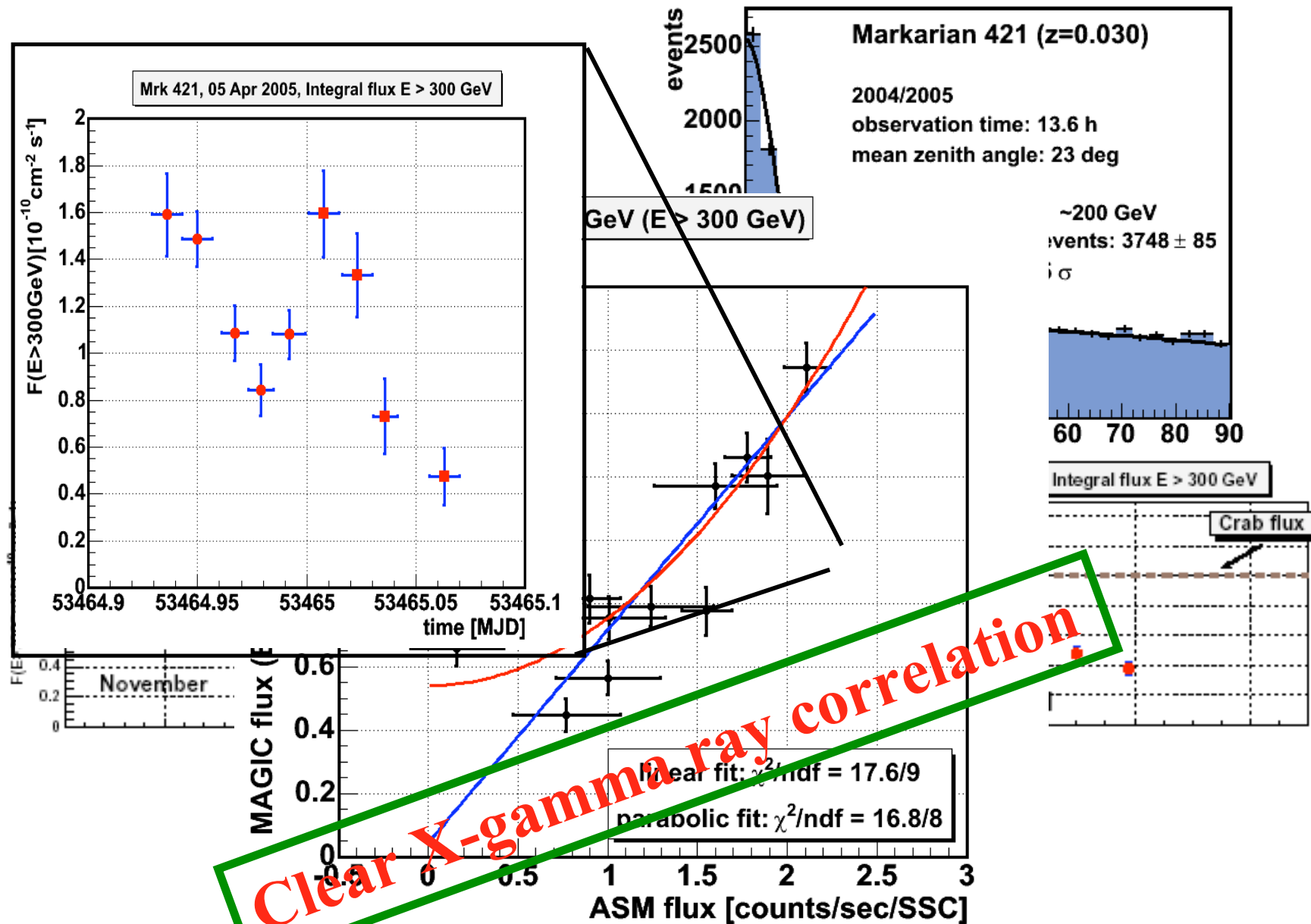
RA = 11h04m

Dec = +38.2°



- First detected in VHE gamma rays by WHIPPLE (*Punch et al, 1992*).  
*First extragalactic detection in VHE gamma rays*
- Highly variable source (doubling flux in 15 minutes) with high correlations between gamma rays and x-rays
- *Super-massive black hole* surrounded by an accretion disk
- Jets of highly energetic particles pointing towards the Earth (***Blazar***)
- Preferred model for the gamma ray emission; Inverse Compton

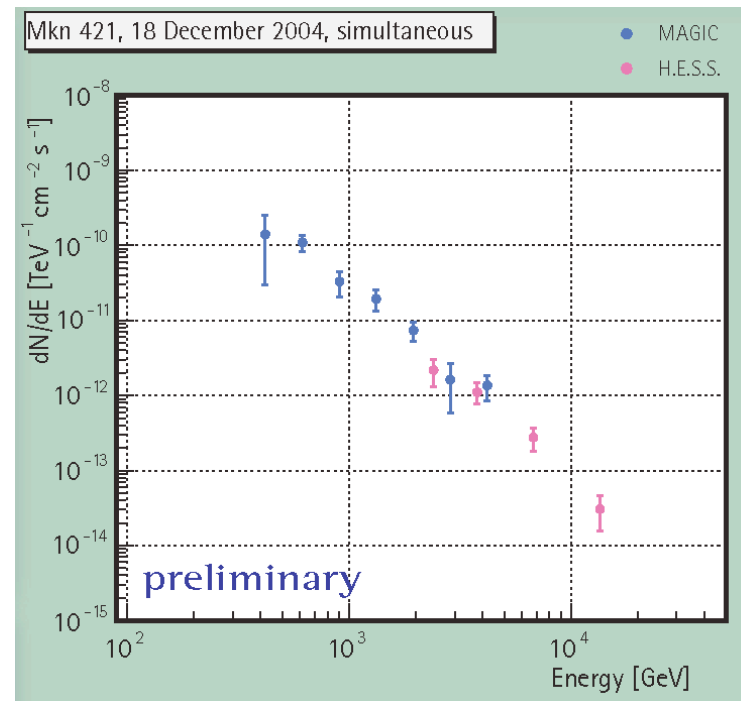
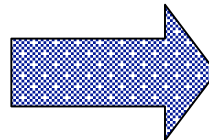
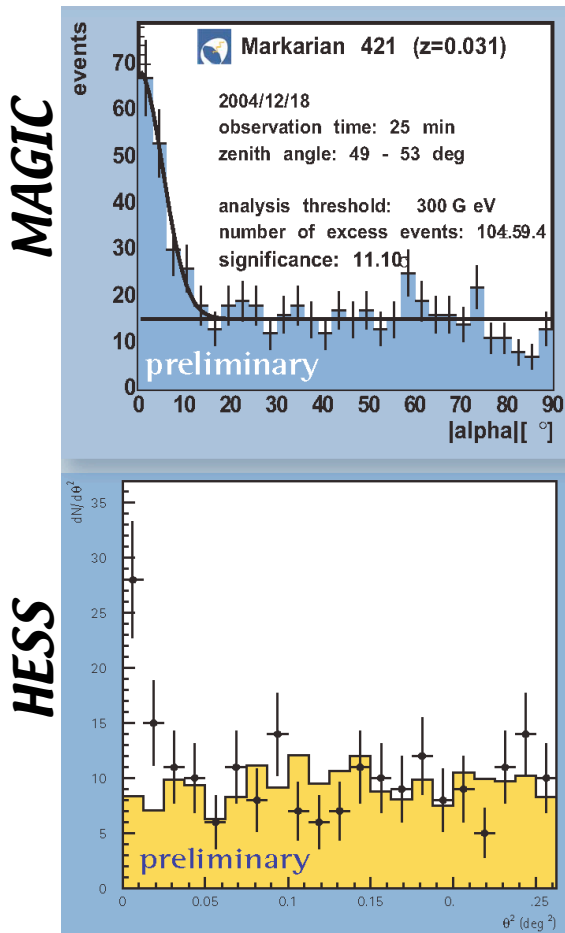
# 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC



