

# Multiwavelength Studies with the MAGIC telescope

## Multimessenger Workshop

6. October 2005  
Zeuthen

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München



# The **MAGIC** telescope

## 17 m Cherenkov Telescope

Design optimized for:

- low energy threshold ( $E_{\gamma} = 30 \text{ GeV}$ )
- fast repositioning ( $t_R < 30 \text{ sec}$ )

operational since End 2003

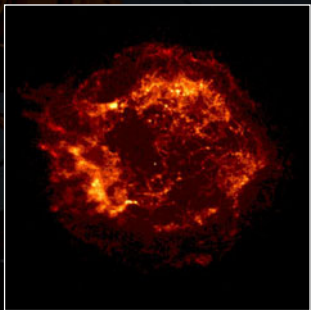
Canary Island **La Palma**  
*2200 m asl*



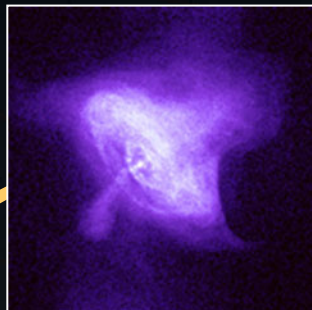
**Collaboration:** > 100 physicists, 18 institutes, 11 countries:  
Barcelona IFAE, Barcelona UAB, HU Berlin, Crimean Observatory, U.C. Davis,  
U. Dortmund, U. Lodz, UCM Madrid, INR Moscow, MPI München,  
INFN/ U. Padua, INFN/ U. Siena, Sofia, Tuorla Observatory,  
Yerevan Phys. Institute, INFN/ U. Udine, U. Würzburg, ETH Zürich



