VHE Gamma Ray Astronomy

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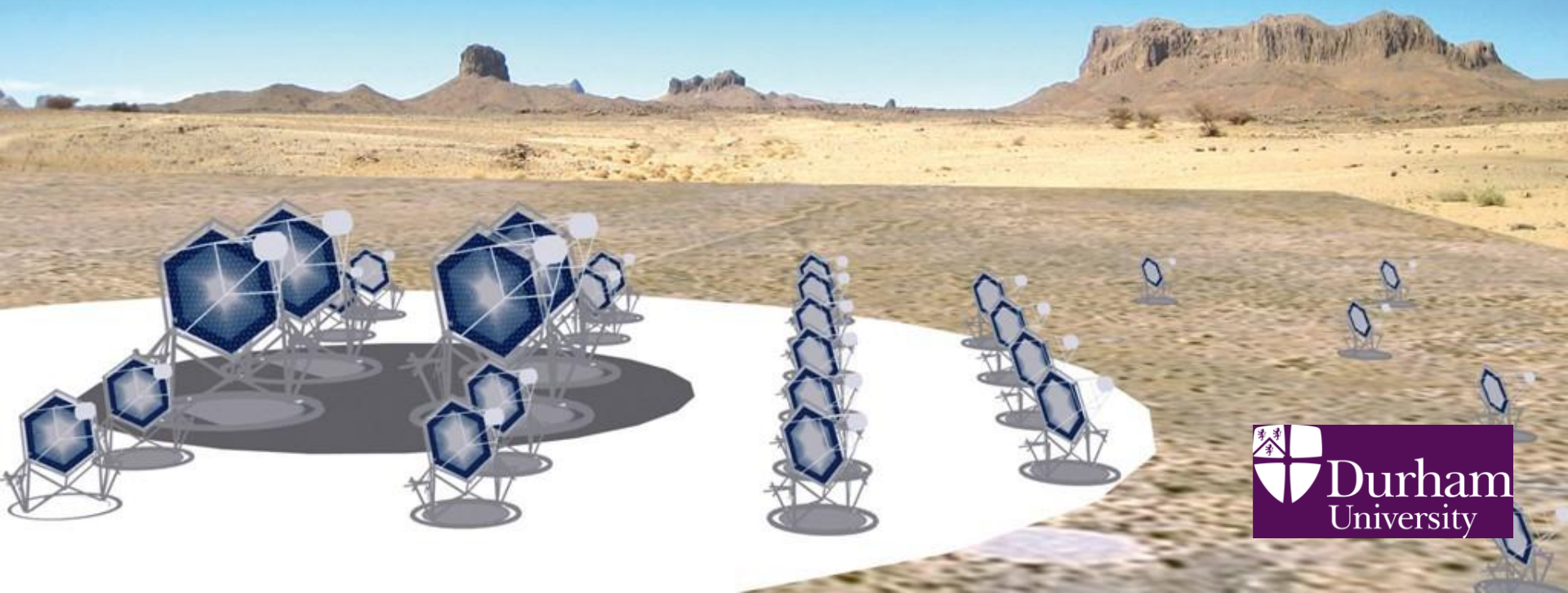
University of Durham



The Plan

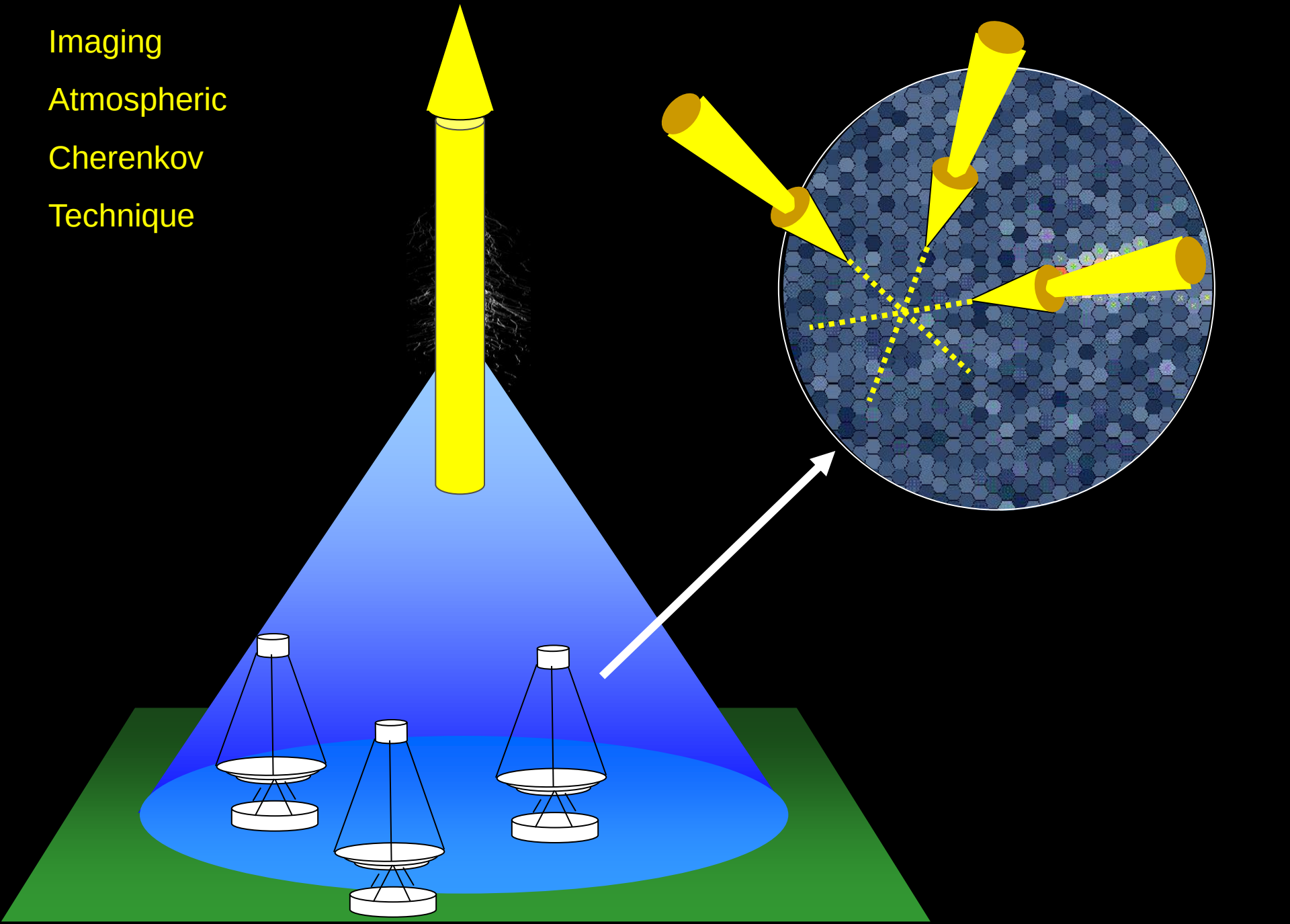
- The VHE world
- A ‘fun run’ through the catalogue
- Things on the horizon?