◆ **December 2004; first simultaneous observations with HESS**

December 14th, RXTE found Mkn421 flaring in X-rays

Coordinated action was performed within days (Detected Flux about 1 Crab)



**Importance of simultaneous obs.**

*Cross calibration*

*Larger Energy range coverage*



## 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

### **1ES1959+650**

Elliptical galaxy

Active Galactic Nucleus

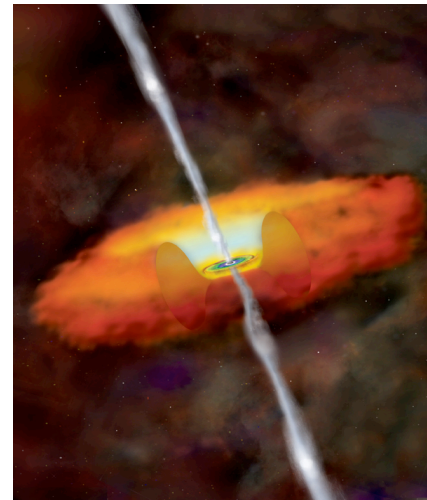
**$z = 0.047$**

RA = 20h00m

Dec = +65.1°

Observability at La Palma:

**May-October 35°-54°**



- 1998: First VHE  $\gamma$  detection: Utah Seven Telescope Array  
(*Nishiyama et al, 1999*)
- Confirmed in 2002 by WHIPPLE and HEGRA  
(*Holder et al, 2003 - Aharonian et al, 2003*)
  - Jets of highly energetic particles pointing towards the Earth (**Blazar**)
  - Preferred model for the gamma ray emission; Inverse Compton

# Interesting things About 1ES1959+650

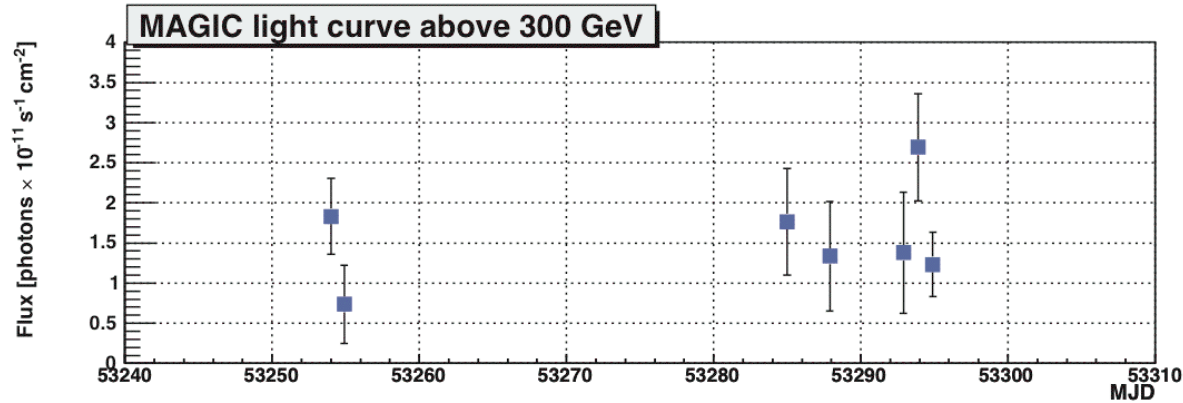
## 2 - Orphan flare in TeV-rays in June 2002

(High activity in  $\gamma$ -rays with low activity in X-rays)

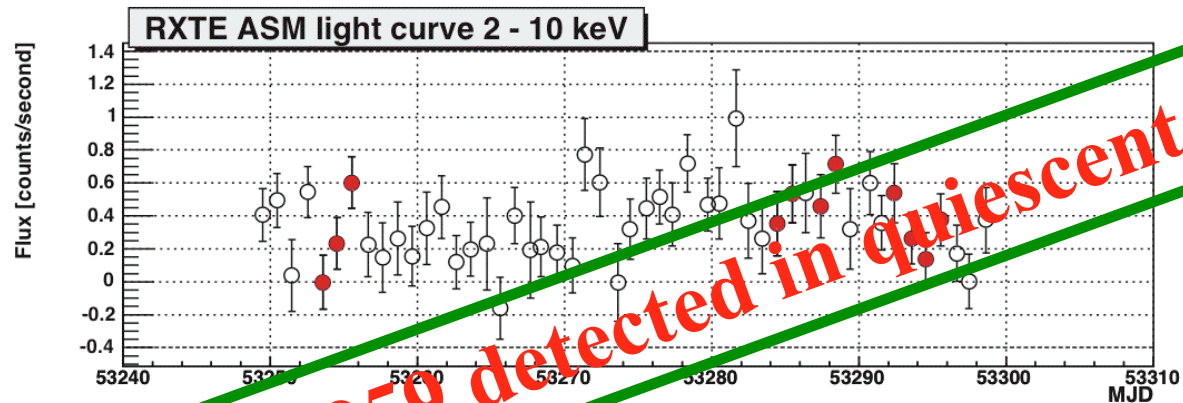
**Leptonic or hadronic acceleration ??**

Hint for neutrino excess recently reported by AMANDA (*Paris, 2005*)