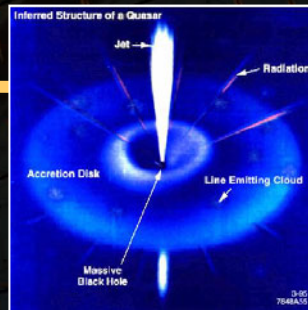
# The MAGIC Physics Program



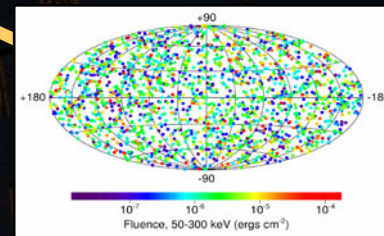
SNRs



Pulsars

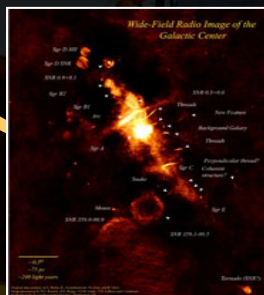


AGNs

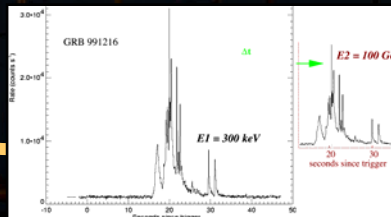


GRBs

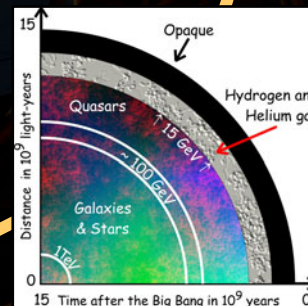
Origin of Cosmic Rays



Cold Dark Matter



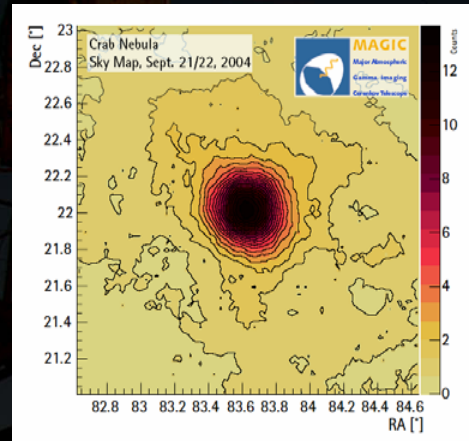
Quantum Gravity effects



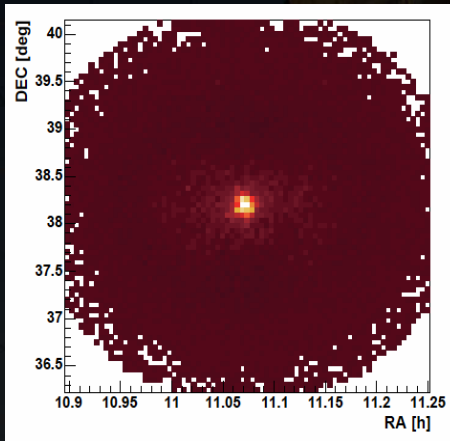
cosmological  $\gamma$ -Ray Horizon



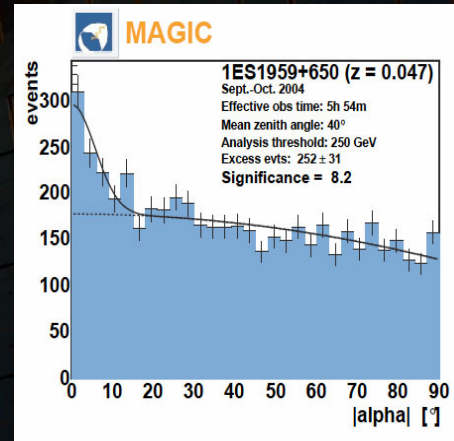
# MAGIC highlights this year



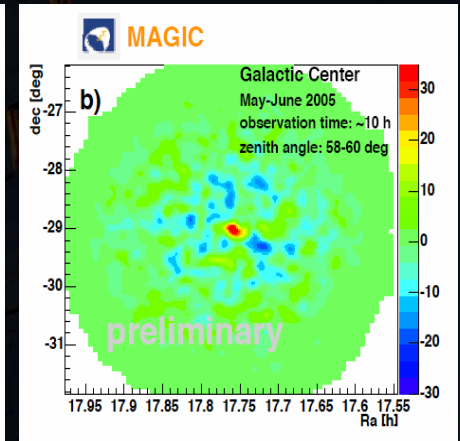
Crab Nebular  
SZA & LZA



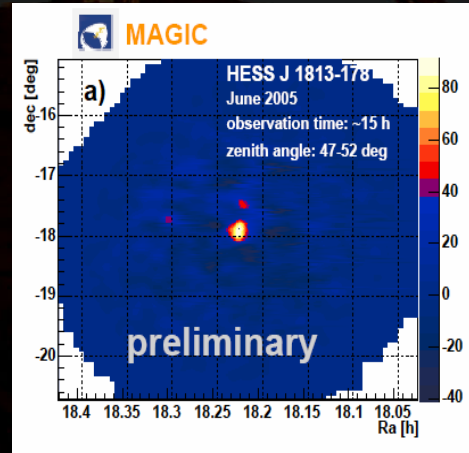
Mrk421  
Campaign with HESS



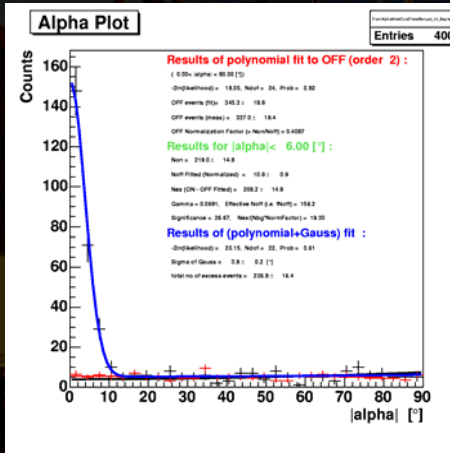
1ES1959+650



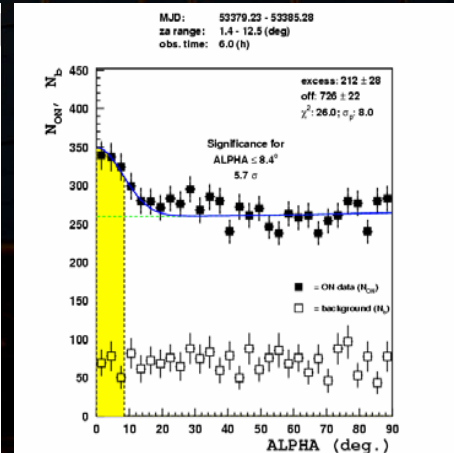
Galactic Center



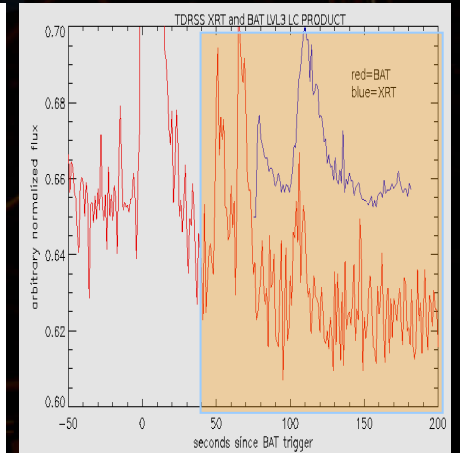
HESS J1813



Mrk501  
IAU Circular #8562



New source  
1ES1218 (z=0.18)



GRB050713a  
Observation 40s after GRB



# Mutliwavelength Studies

- proper **understanding of physics** of  $\gamma$ -ray sources requires observations in **other wavelengths**
- variable sources require **simultaneous observations**

=> **MAGIC ++**

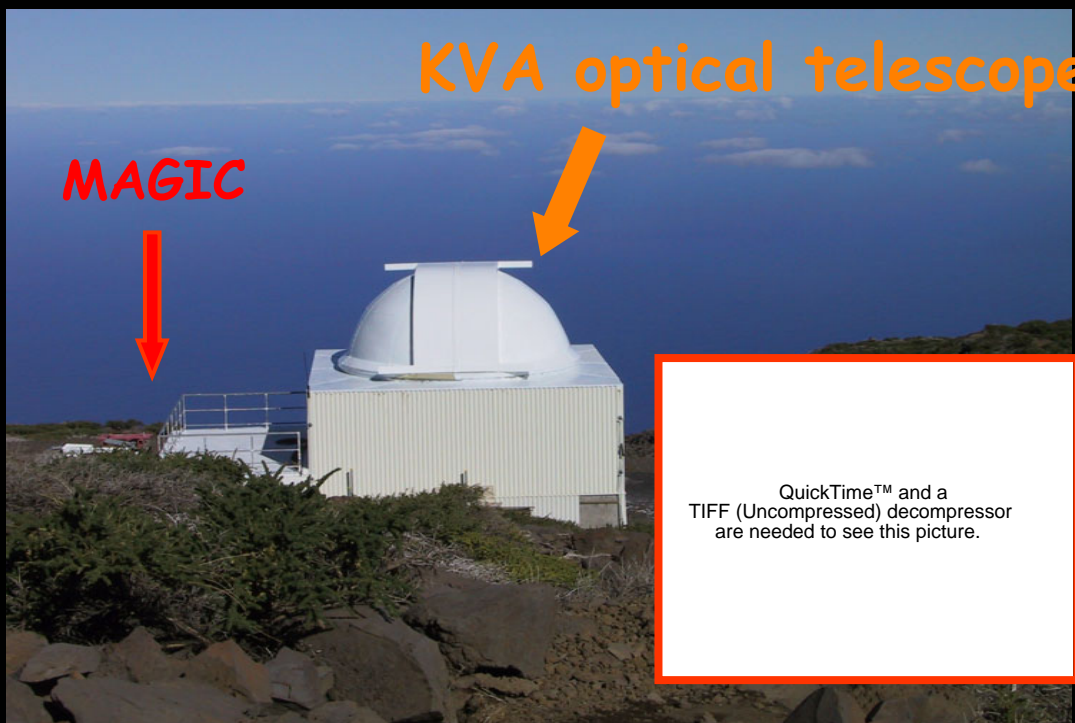
- **radio** telescopes (GMRT, MRAO)
- **optical** telescopes (Tuorla, KVA, ...)
- **X-ray satellite** (RXTE-ASM, Chandra, XMM, HETE, Integral, Swift, ..)
- other **Cherenkov telescopes** (HESS, Veritas, Cangaroo)
- **neutrino** telescopes



# Optical Monitoring

- KVA 60 cm optical telescope at La Palma
- remote operation from Tuorla, Finland
- simultaneous observations with MAGIC

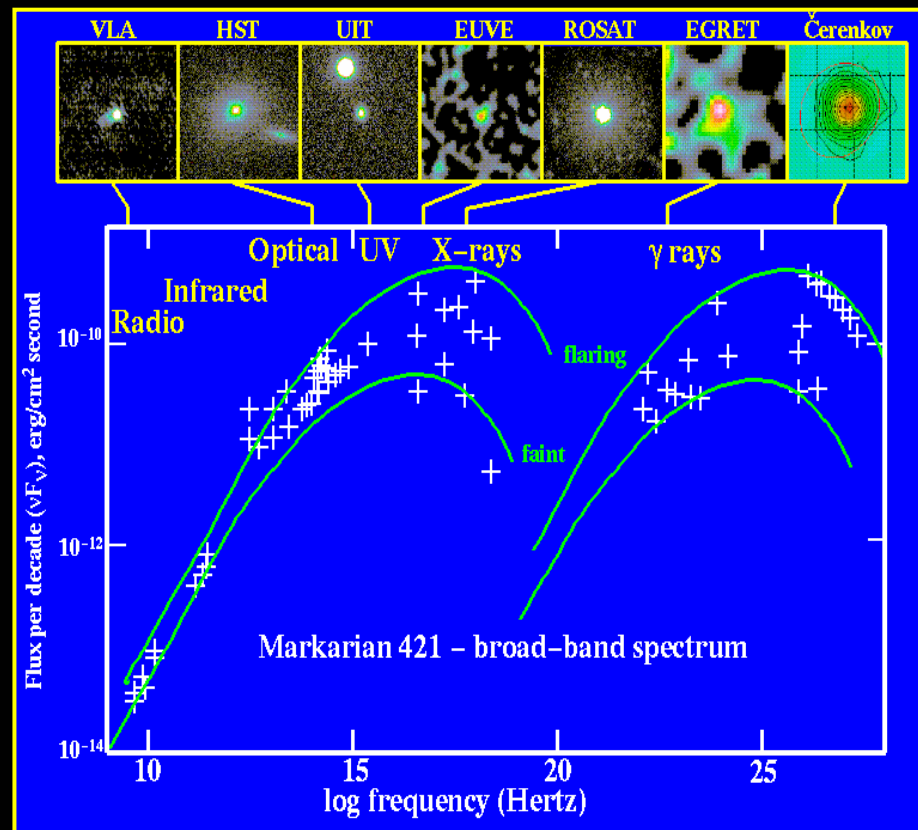
QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.



