Highlights of MAGIC results

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Univ. & INFN Padova

Highlights of MAGIC Results

- The MAGIC Telescope
- Galactic sources
- Extragalactic sources
- MAGIC II

5th Integral Birthday - Chia Laguna, October 17th 2007

MAGIC: The Collaboration

IFAE, UAB, IEEC, U Barcelona, Inst Astrof Andalucía, Inst Astrof Canarias, UC Madrid, MPI München, U Würzburg, HU Berlin, U Dortmund, Desy, INFN/U Pd, INFN/U Si, INFN/U Ud, INAF, UC Davis, ETH Zürich, U Lodz, Tuorla Obs, Yerevan Ph Inst, INR Sofia

Many World Records:

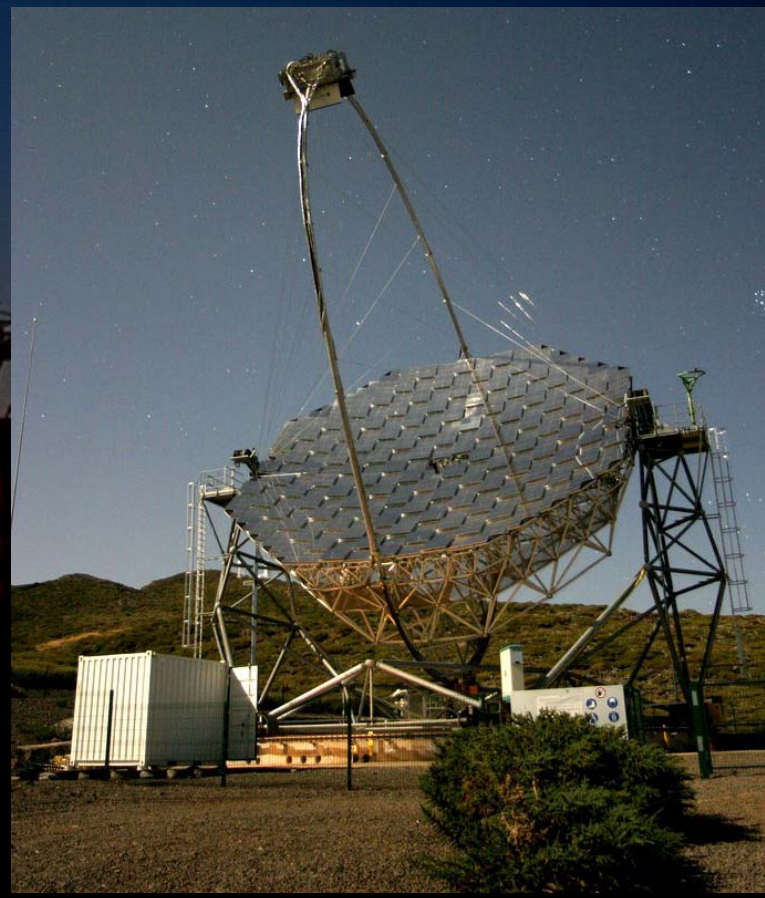
- 1st working system of analogue transmission via optical fibres
- 1st tentative and achieved coupling between C-fibres and Al
- 1st sub-μs topological trigger

among Cherenkov detectors:

- widest refl. surface (236 m^2, 17 m ∅)
- lowest energy threshold
- fastest slewing system (<40 s)

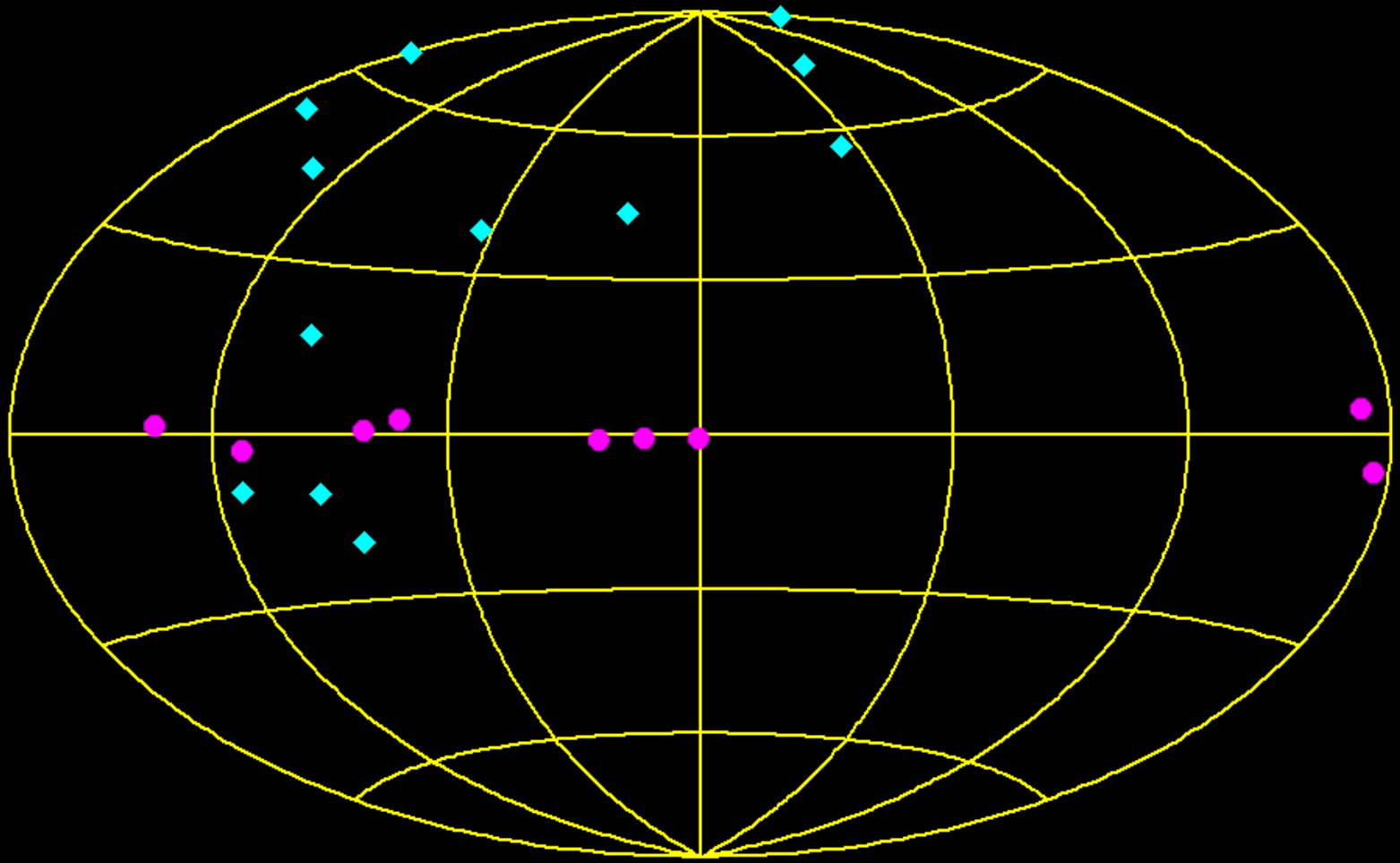
Main features:

- 3.5° FoV Camera, 576 enhanced QE PMTs
- Trigger threshold: 50 GeV
- Sensitivity: 2.5% Crab @50 hrs
- Energy res: 20÷30%
- Ang. res (γ PSF): 0.1°

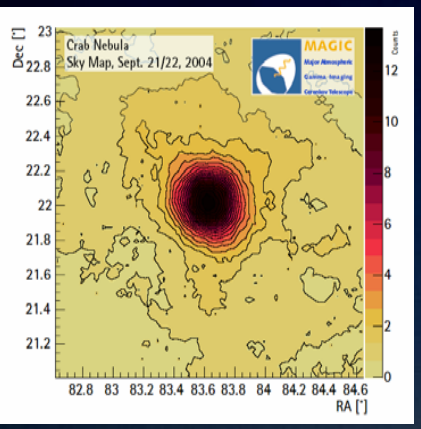


21 sources!