Imaging

Atmospheric

Cherenkov

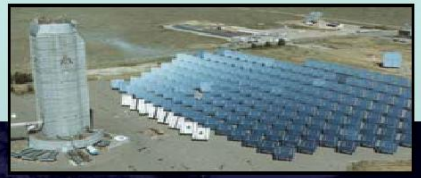
Technique



VHE Experimental World

MILAGRO

STACEE



MAGIC

TIBET

VERITAS

TACTIC

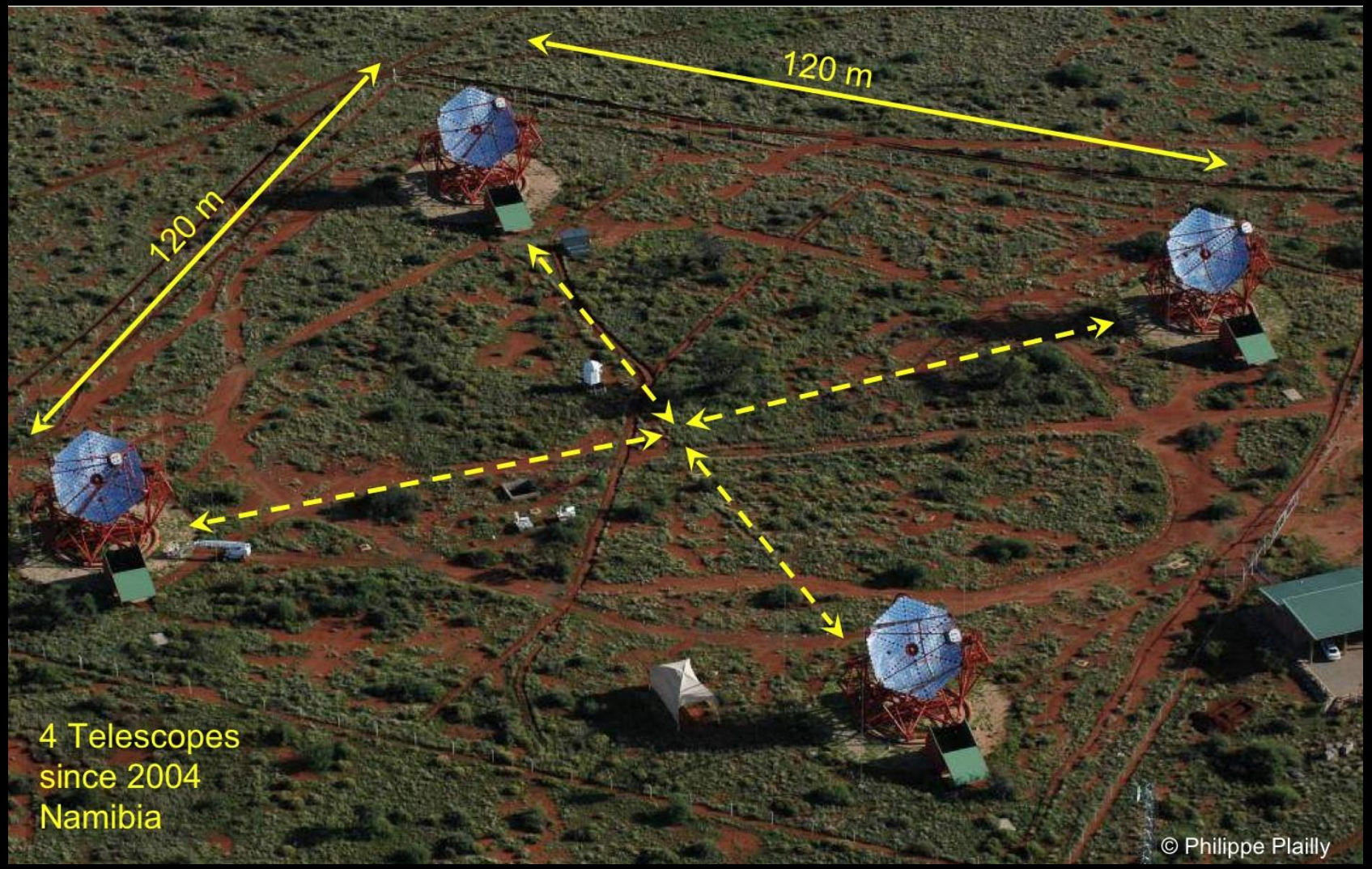
From Rene Ong

OG 1

HESS

CANGAROO

H.E.S.S.


120 m
120 m
4 Telescopes
since 2004
Namibia
© Philippe Plailly

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

LLR Ecole Polytechnique; LPNHE; APC College de France; University of Grenoble; CESR Toulouse; CEA Saclay; Observatoire de Paris-Meudon; LPTA Montpellier; LAPP Annecy

Durham University; University of Leeds

Dublin Institute for Advanced Studies

Polish Academy of Sciences (Astronomical Center & Institute of Nuclear Physics); Jagiellionian University; Nicolaus Copernicus University

Charles University, Prague

Yerevan Physics Institute, Armenia

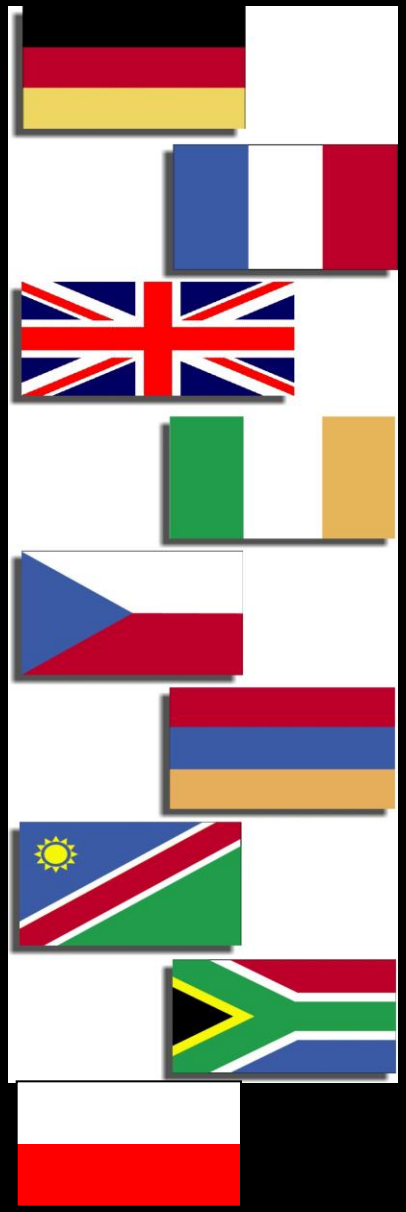
University of Namibia

North-Western University, South Africa

University of Adelaide, Australia

University of Innsbruck, Austria

SWEDESI



VERITAS

Smithsonian Astrophysical Observatory; Purdue University; Iowa State University; Washington St Louis University; University of Chicago; University of Utah; UCLA; Adler Planetarium; Argonne National Lab.; Barnard College; DePauw University; Grinnell College; University of California, Santa Cruz; University of Iowa; University of Massachusets;

University of Delaware/Bartol

University College Dublin; Cork Institute of Technology; Galway-Mayo Institute of Technology; NUI, Galway

University of Leeds

McGill University




MAGIC

IFAE, Barcelona; Universitat Autonoma de Barcelona; Universitat de Barcelona; IEEC-CSIC, Bellaterra; Instituto de Astrofisica de Andalucia, Granada; Instituto de Astrofisica de Canarias, La Laguna; Universidad Complutense, Madrid

Max Planck Institut fur Physik, Munich; University of Dortmund; University of Wurzburg; DESY, Zeuthen

University of Padova and INFN, Padova; INAF, Rome; University of Sienna and INFN, Pisa; University of Udina and INFN, Trieste

ETH, Zurich

University of Lodz

Institute for Nuclear Research & Nuclear Energy, Sofia

Tuorla Observatory, Piikkio

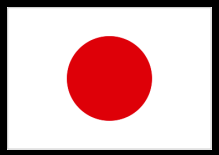
Institute R. Boskovic; University of Rijeka; University of Split

CANGAROO III

Was 4 telescopes, but thanks to technical problems (and lightning!) only two now operational.

University of Adelaide; Mount Stomlo & Siding Springs Observatory; ATNF

Ibaraki University; Institute for Cosmic Ray Research, University of Tokyo; National Observatory of Japan; Tokai University; Kyoto University; Solar-Terrestrial Environment Laboratory, Nagoya University; Yamagata University; Yamanashi Gakuin University; Konan University; Ibaraki Prefectural University of Health Sciences; Kitasato University; Hiroshima University; Tokyo Institute of Technology; Ritsumeikan University; KEK



