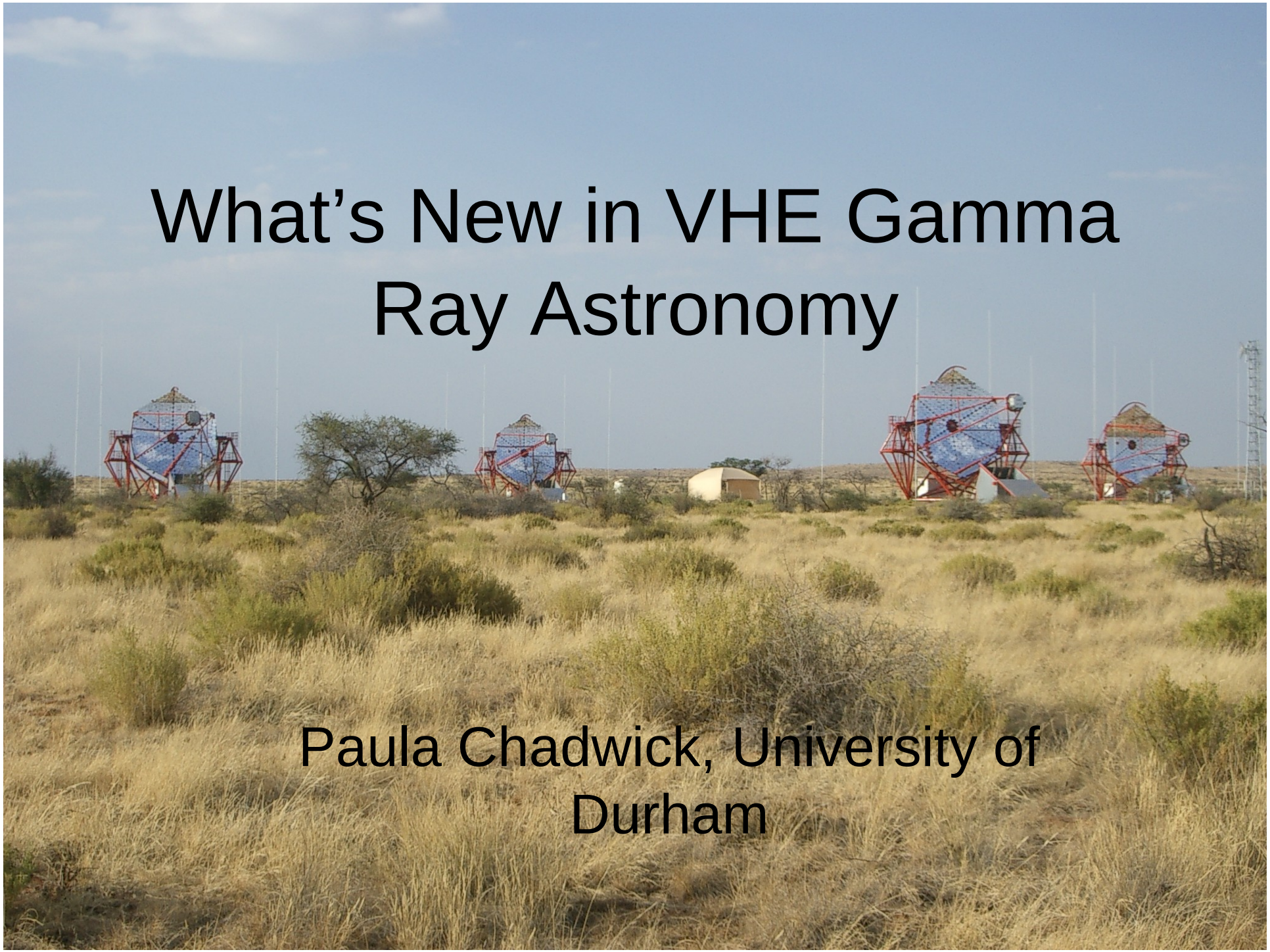
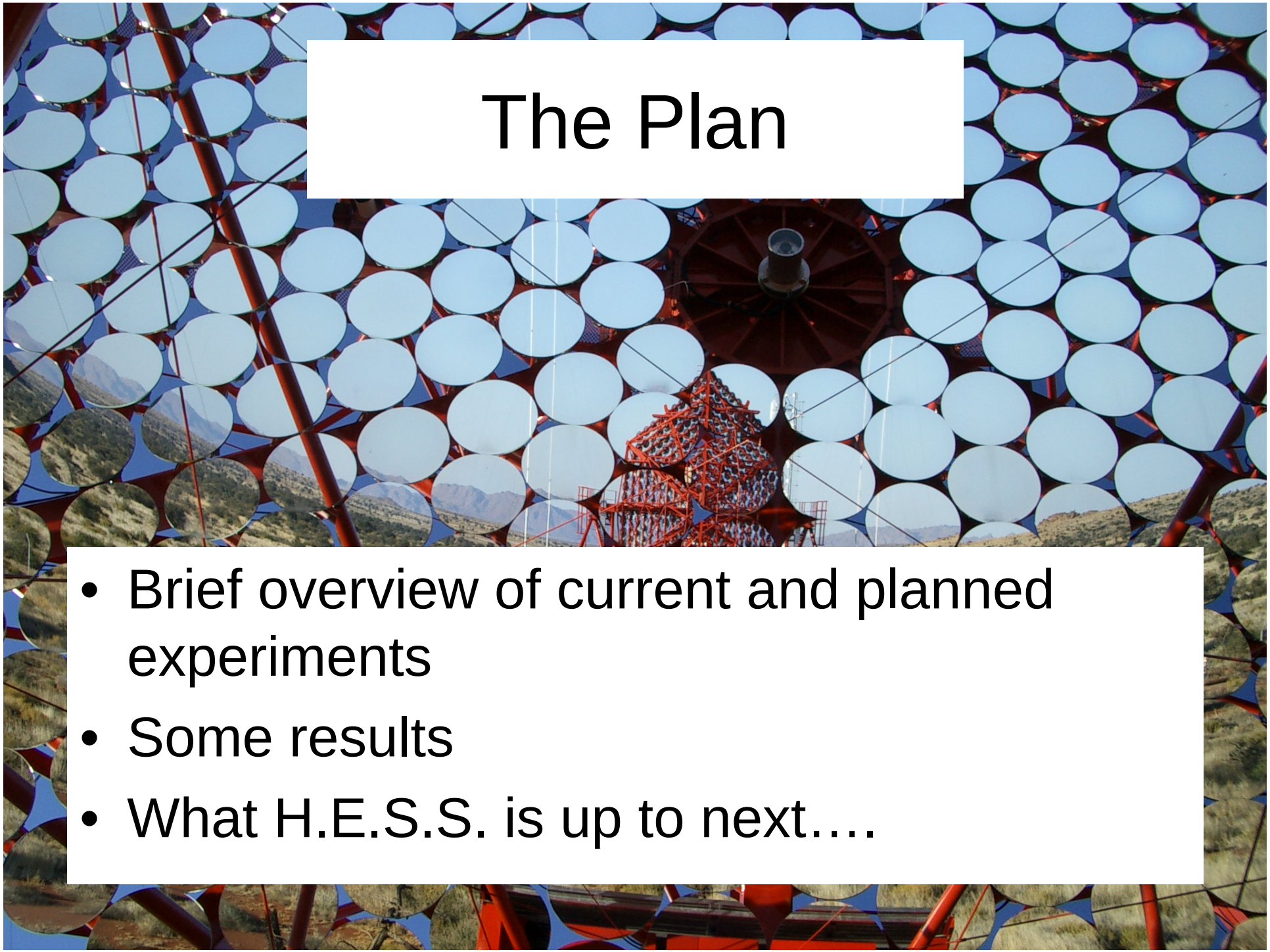


What's New in VHE Gamma Ray Astronomy

Paula Chadwick, University of Durham



The Plan

- Brief overview of current and planned experiments
- Some results
- What H.E.S.S. is up to next….

The ‘Big 4’ IACTs

VERITAS

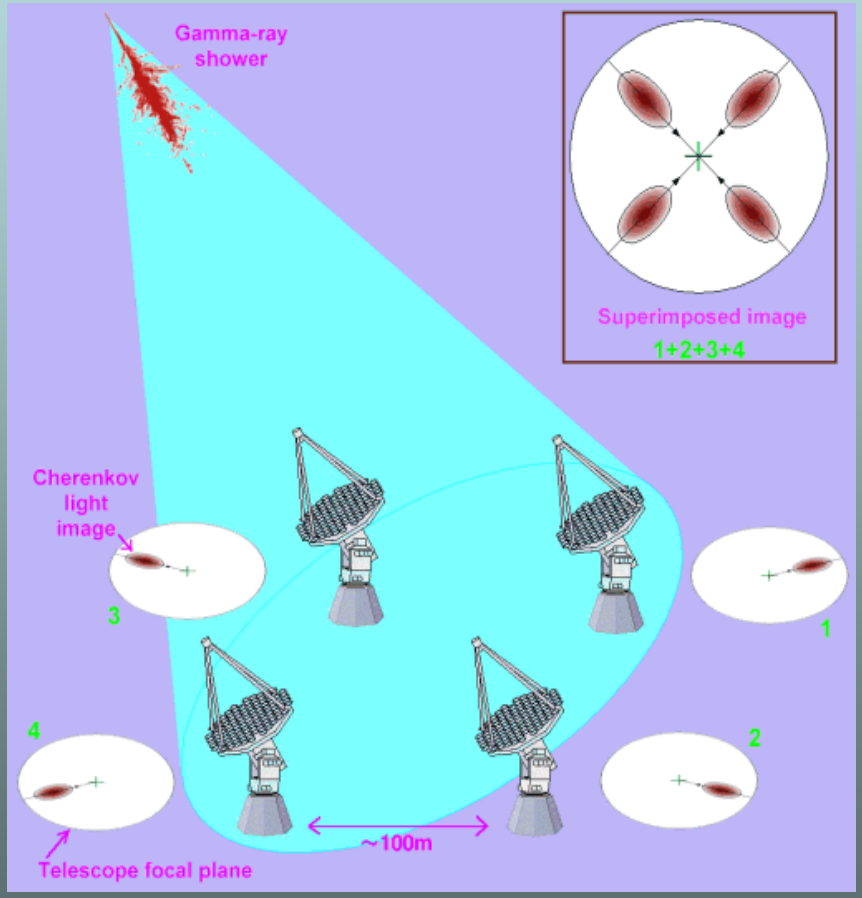
MAGIC

H.E.S.S.

CANGAROO III

Imaging Atmospheric Cherenkov Technique

- (Multiple) Images of showers
- Gamma rays form consistent pattern
- Excellent gamma-hadron separation (~100%)
- Showers located to ~0.1° at threshold
- Point source location to ~ 20”



CANGAROO III

Four 10m telescopes

Parabolic design, 114 mirrors each 80 cm diameter

FoV 4°

T1 has 552 pixel camera (0.5”, 0.115°), others 427 pixel (0.75”, 0.168°)

Full array operational since March 2004

Two telescopes struck by lightning Summer 2004

136.786 degree E, 31.099 degree S, 160m a.s.l.

High Energy Stereoscopic System – H.E.S.S.

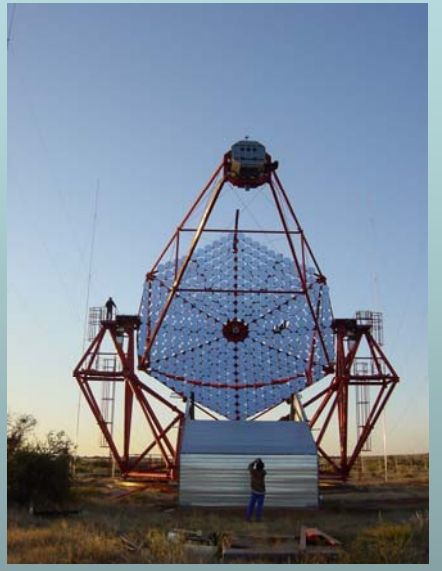
Four 13m diameter telescopes

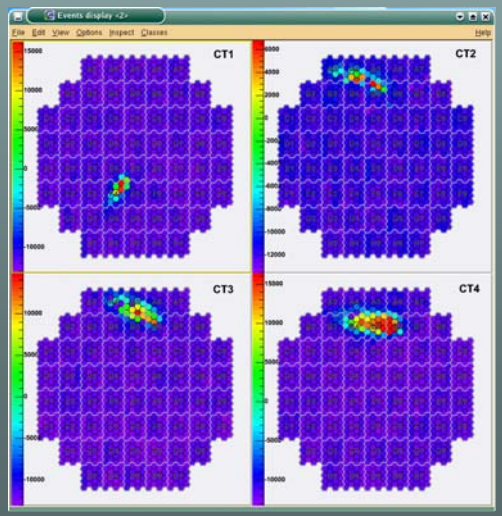
Davies-Cotton design, 382 0.6 m diameter mirrors

FoV 5°

960-pixel cameras

Routine operations since January 2004





23°16'18" S, 16°30'00" E 1.8 km a.s.l

M-PIK Heidelberg; Humboldt University, Berlin; University of Hamburg; Ruhr University, Bochum; Landessternwarte Heidelberg

LLR Ecole Polytechnique, LPNHE, PCC College de France, University of Grenoble, CERS Toulouse, CEA Saclay, Observatoire de Paris-Meudon, University of Montpellier II