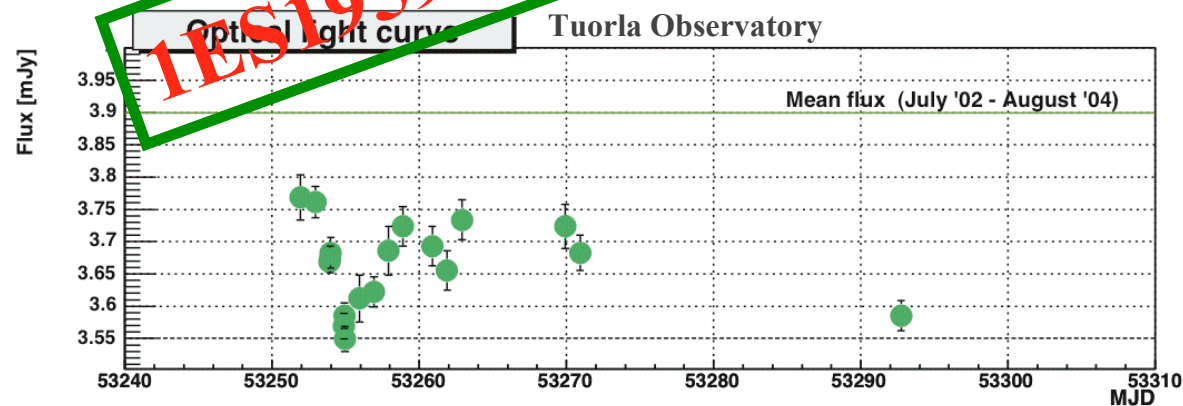
# Light curves



No variation observed  
Mean flux:  
15% Crab flux



X-ray flux without  
substantial variations

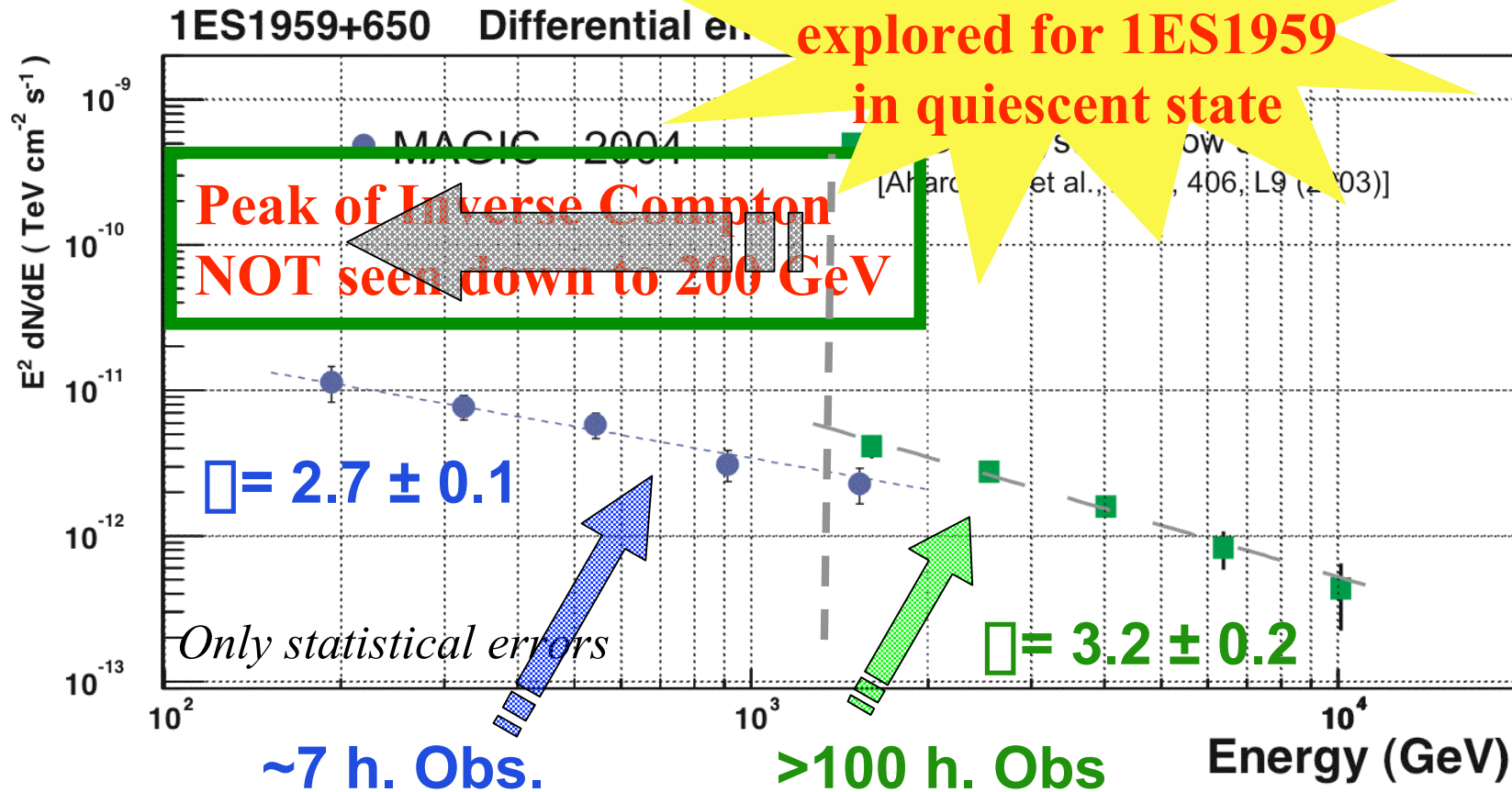


Optical flux lower  
than previous period

### 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

*Atro-ph/0508543 (Accepted in ApJ)*

**New energy domain explored for 1ES1959 in quiescent state**



**Performance of the new IACT instruments allow to do VHE  $\Gamma$ -astronomy of blazars in quiescent state**

## 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

### MARKARIAN 501

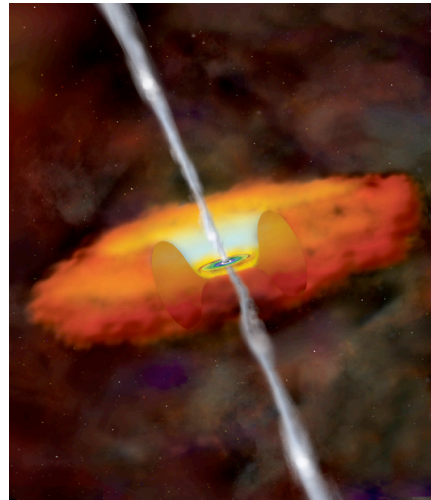
Elliptical galaxy

Active Galactic Nucleus (AGN)

**$z = 0.034$**

RA = 16h54m

Dec = +39.8°

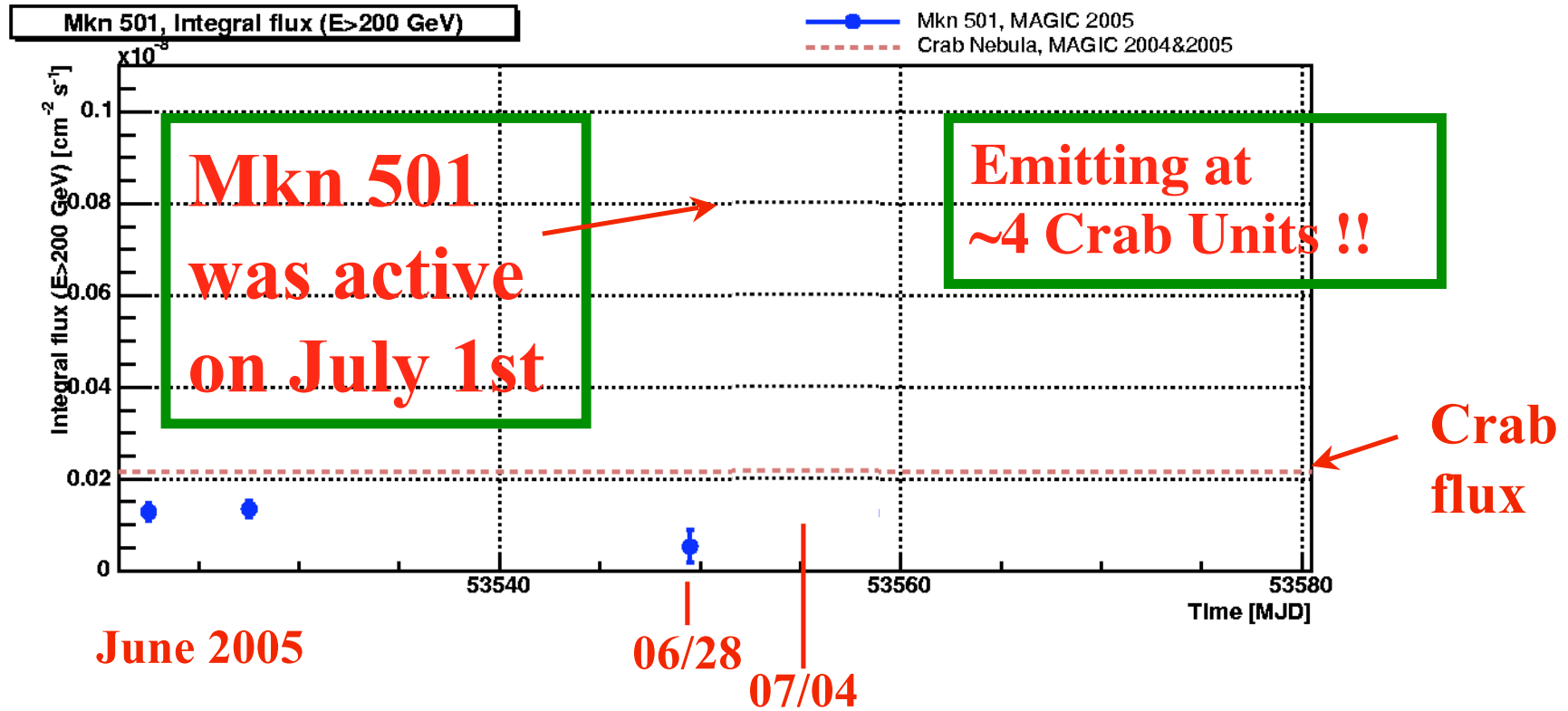


- First detected in VHE gamma rays by WHIPPLE (Quinn et al, 1996) and HEGRA CT1 (Bradbury et al, 1996).  
Second extragalactic detection in VHE gamma rays  
**147 h. of ON observation; 5.2 sigmas detection with CT1** (quiescent state)
- Variable source with high correlations between gamma rays and x-rays  
(*Huge flare in 1997, up to 10 Crabs*)
- Jets of highly energetic particles pointing towards the Earth (**Blazar**)
- Preferred model for the gamma ray emission; Inverse Compton