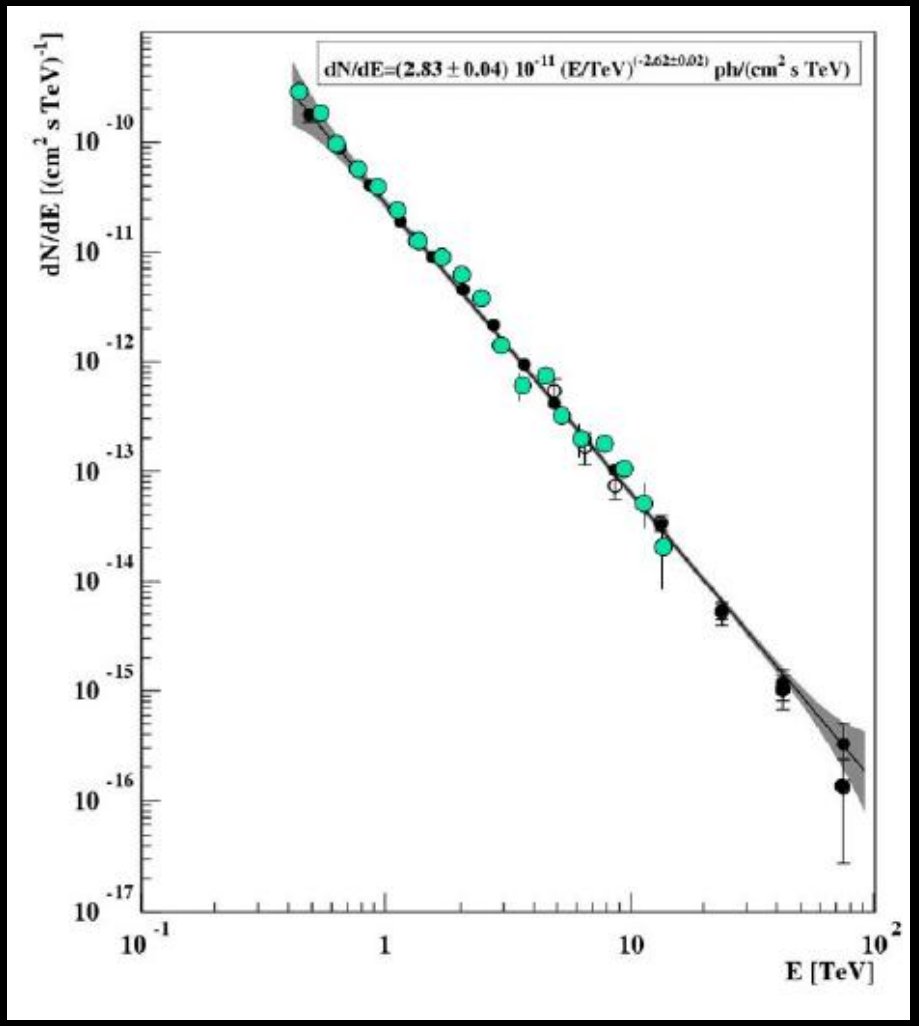
The ‘typical’ VHE gamma ray instrument…

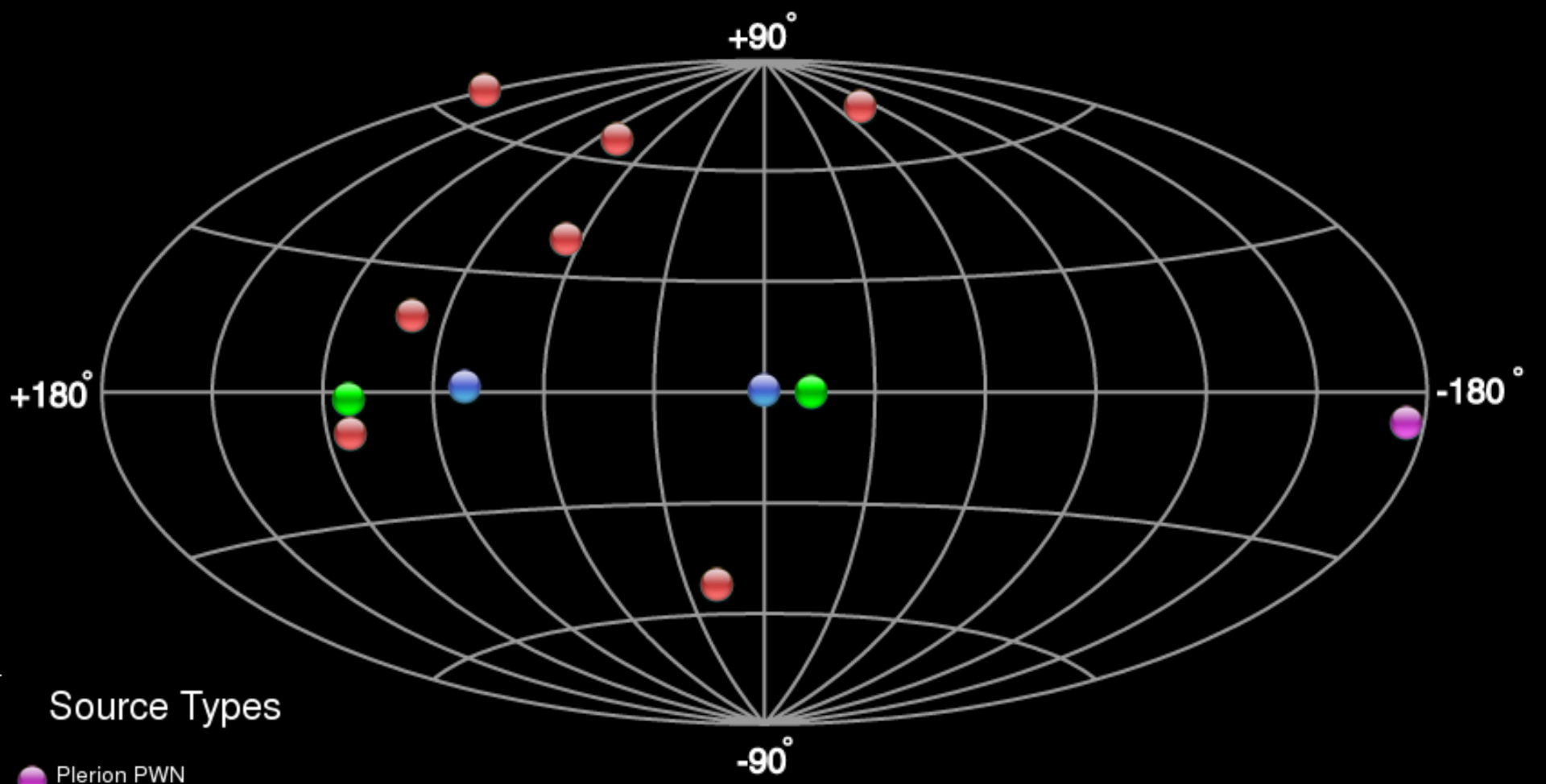
- Consists of more than one telescope
- Has a wide FoV (3-5 degrees)
- Has a very large effective area (~10^4 m^2)
- Does not in general take data at elevations less than around 45-50 degrees…unless a high energy threshold is desirable
- Has a duty cycle of around 10% (900-1000h per annum)

Improvement in Sensitivity – The Crab Nebula

The Crab Nebula is the ‘standard candle’ in this field – it is a bright, constant source of gamma rays right up to several 10s of TeV.

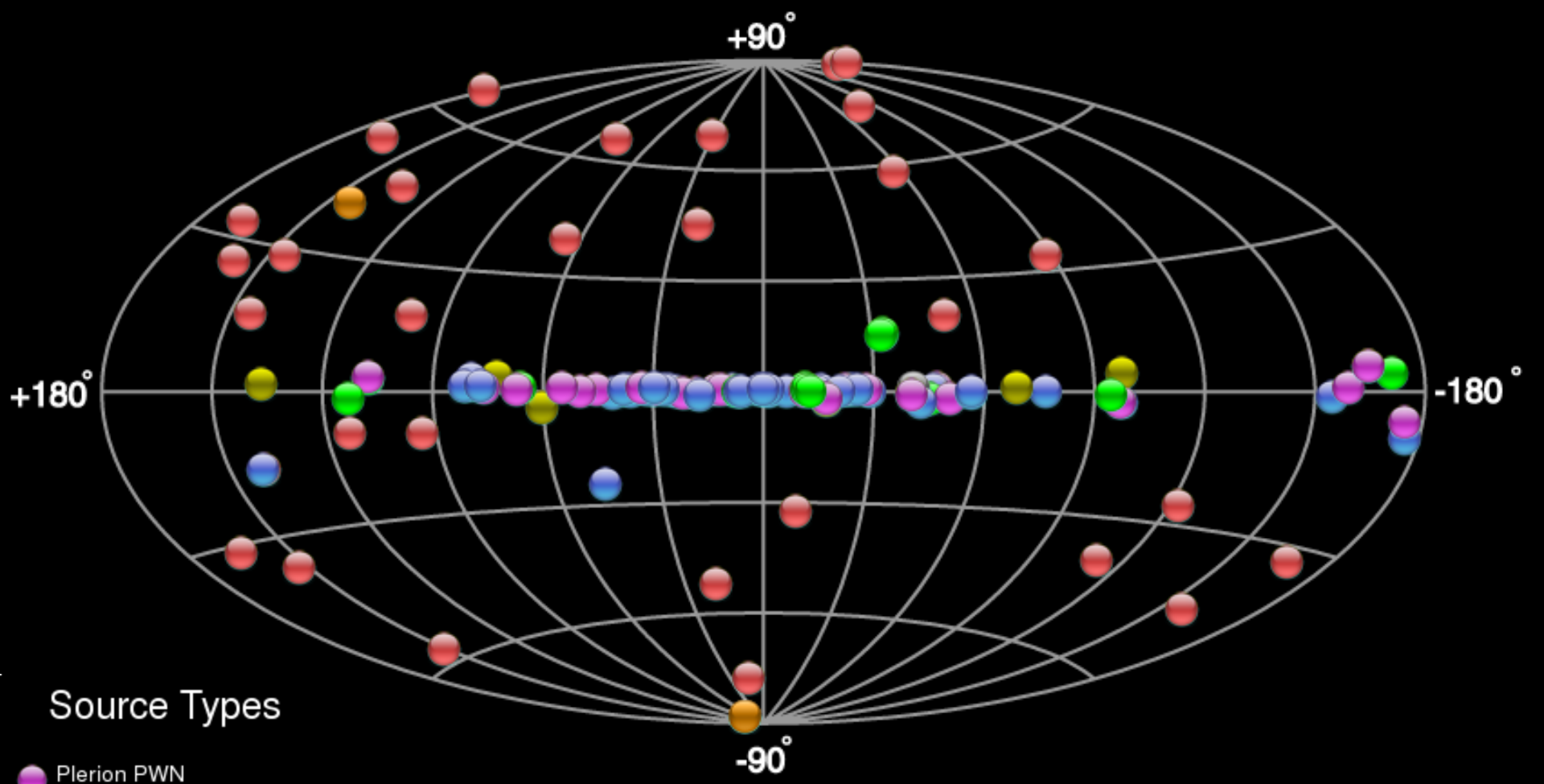
Crab flux fraction	Obs. Time required
0.005	100 hr
0.01	25 hr
0.05	1 hr
0.1	20 min
0.5	1.5 min
1	30 sec