Durham University

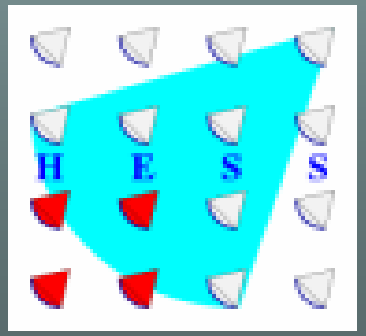
Dublin Institute for Advanced Studies

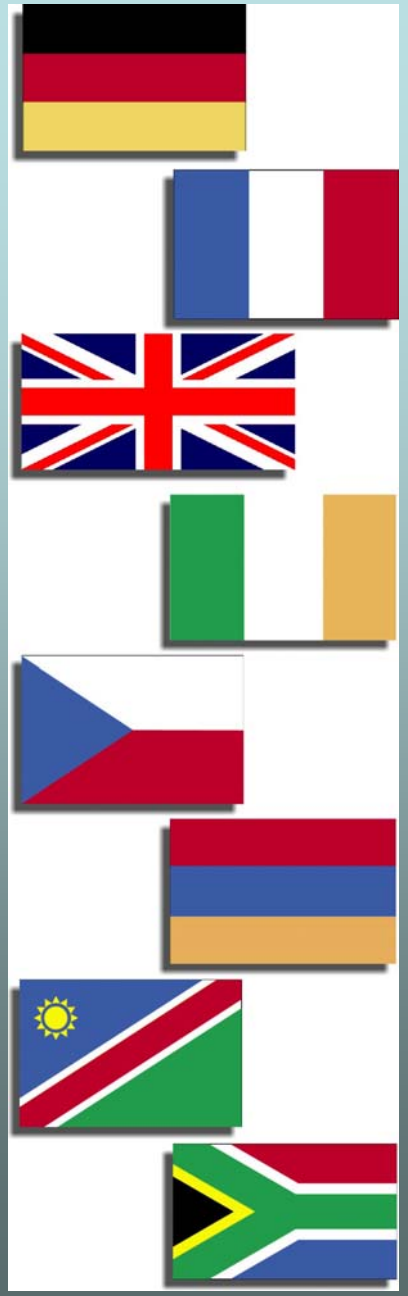
Charles University, Prague

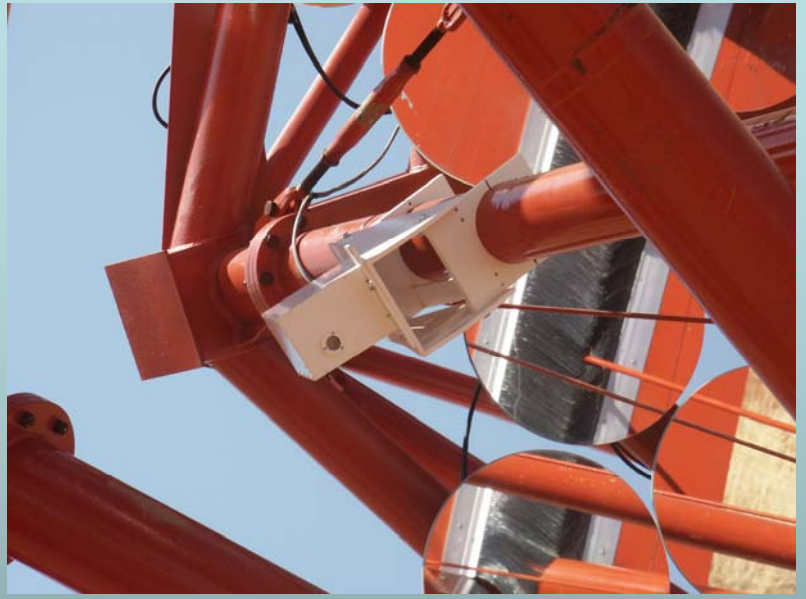
Yerevan Physics Institute, Armenia

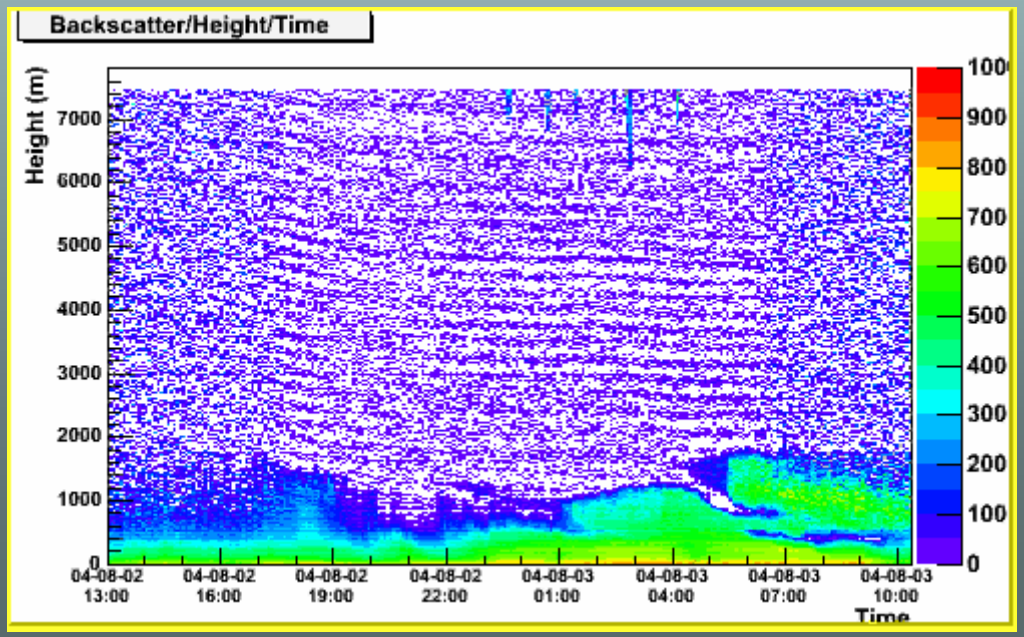
University of Namibia

North-Western University, South Africa








Backscatter/Height/Time
Height (m)
7000
6000
5000
4000
3000
2000
1000
0
04-08-02 13:00
04-08-02 16:00
04-08-02 19:00
04-08-02 22:00
04-08-03 01:00
04-08-03 04:00
04-08-03 07:00
04-08-03 10:00
Time
900
800
700
600
500
400
300
200
100
0

MAGIC

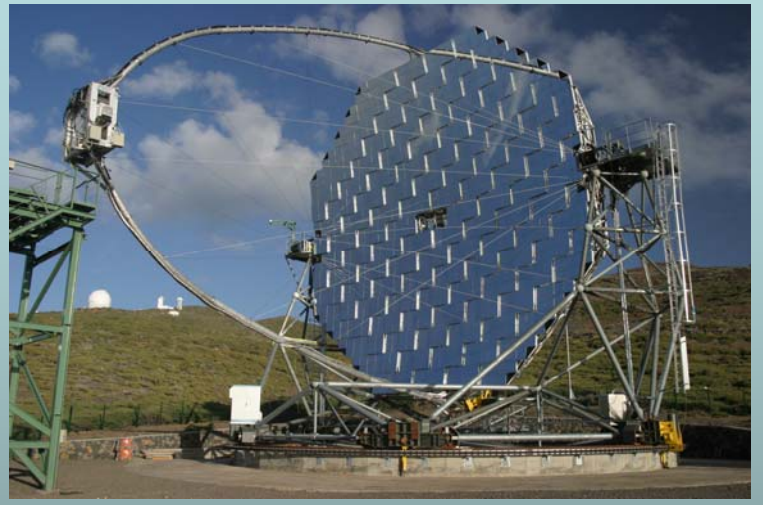
Single 17m diameter telescope

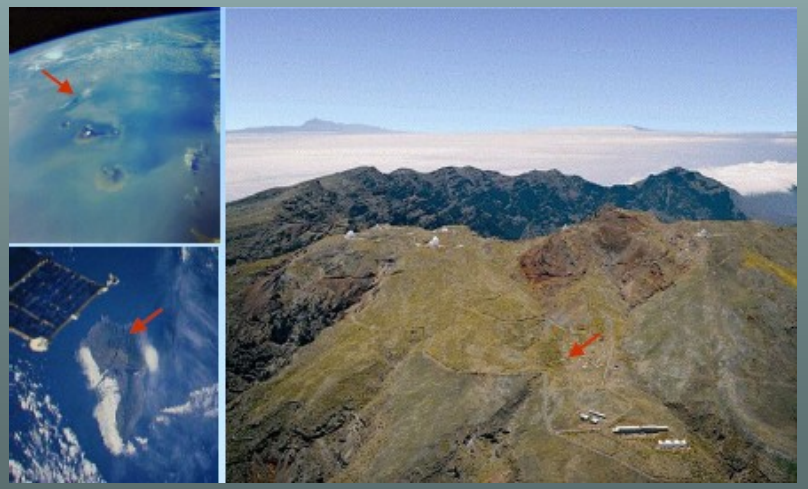
(MAGIC II on its way)

Camera 396 1” PMTs plus 180 1.5” – high QE

Carbon fibre structure

In operation since November 2003





Roque de los Muchachos, 2 km a.s.l

Institut de Física d'Altes Energies, Barcelona

Universitat Autònoma de Barcelona

Institut für Physik, Humboldt-Universität Berlin

Crimean Astrophysical Observatory

University of California, Davis, USA

Division of Experimental Physics, University of Lodz

Universidad Complutense, Madrid

Max-Planck-Institut für Physik, München

Dipartimento di Fisica, Università di Padova and INFN sez. di Padova, Italy

Detektorphysik und Elektronik, Fachbereich Physik, Universität-GH Siegen

Dipartimento di Fisica, Università di Siena and INFN sez. di Pisa, Italy

Institute for Nuclear Research and Nuclear Energy, Sofia

Tuorla Observatory, Pikkiö, Finland

Dipartimento di Fisica dell'Università di Udine and INFN sez. di Trieste, Italy

Universität Würzburg

Yerevan Physics Institute, Cosmic Ray Division, Yerevan

Institute for Particle Physics, Swiss Federal Institute of Technology (ETH) Zurich

VERITAS-4

Four 12m diameter telescopes

Davies-Cotton design, 345 mirrors

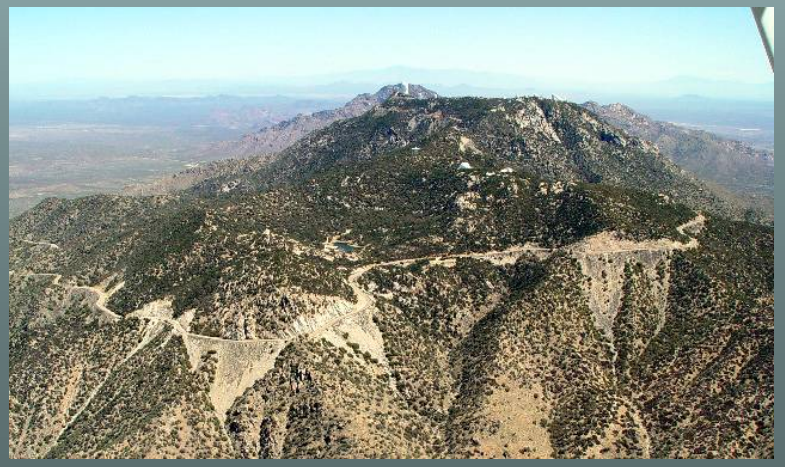
FoV 3.5°

499 1.125” diameter PMTs

Prototype completed

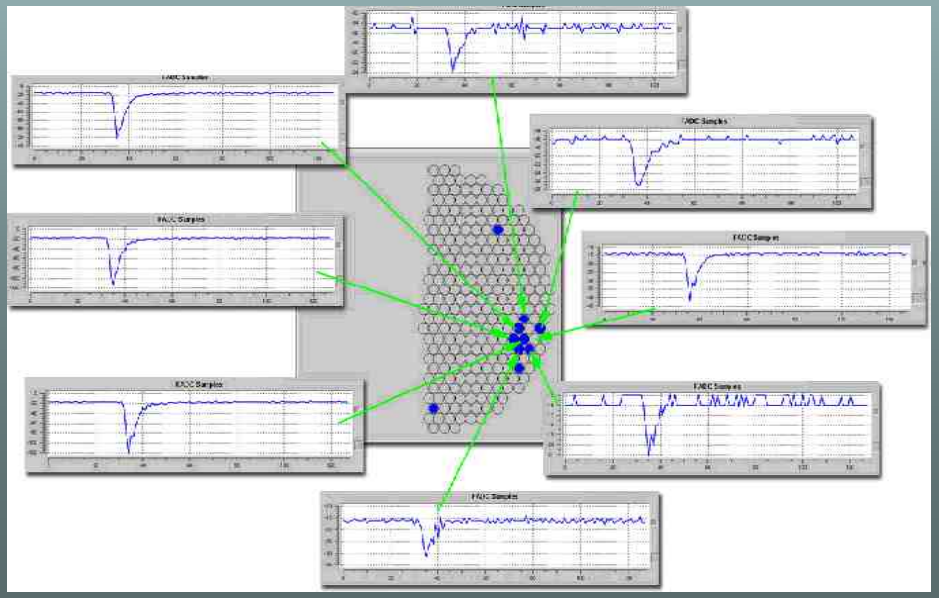
Run at temporary site for 1 year before full deployment

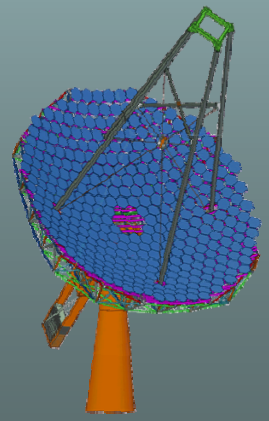
Completion by end 2006



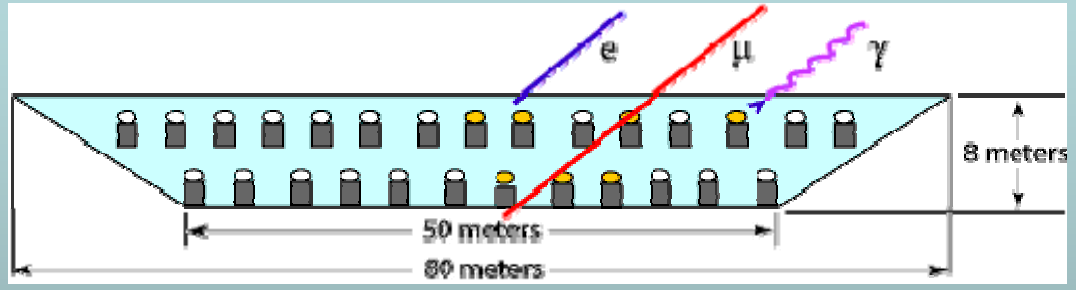
Horseshoe Canyon, Kitt Peak, 5800 ft (!) a.s.l