- 1.03 m optical telescope at Tuorla Observatory, Finland
- long term optical monitoring of 24 TeV-sources/candidates

# AGN & multiwavelength studies

- non-thermal emission covers full range of E.M. radiation
- emission **highly variable**
- need **simultaneous multiwavelength observations** to discriminate mechanisms:
  - leptonic SSC models
    - many spectral features
    - correlations of X-ray and  $\gamma$ -ray flares
  - hadronic models (orphan flares)





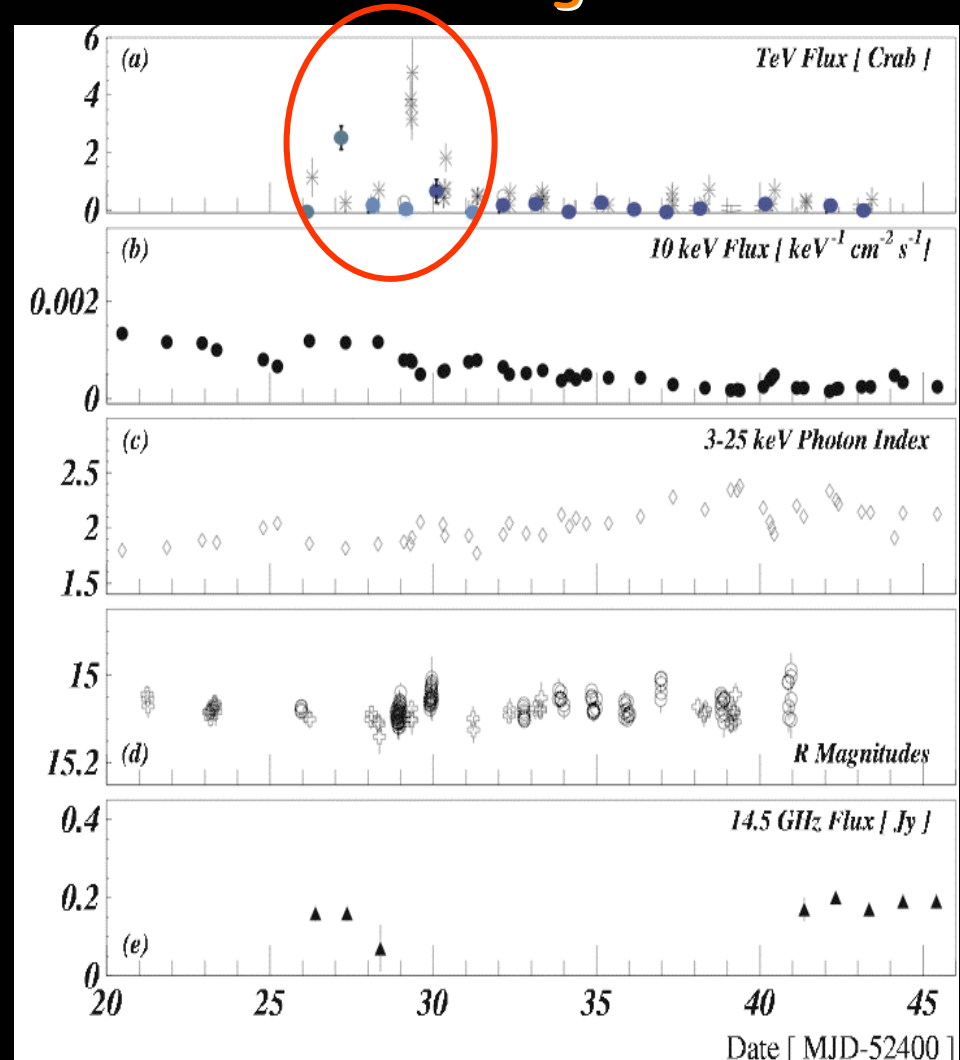
# AGN 1ES1959+650

(Blazer type AGN,  $z = 0.047$ )

## June 2002 light curve

### "orphan flare"

- multiwavelength campaign in June 2002:
  - Whipple & CT1 observed independent **TeV flares** without X-ray counterpart
  - Amanda: 3 (1) **neutrinos** coincident with (orphan) flares
- **leptonic** models:
  - multiple component SCC
  - external Compton
- **hadronic** models

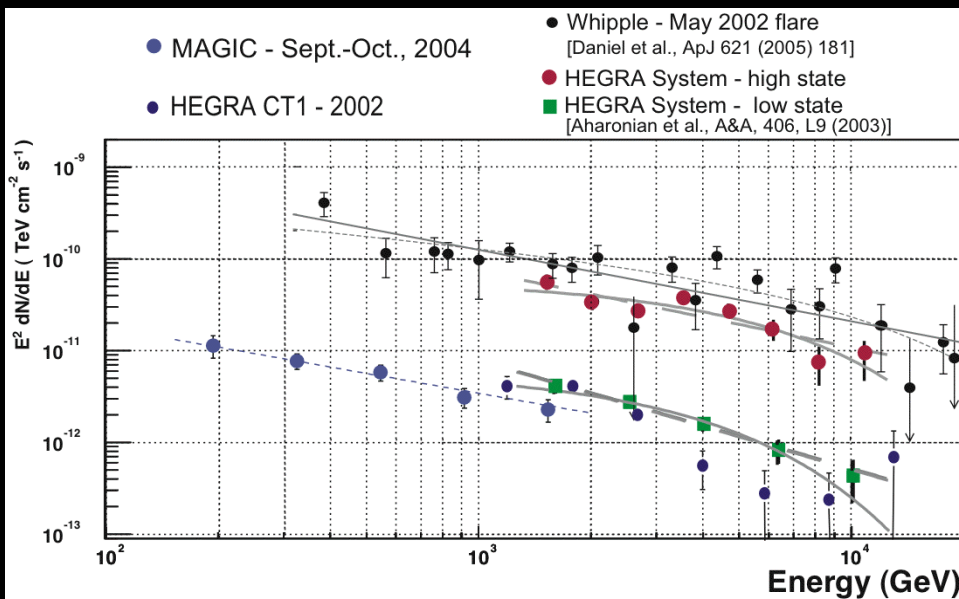
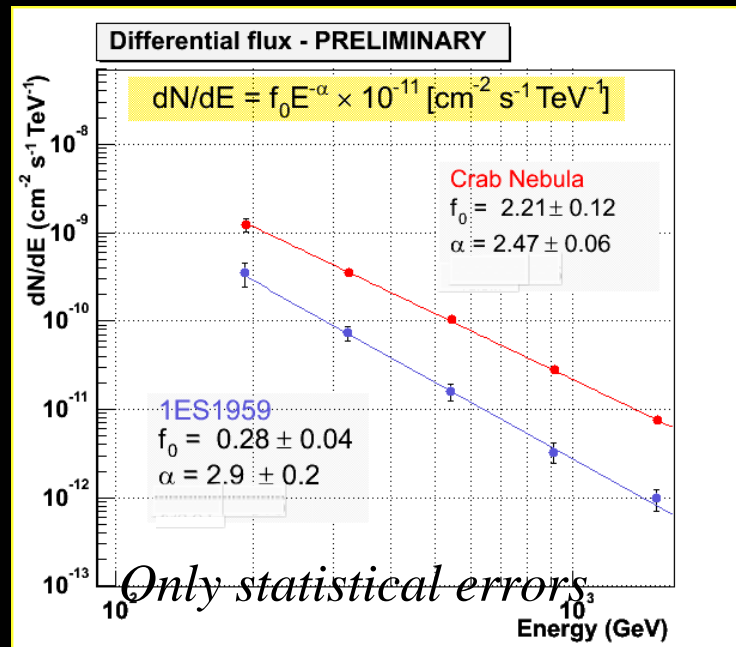






# 1ES1959+650: MAGIC observations

- observation in September / October 2004
- 7 h @ mean zenith angle  $\sim 40^\circ$
- $8.2 \sigma$  excess ( $E > 300 \text{ GeV}$ )