Source Types

- Plerion PWN
- XRB PSR
- HBL IBL FRI FSRQ LBL
- Shell
- Starburst
- DARK
- MQS Cat. Var. UNID Other BIN WR



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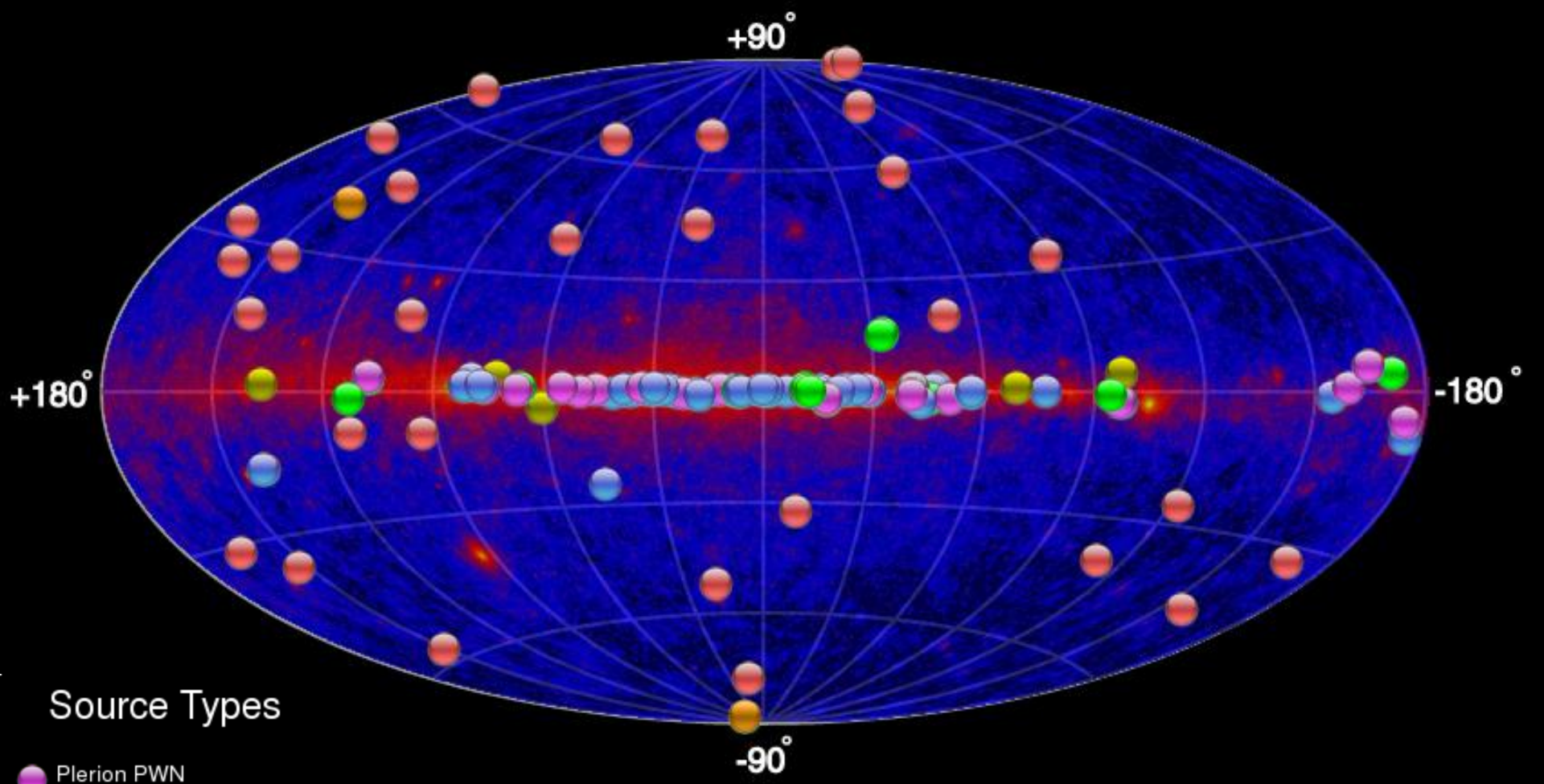

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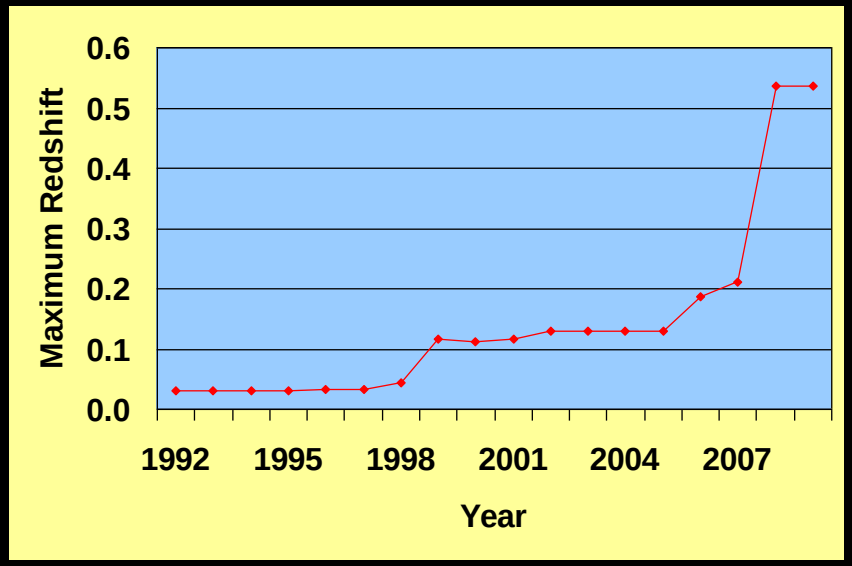
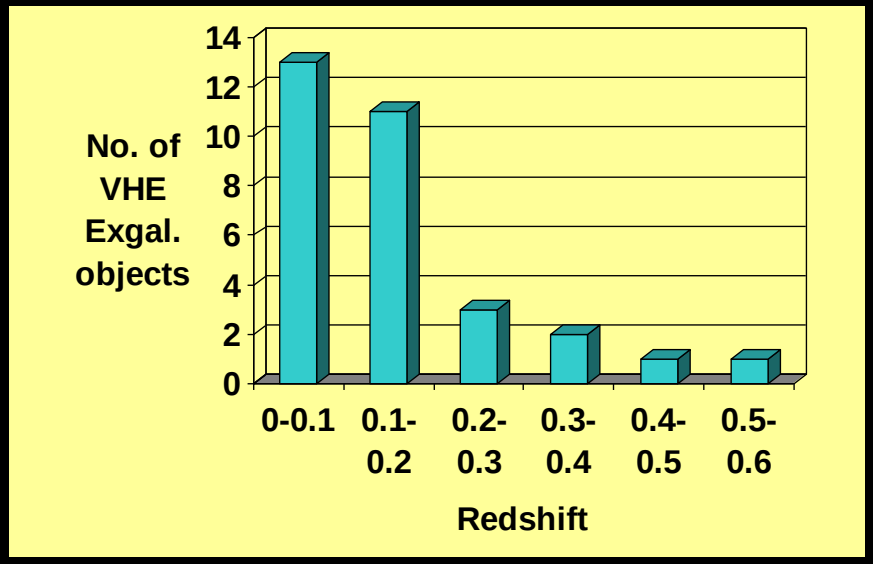
Sources by Type

Unidentified	26 (and falling)	HBL	23
PWN	17	IBL	3
Shell SNRs	13	LBL	2
Binaries	5	FRI	2
Clusters/WR	3	Starburst Galaxies	2
Diffuse	2	FSRQ	1
		Gal. Centre	1 (!)