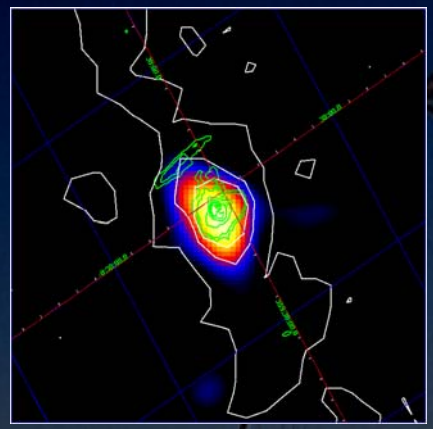
17 already published
1 soon to be published
3 to be refined



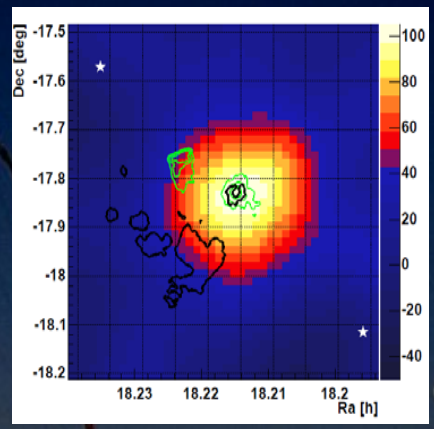
MAGIC: Galactic Sources



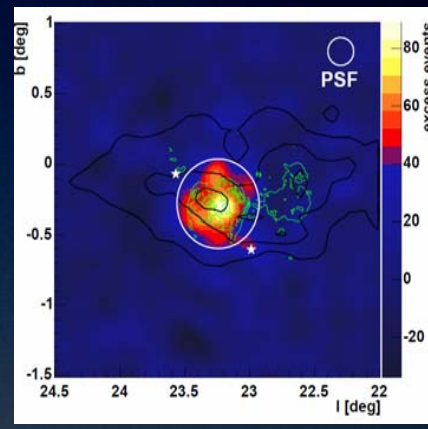
Crab Nebula



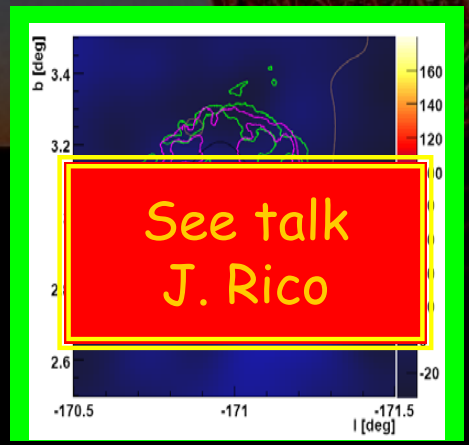
Galactic Centre



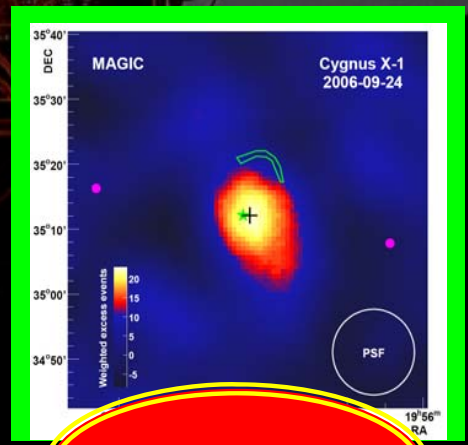
HESS J1813

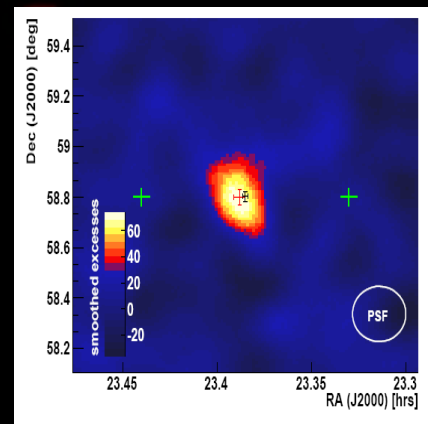


HESS J1834



See talk
J. Rico





Cassiopeia A

LS I+61

MAGIC J0616+225
→ IC 443

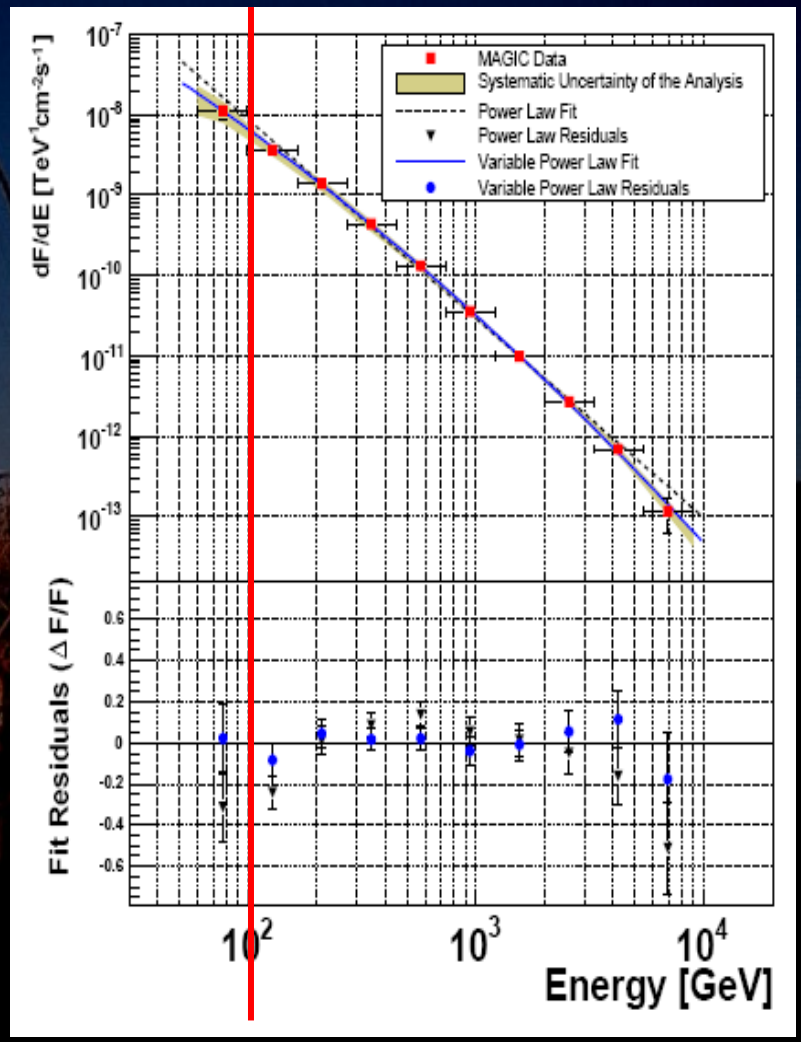
Cygnus X-1

The Crab Nebula: toward the Compton Peak

ApJ 669, 1143 (2007)

- Zenith angle < 20° @LE
- Spectrum measured between 60 GeV and 9 TeV
- Spectral idx ≈ 2.31
- Spectrum shows a clear peak at 77 ± 47 GeV
- Spectrum steady
- Source pointlike

1st measure below 100 GeV with Cherenkov!