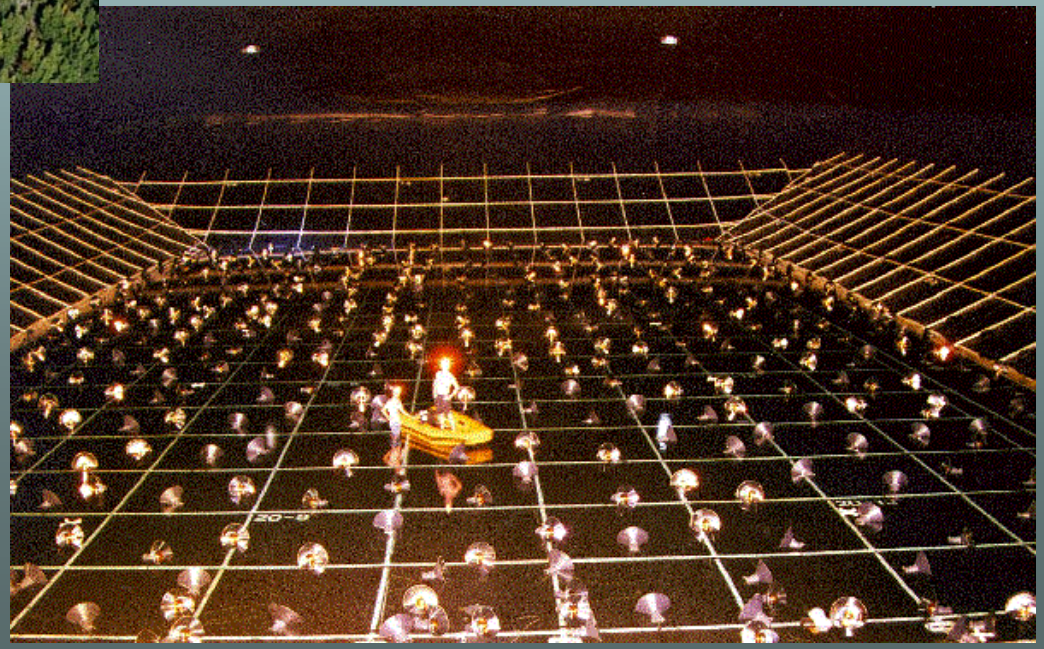
Iowa State University
Leeds University, UK
McGill University, Canada
National University of Ireland, Dublin
Purdue University
Smithsonian Astrophysical Observatory
University of California, Los Angeles
University of Chicago
University of Utah
Washington University, Saint Louis





MILAGRO





723 PMTs

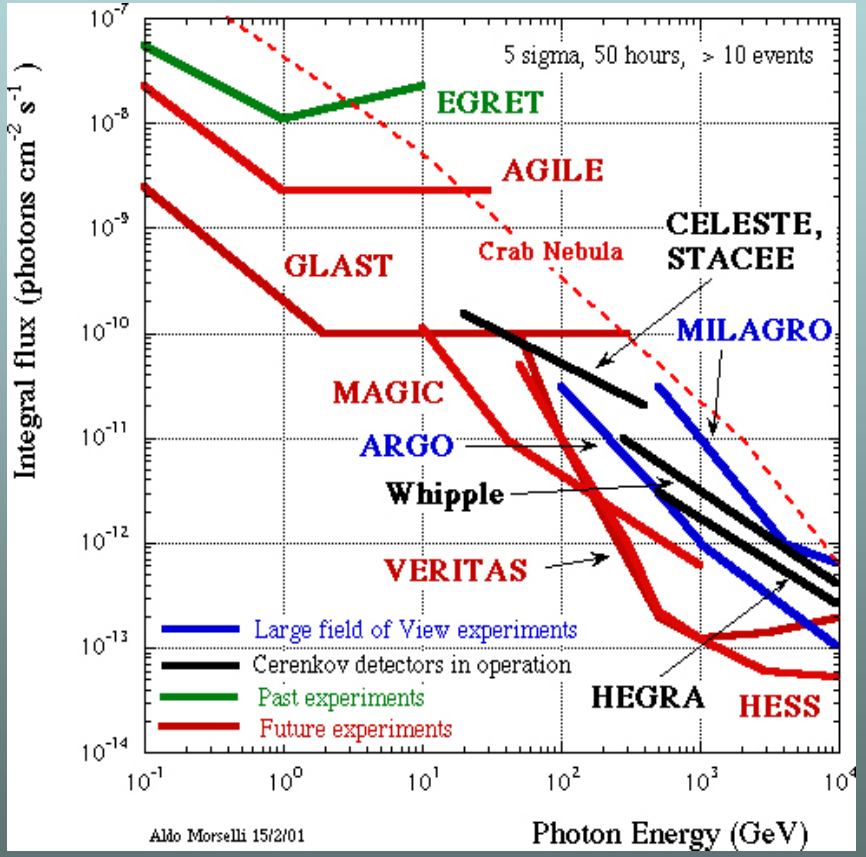
25 million litres of water

LANL, New Mexico

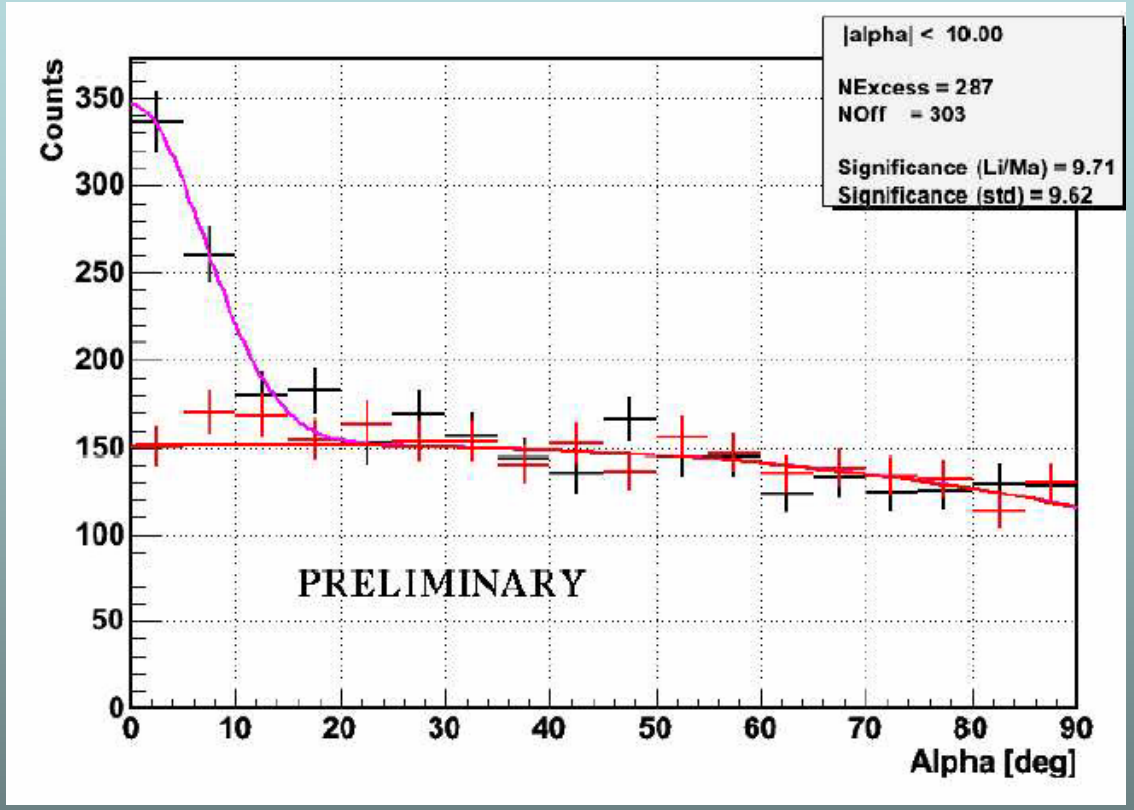
2.6 km a.s.l.

Sensitivity

- 10 mCrab
- Single telescope (non-imaging) down to ~30 GeV
- 10 – 100 x previous generation

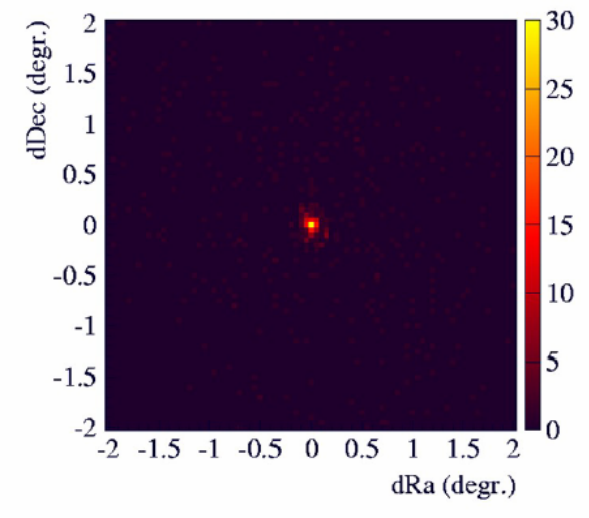


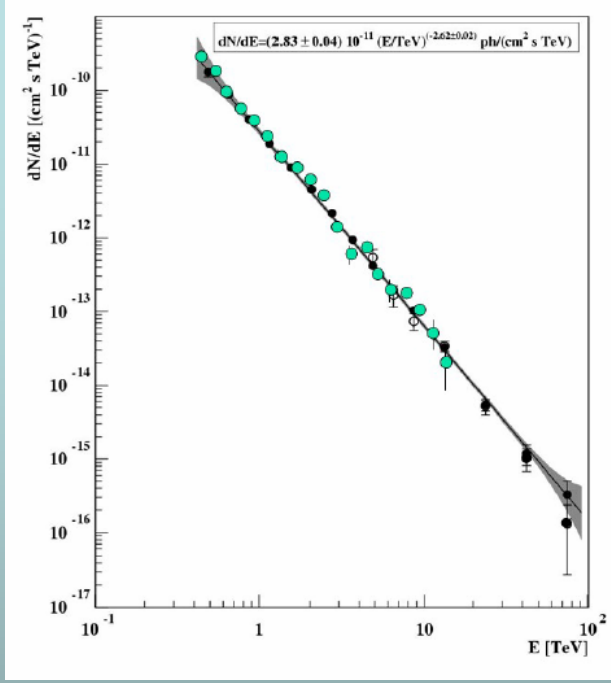
Tests on the Crab Nebula

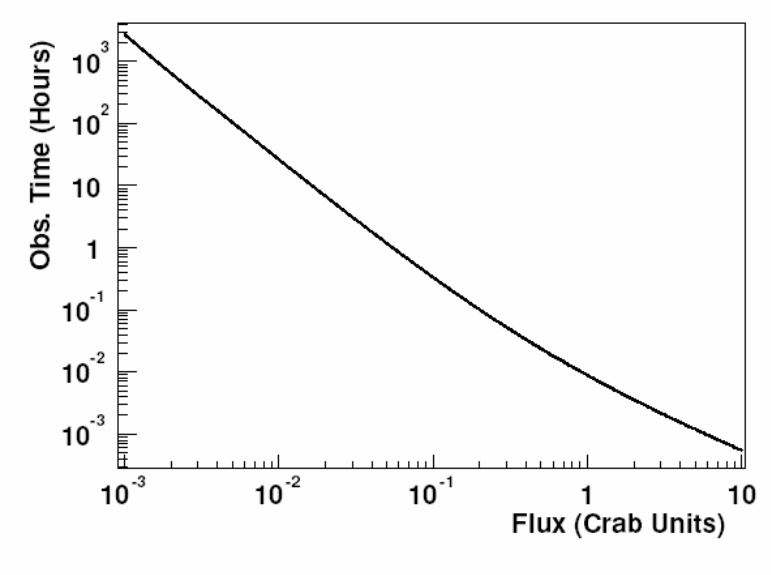


MAGIC first observations: 60 minutes livetime at low zenith angles.

H.E.S.S. observations at z.a. ~ 45°







Crab flux fraction	Obs. Time required
0.005	100 hr
0.01	25 hr
0.05	1 hr
0.1	20 min
0.5	1.5 min
1	30 sec