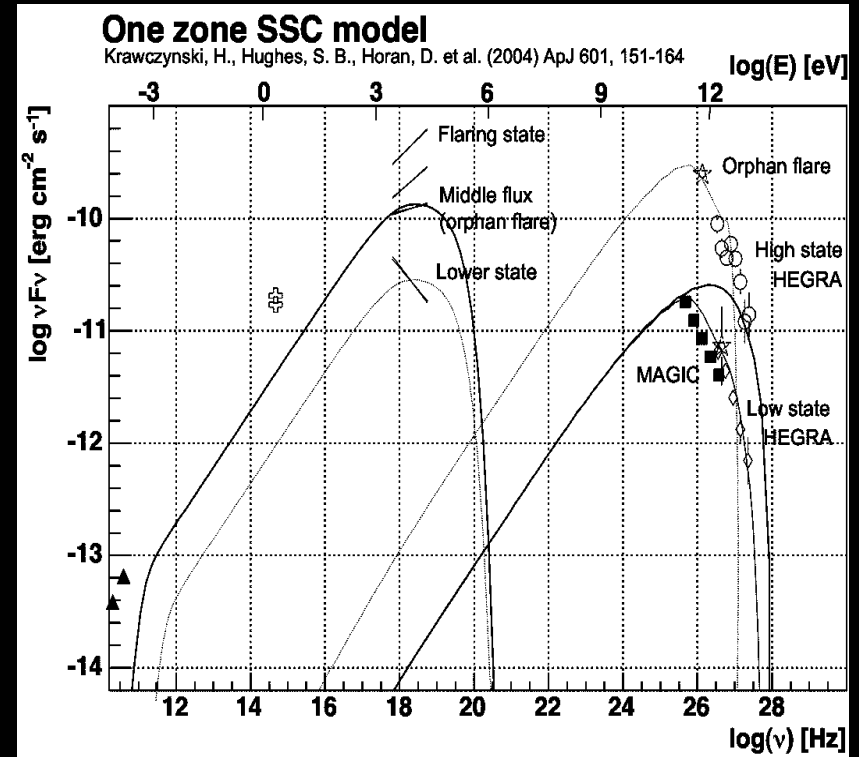
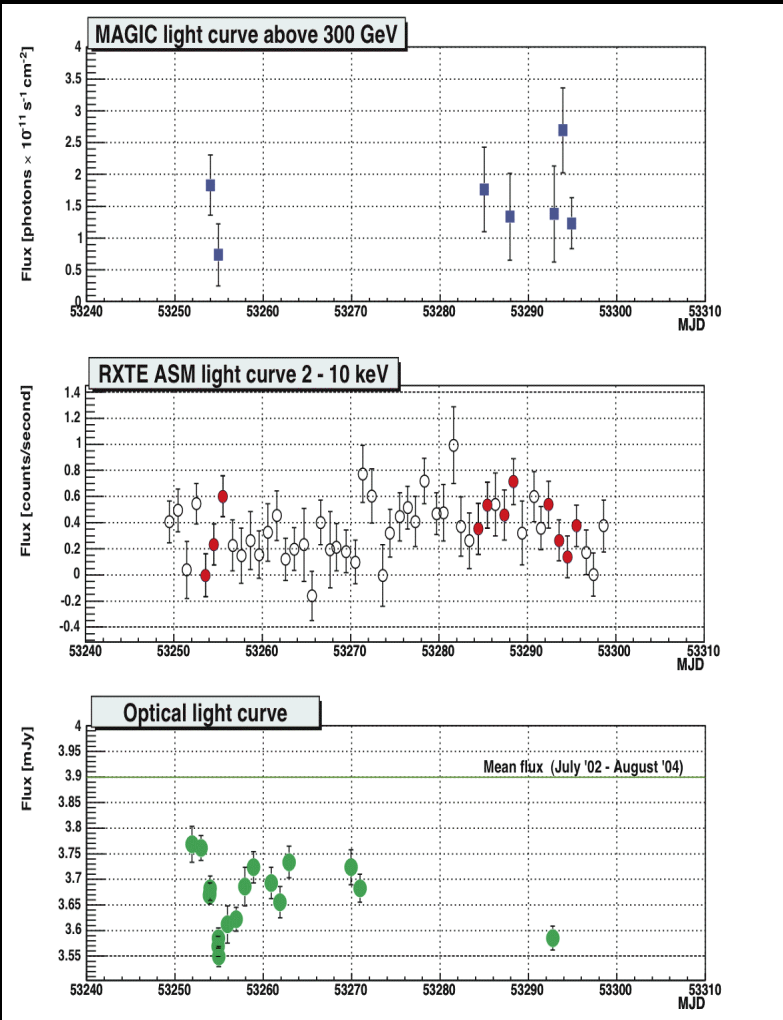


- Mean integrated flux  $\sim 15\%$  Crab ( $> 300 \text{ GeV}$ )
- spectral index  $\alpha = 2.72 \pm 0.14$
- Inverse Compton peak not resolved down to  $200 \text{ GeV}$ .



# 1ES1959+650: MAGIC observations

- multiwavelength observations



- leptonic SSC model: ok but ... orphan flare (?)

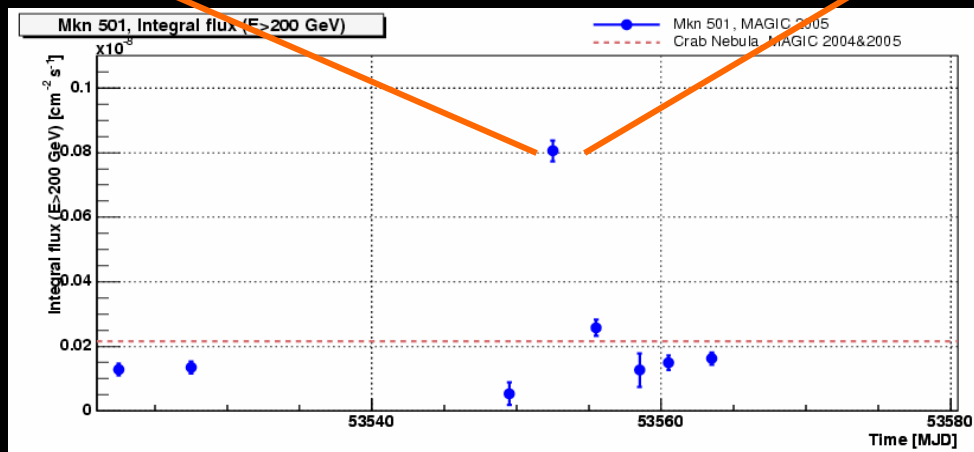
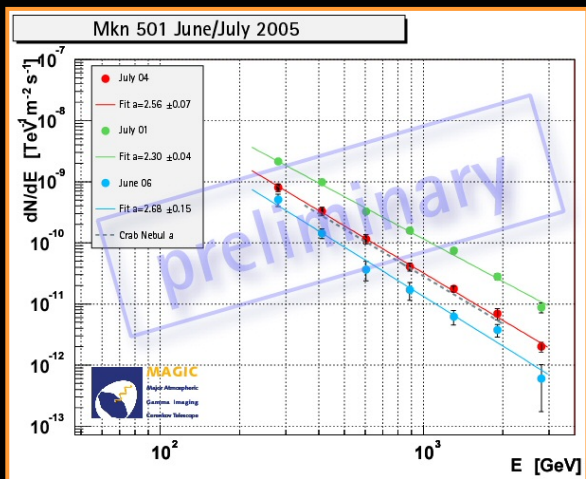
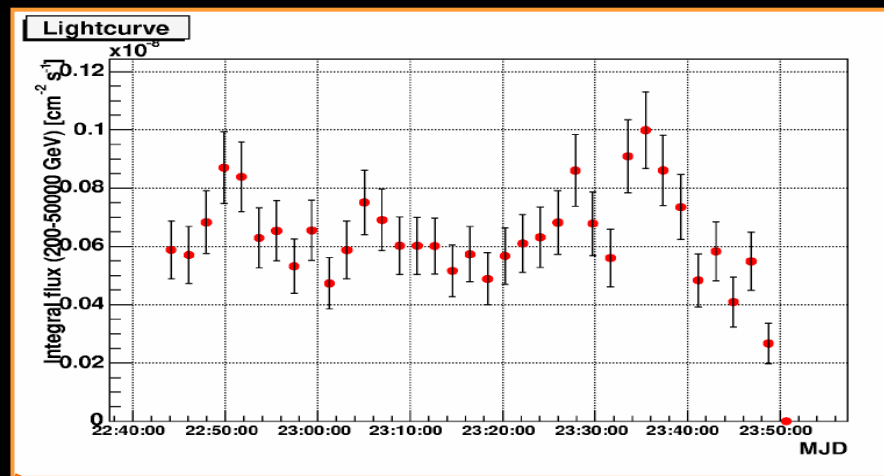