Fortuitously, that comes to 100 – but it's subjective!

Probing Greater Distances





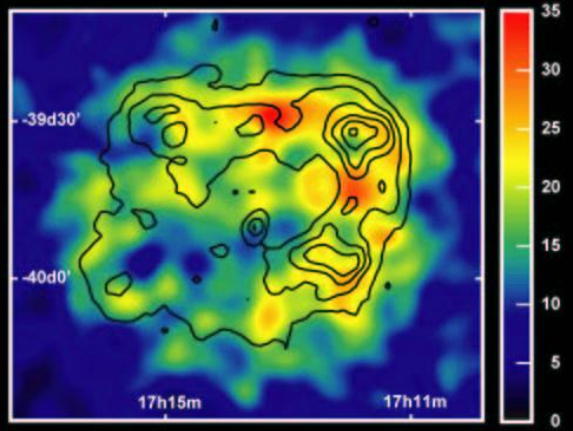
What do ‘proper’ astronomers do?

- Imaging
- Astrometry
- Surveys
- Timing
- Photometry
- Spectroscopy

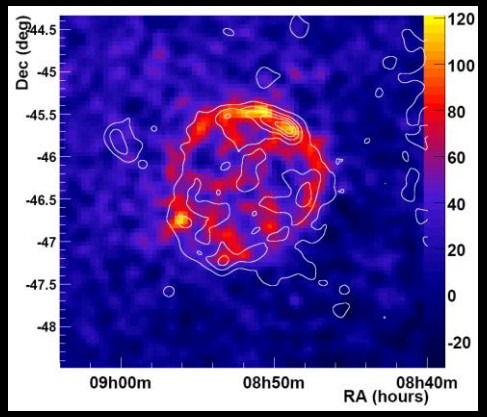
AND VHE gamma ray telescopes can perform ‘particle physics experiments’ e.g. the electron spectrum, first interaction Cherenkov light etc.

All of these core astrophysical functions have greatly improved in recent years

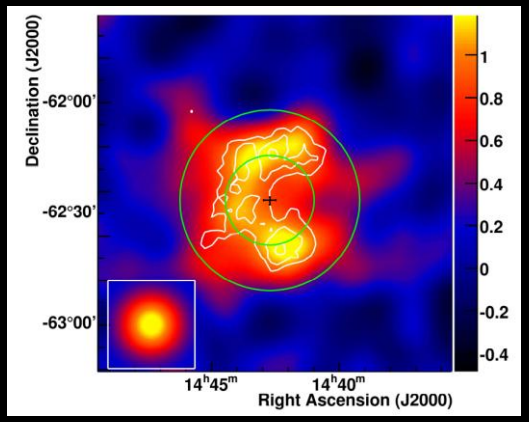
Imaging – Shell SNRs & PWN



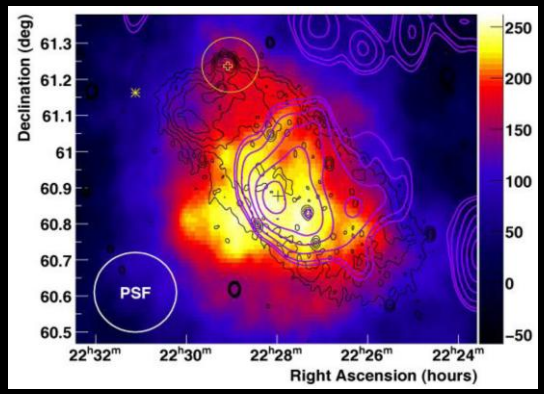
RXJ1713-3946
Aharonian et al., *Nature*, **432**, 75 (2004)



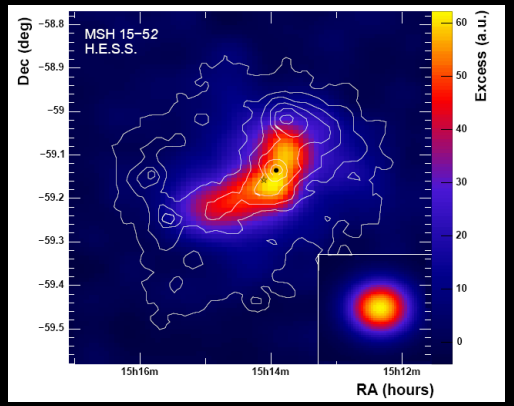
RXJ0852.0-4622
Aharonian et al., *ApJ*, **661**, 236 (2007)



RCW 86
Aharonian et al., *ApJ*, **692**, 1500 (2009)



G106.3+2.7
Acciari et al., *ApJ.*, **703**, L6 (2009)



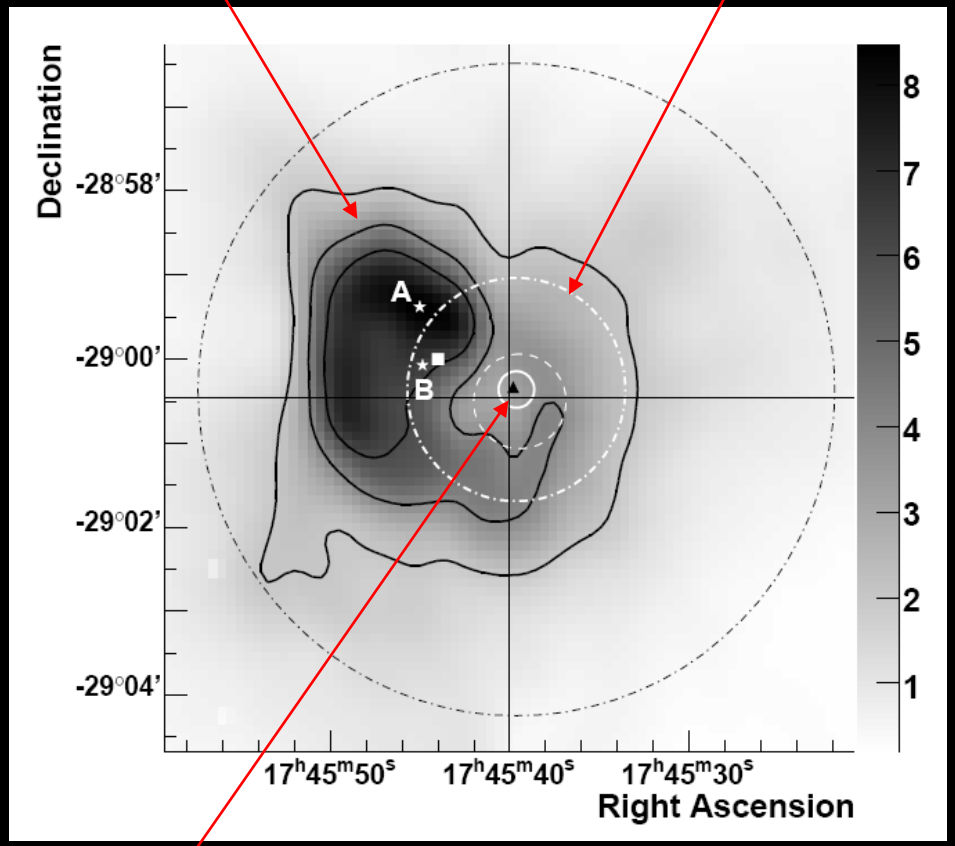
MSH 15-52
Aharonian et al., *A&A*, **435**, L17 (2005)

Angular resolution is typically a few arcmin

Astrometry – the Galactic Centre

Radio contours of Sgr A East (VLA)