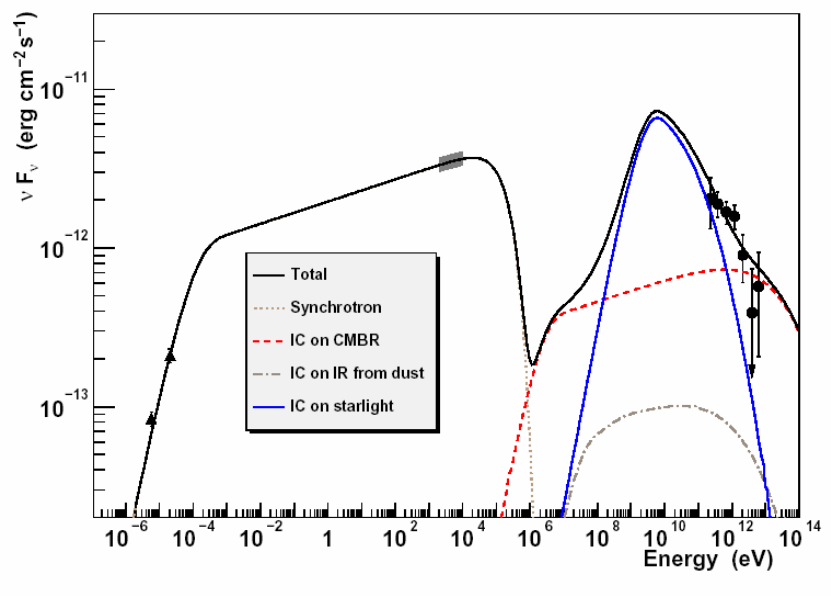
G0.9+0.1 – a pulsar wind nebula

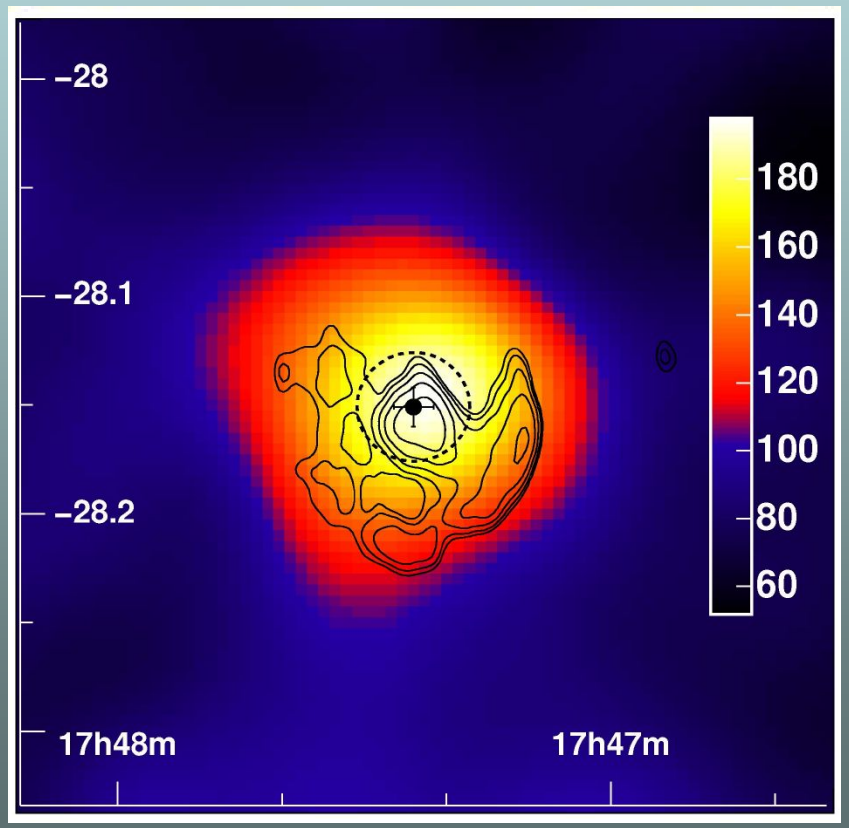
Total significance ~13σ after 50h

Flux is ~2% of Crab at E > 200 GeV

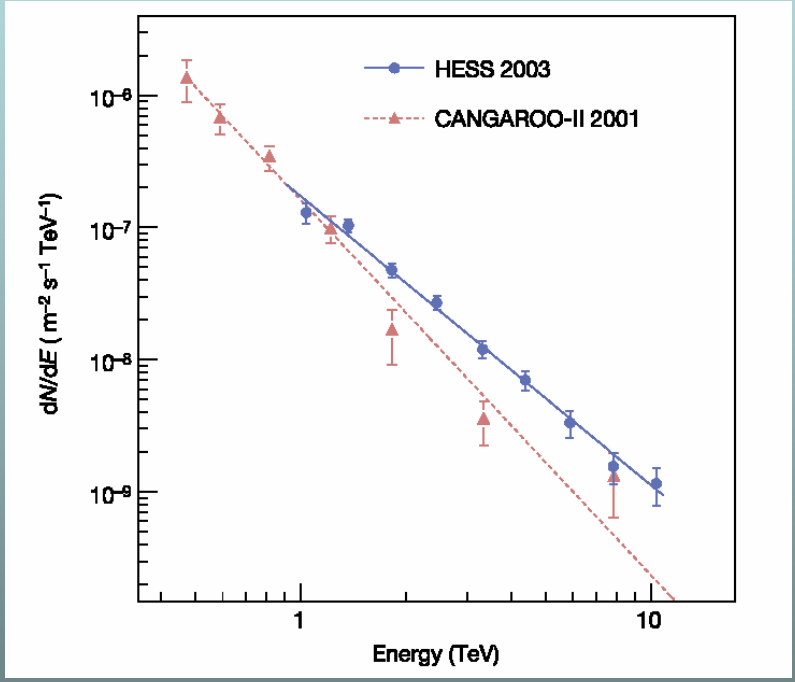
Not an EGRET source

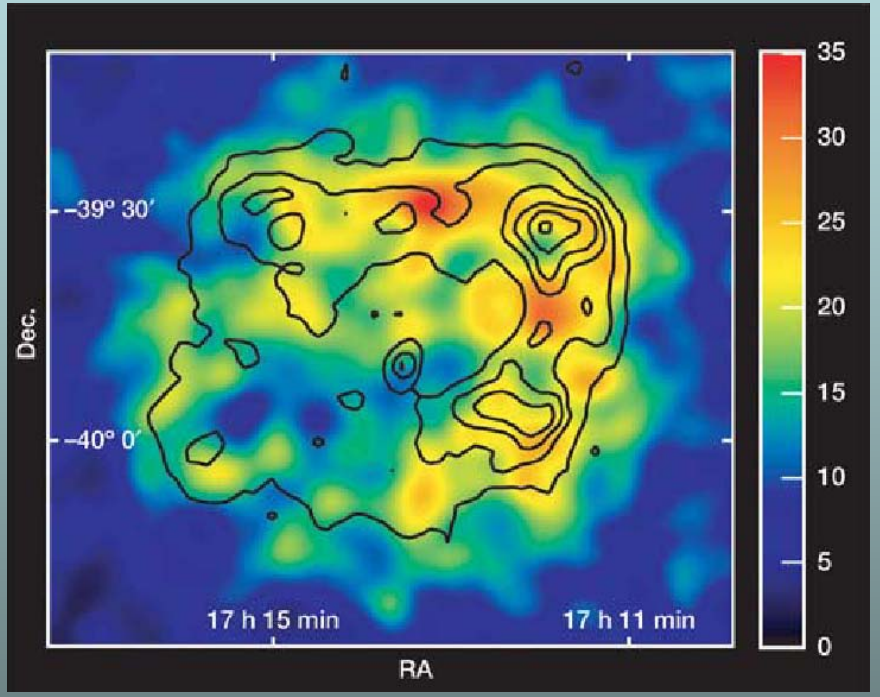
Spectrum seems to fit well with PWN origin





RXJ1713.7-3946





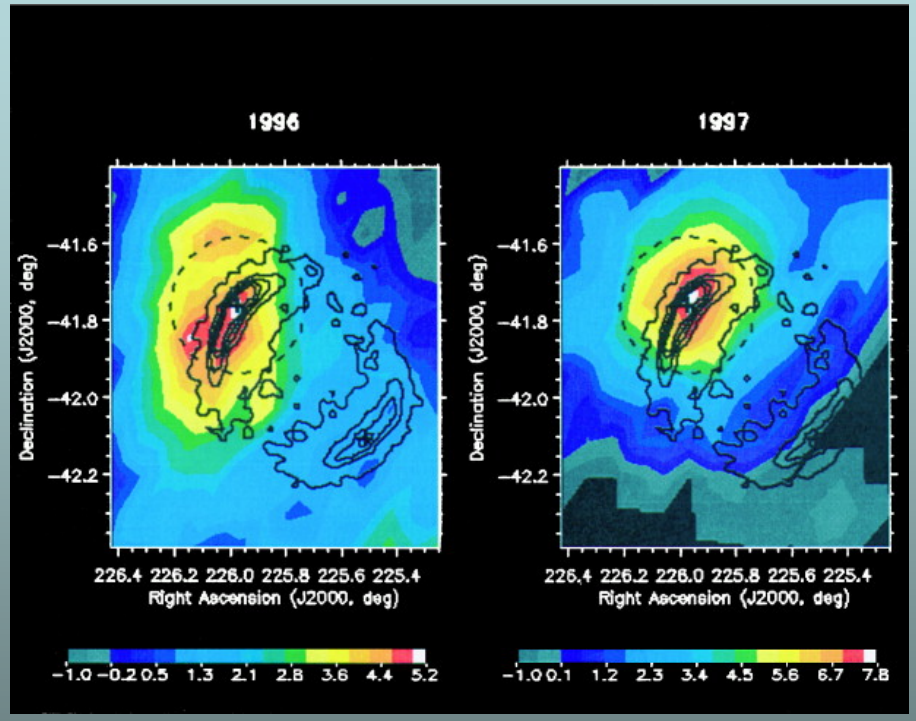
2 telescopes with/without array trigger

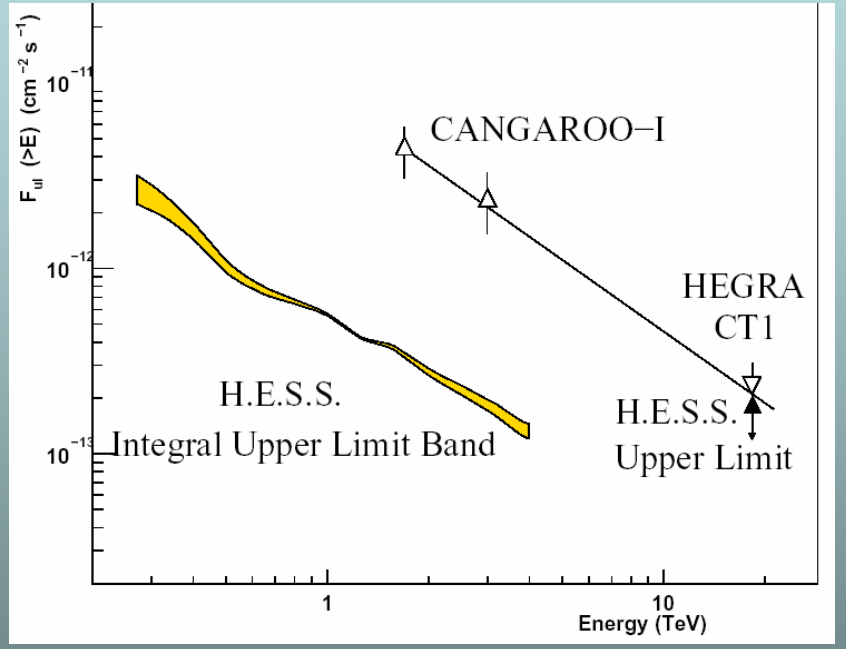
E > 800 GeV; angular res. Gaussian with σ = 3 arcmin

Aharonian et al., Nature, 75, 432 (2004)

Enomoto, R. et al.,Nature, 416, 823-826 (2002)

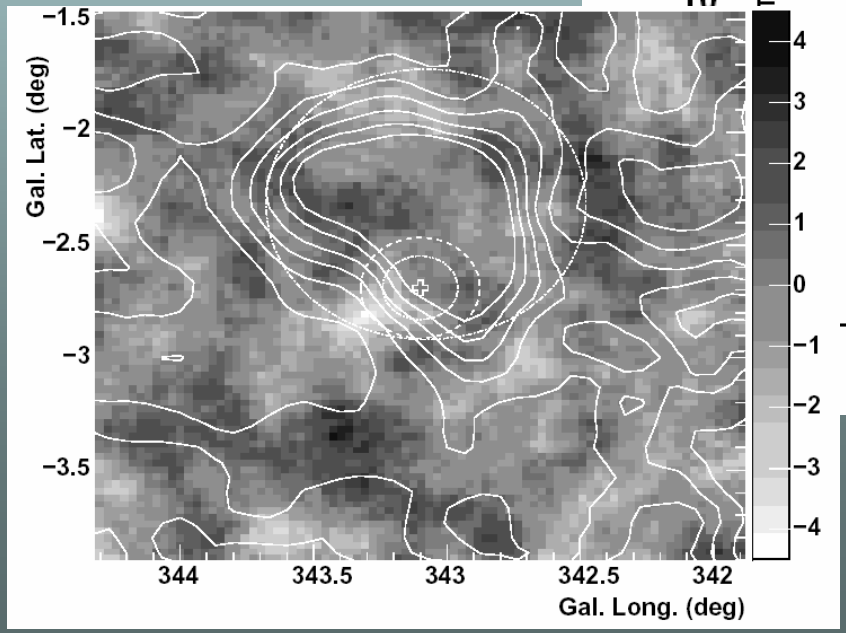
SN1006

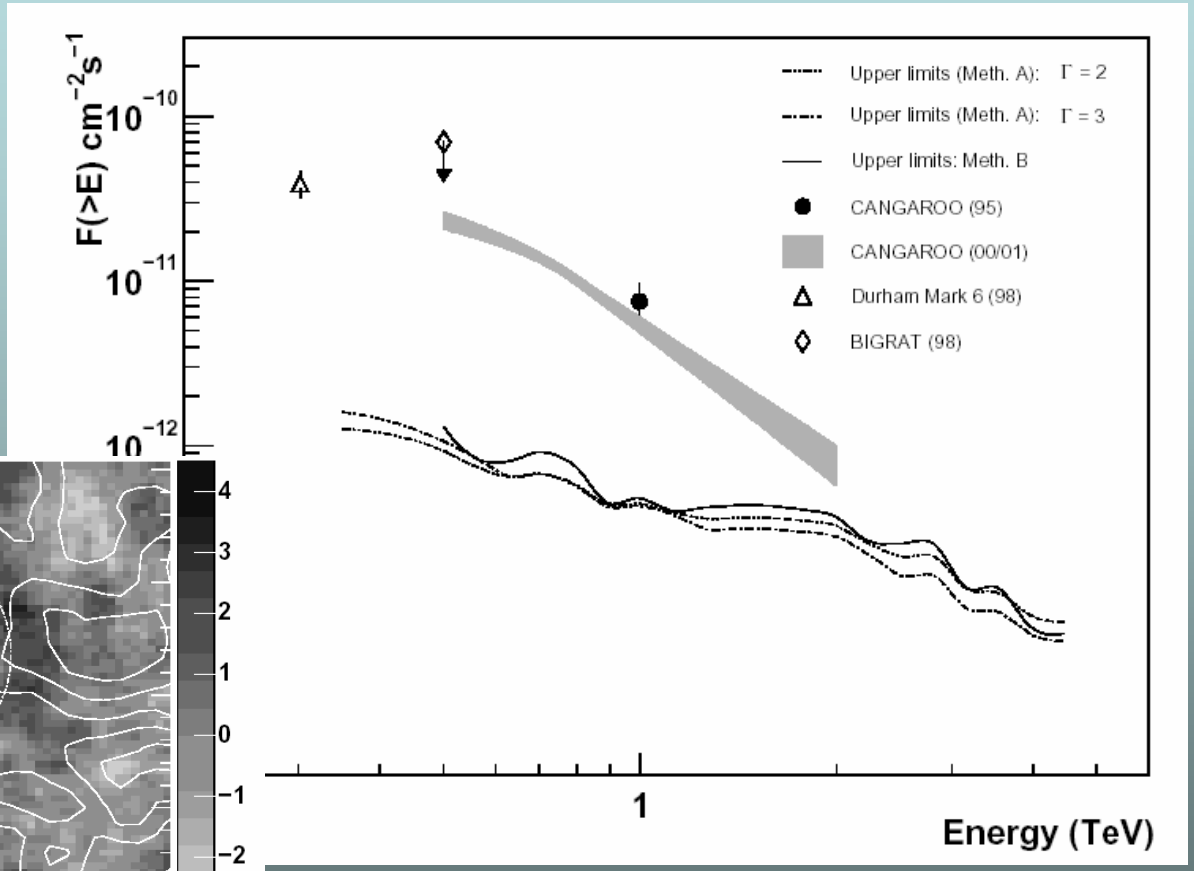




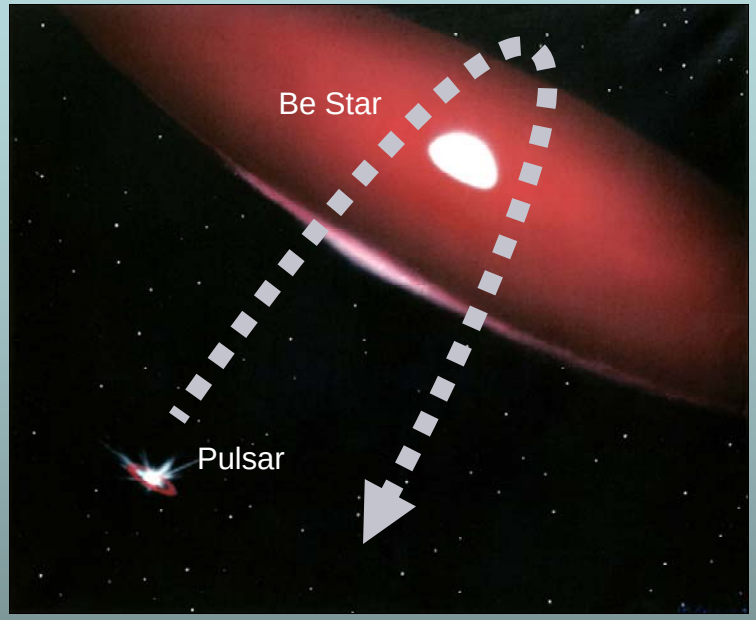
Tanimori et al., Ap. J., 497, L25 (1998)