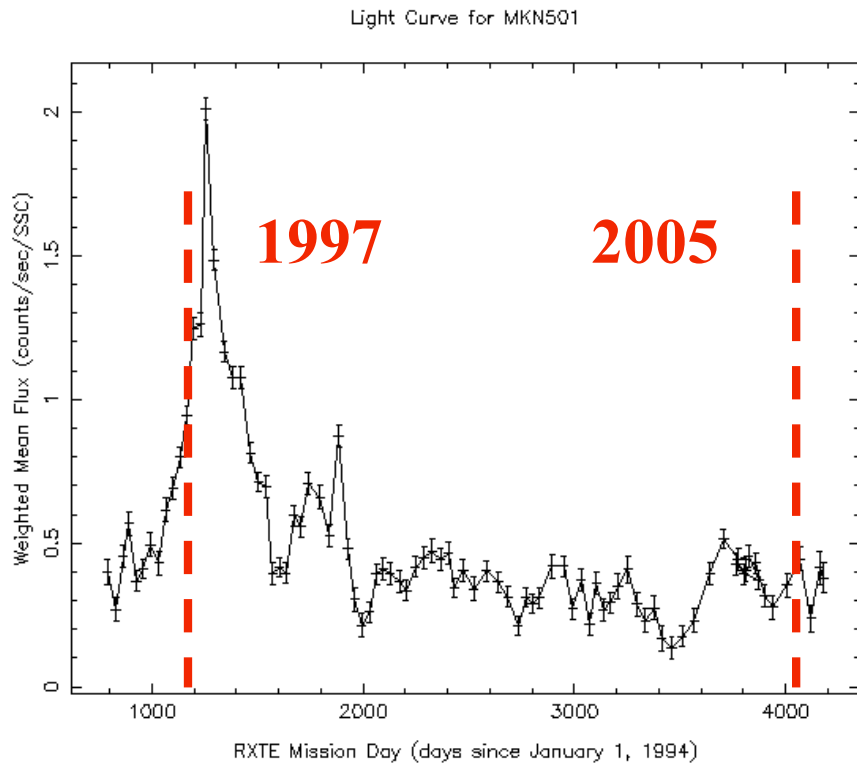
# Mkn 501 was observed with MAGIC in June and July 2005

- Source found mostly in quiescent state (0.3-0.5 Crab Units above 200 GeV). Not all data analyzed yet...

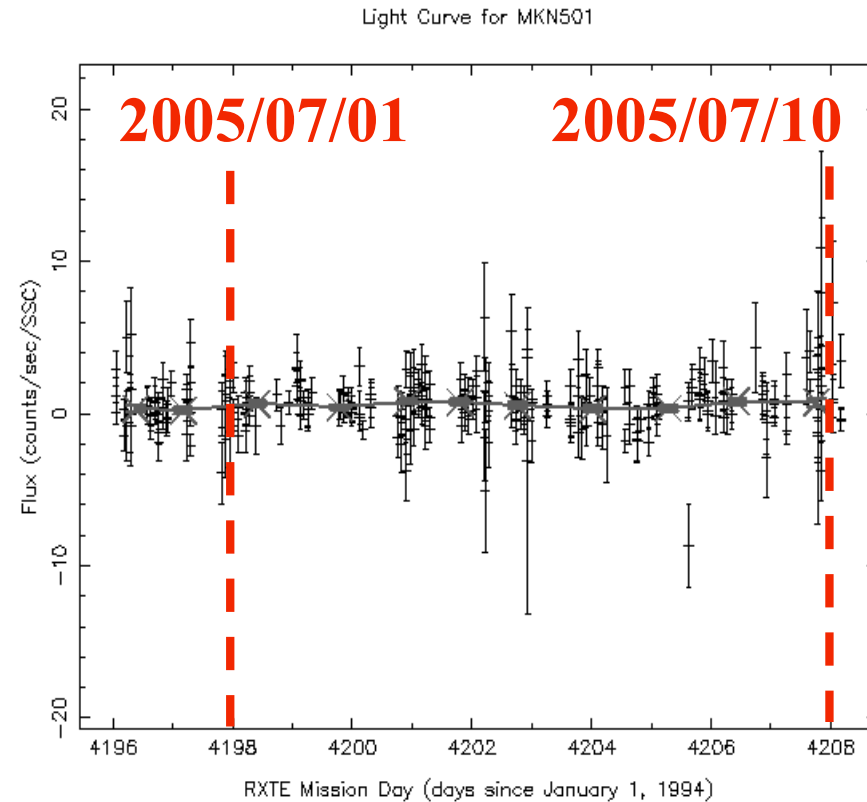
- Signal above 5 sigmas in only 1/2 hour (for 30% Crab) !!!!



# X-rays measured by ASM since 1994 (average over 700 obs.)



# X-rays measured by ASM during last 2 weeks



➤ Source was not found active by the ASM detector

**!!! ORPHAN flare !!!!**

**That's getting exciting ...  
data analysis ongoing...**

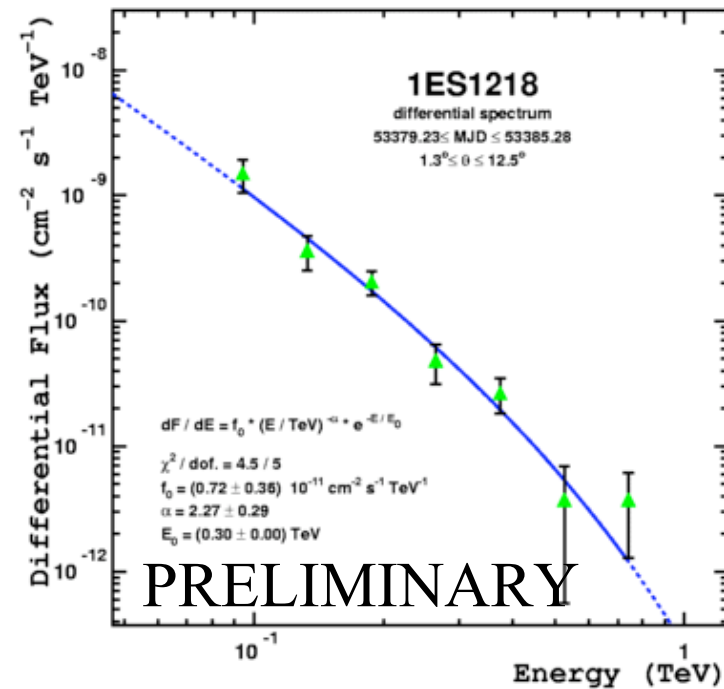
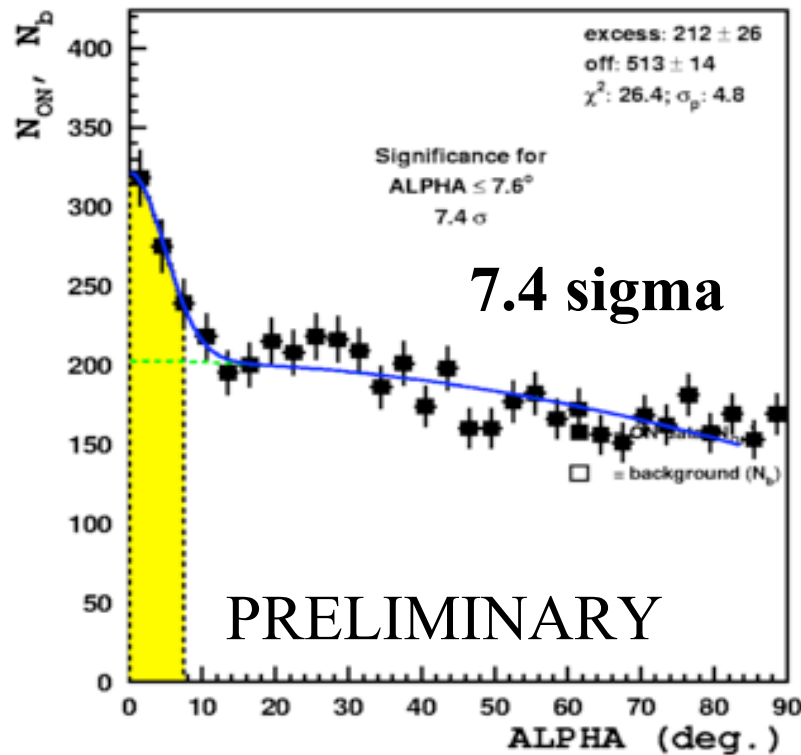
# 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