# AGN Mkn501

- well established TeV source (Blazer type AGN,  $z = 0.034$ )

July 2005 flare:

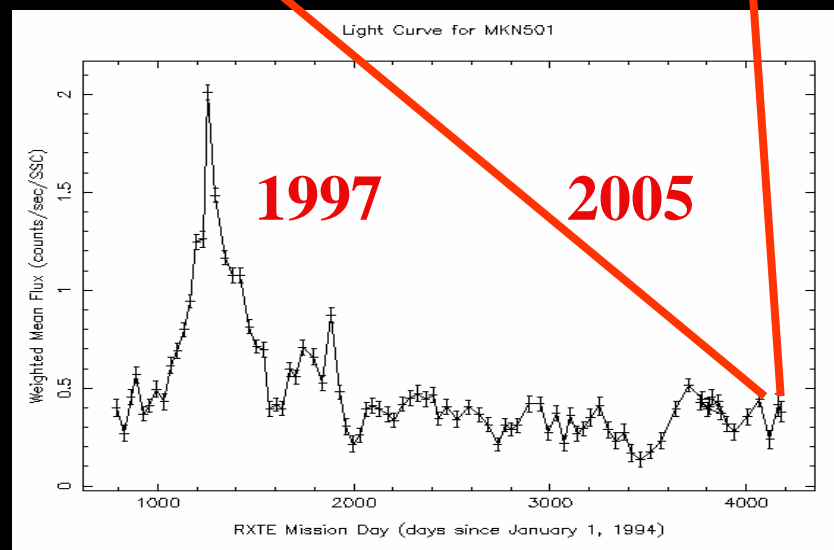
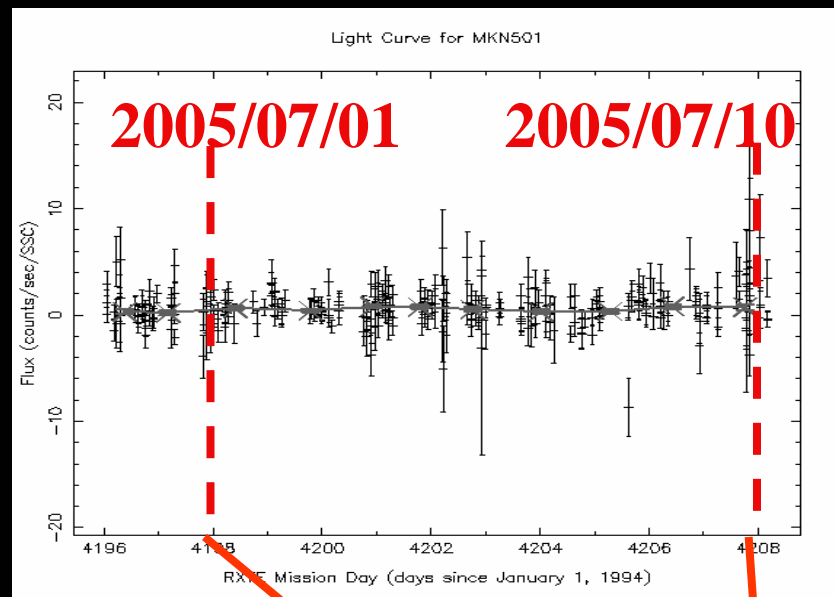
- strong flux (4 Crab)
- fast  $\sim 10$  min resolved in 2 minutes bins





# Mkn501 flare - X-ray data

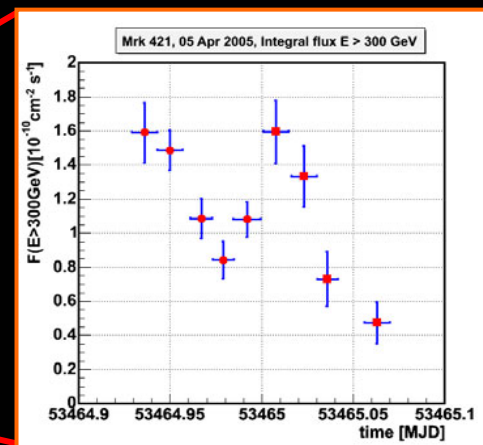
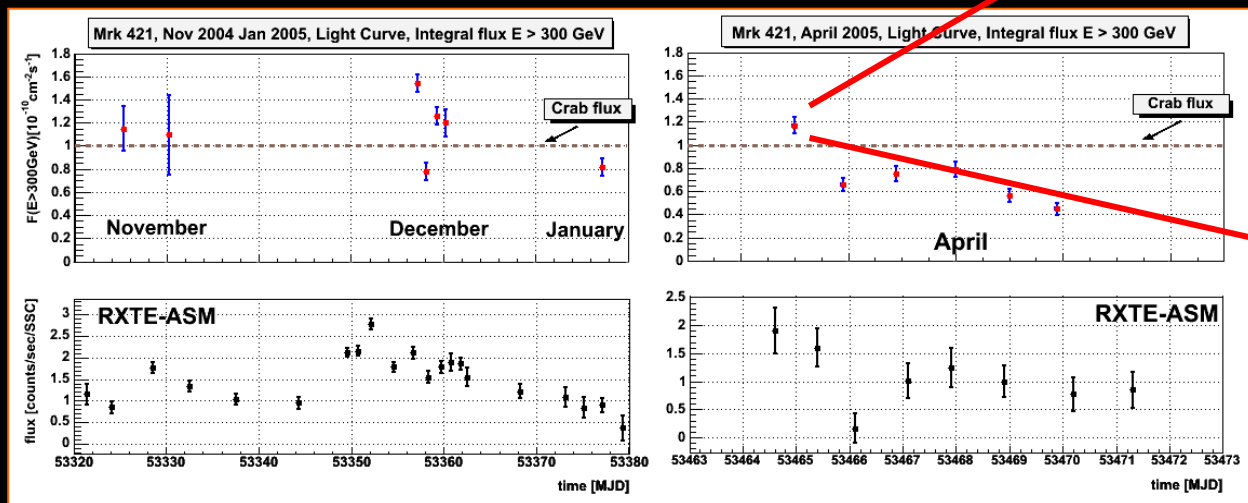
- No flare in X-ray data (RXTE ASM)
- orphan flare?
- is ASM sensitive enough?
- need dedicated simultaneous data with high sensitivity