PSR B1706-44


−1.5
−2
−2.5
−3
−3.5
Gal. Lat. (deg)
344
343.5
343
342.5
342
Gal. Long. (deg)
4
3
2
1
0
−1
−2
−3
−4


F(>E) cm^{-2}s^{-1}
10^{-10}
10^{-11}
10^{-12}
Upper limits (Meth. A): Γ = 2
Upper limits (Meth. A): Γ = 3
Upper limits: Meth. B
CANGAROO (95)
CANGAROO (00/01)
Durham Mark 6 (98)
BIGRAT (98)
1
Energy (TeV)

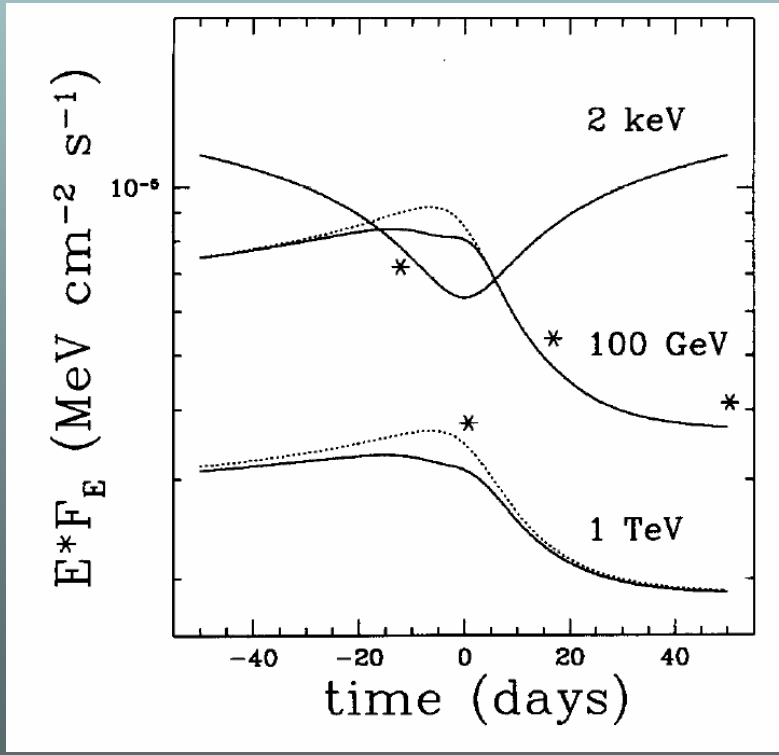
PSR B1259-693

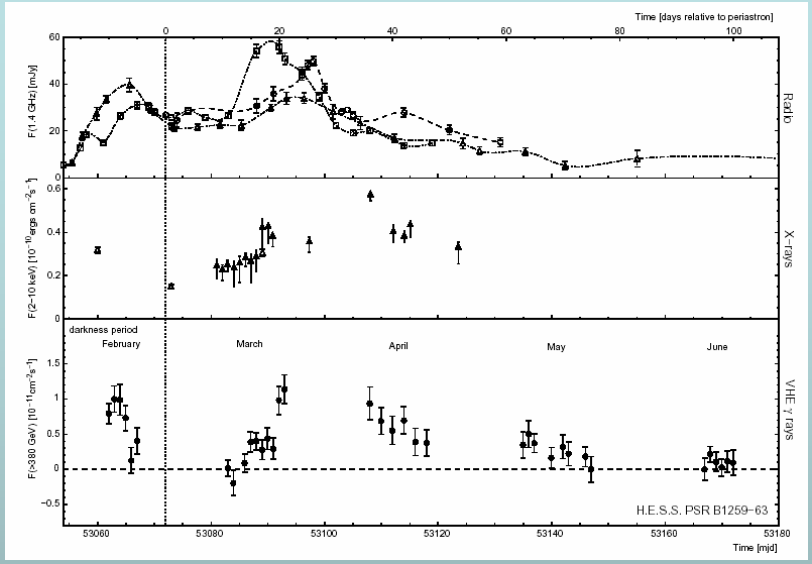


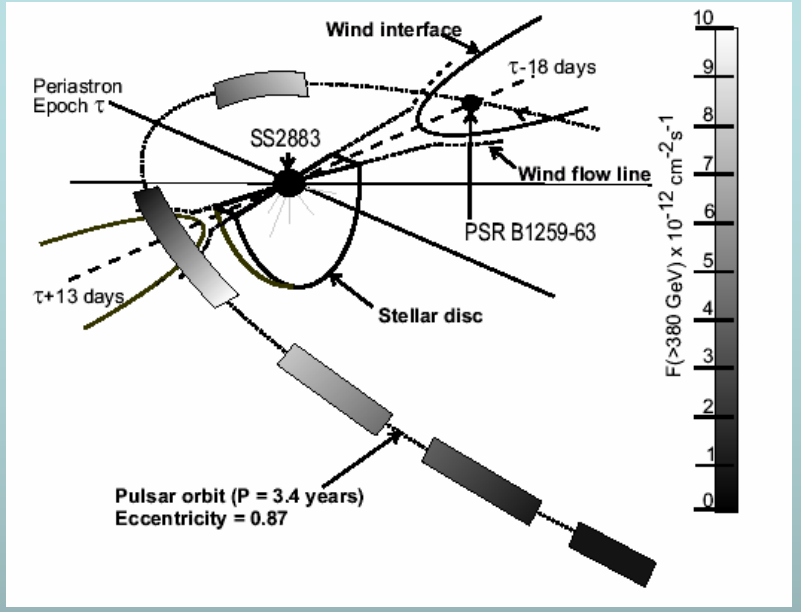
Artist view of the binary system PSR B1259-63/SS2883

Predicted by Kirk et al. (*Astropart. Phys.*, ***10***, *31, 1999*) to emit VHE gamma rays around periastron. This is the prediction for dominant IC losses.

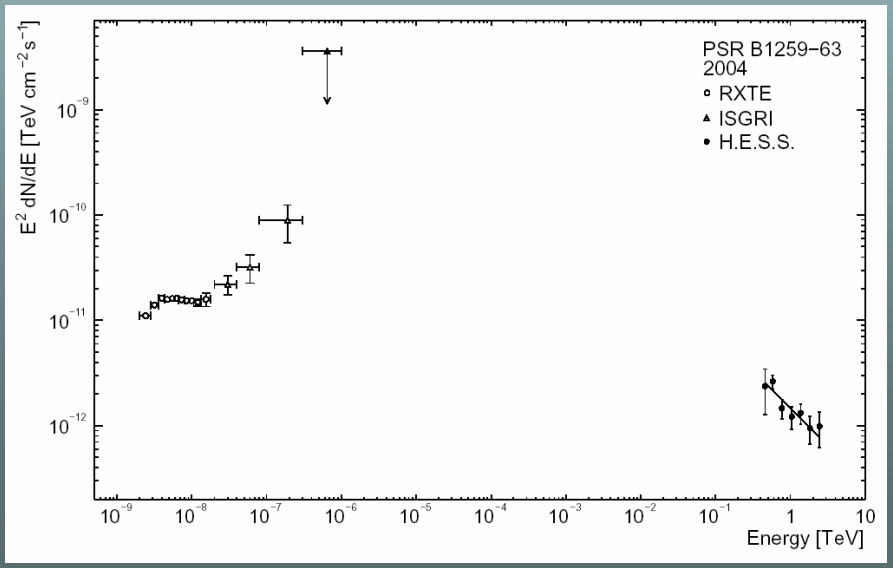
Trouble is, periastron occurs only once every 3.5 years