Previous H.E.S.S. best-fit centroid



New H.E.S.S. best-fit centroid

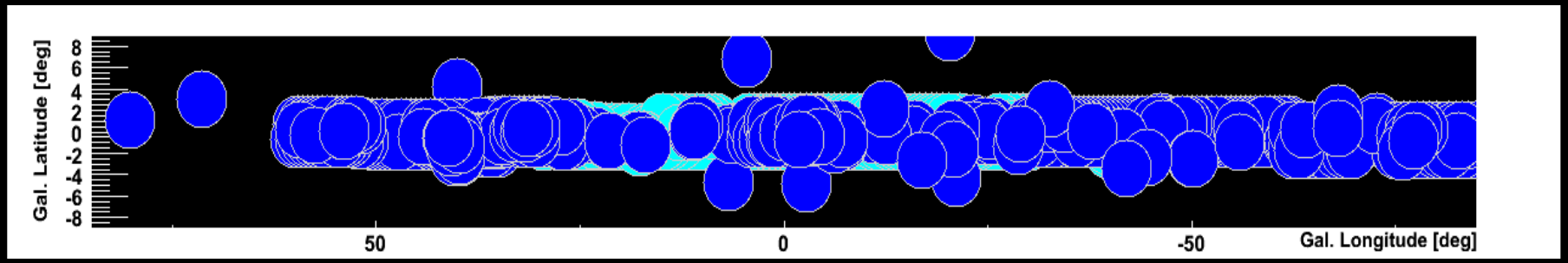
First H.E.S.S. result was compatible with Sgr A East, Sgr A* and PWN candidate G359.95-0.04. Using paraxial optical cameras on telescopes reduced pointing errors from 20 arcsec to 6 arcsec per axis. Sgr A East looks to be ruled out as source of emission.

Aharonian et al., *MNRAS*, Dec 2009 (astro-ph 0911.191v2)

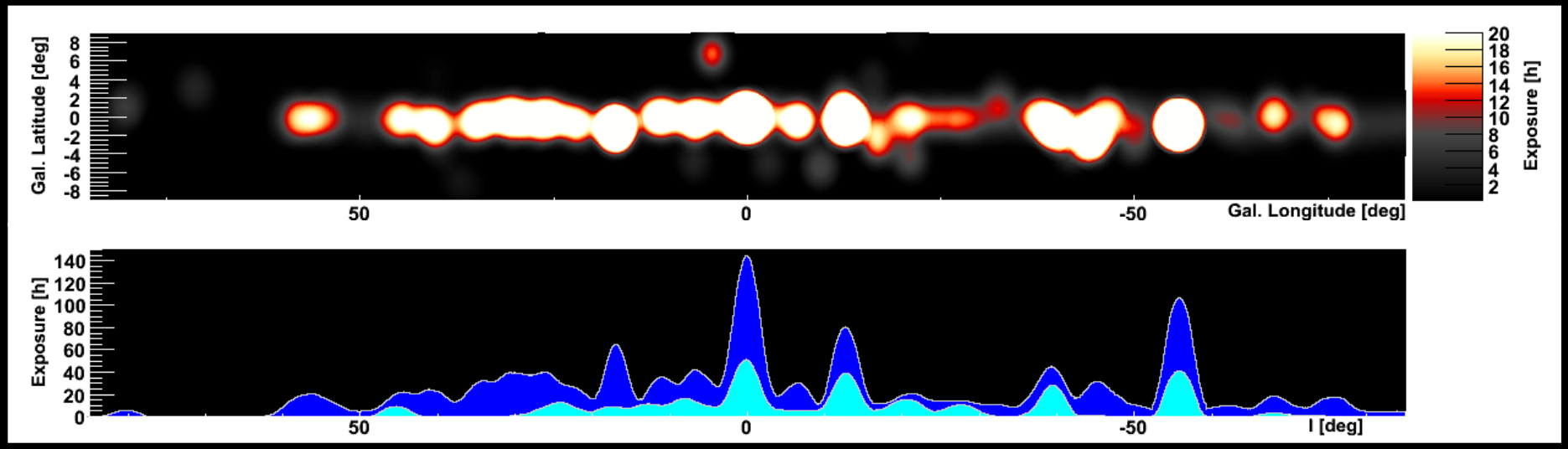
Surveys - The H.E.S.S. Galactic Plane Survey