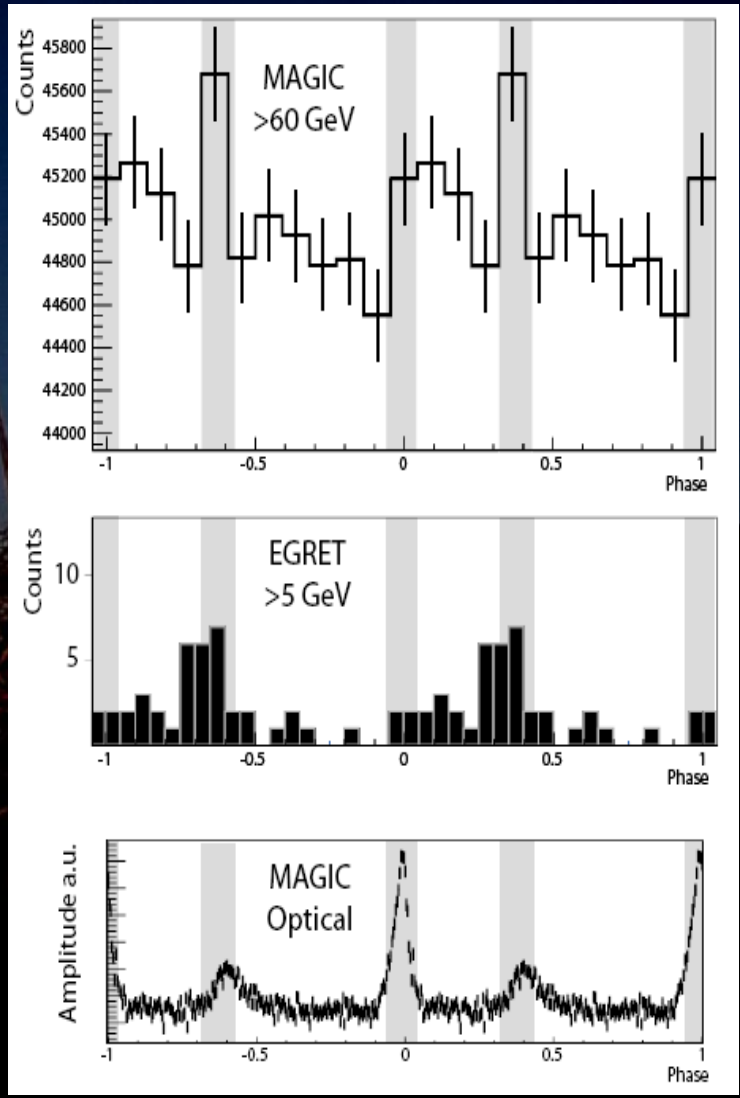
The Crab Pulsar

- Steady emission coincident with pulsar
- Optical phaseogram read "on-site"
- No evidence of pulsation
- Constraints set

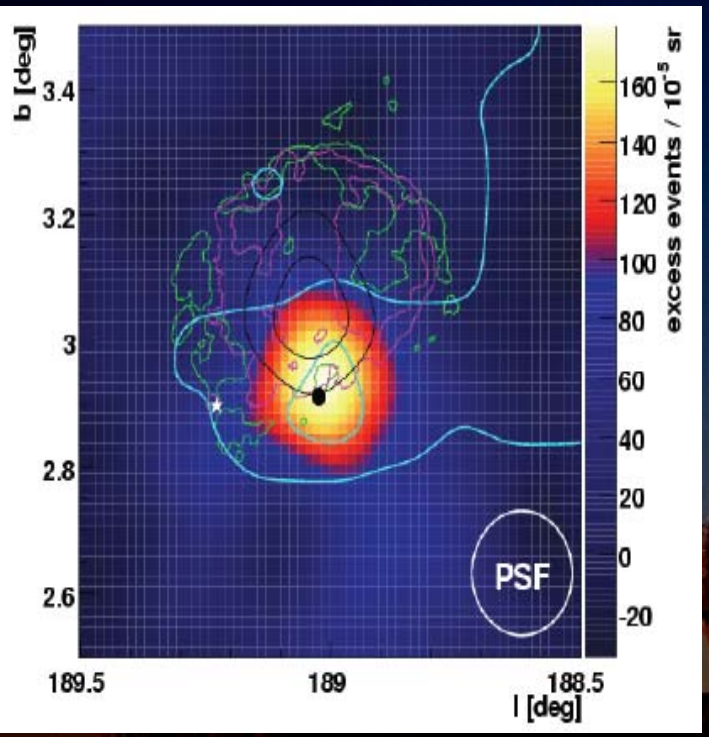
⇨ exponential cutoff
< 27 GeV

⇨ supra-exp cutoff
< 60 GeV

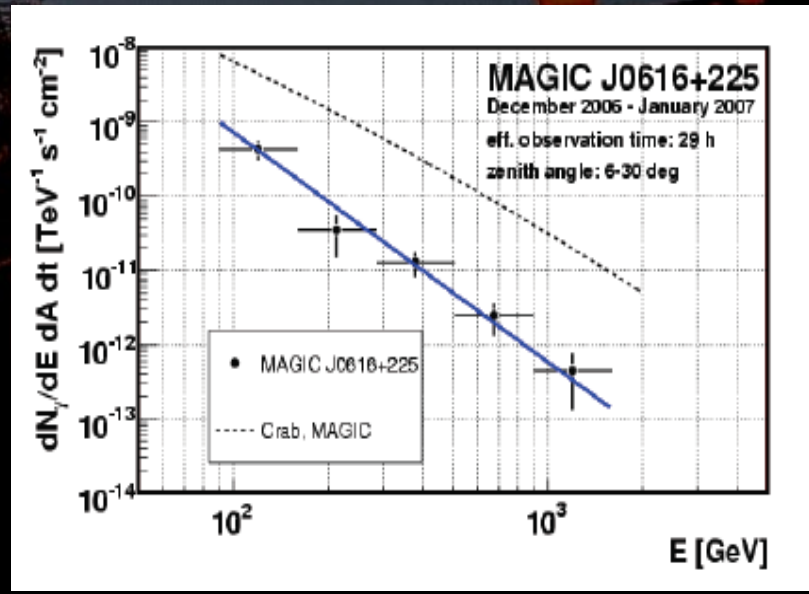
Phaseograms



MAGIC J0616+225 (in IC443): ApJ 664 L87 2007

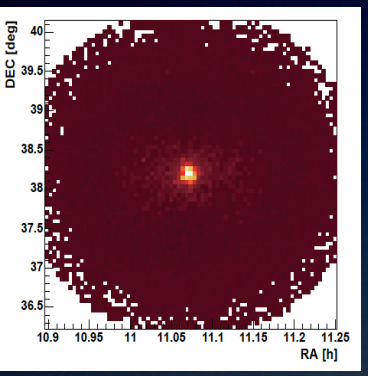


- 6.5% CU @100GeV, 3% CU @300GeV
- spct. idx 3.1 ± 0.3
- no flux variations
- pointlike emission
- correlated w/ mol. clouds (10^4 $M_\odot$)
- well corr. w/1720 MHz maser (shock?)
- alternative: PWN displaced emission?