**1ES1218+304 (z = 0.182)**

MJD: 53379.23 - 53385.28  
za range: 1.3 - 12.5 (deg)  
obs. time: 7.1 (h)



Analysis still ongoing



Furthest object detected in the VHE domain (for few days...)

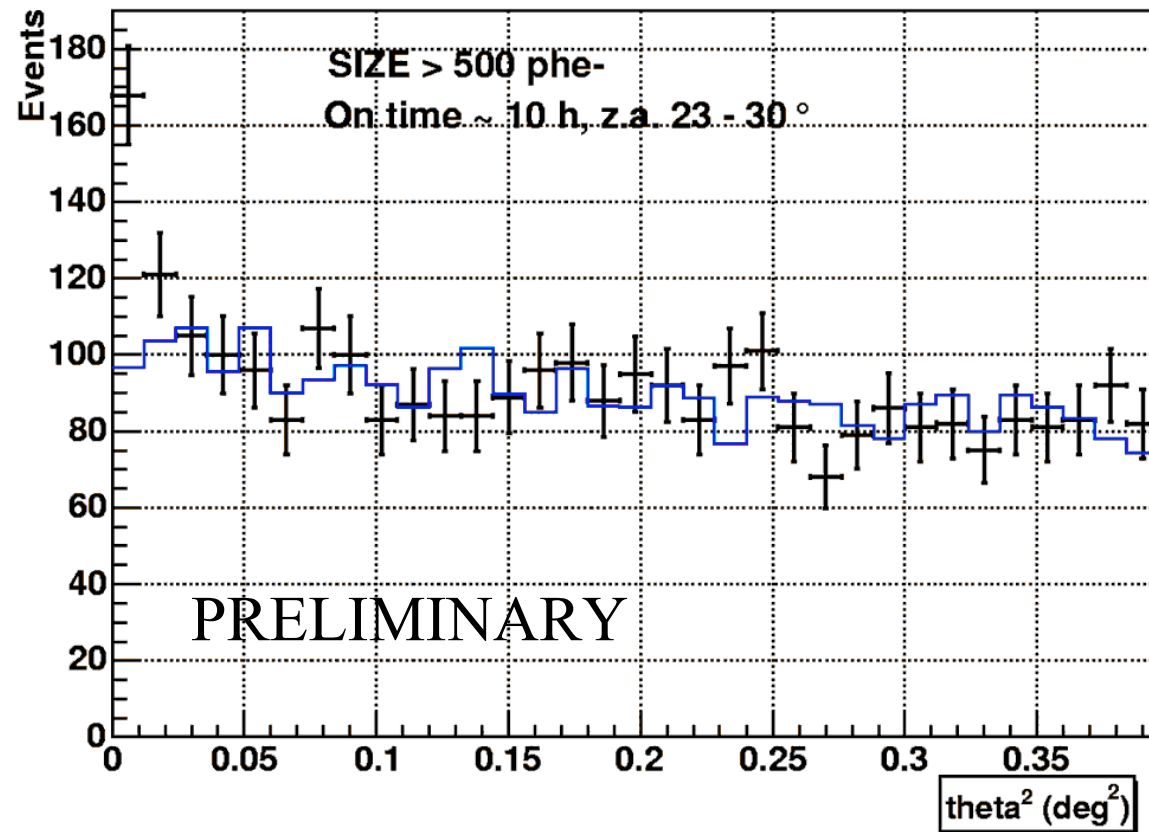
Good candidate for EBL studies



## 3.4 - First year operation (Sep04-Sep05): EXTRAGALACTIC

1ES2344+514 (z = 0.044)

*Fresh detection*



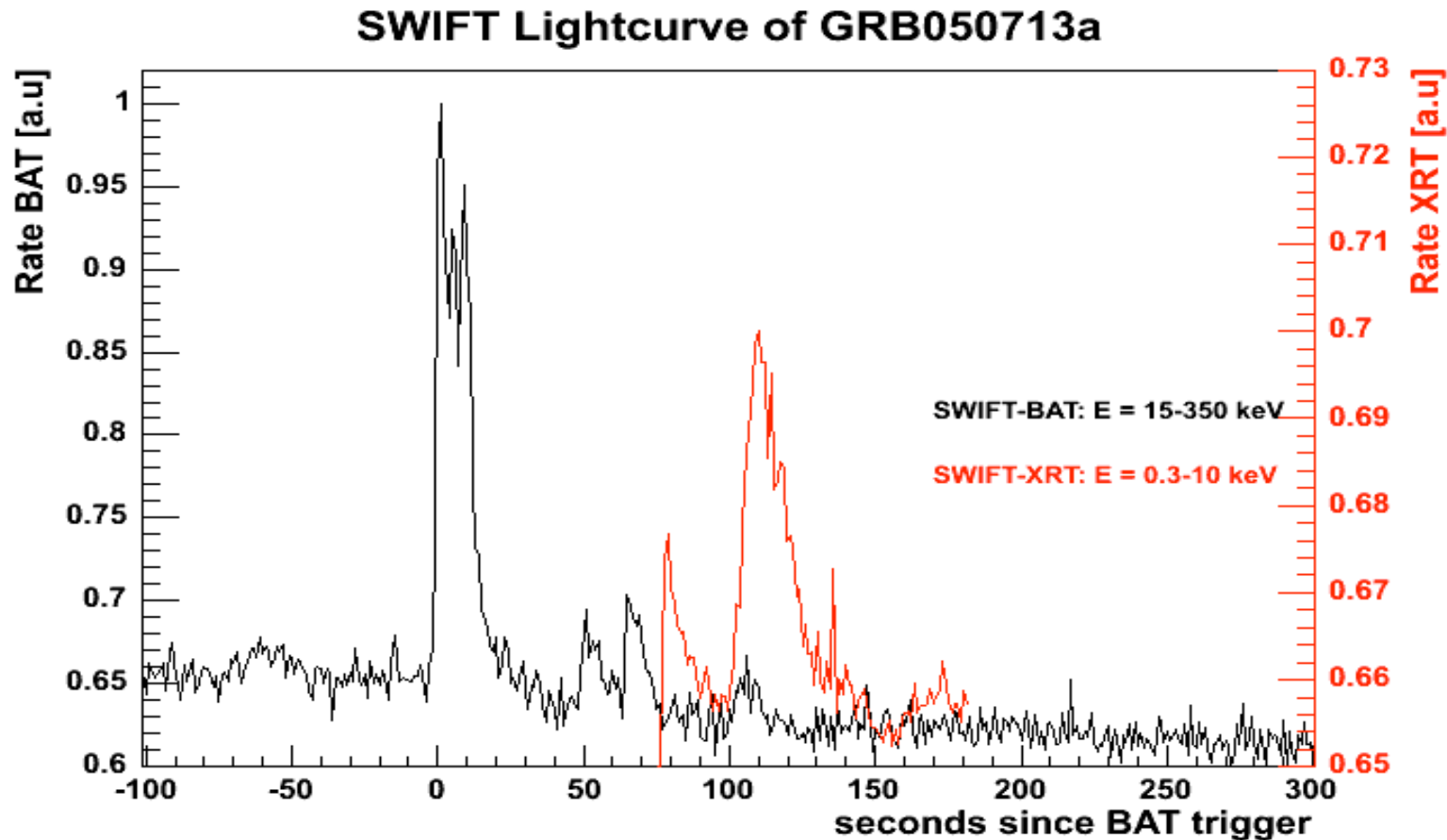
### 3.5 - First year operation (Sep04-Sep05): Gamma-Ray Bursts