The Extended H.E.S.S. GPS

2005 - 2008

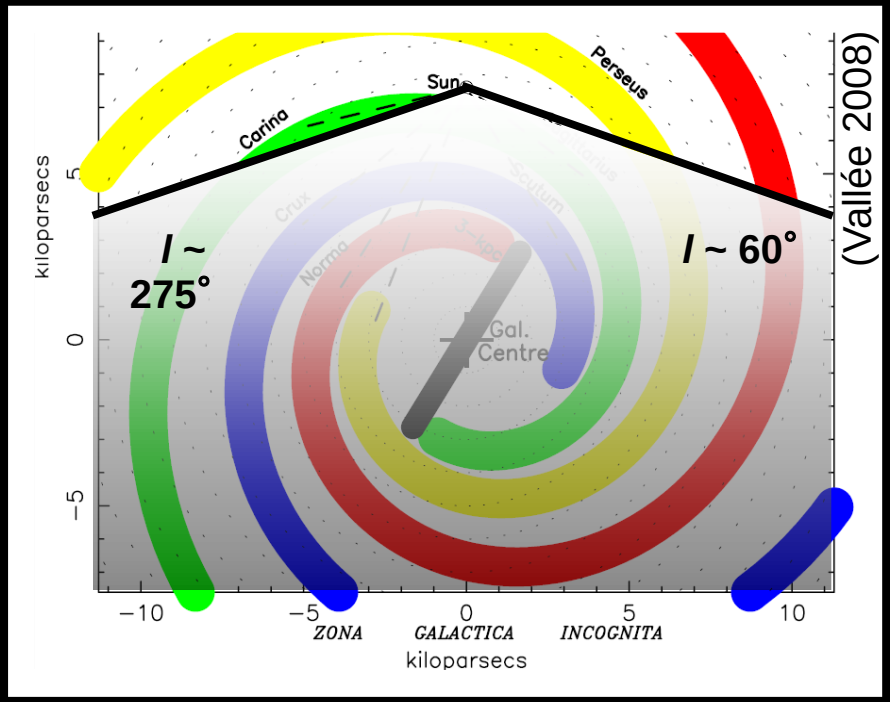


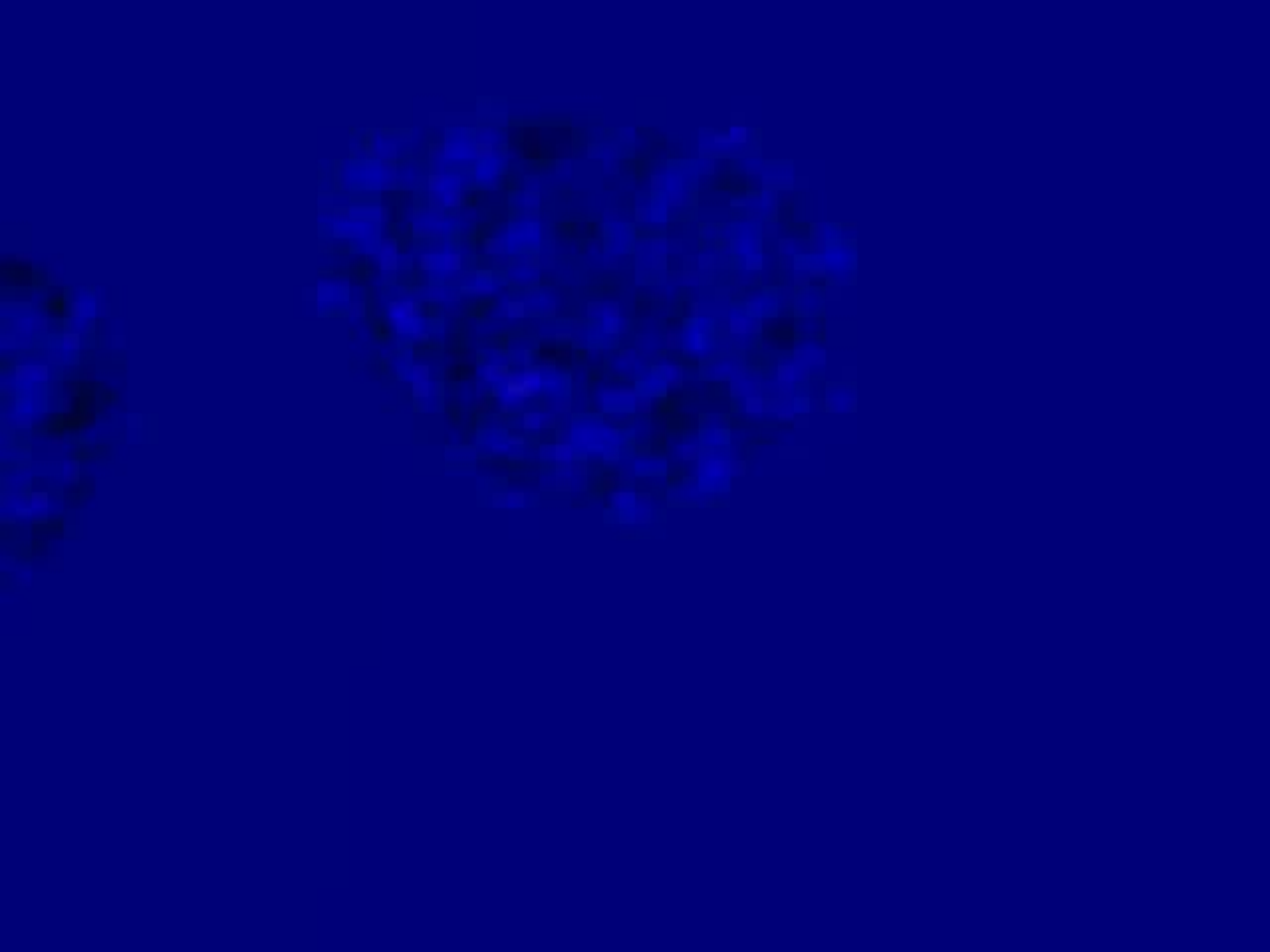
Acceptance-corrected Exposure



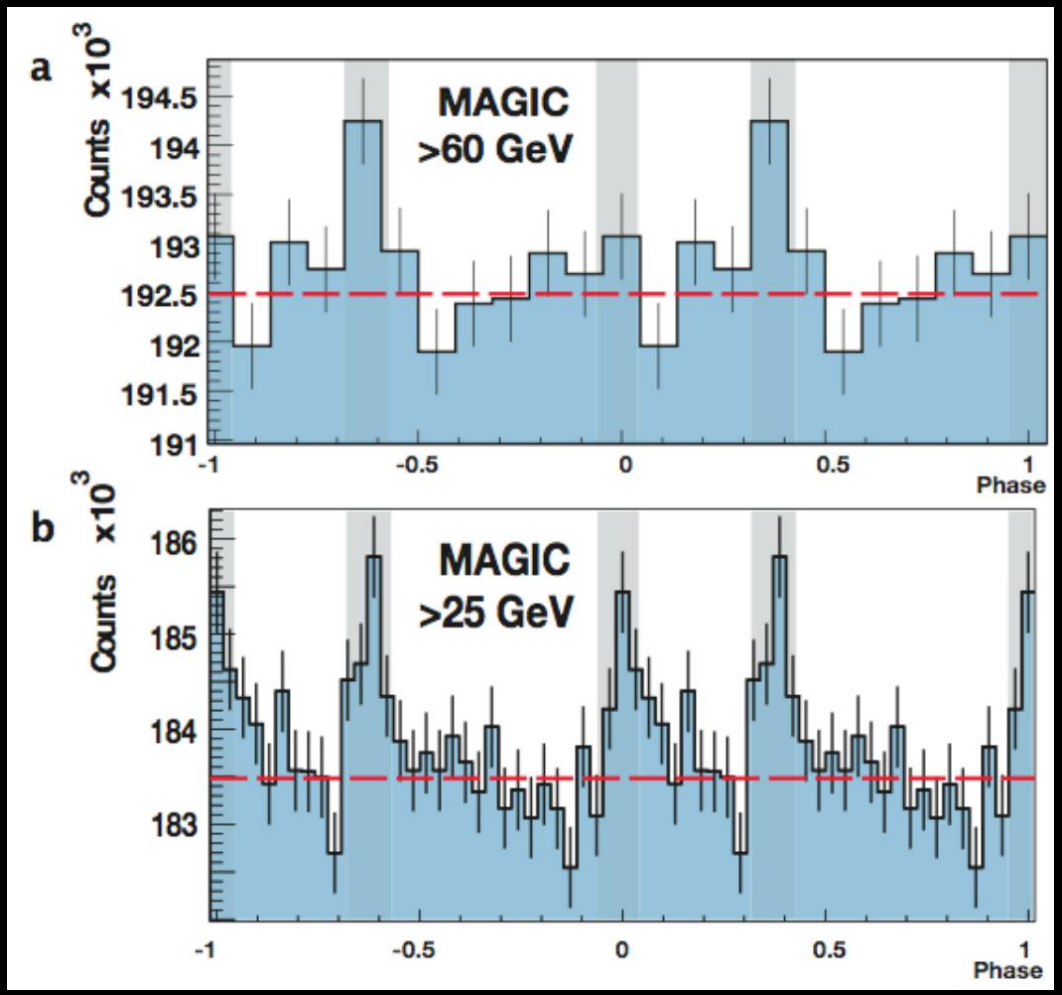
Extended H.E.S.S. GPS

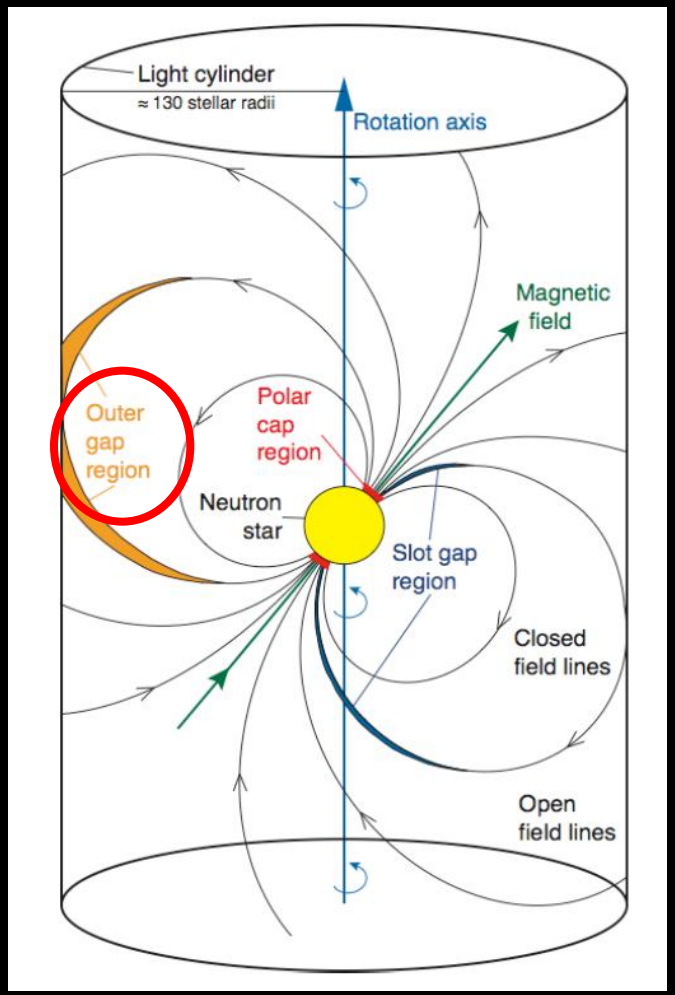
- **-85° < *l* < 60°**
- -3° < *b* < 3°
- Scan mode: **400** h
- Detected **50+ Galactic sources** of VHE gamma-rays
- ICRC 2007, DPG 2008, Gamma08





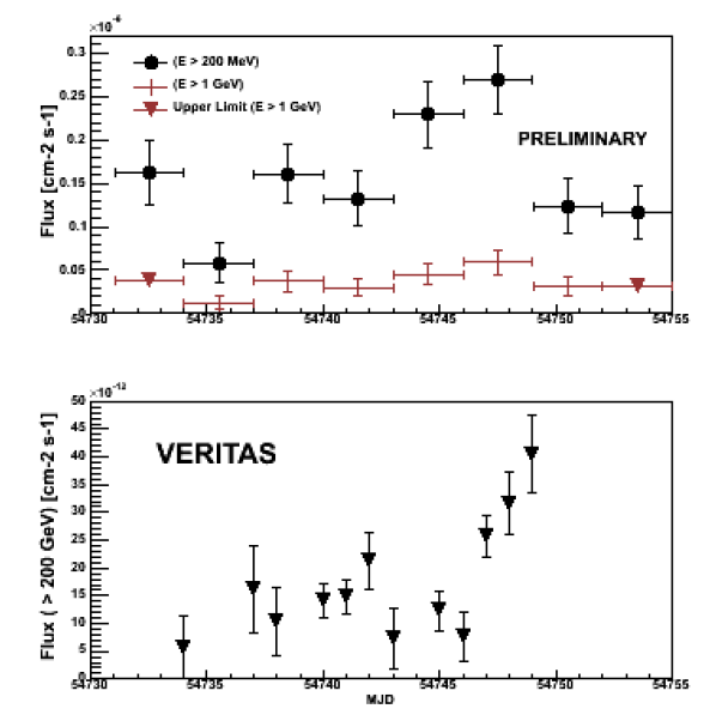
Timing – Crab Pulsar





Aliu et al., *Science*, **322**, 1221 (2008)