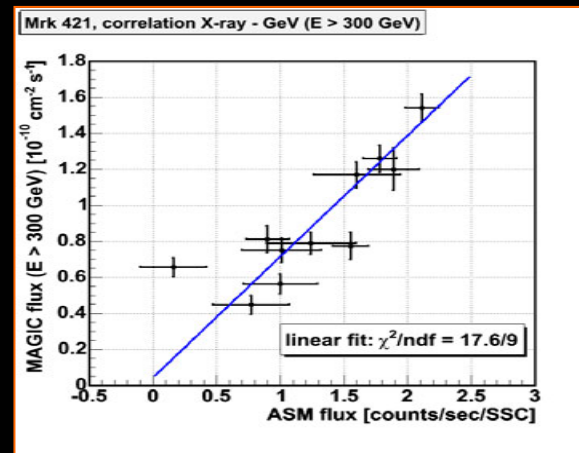


# AGN Mkn421

- well established TeV source (Blazer type AGN,  $z = 0.031$ )



- several MAGIC observations during winter 2004/5
- o(1h) flares up to 1-2 Crab
- clear correlation with X-ray (public RXTE-ASM)

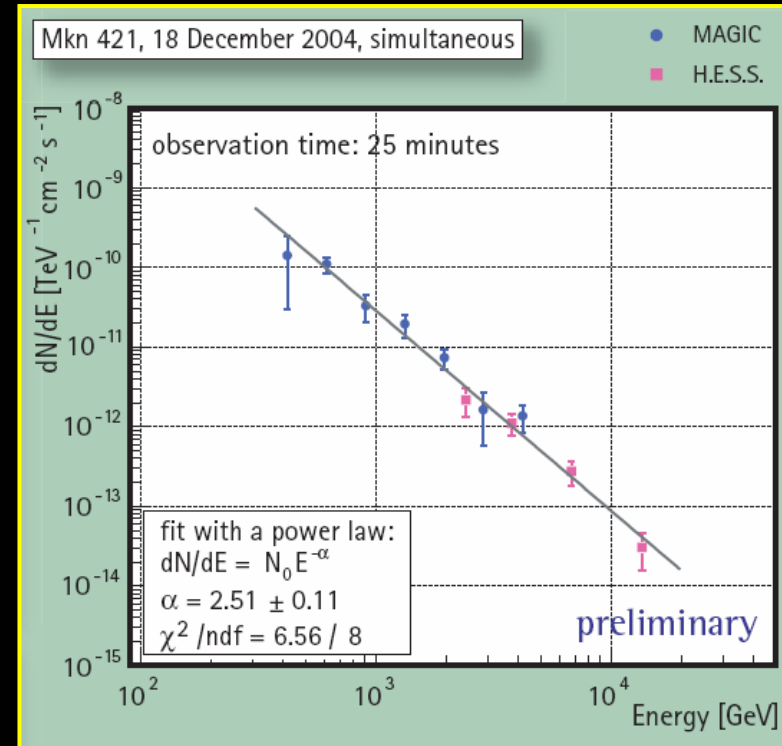
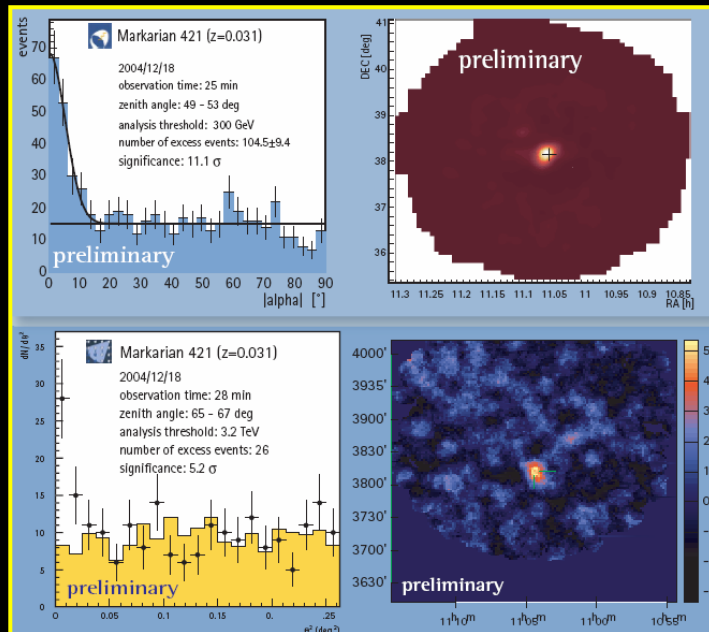




# Mkn 421: simultaneous H.E.S.S. & MAGIC observations

First joint observations:

- triggered by high X-ray activity and Veritas
- H.E.S.S. & MAGIC organized simultaneous observation on 18. Dec. 2004

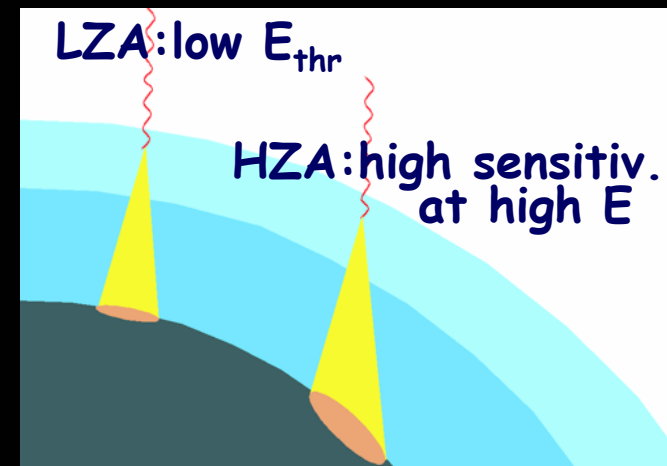


# Concept of a Global Network of Cherenkov Telescopes



- "Big 4" Cherenkov Telescopes cover wide longitude range ( $137^{\circ}\text{E} - 110^{\circ}\text{W}$ )
- => **continuous observations** of transient sources

- similar longitude of H.E.S.S. ( $16^{\circ}\text{E}$ ) and MAGIC ( $17.9^{\circ}\text{W}$ )
- **simultaneous observation at largely different zenith angles**
- => cover **large energy range** (up to 3 orders of mag.)



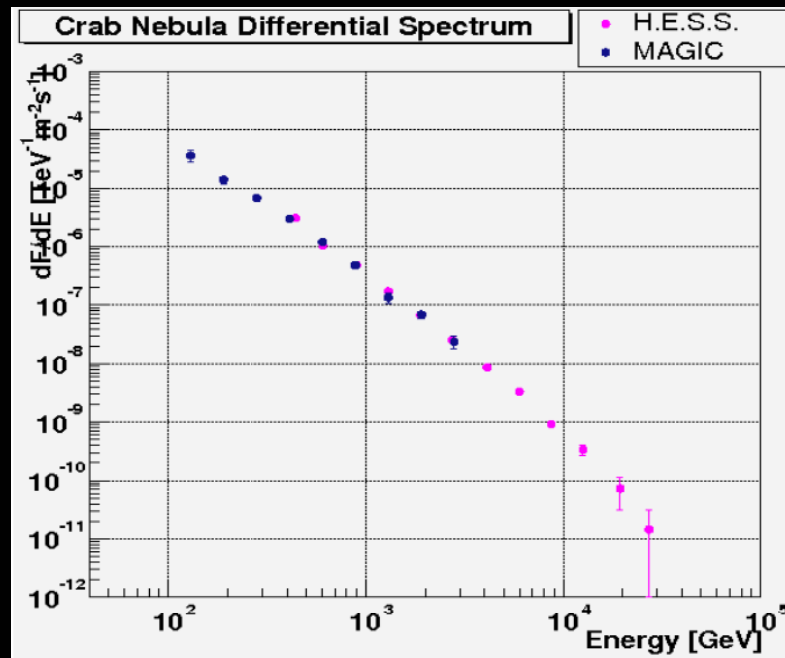


# First steps & proof of principle: Joint observations H.E.S.S. & MAGIC

## Crab Nebula

standard  $\gamma$ -ray candle  
 $\Rightarrow$  ideal **calibration** source

- steady  $\Rightarrow$  no need for simultaneous observations
- independent ("blind") MAGIC and H.E.S.S. analyzes
- good agreement in overlap region



agreement on trigger criteria for **future joint observation**

- simult. observ. of flares of **known AGNs** (incl. galact. sources in future)  
 $\Rightarrow$  study **broadband variability**  
 $\Rightarrow$  use extended spectrum to **disentangle EBL absorption** effect