#	GRB Event	Satellite	Onset [UTC]	Δt alert [sec]	Δt obs. [sec]	Δ [deg]	z
1	GRB050408	HETE	16:22:50	14	3138	48	1.23
2	GRB050421	SWIFT	04:11:52	58	112	52	
3	GRB050502	SWIFT	02:14:18	18	990	33	3.79
4	GRB050505	SWIFT	23:22:21	540	793	50	4.27
5	GRB050509	SWIFT	01:46:29	16	115	57	
6	GRB050509	SWIFT	04:00:19	15	368	69	0.23
7	GRB050528	SWIFT	04:06:45	43	77	52	
8	GRB050713	SWIFT	04:20:02	13	40	49	
9	GRB050904	SWIFT	01:51:44	82	92	20	6.29

*Drive system improvement*

**On 13 July 2005 MAGIC observed a GRB only 40 s after prompt emission**

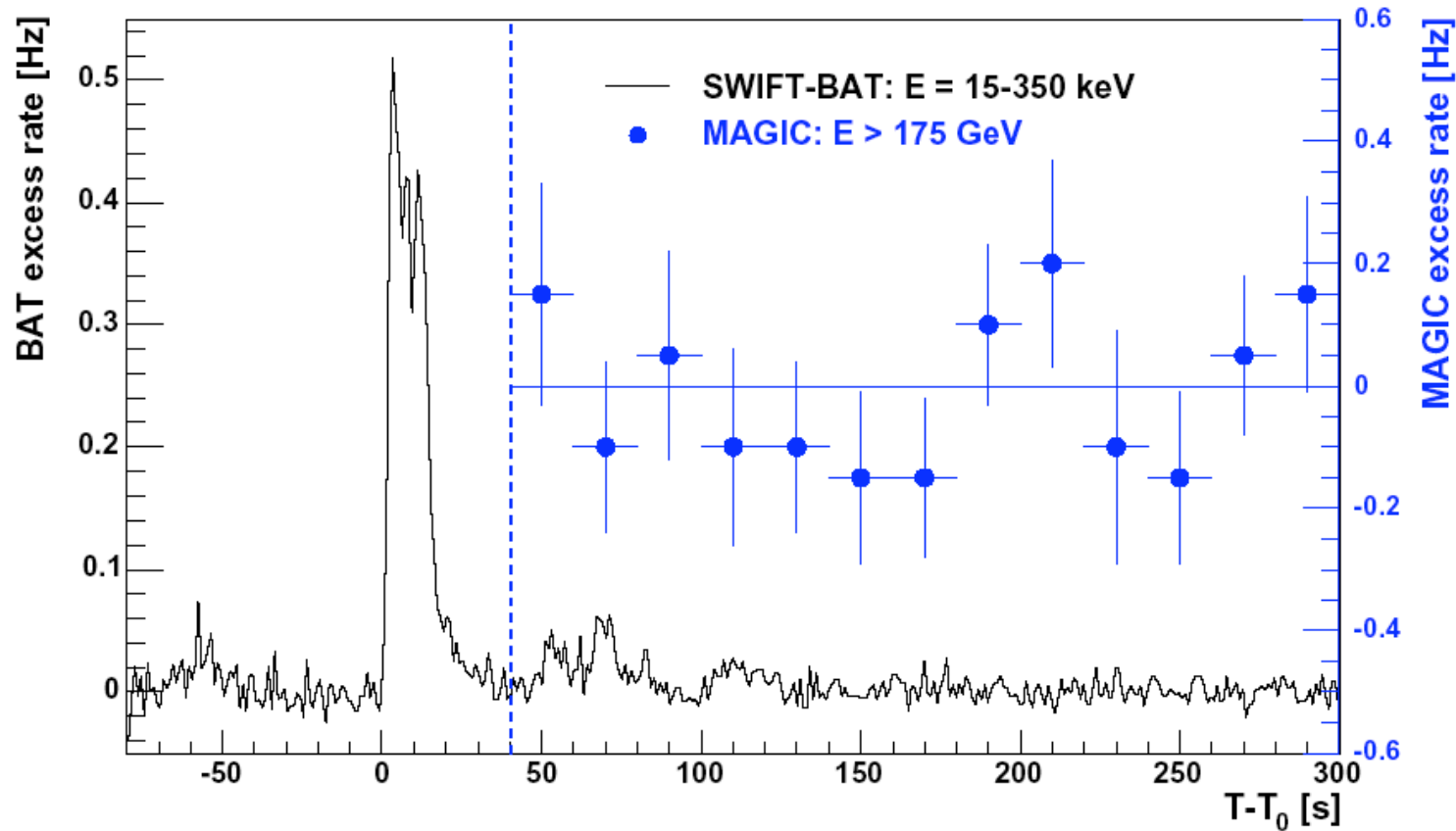
## 3.5 - First year operation (Sep04-Sep05): Gamma-Ray Bursts



Second GRB that is observed by XRT instrument at SWIFT

## 3.5 - First year operation (Sep04-Sep05): Gamma-Ray Bursts

### Light curve GRB050713, as observed with MAGIC



*Submitted to ApJ Letters*

**No significant excess above 175 GeV**

## 3.6 - Upgrade of DAQ system

*astro-ph/0506459*

*Supported by  
großgeräteförderung der MPG*

**Current FADC  
300 MSample/s**



**New FADC  
2 GSample/s**

### **Motivation for this upgrade**

Reduction of NSB effect due shorter integration times

Improve in signal arrival time resolution ( $1.3 \text{ ns} \rightarrow 0.4 \text{ ns}$ )

Exploit better the time profile of the individual signals ( $2\text{-}5 \text{ ns}$ )