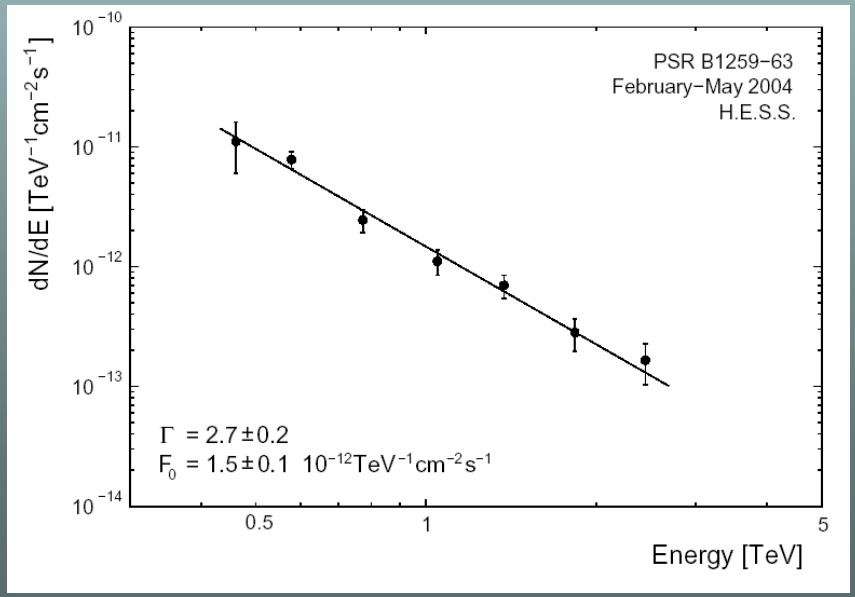




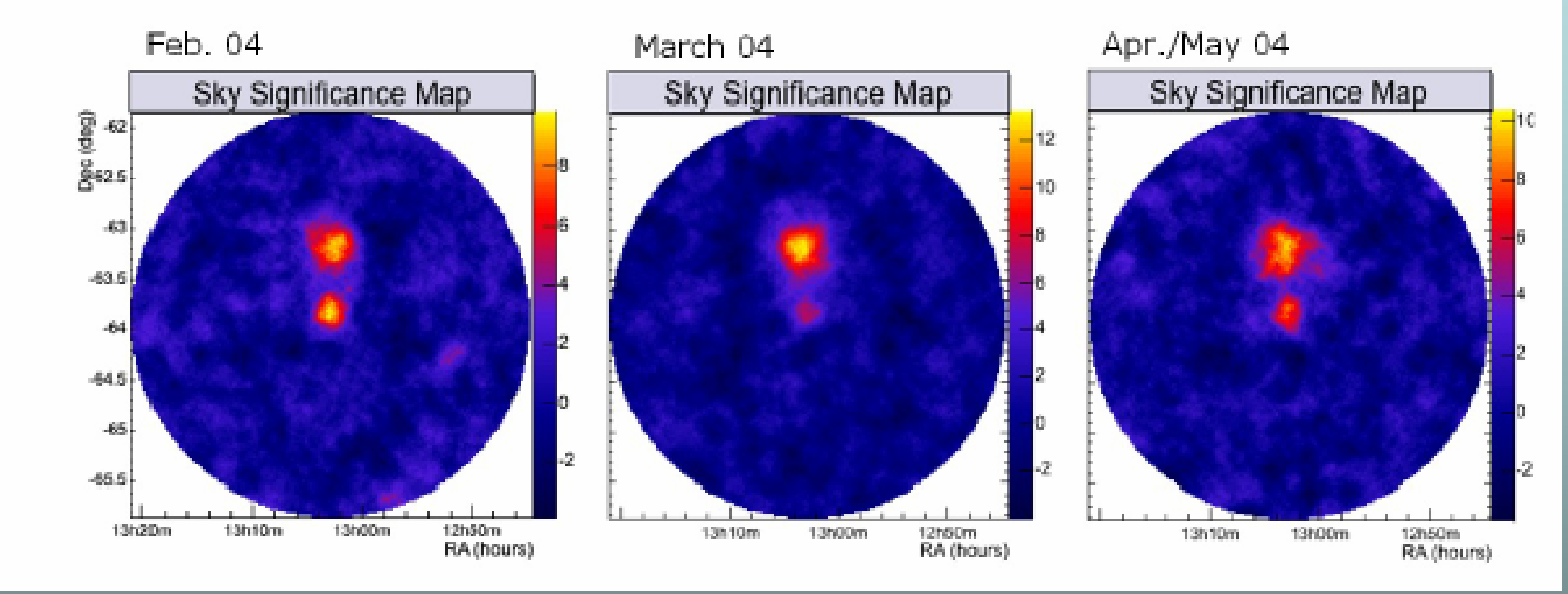


Overall significance 8.8σ





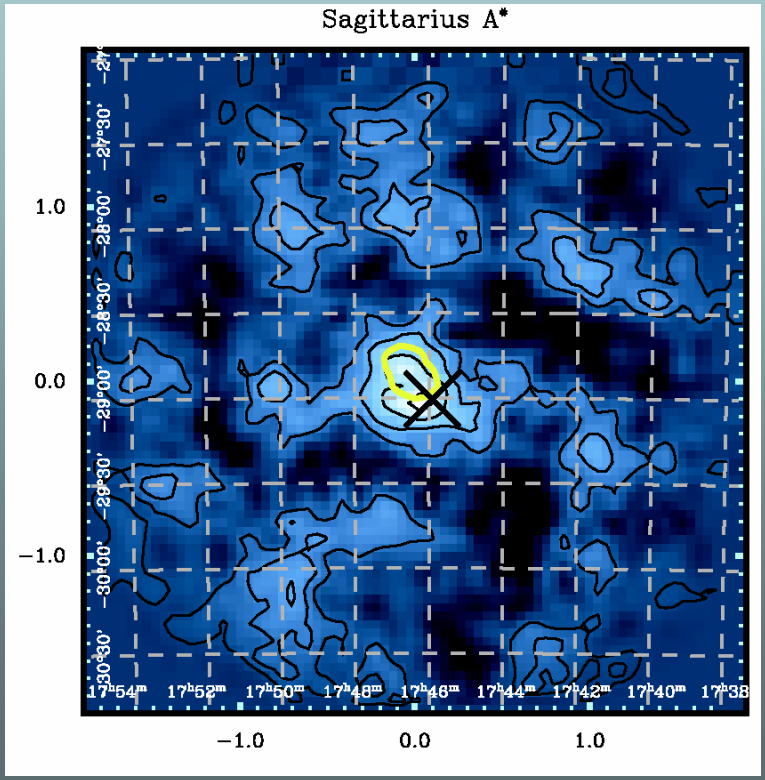
HESS J1303-631



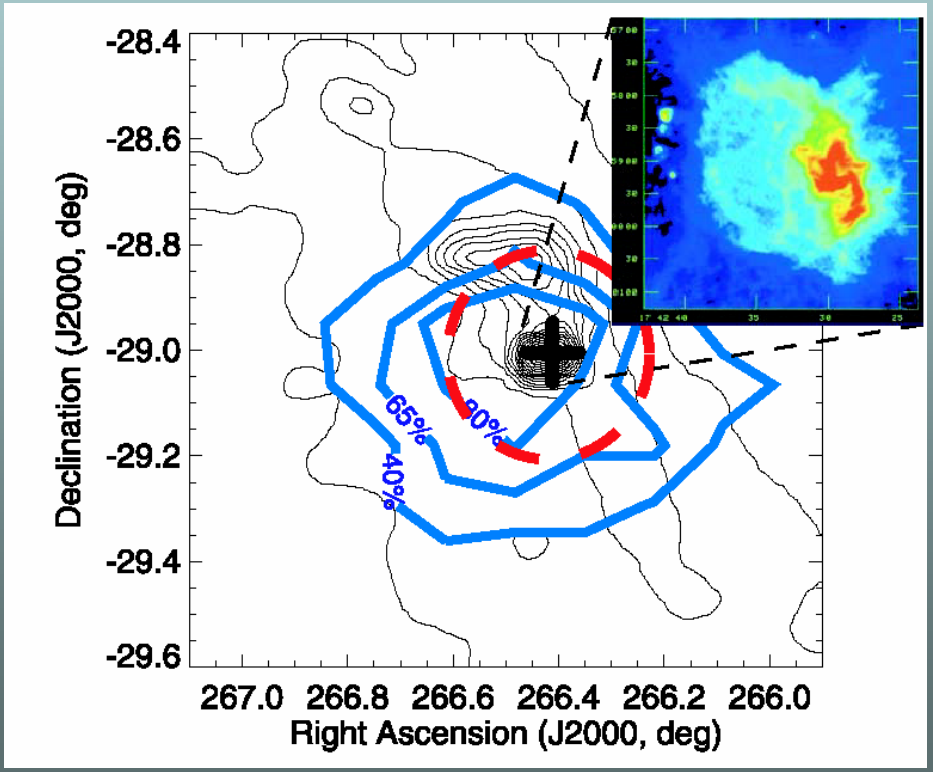
Nothing in the catalogues at this position!

Galactic Centre

Detections of VHE gamma rays from the galactic centre have been reported from both the CANGAROO II and Whipple groups.

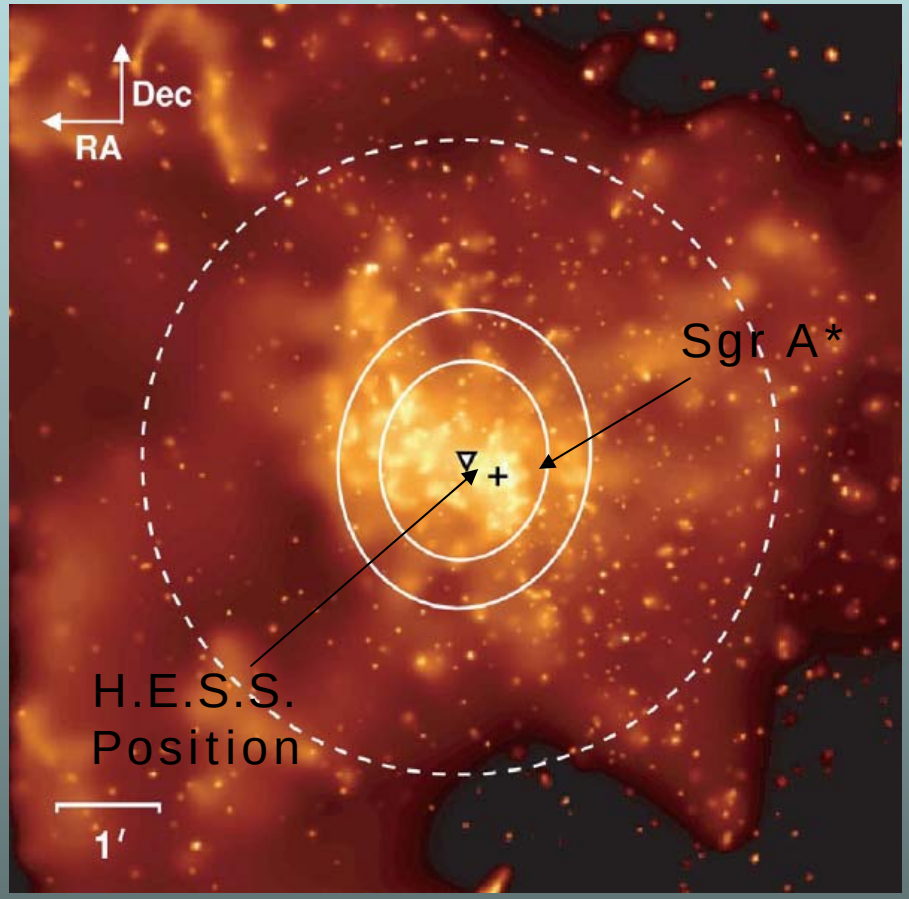


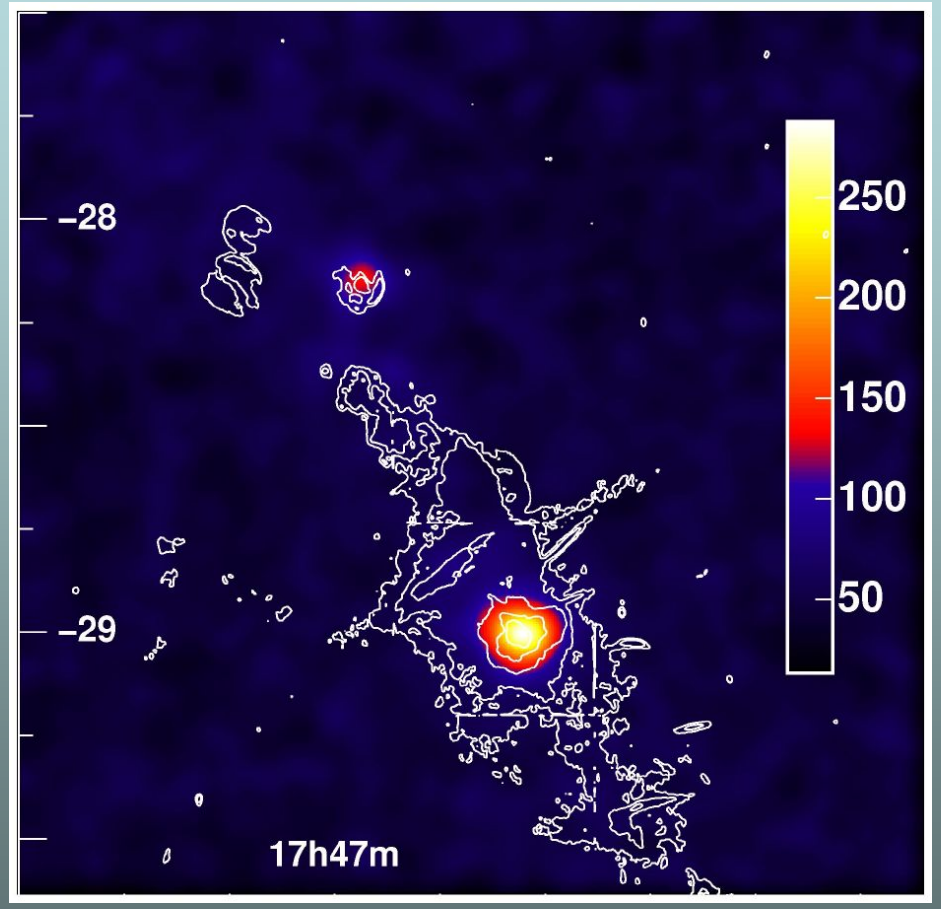
Kosack et al., Ap. J., 608, L97 (2004).



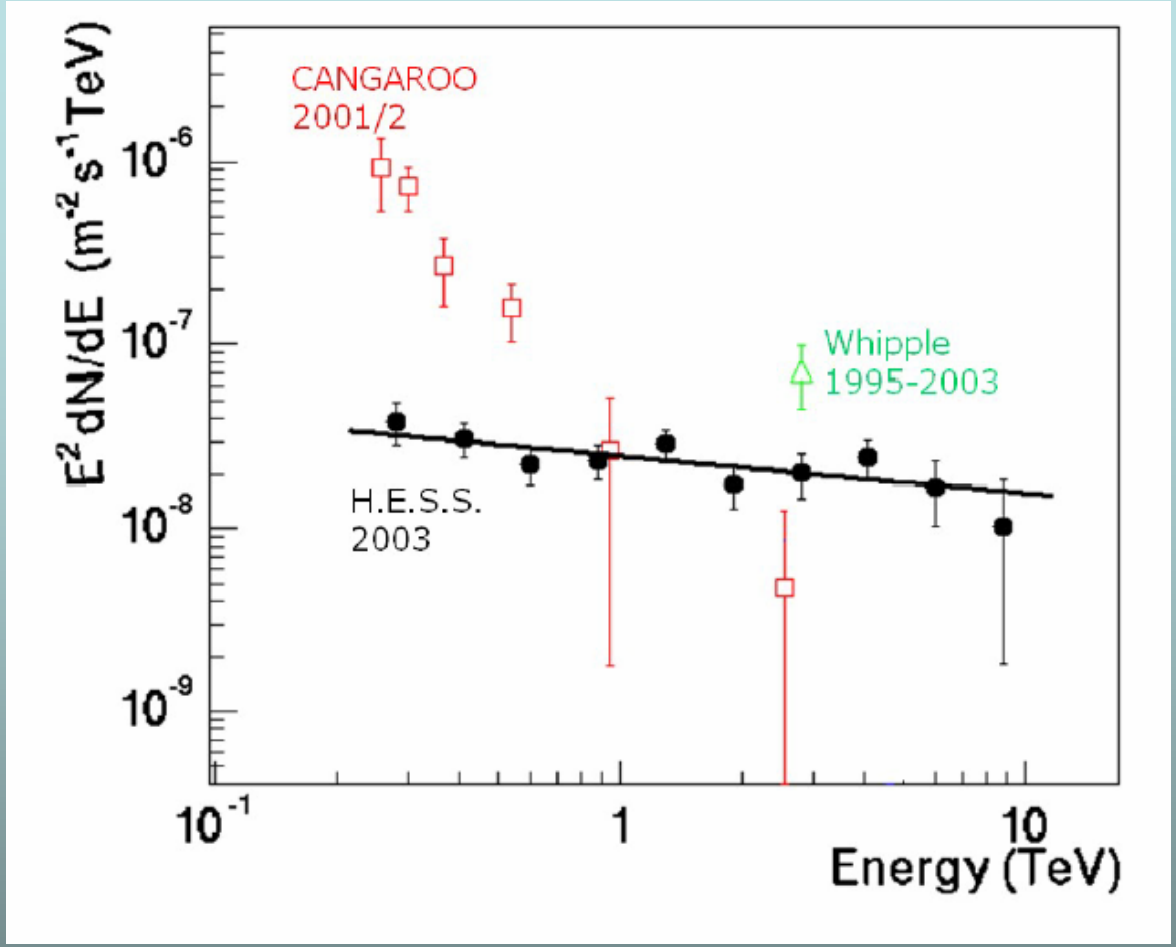
Tsuchiya et al., Ap. J., 606, L115 (2004)

H.E.S.S. observations show a source which is consistent with the position of Sgr A* and with a nearby SNR. Significance with 2004 data > 30σ



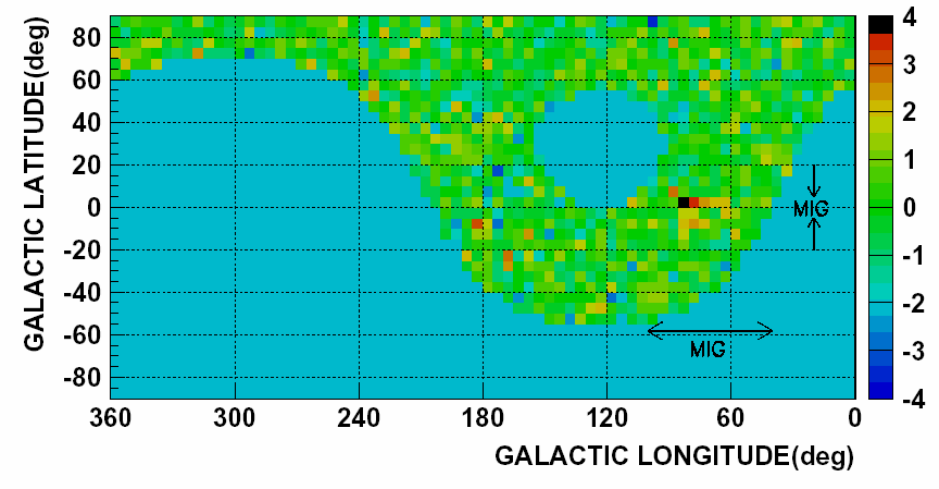


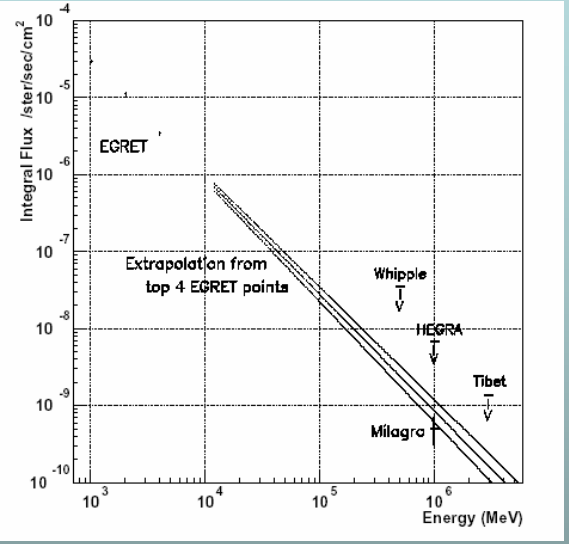
Aharonian et al., Astron. Astrophys., 425, L13 (2004)



The H.E.S.S. spectrum is harder that that observed with CANGAROO. It also probably rules out WIMPs with masses < 12 TeV.