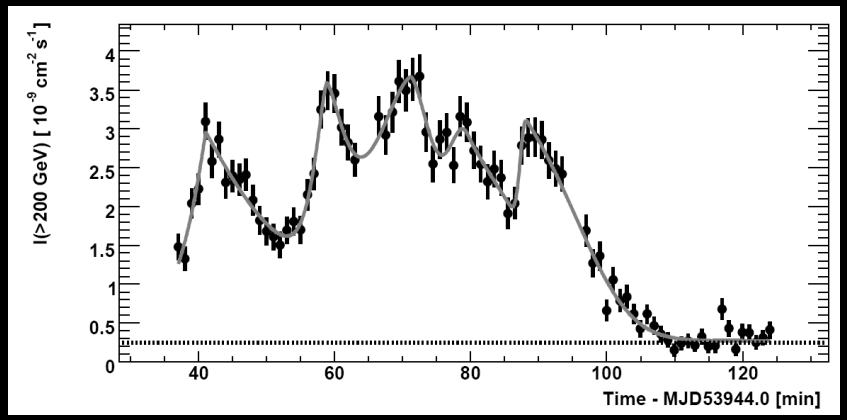
Photometry - AGN



3C66A

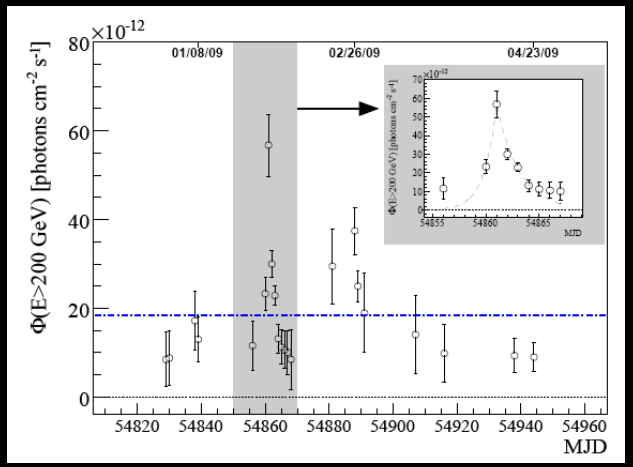
Fermi/VERITAS Collaborations, Proc. 31st ICRC, Lodz (2009)

Variations on timescales of ~2 min observed



PKS2155-304

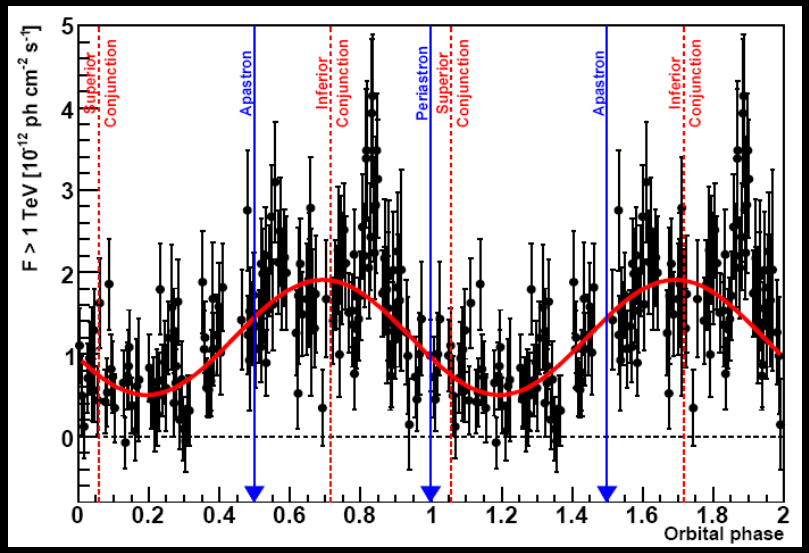
Aharonian et al., *ApJ.*,**664**, L71 (2007)

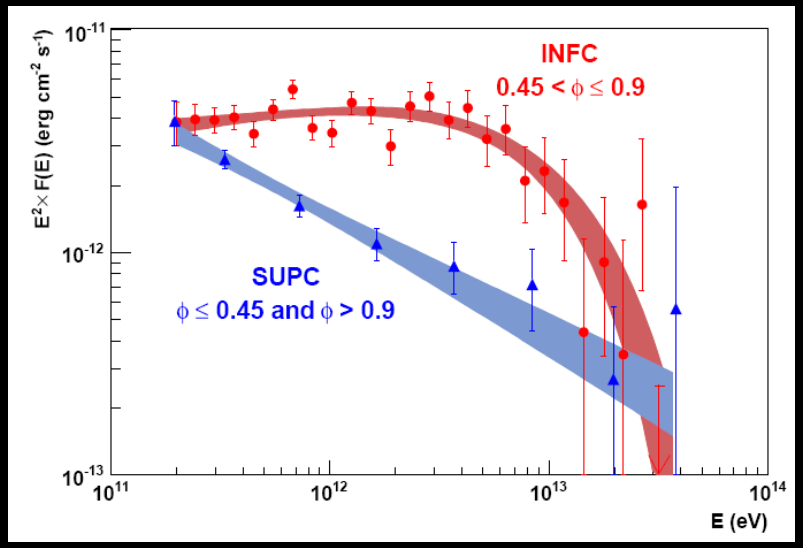


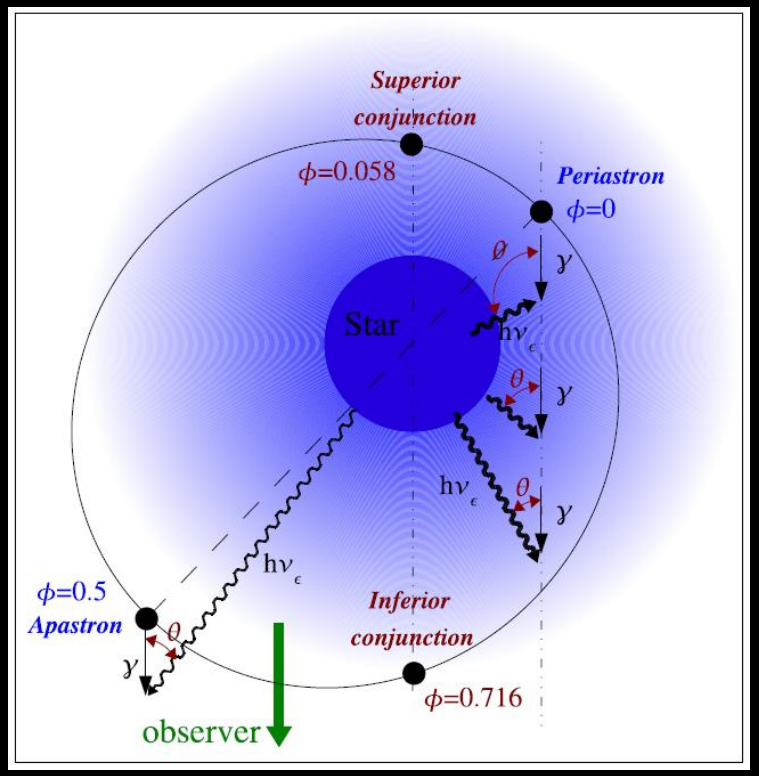
IES 1218+304

Acciari et al., *ApJ.*, **709**, L163 (2010)

Spectroscopy I – LS5039







Energy resolution typically 15-20%

Aharonian et al., *A&A*, **460**, 743 (2006)

What Next?

- H.E.S.S. I to undergo refurbishment this year
- H.E.S.S. II should start observations next year
- Many synergies with Fermi
- It would be nice to detect…
  - A GRB
  - A ‘real’ microquasar
  - A globular cluster (Fermi has ‘seen’ 47 Tuc)
  - A Seyfert galaxy