### **Problem: 2GSample/s FADC are expensive (5 k€)**

**Solution: Same FADC chan. to digitize 16 PMT chan.**

**Working on this idea since many years.**

**Everything (almost) ready. Estimated date for upgrade: April 2006**

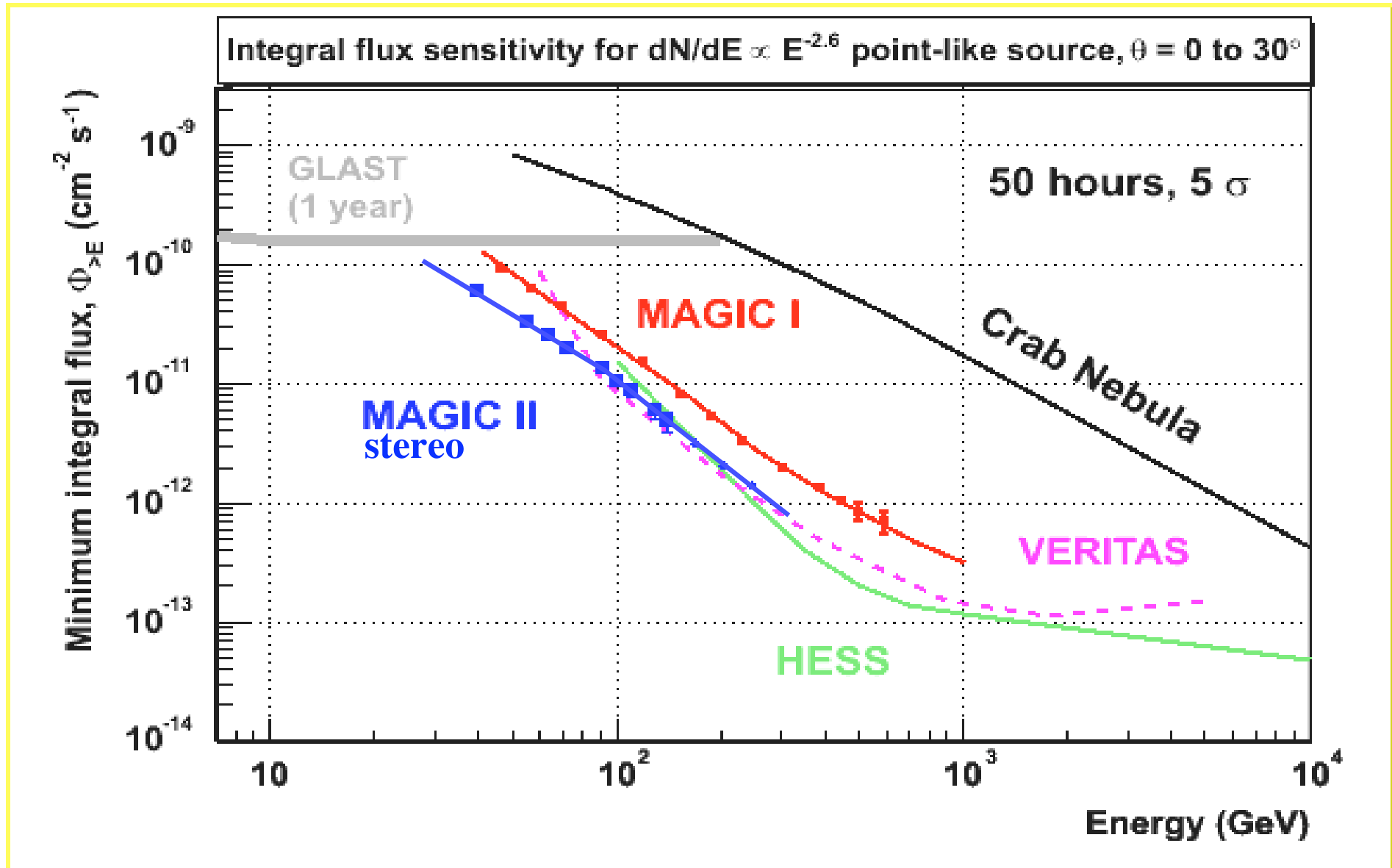
*(Talk of A. Wassatsch)*

# Construction of MAGIC II



## 4.1 - Motivation to build MAGIC II

Stereo observation improves sensitivity by  $\sim 2$



## 4.2 - Task distribution in the construction of MAGIC II

### Principal task

### Responsible institution + Others

Fundations

**MPI**

Telescope mount

**MPI**

Undercarriage

**MPI**

Drive motors

**MPI**+German Univ.

Camera

**MPI**+German Univ.

Optical System

**MPI**+IFAE + INFN Udine + UAB

FADC

IFAE + INFN Padova + IFAE

DAQ

INFN Udine

Trigger

INFN Siena + INFN Padova

Mirror

INFN Padova + UAB

Motor Control

ETH + INFN Udine + **MPI**

Local Computing

INFN Udine + ETH

Central Control

IFAE

Calibration System

**MPI**

Monte Carlo Center

INFN + ETH + **MPI**

**Scientifically operational before GLAST (August 2007)**

## 4.3 - Construction of the telescope structure

Construction started in **September 2005**

**Foundations done**

**Telescope structure on schedule (to be finished on Jan 2006)**



21/12/2005

David Paneque

45

## 4.3 - Construction of the telescope structure

Construction started in **September 2005**

Foundations done

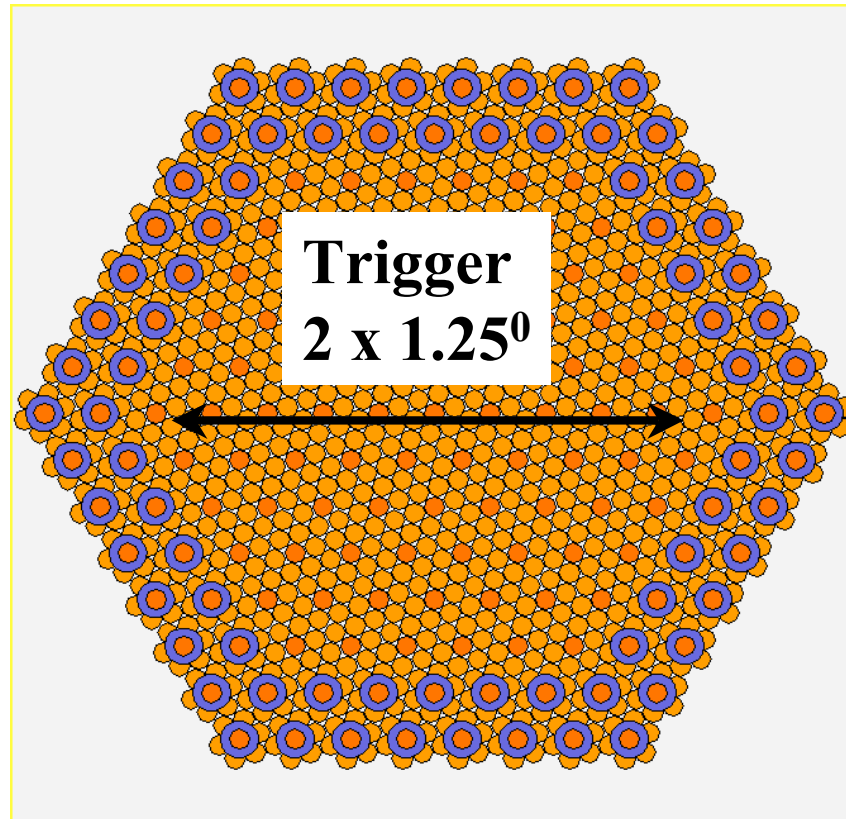
Telescope frame on schedule (to be finished on Jan 2006)



Installation of  
telescope frame  
on the mount

*First trial failed due to  
bad weather conditions*

## 4.4 - Construction of the telescope camera



### **MAGIC II**

Total 1183 pixels:

*Radius*

1.81 deg

Same dimensions that MAGIC I  
More pixels than MAGIC I

Trigger region increased by  
 $2 \times 0.3 \text{ degrees}$

Better for extended sources  
Better for off-center obs.