Diffuse Emission from the Galactic Plane

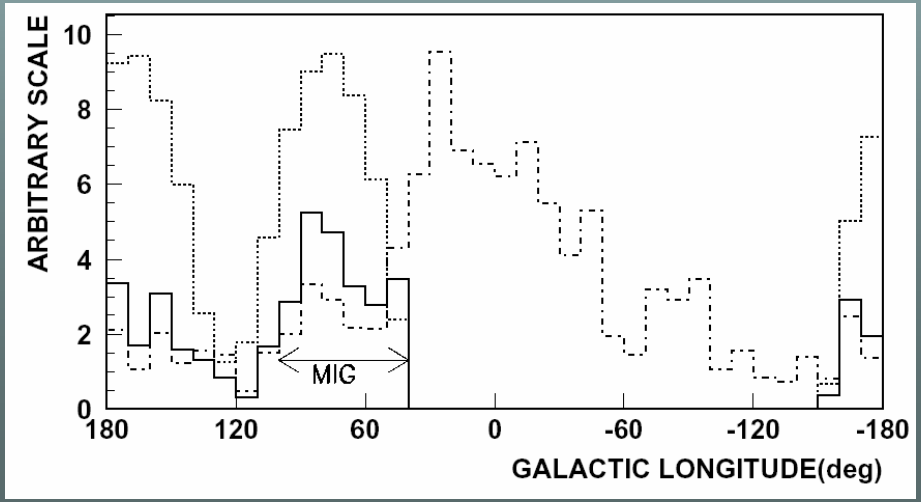




MILAGRO observation

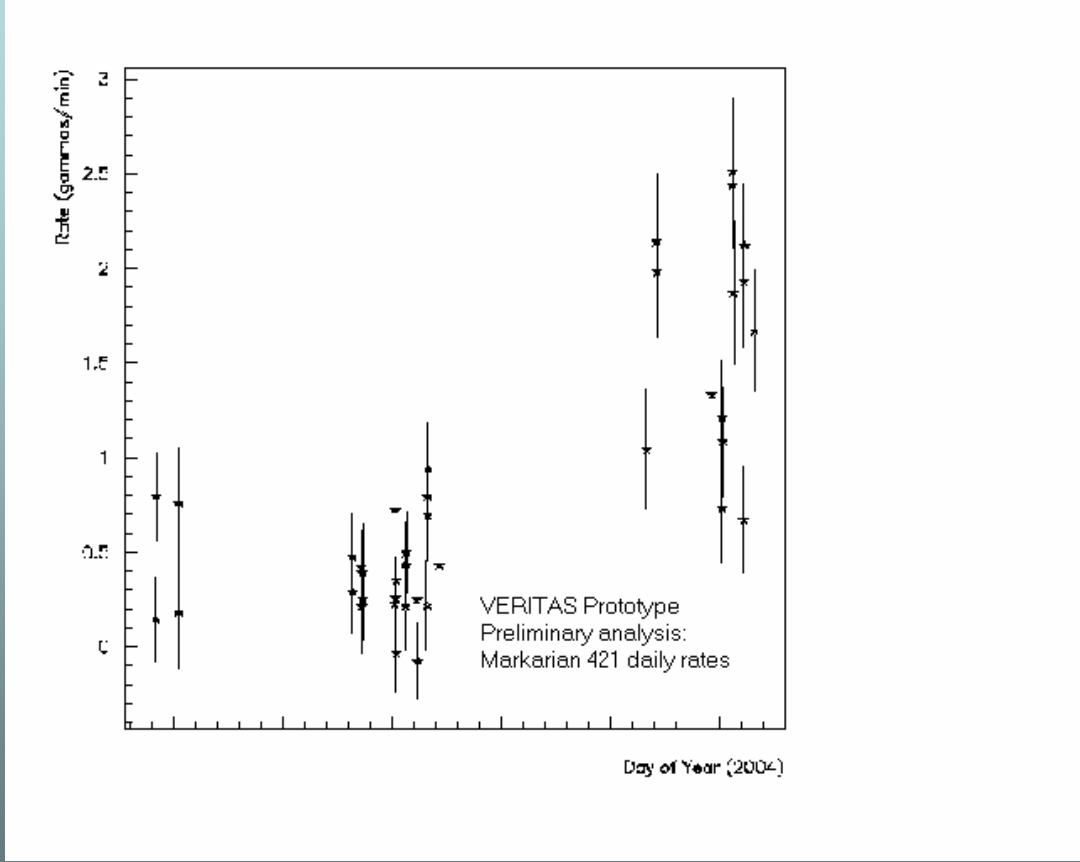
3 years – 2000-2003

Significance ~4.5σ



Astro-ph/0502303, 15th Feb 2005

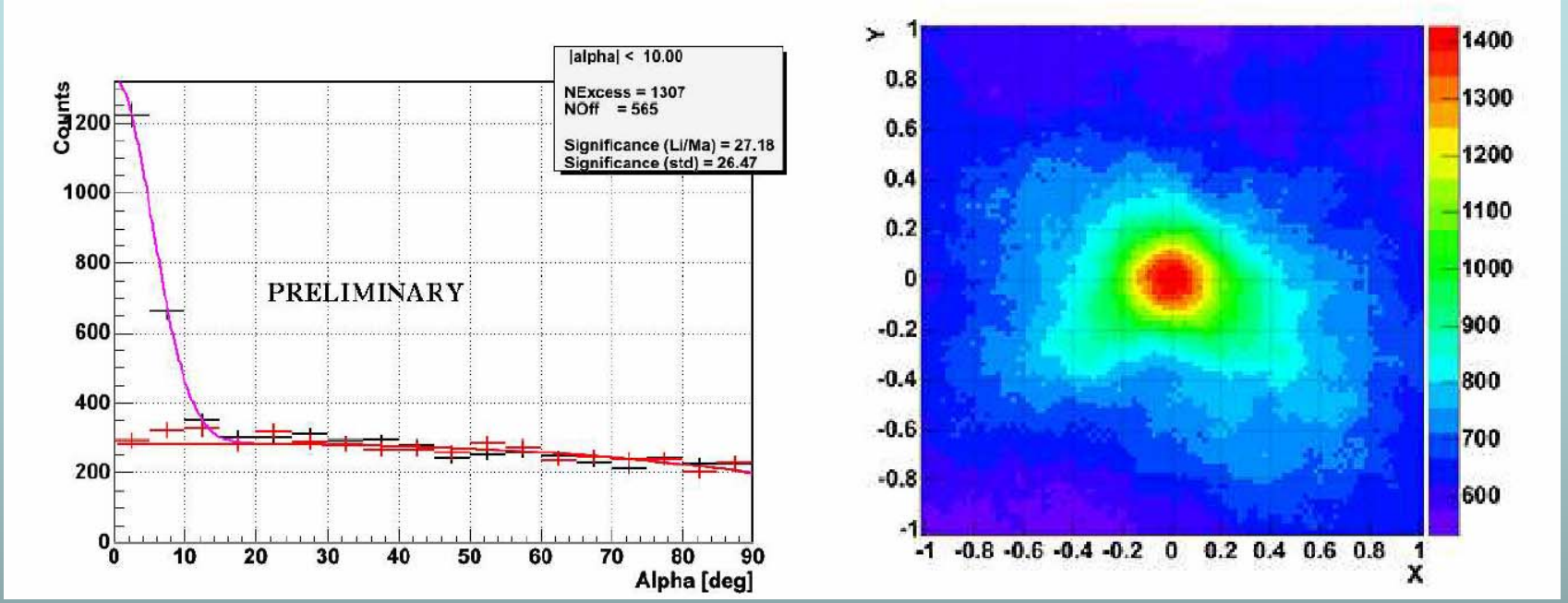
BL Lac Mkn 421



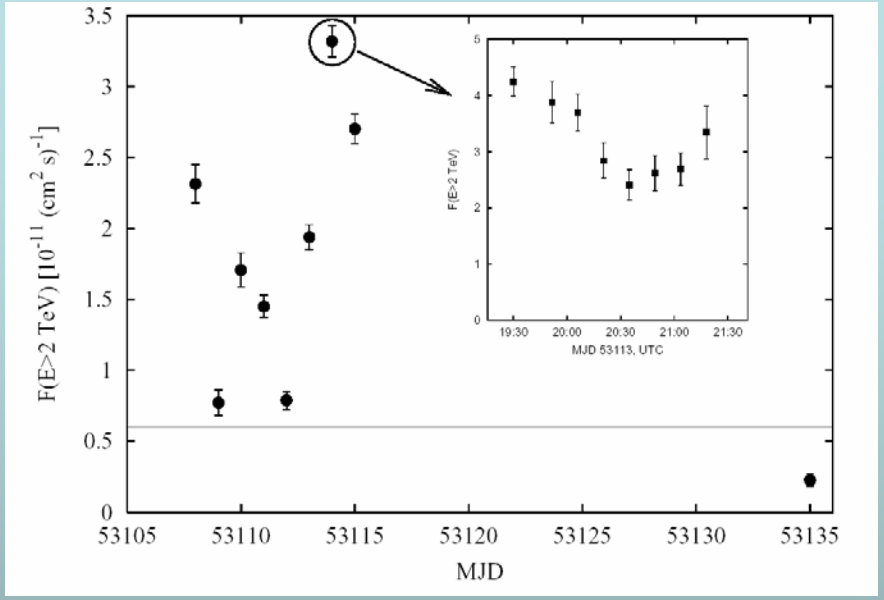
Well-known close (z ~ 0.031) BL-Lac

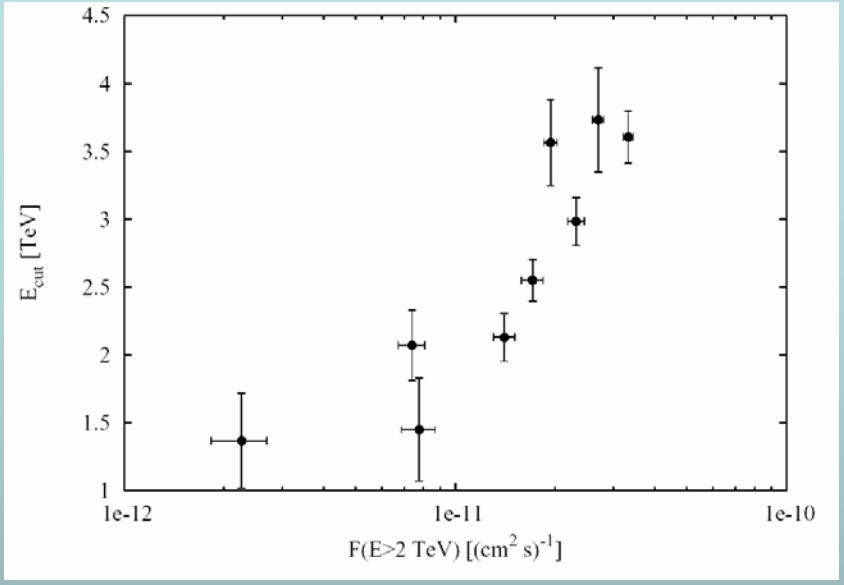
Outburst in April/May 2004

VERITAS result with just the prototype telescope



MAGIC results on Mkn 421 – 96 minutes, 1307 excess events, 27σ





~ 7000 gamma rays detected in 14.7 hours (EGRET detected a *total* of 5134 gammas from the Crab)
Average rate 8 min^{-1}
Overall significance > 100σ
E > 1.5 TeV (60-65° z.a.)
Average integral flux above 10 TeV ~ 2x Crab
Changes in diurnal flux by up to a factor of 4.5

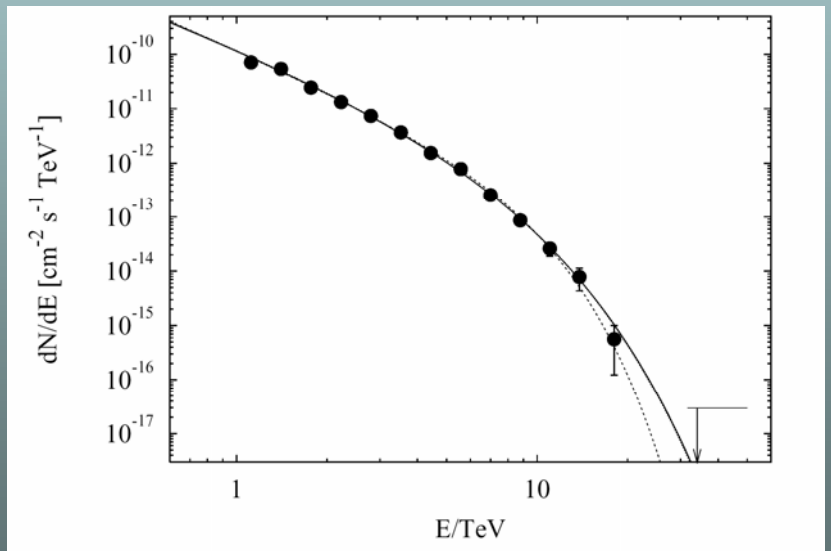
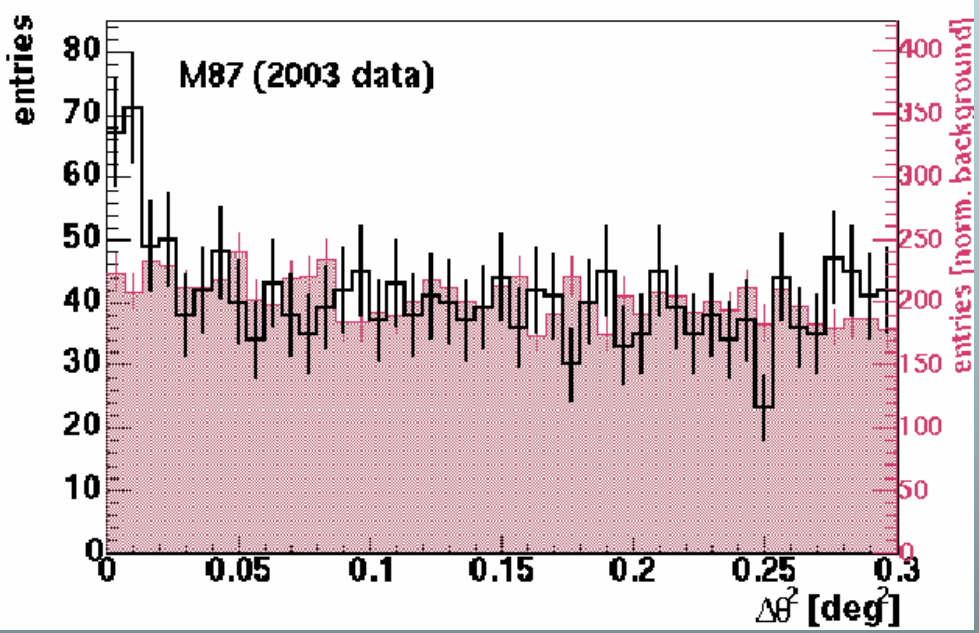
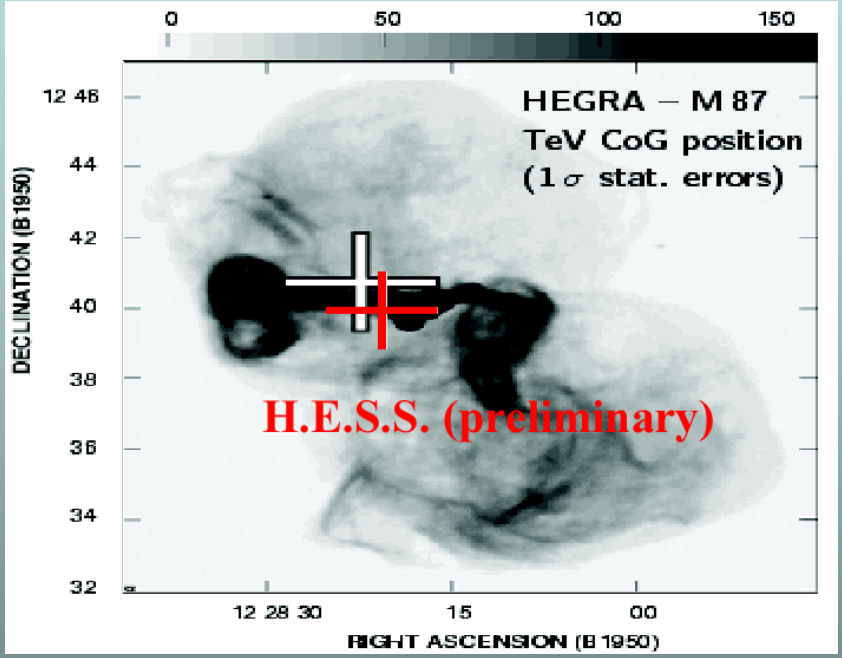