# AGN: multiwavelength activities

**scheduled ToOs** (Target of Opportunity) for total of 113 AGNs

- trigger criteria for observation with MAGIC include:

- X-ray brightening

- (RXTE/ASM, Chandra, XMM-Newton, HETE-2, Integral/IBIS, Swift/Bat)

- optical brightening

**multiwavelength ToOs** for known AGNs with:

- Integral, XMM and RXTE



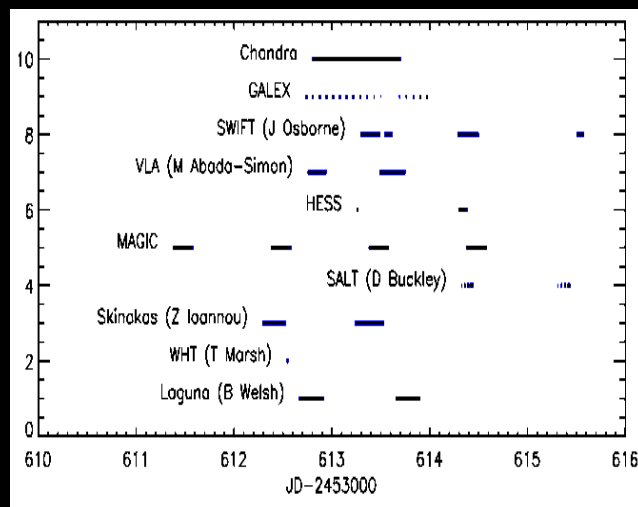
# Galactic Sources

ToO for **X-ray binaries, Microquasars** (GRS 1915, Cyg X-3)

- trigger from radio telescopes (MRAO, Ratan-600)

Multiwavelength campaign: **Cataclysmic variable** (AE Aqr)

- Aug 28. - Sep 1. (25h observation)
- together (partially) with GALEX, VLA, Chandra, JCMT and Keck

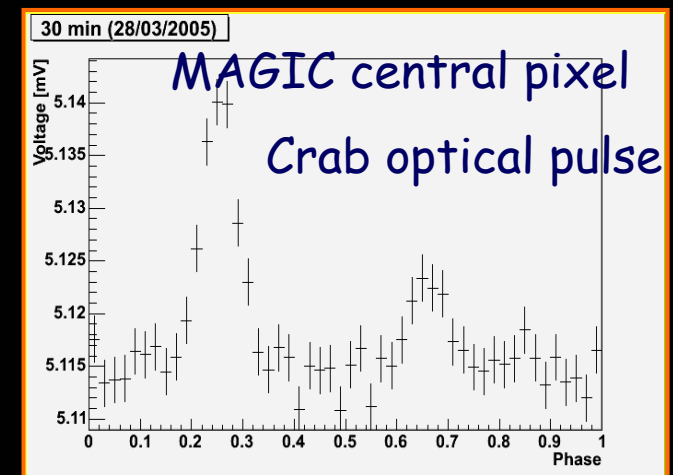


# Pulsars

- search for **10-100 GeV pulsed emission** (where is cutoff? => discriminate models)
- need very precise **knowledge of ephemerides** (low E -> low signal to background)
- update of pulsar frequency from radio telescopes (GMRT)

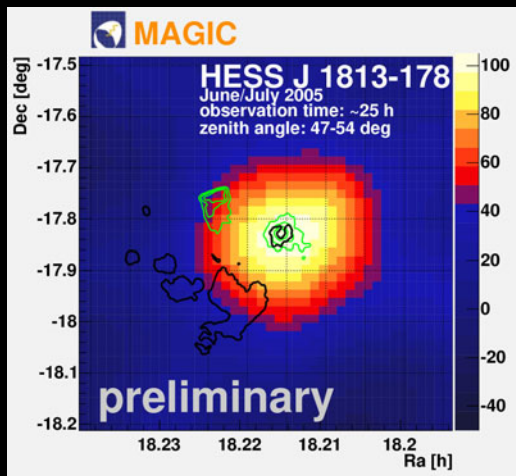


- Crab Pulsar:
  - **pulsed optical signal**
  - ⇒ central pixel to detect optical signal
  - ⇒ phase information



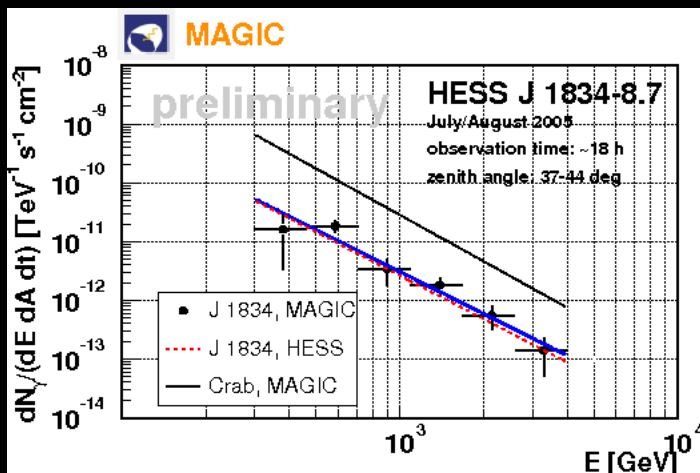
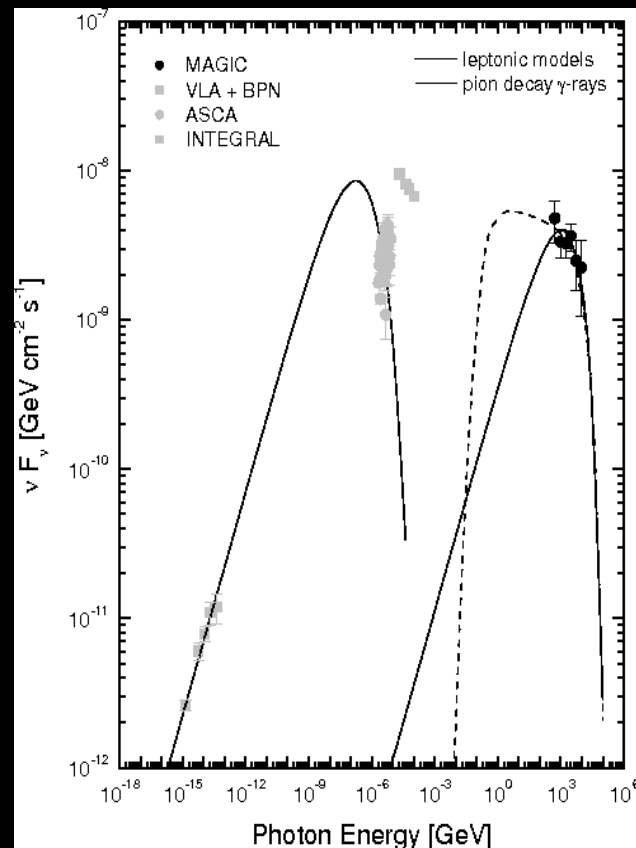