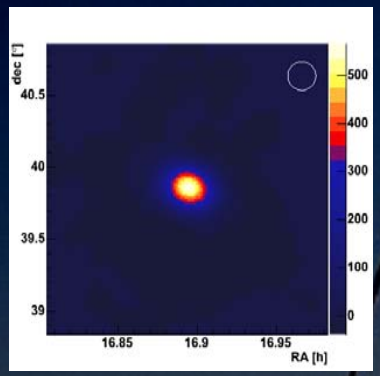


^{12}CO emission (cyan), 20 cm VLA (green)
ROSAT (purple), EGRET (black),
CXOU J061705.5+222127 (white star),
1720 MHz OH maser (black dot)

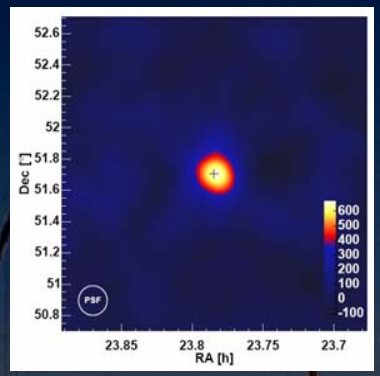
MAGIC: Extragalactic Sources



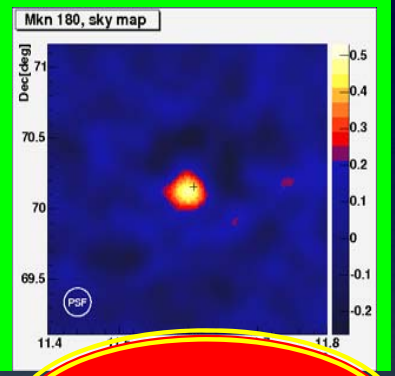
Mrk 421 (0.031)



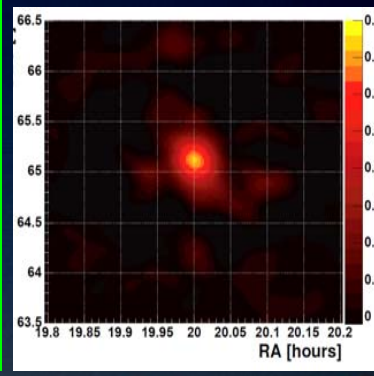
Mrk 501 (0.034)



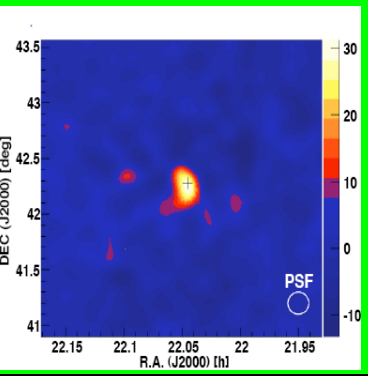
1es2344 (0.044)



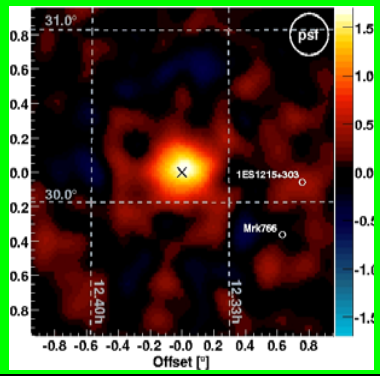
Mrk 180 (0.045)



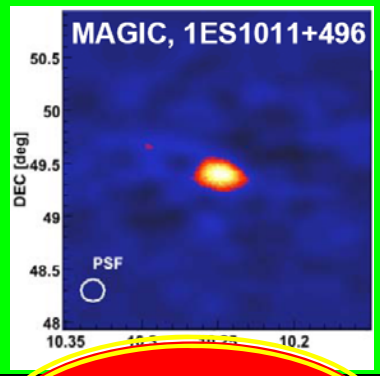
1es1959 (0.047)



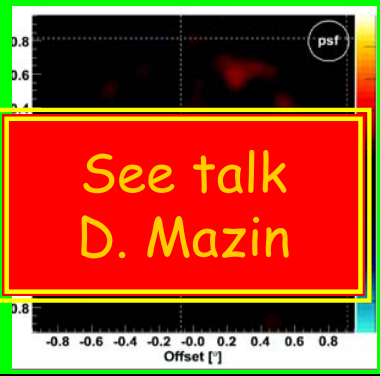
BL Lac (0.069)



1es1218 (0.18)

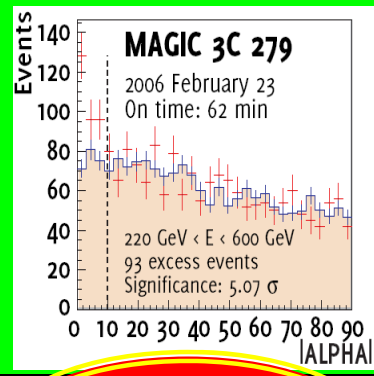


1es1011 (0.212)



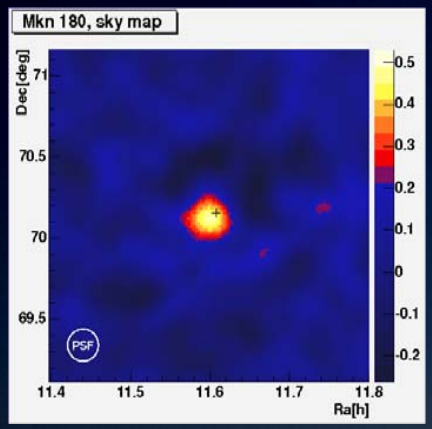
See talk D. Mazin

PG1553 (>0.25)



3c279 (0.536)

Extragalactic Sources: overview



ApJ 648 L105 2006

→ E_{th} ~200 GeV

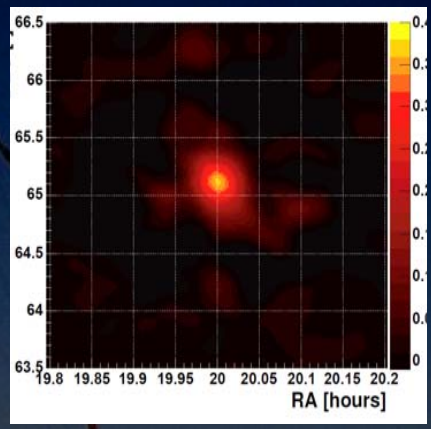
Spct. idx: 3.3 ± 0.7

MAGIC discovery!