Fig. 1. Differential energy spectrum of Mkn 421: The curvature is evident and described by a power-law with a photon index of $\Gamma = 2.1 \pm 0.1$ with an exponential cutoff at $E_c = (3.1(+0.5-0.4)_{\rm stat} \pm 0.9_{\rm sys})$ TeV (solid line) or alternatively with a super-exponential cutoff ($\exp(-(E/E_c)^{1.55})$ at $E_c = (6.25 \pm 0.4_{\rm stat} \pm 0.9_{\rm sys})$ TeV (dashed line).

M87



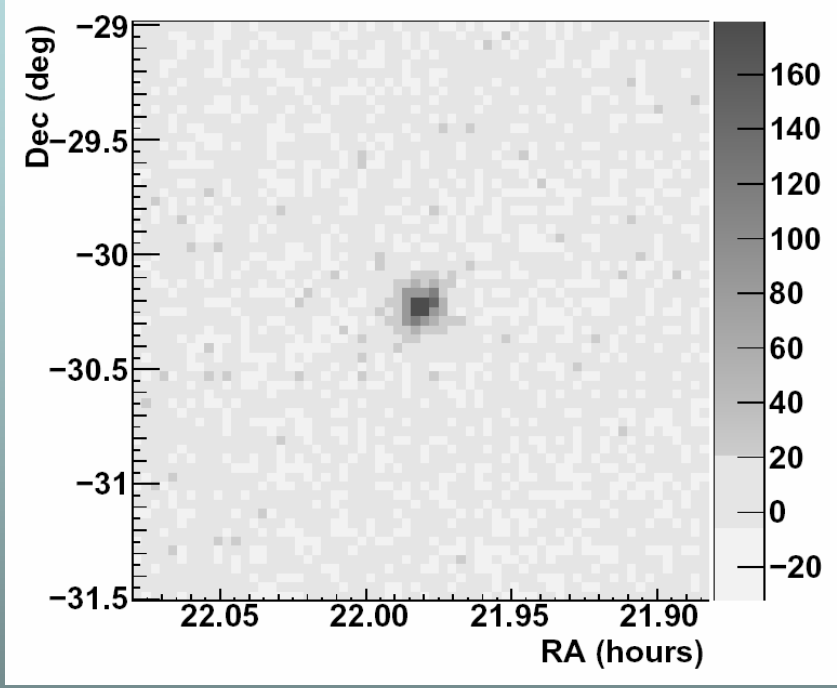


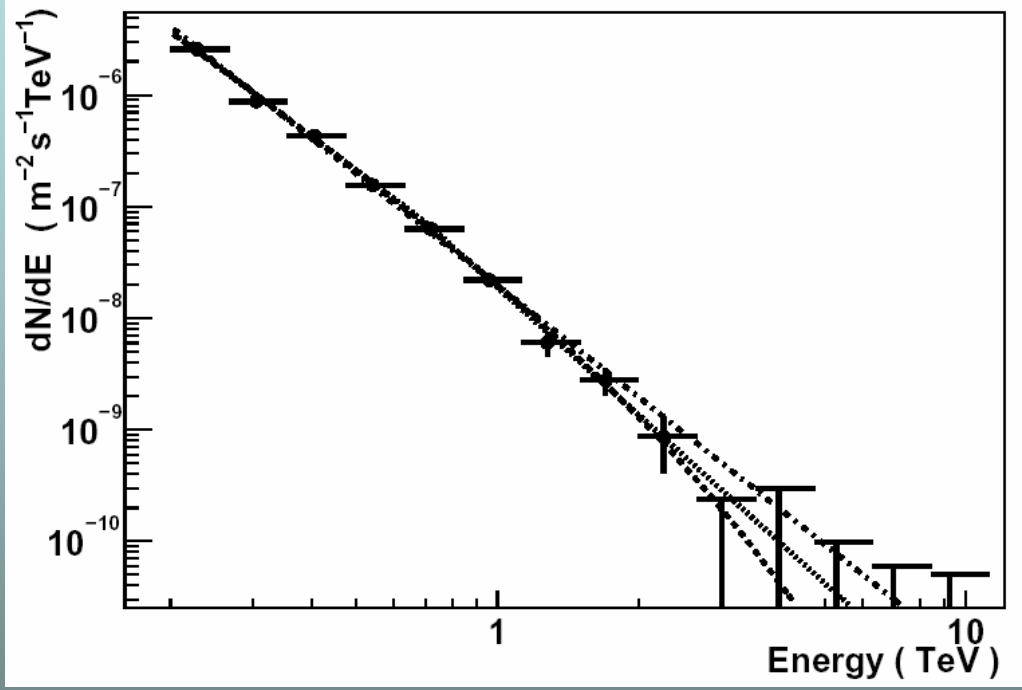
4σ, 25 hours

2 telescopes only

Only ~1% of the Crab

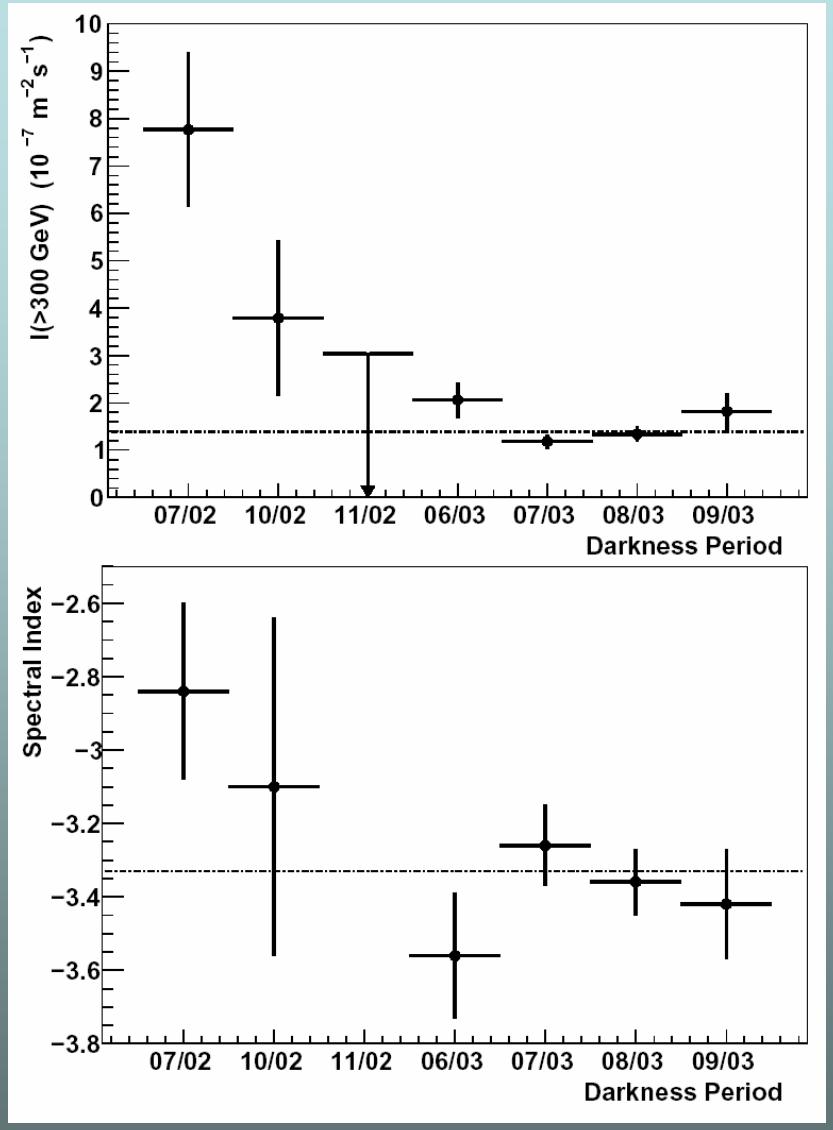
PKS 2155-304

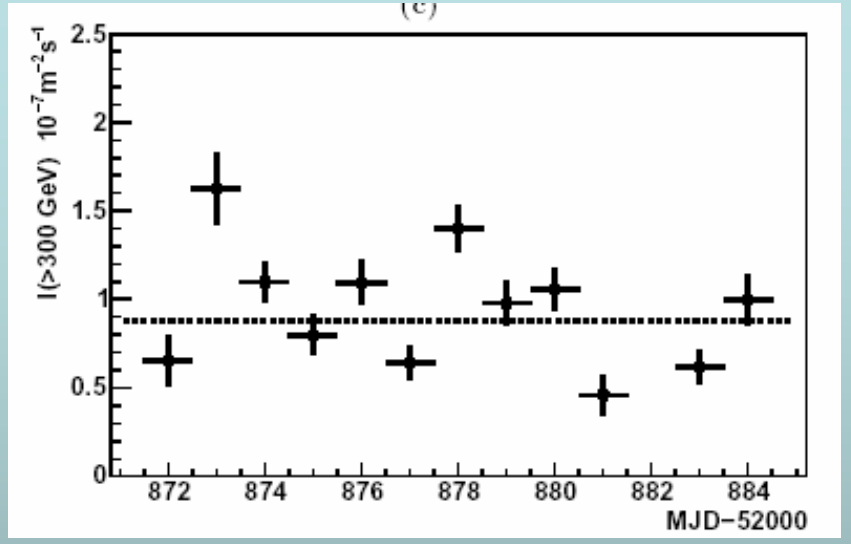


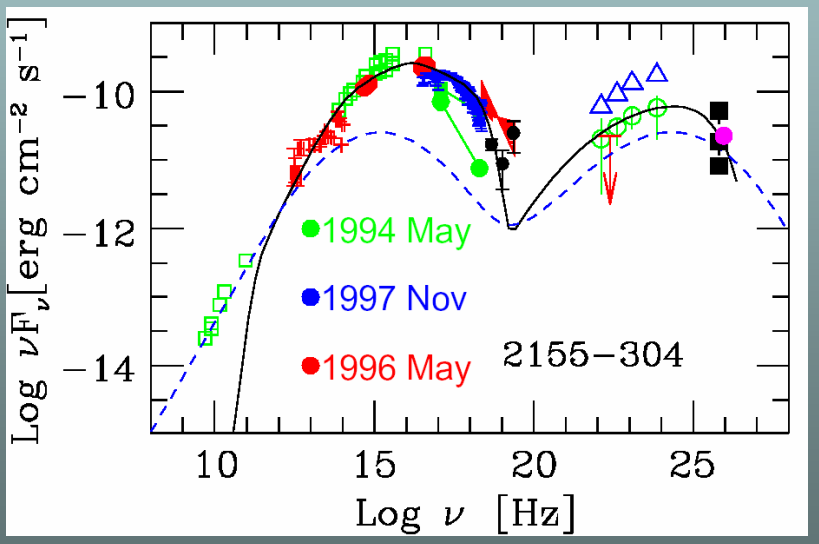


2002/3 observations with variously 1,2 and 3 telescopes

~ 45σ, E > 160 GeV


I(>300 GeV) (10^{-7} m^{-2}s^{-1})
07/02
10/02
11/02
06/03
07/03
08/03
09/03
Darkness Period
Spectral Index
07/02
10/02
11/02
06/03
07/03
08/03
09/03
Darkness Period

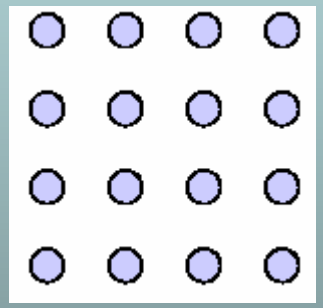

I(>300 GeV) 10^{-7}m^{-2}s^{-1}
MJD−52000


Log νF$_ν$[erg cm^{-2} s^{-1}]
1994 May
1997 Nov
1996 May
2155−304
Log ν [Hz]


So what next???

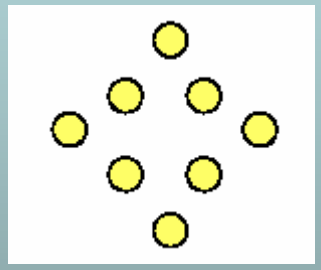
H.E.S.S. Phase II

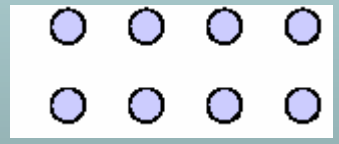
Original idea – have an array of 16 telescopes in total….



…provides about a factor of 4 extra in area, slightly better angular resolution and a factor of 2-3 in sensitivity.

…it's also expensive, so how about another 4 telescopes?





Factor of about 2 improvement in area, slightly better angular resolution and $2^{0.5}$ improvement in sensitivity.

Hmmm….

Funding now approved by MPG and French agencies ~ 7 MEuro

Order for structure soon

New H.E.S.S. members welcome….

Better op
large (60

Lower e
GeV) in standalone mode

Improved sensitivity at higher energy in coincidence mode