Pixels will be  
High QE PMTs (phase I)

More details about camera

In talks:

T. Haubold

A. Wassatsch

## Hybrid Photomultipliers will be tested (and used in second phase)

**Collaboration with Hamamatsu**  
*R9792U-40: Quality being studied*

*Supported by  
großgeräteförderung der MPG*

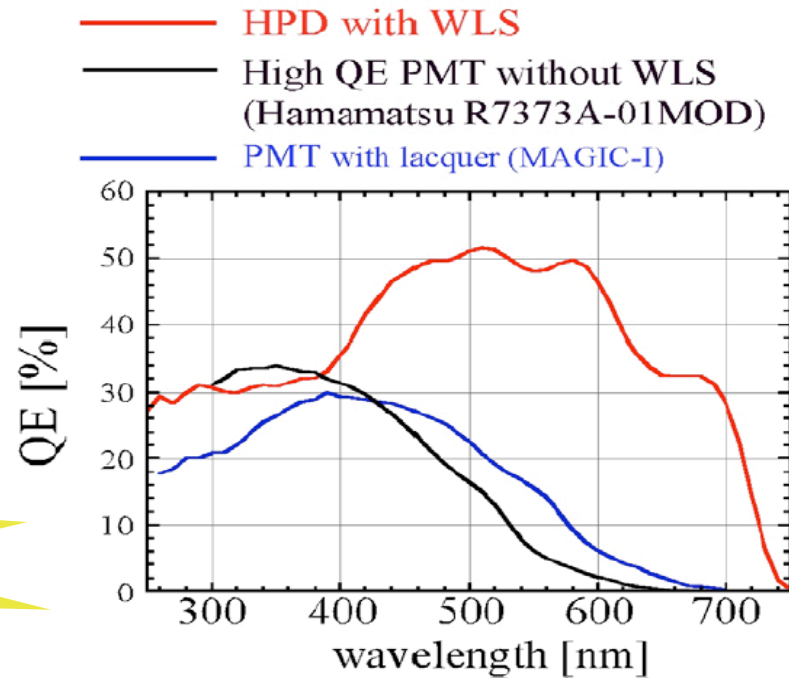
**HPDs improve the photon  
sensitivity of IACT by ~2**

**17 m  $\emptyset$   $\longrightarrow$  24 m  $\emptyset$**

**Lower energy threshold**

**Never used in IACTs so far**

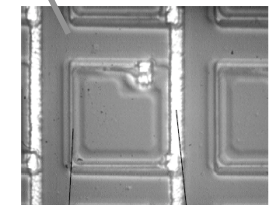
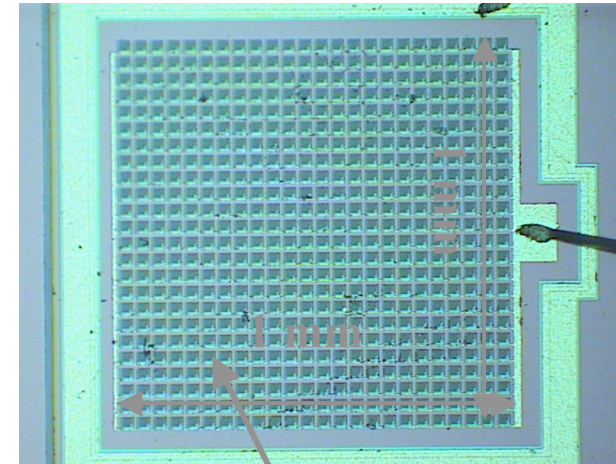
**7-HPD pixel clusters will be built and  
tested under real conditions**





## Silicon Photomultipliers for the future

- **Matrix of avalanche diode pixels**
  - operated in limited Geiger mode
  - common readout
- **Characteristics:**
  - excellent multiple photo electron resolution
  - **potentially very high QE (60 - 80%)**
    - **Lower energy threshold**
  - Ultra-fast signal response
  - Robust / easy operation
  - **Cheap (at some point)**



**Development phase** in collaboration with  
MEPhI & Pulsar

*Ready Prototype of 5x5mm; 35% QE (400nm)*

Halbleiter labor (*back illumination* concept, see talk H.G. Moser)

*Prototype (5x5mm or 10x10mm) expected for 2007*

# 5 - CONCLUSIONS

**Construction of MAGIC I was a technological challenge**

**MAGIC I is operating regularly since fall 2004. Reasonable understanding of the telescope performance achieved.**

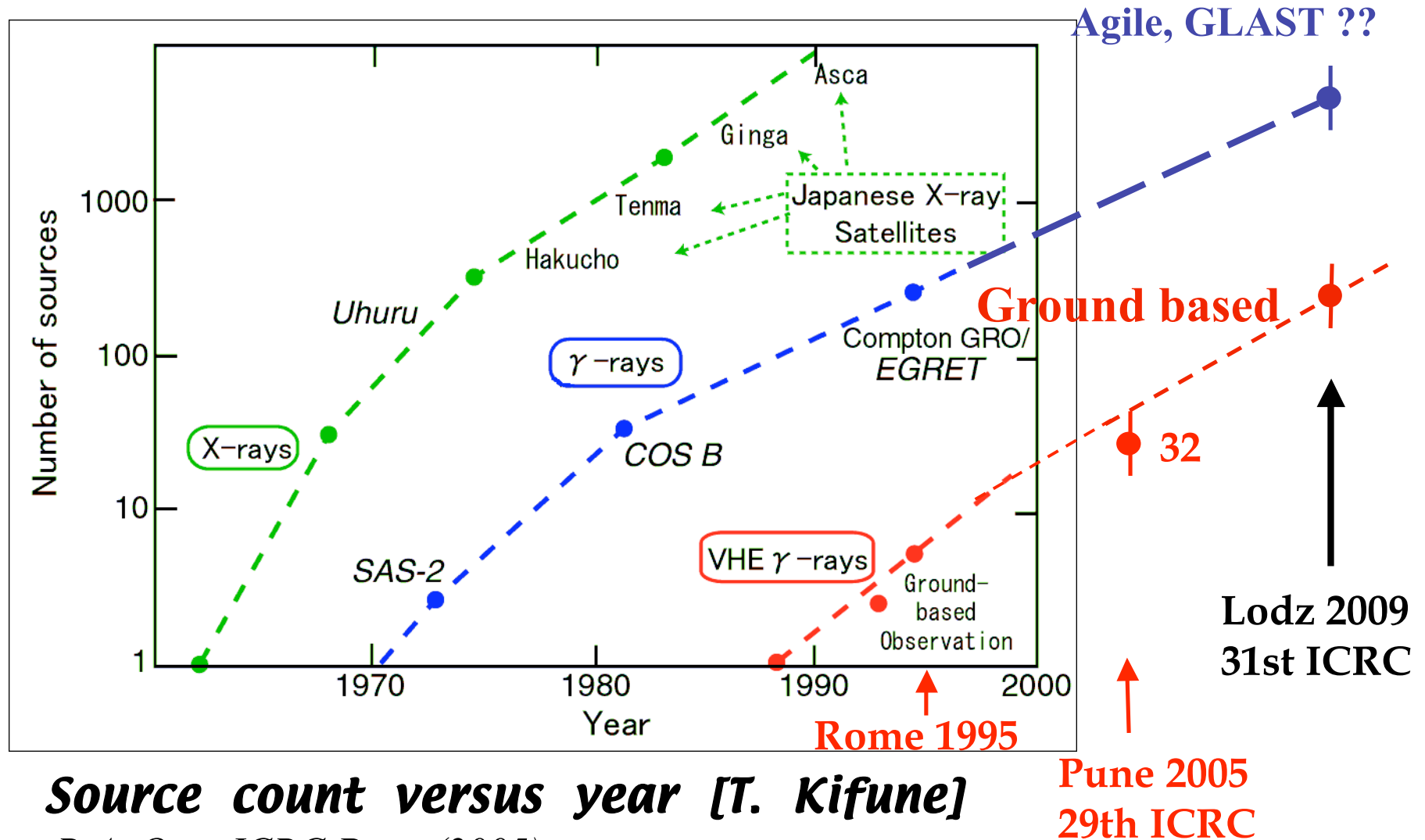
**Clear gamma-source detections down to 100 GeV have been performed with high significance**

**9 sources detected; 1 discovery of distant AGN**

**Construction of MAGIC II already started**

**It will be scientifically operational before GLAST's launch**

# “Kifune Plot”



# 5 - CONCLUSIONS

**MAGIC, as the other *new generation of instruments* that aim for exploring new gamma-ray energy domains, are *expected* to bring key data for understanding the “non-thermal Universe”**

**!!!! Very exciting time for gamma-ray astronomy !!!!**

*The real voyage, is not to travel to new landscapes,  
but to see with new eyes...*

**Marcel Proust  
(1871-1922)**