Trig. by Opt+X-ray

11% Crab

Mrk 180 (0.045)



ApJ 642 L119 2006

→ E_{th} ~180 GeV

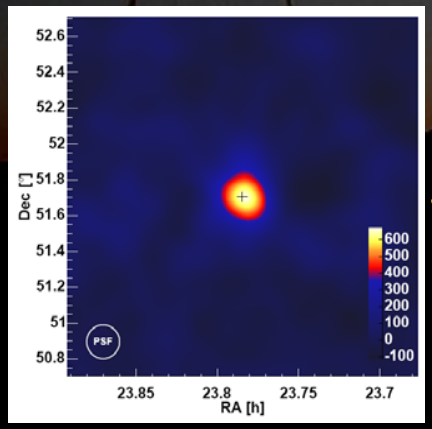
Spct. idx: 2.9 ± 0.2

Orphan flare

1st obs quiescent!

11% Crab

1es1959+650 (0.047)



ApJ 662 892 2007

→ E_{th} ~350 GeV

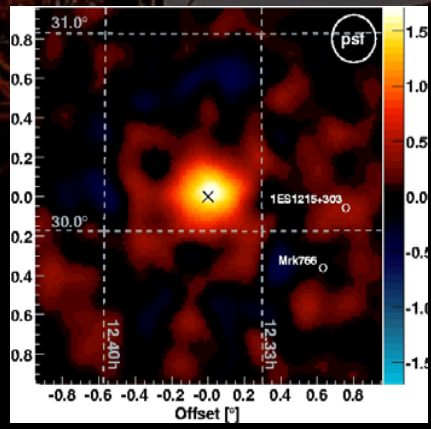
Spct. idx: 2.95 ± 0.2

W+H evidence

W: in flare @0.6CU

5% Crab!

1es2344+514 (0.044)



ApJ 639 761 2006

→ E_{th} ~120 GeV

Spct. idx: 3.0 ± 0.4

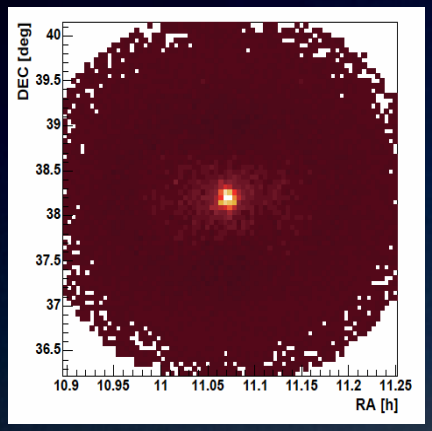
MAGIC: 13% CU

W: $\Phi_{>350GeV} < 8\%$CU

H: $\Phi_{>750GeV} < 12\%$CU

1es1218+304 (0.18)

Extragalactic Sources: overview 2



Mrk 421 (0.031)

ApJ 663 125 2007

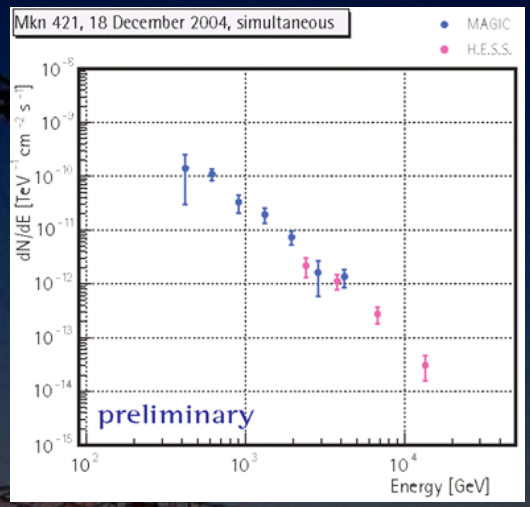
→ E_{th} ~150 GeV

Spct. idx: 2.2 ± 0.2

<evts> ≈5 min^{-1}

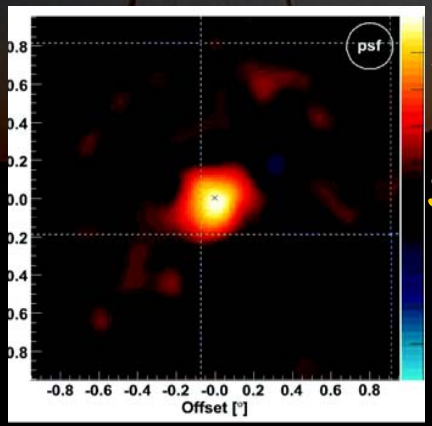
good VHE/X corr.

0.5 ÷ 2 Crab



Simultaneous observation with HESS

- Cross-calib
- Wider energy coverage



PG1553+113 (z>0.25)

ApJ 654 L119 2007

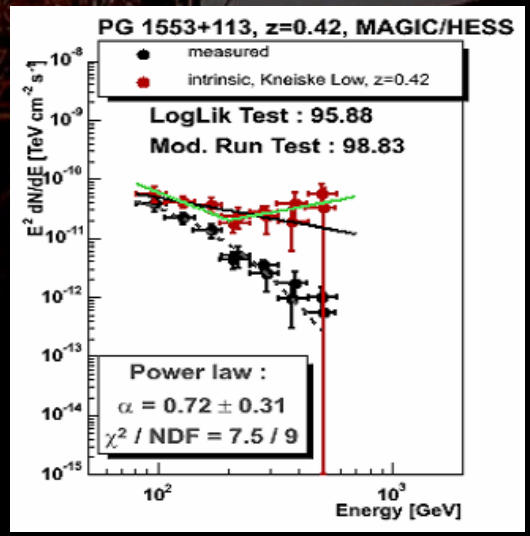
→ E_{th} ~150 GeV

Spct. idx: 4.21±0.25

Evidence by HESS

MAGIC detection

2% Crab



z limit by IACTs

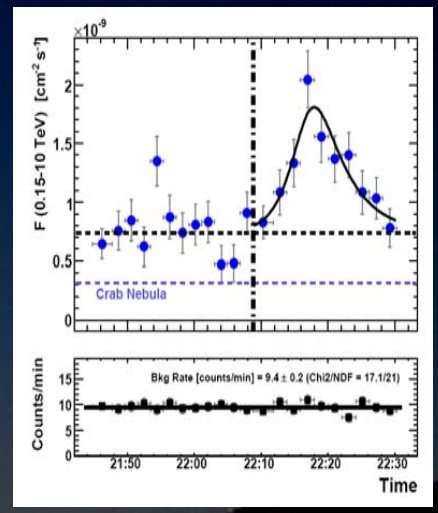
- Conserv. EBL
- dN/dE~ $E^{-\gamma}$, γ>1.5

New preliminary

UL: z<0.42

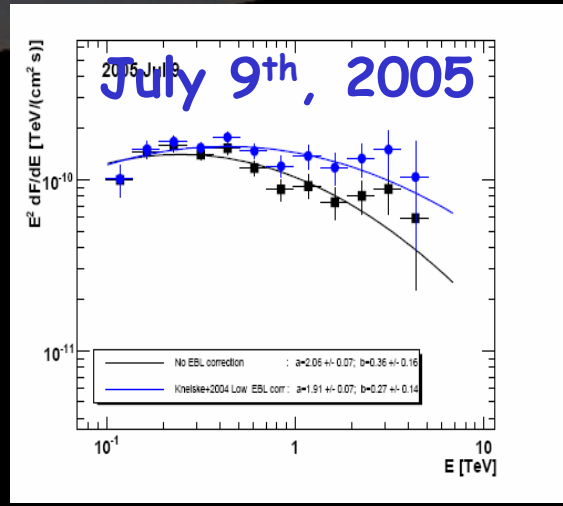
Markarian 501: Fast variability (ApJ 669 862 2007)