# HESS1813-178



following HESS detection:

- likely identification as **SNR G12.82-0.02** (in **radio** and **X-ray** data)
- TeV spectrum confirmed by MAGIC



- radio +  $\gamma$ -ray data consistent with both **leptonic** SSC model and **hadronic** models
- **1 - 100 GeV region decisive** (GLAST, MAGIC II, HESS II)



# GRB - observation strategy

## MAGIC GRB-Alarm-System

- E-mail
- Web
- sound alarm

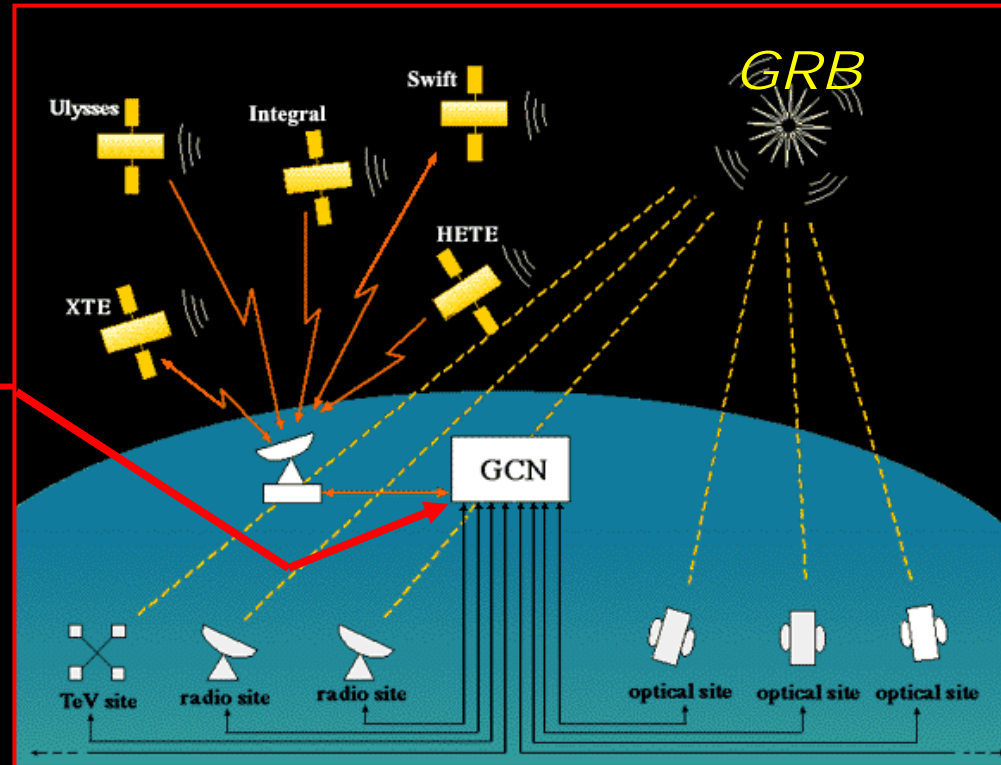
alarm  
system

Central  
Control

5-15 seconds



MAGIC Telescope  
drive system



reposition by 180°  
in less than 26 sec



# GRB observations

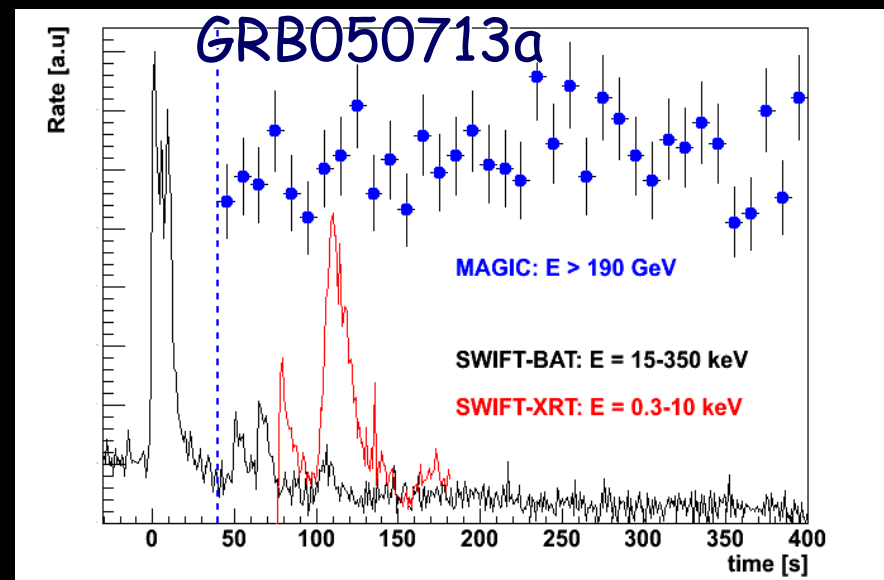
- Commissioning of GRB alarm system in April 2005
- 124 alerts with usable GRB coordinates  
(= 85 SWIFT + 28 HETE + 11 INTEGRAL)
- 11 GRBs observed by MAGIC
- 2 observations during prompt emission phase:

## GRB050713a ( $z=0.55$ , zenith= $50^\circ$ )

- observed 40 sec after burst onset
- $T_{90}=70$  sec  $\Rightarrow$  prompt emission
- no signal for  $E_\gamma > 175$  GeV

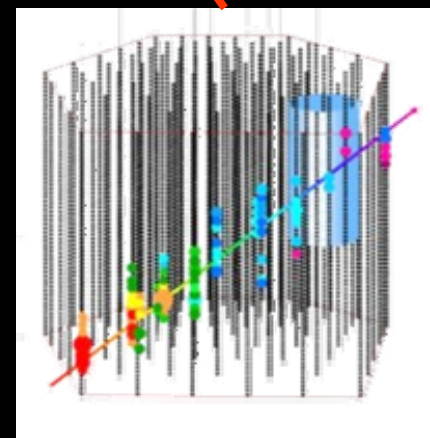
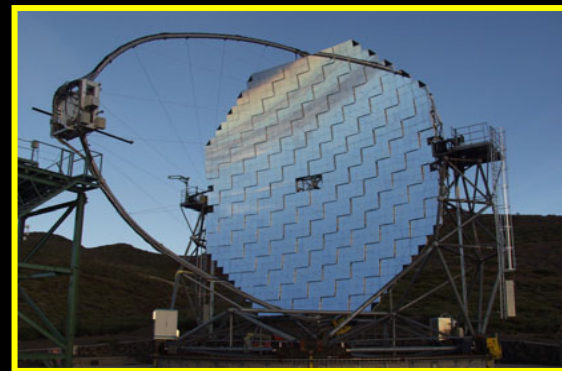
## GRB050904 ( $z=6.3$ , zenith= $20^\circ$ )

- observed 92 sec after burst  
( $T_{90}=225$  sec)
- analysis ongoing



# in future: Multimessenger Observations

- ultimate signature of hadronic acceleration:  
=> **neutrino emission**
  - increase statistical significance of neutrino telescopes by simultaneous observation of flares
  - continuous AGN monitoring too time consuming for MAGIC (see E. Lorenz talk)
- => **schedule AGN observations following neutrino detection from direction of AGN**





# (fast) Astroparticle Circular

need circular for:

- fast (hours) communication of flaring objects to astro(particle) community
- allows fast (automatic) follow up (multimessenger) observations
- ensures proper credit for discovery
- Who? Where?



# Conclusions

- **MAGIC** has successfully started datataking producing first results
- **Multiwavelength measurements** together with radio, optical, X-ray and  $\gamma$ -ray telescopes are essential for the interpretation of results