- 24 nights: $\Phi < 0.5$ CU and $\Phi > 1$ CU
- for 2 nights: $\Phi > 3$ CU $T_{2\times} \approx 2$ min
- harder spectra @ harder fluxes
- Variability increased with energy



Curved spectrum:

$$\frac{dN}{dE} = \left(\frac{E}{300\ GeV}\right)^{-1.9-0.27\log_{10}(E/300GeV)}$$



$\Rightarrow$ SSC: δ=25÷50, B=0.1÷0.5 G

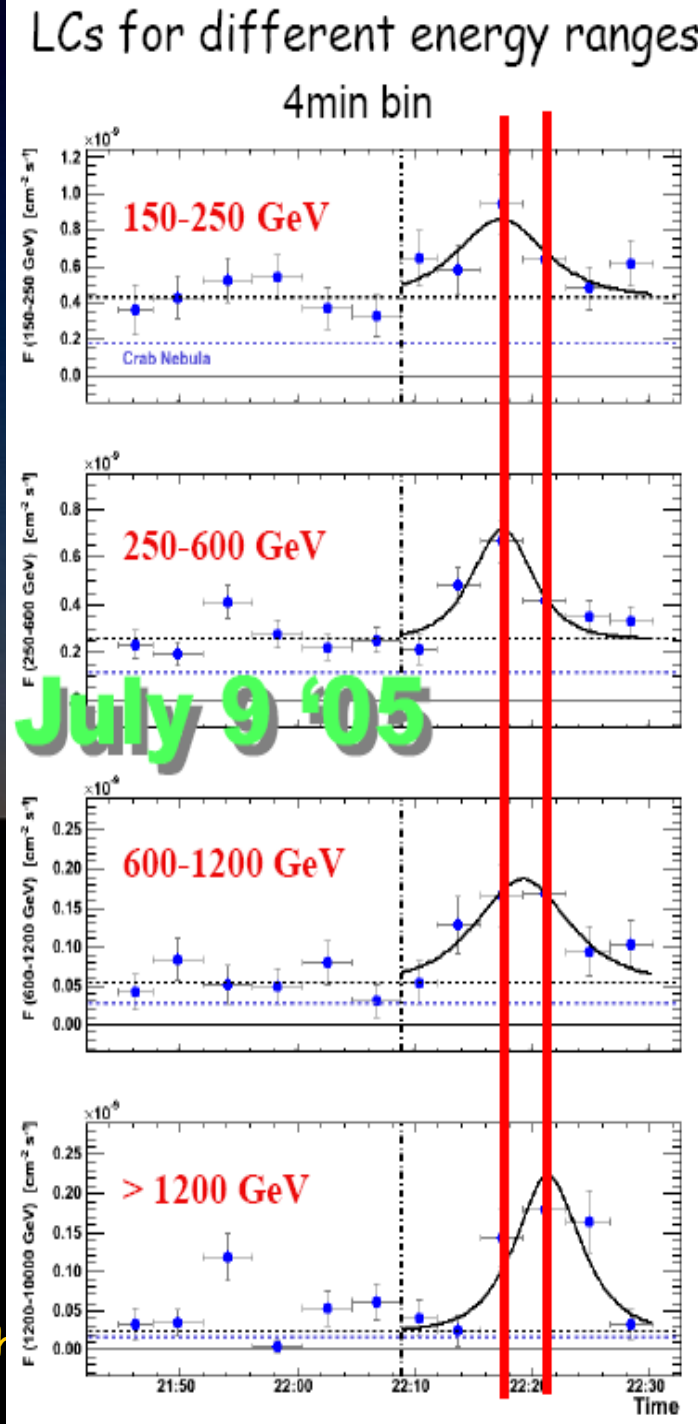
Markarian 501: Time lag

- Evident 4±1 min Time Lag between $\Phi_{<250GeV}$ and $\Phi_{>1.2TeV}$
- May be explained by the particle acceleration process
- BUT, if photons at diff. E emitted simultaneously:

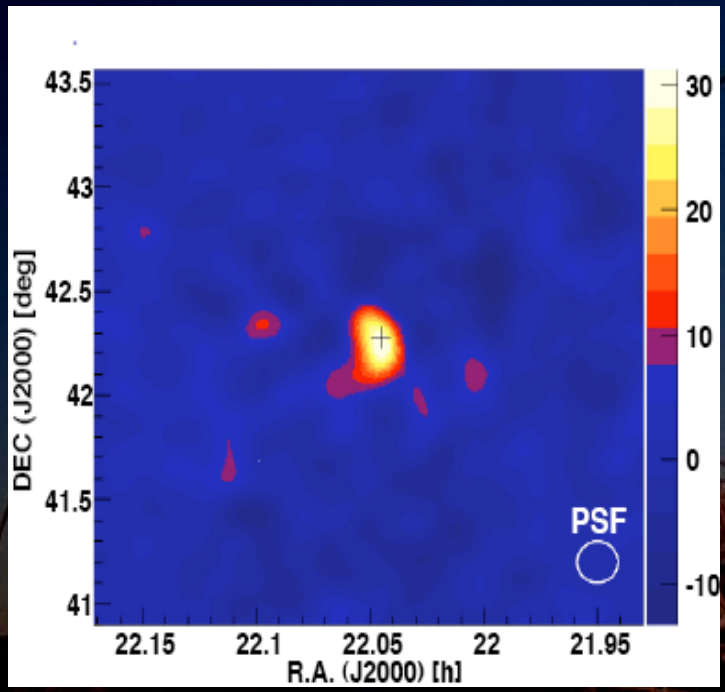
Lorentz invariance violation?

$\Delta T \sim 4$ min, $\Delta E \sim 1$ TeV

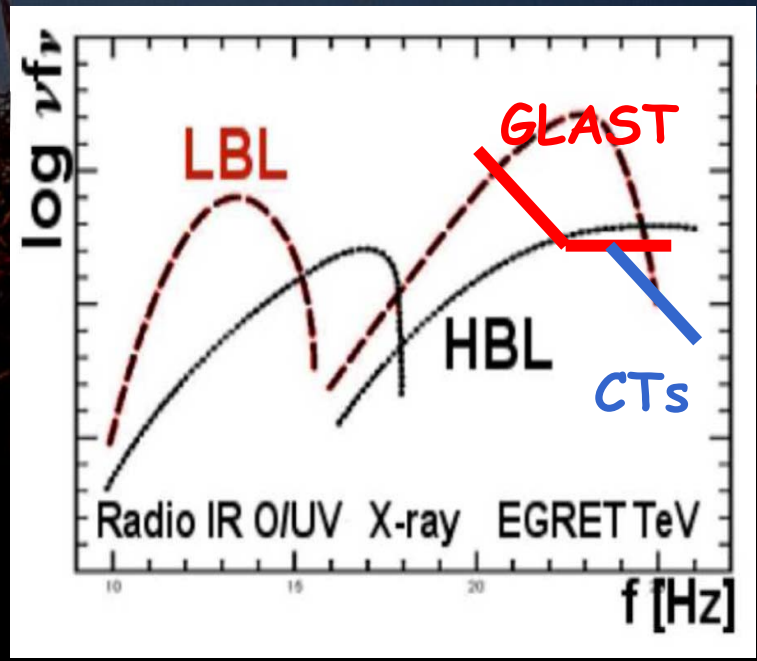
$\Rightarrow E_{scale} \sim 10^{17\div18}$ GeV



BL Lac: new source/new class (ApJ 666 L17 2007)



From Aug to Dec 2005 (22 hrs)
→ 3% Crab @200 GeV, idx: -3.6± 0.5
no flux variation
From Jul to Sept 2006 (26 hrs)
→ NO EXCESS!
Follows the trend in optical activity

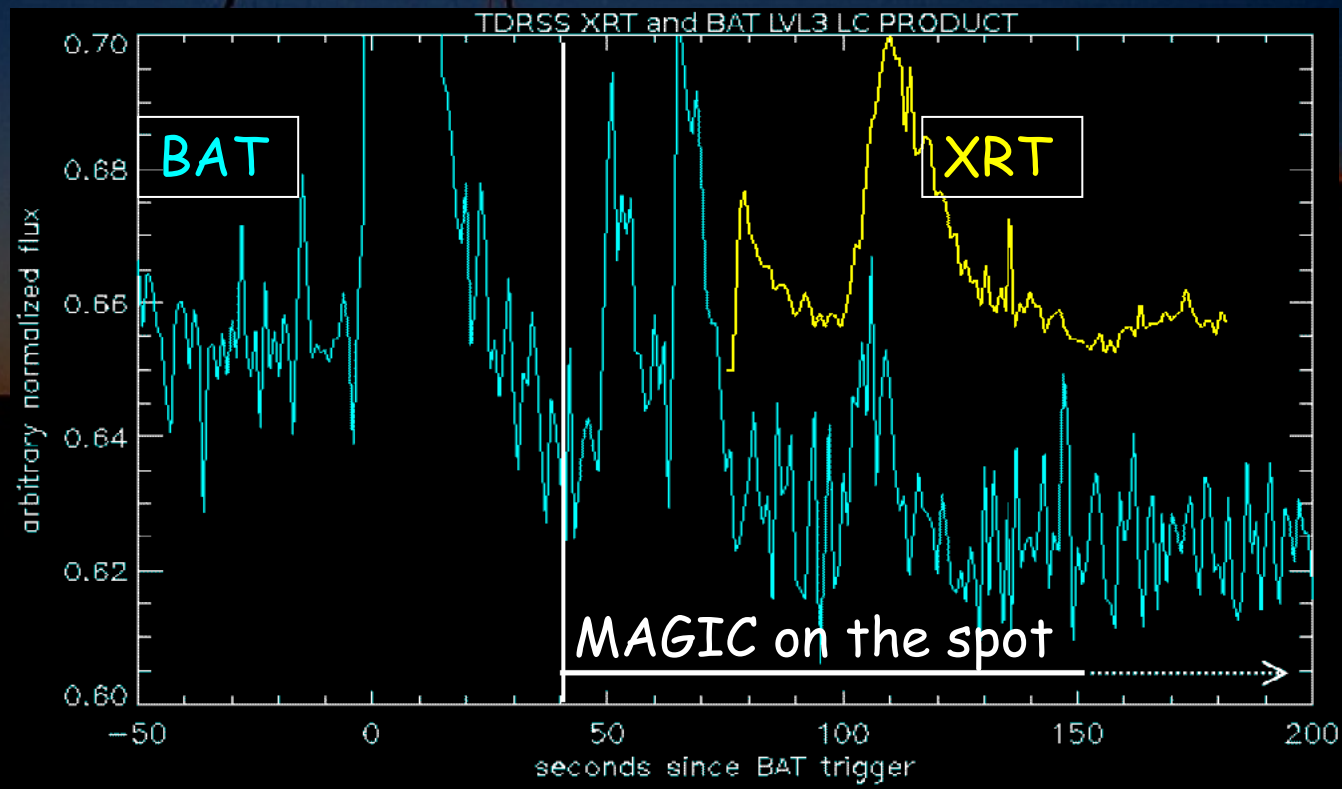


LBL: low frequency BL Lac
For Cherenkov telescope:
low energy threshold
For GLAST: easier to detect

GRB Observations

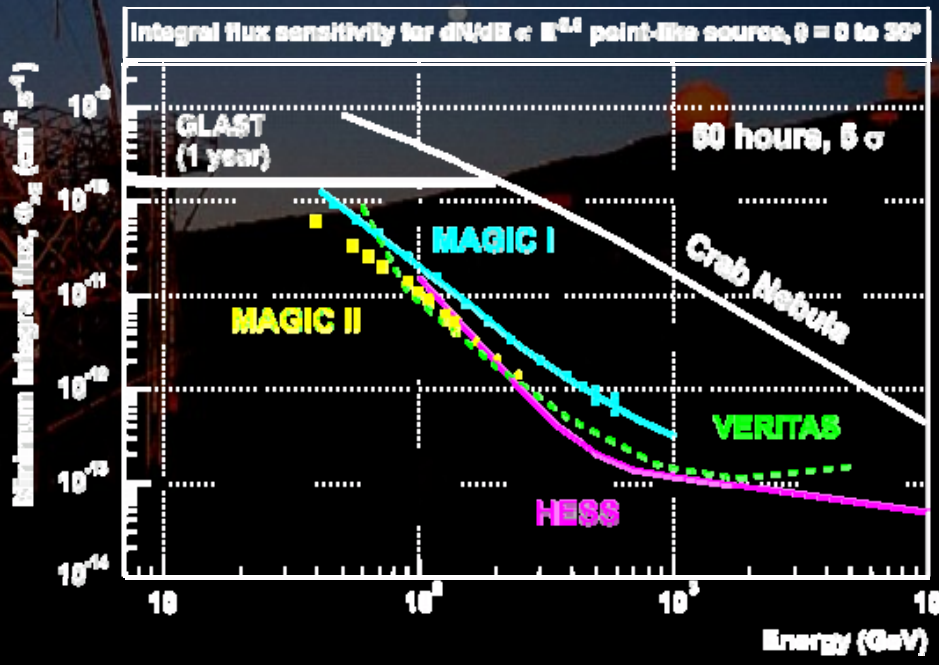
- 22 GRBs follow-up: 2 even during the prompt emission
- UL ≈ 80 GeV
- Analysis results sent via GCN asap!
- Need a closer GRB

- GRB 050713a ApJ 641 L9 (2006)
- 1st DC: ApJ 667 358 (2007)



The future: MAGIC][

- Mirror redesign: 0.5×0.5 m^2 → 1×1 m^2
  ⇒ Better sealed and more reliable
- Faster DAQ: 300 MHz → 2 GHz
  ⇒ cleaning: multi-cluster
  ~50% better bkg/rej
  ⇒ "time" Hillas:
  improve sens by ~30%
  @LE: 19σ/√h → 27σ/√h
- Better DAQ:
  lower dead time
- Higher QE PMT (2×)
- Stereo observation



Conclusions

MAGIC scientific campaign (1+0.8 years):

>>> VHE Physics @ 2% Crab level <<<

- 6 new extragalactic sources
- 3 new galactic sources

Among them:

- Variable source (binary LSI +61 303)
- Short term flux and spct. variability (Mrk 501)
- New "VHE-loud" classes (FSRQ, LBL, BHs)

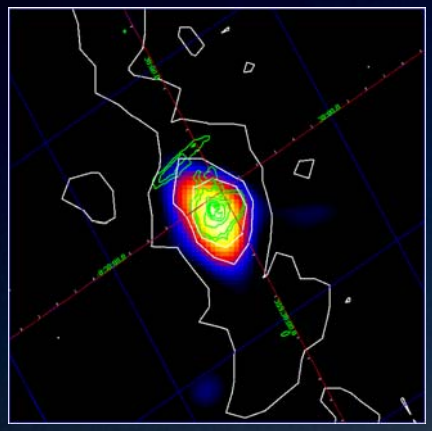
A MAGIC Catalogue of 21? sources after 2 years

Inauguration
21-IX-2008

Data cycle 3 has just started:

>>> MAGIC 2 completion and physics below 1% Crab <<<

Galactic Sources: overview



ApJ 638 L101 2006

→ E_{th} ~600 GeV

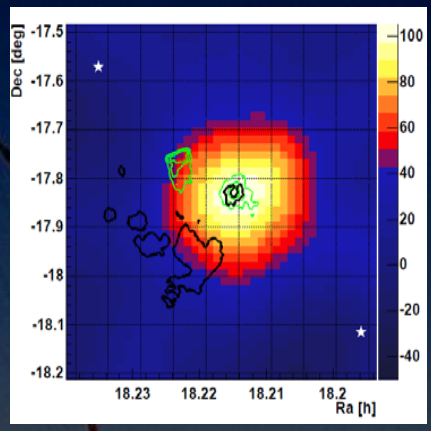
Spct. idx: 2.2 ± 0.2

compatible w/HESS

No variability

DM? SNR!?

The Galactic Centre



ApJ 637 L41 2006

→ E_{th} ~400 GeV

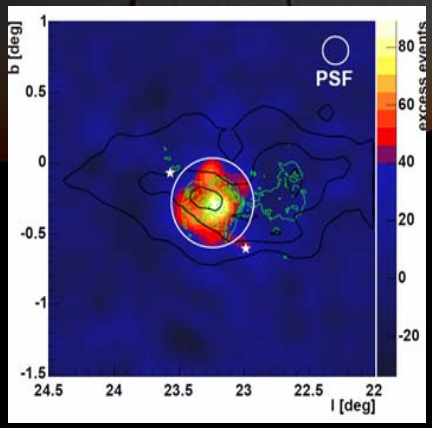
Spct. idx: 2.15 ± 0.3

compatible w/HESS

more data needed

Lept/had discrim.

HESS J1813-178



ApJ 643 L53 2007

→ E_{th} ~150 GeV

Spct. idx: 2.5 ± 0.2

compatible w/HESS

inter. dense cloud

Hadronic acc?

HESS J1834-087

Sci 312 1771 2006

→ E_{th} ~200 GeV

Spct. idx: 2.6 ± 0.2

Variable!

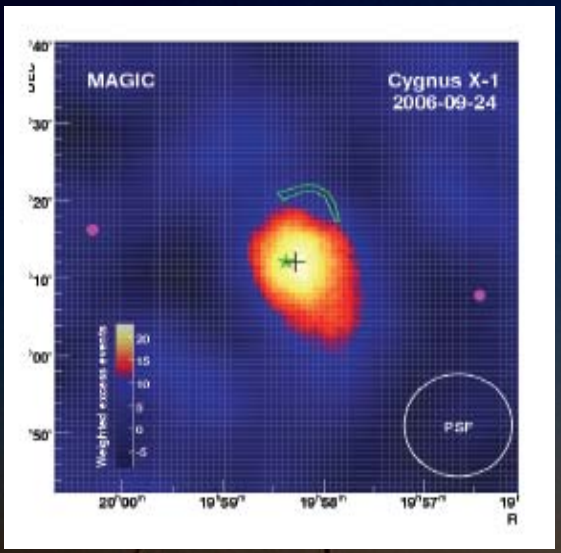
Miniature AGN

Talk J. Rico

LS I+61

Cygnus X1: THE Black Hole

1st evidence of BH in VHE



ApJ 665, L87 (2007)

42.6 hrs in 26 night

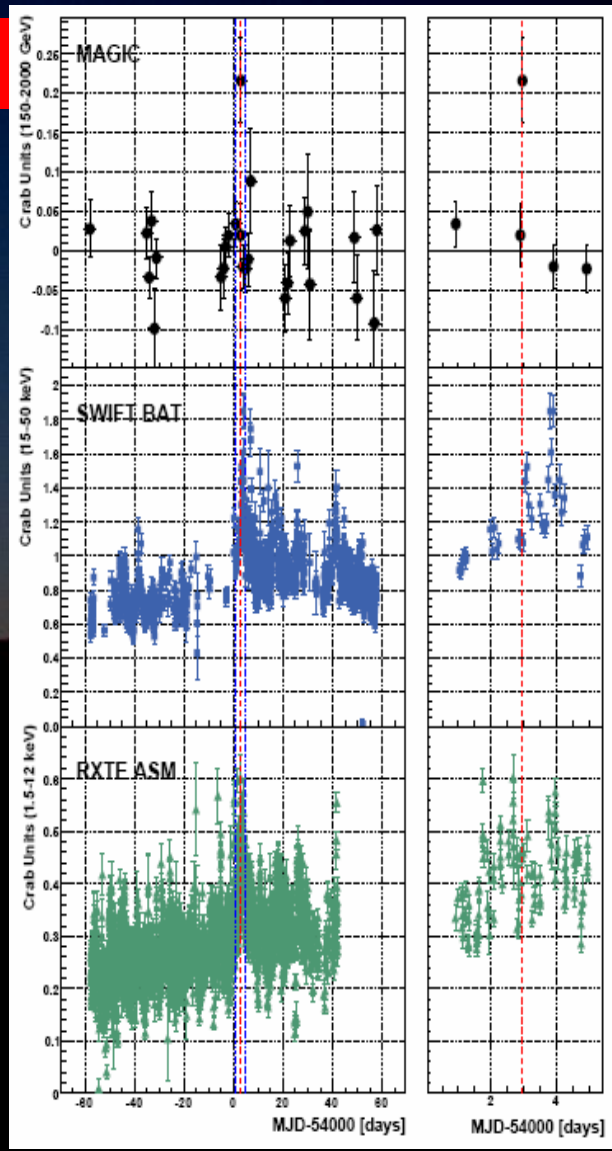
UL @ 1÷5% CU

26/09/2006: 4.0σ

27/09/2006: 4.9σ

Coincident with CygX1

Coinc. w/ hard X flare



Cygnus X1, BH X-ray binary:

BH 21 $M_\odot$ + O9.7 40 $M_\odot$

- 5.6 days period
- X ray flaring activity well known
- arclike from jet-ISM interaction

See talk J. Rico