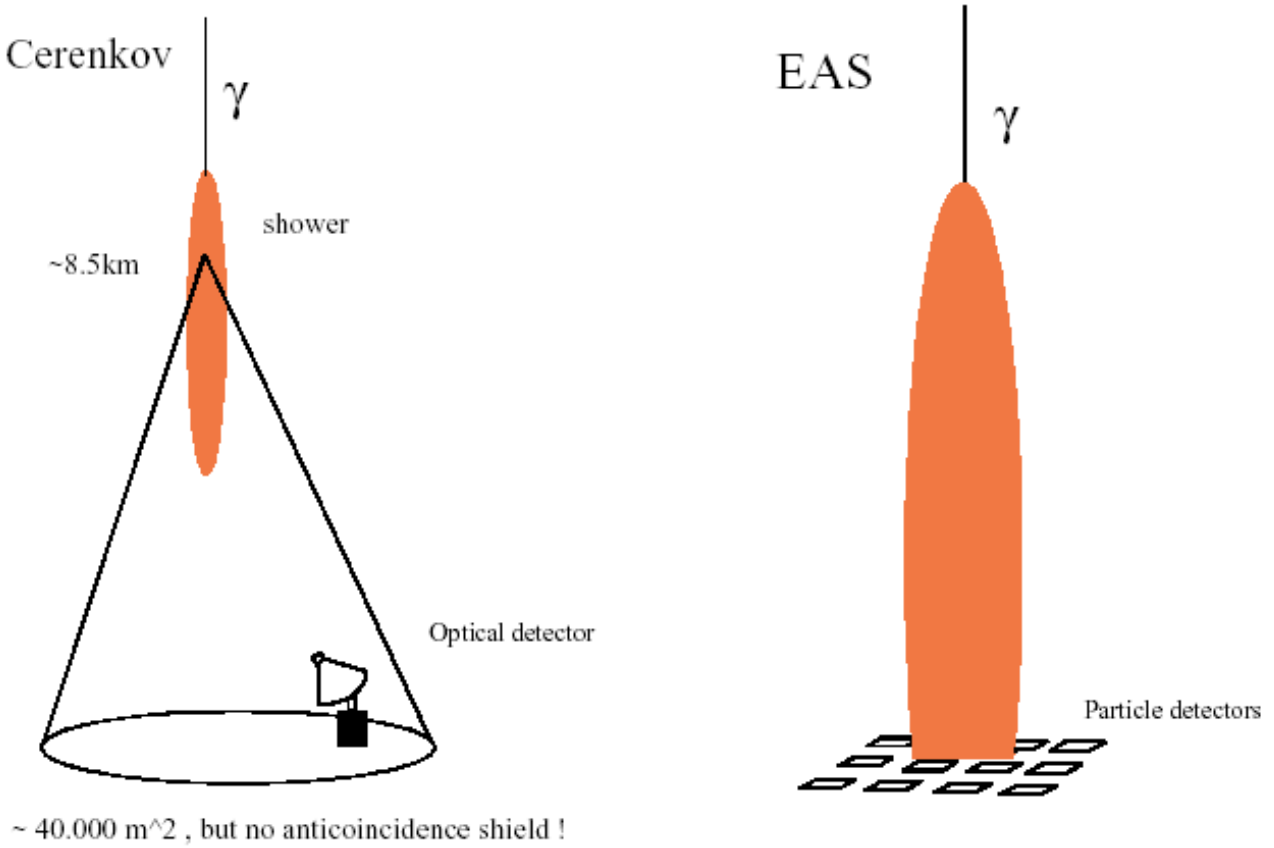
Astrofisica Nucleare e Subnucleare

TeV Astrophysics

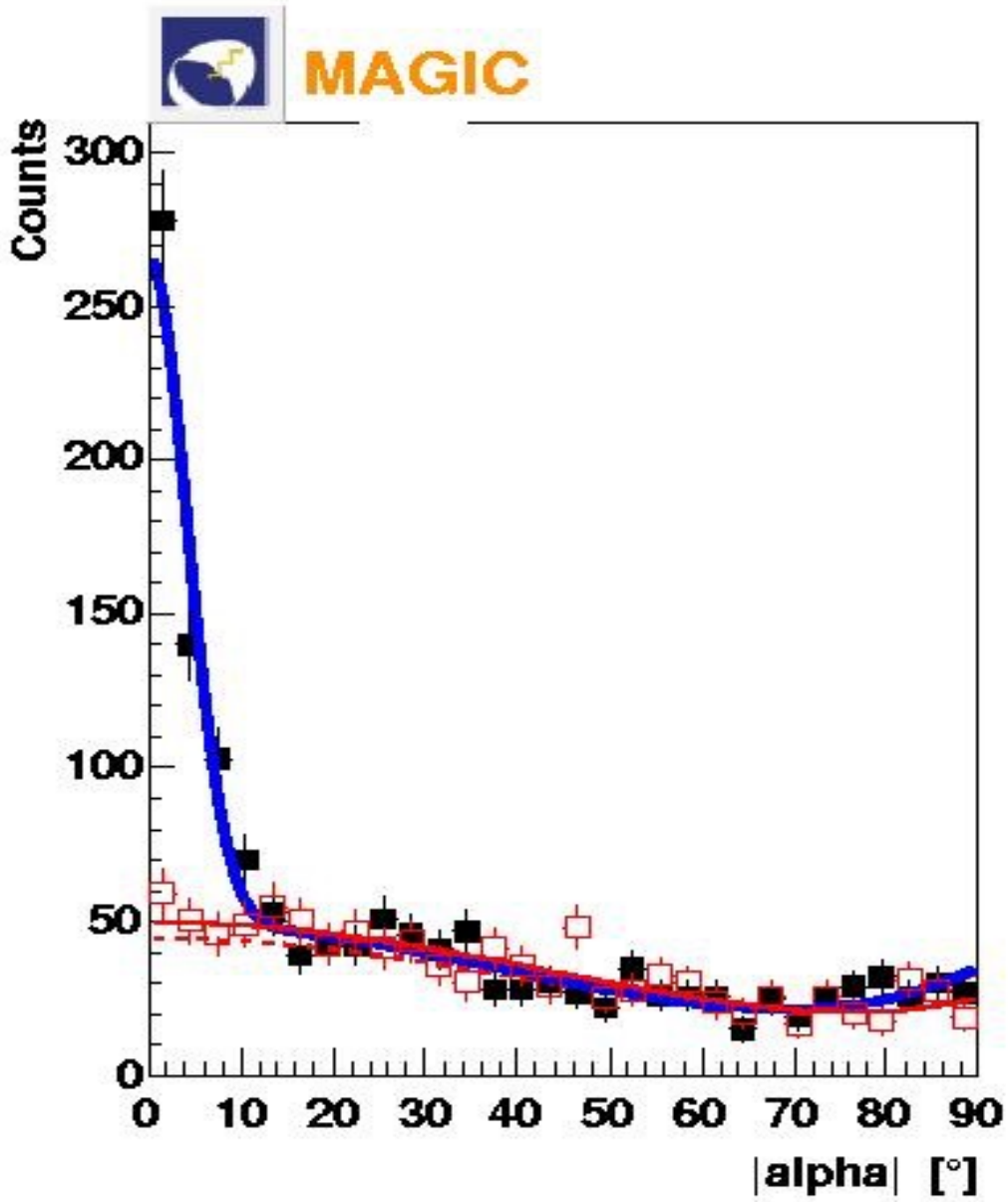
TeV detectors

Cerenkov and Extensive air shower (EAS) gamma ray telescope concepts



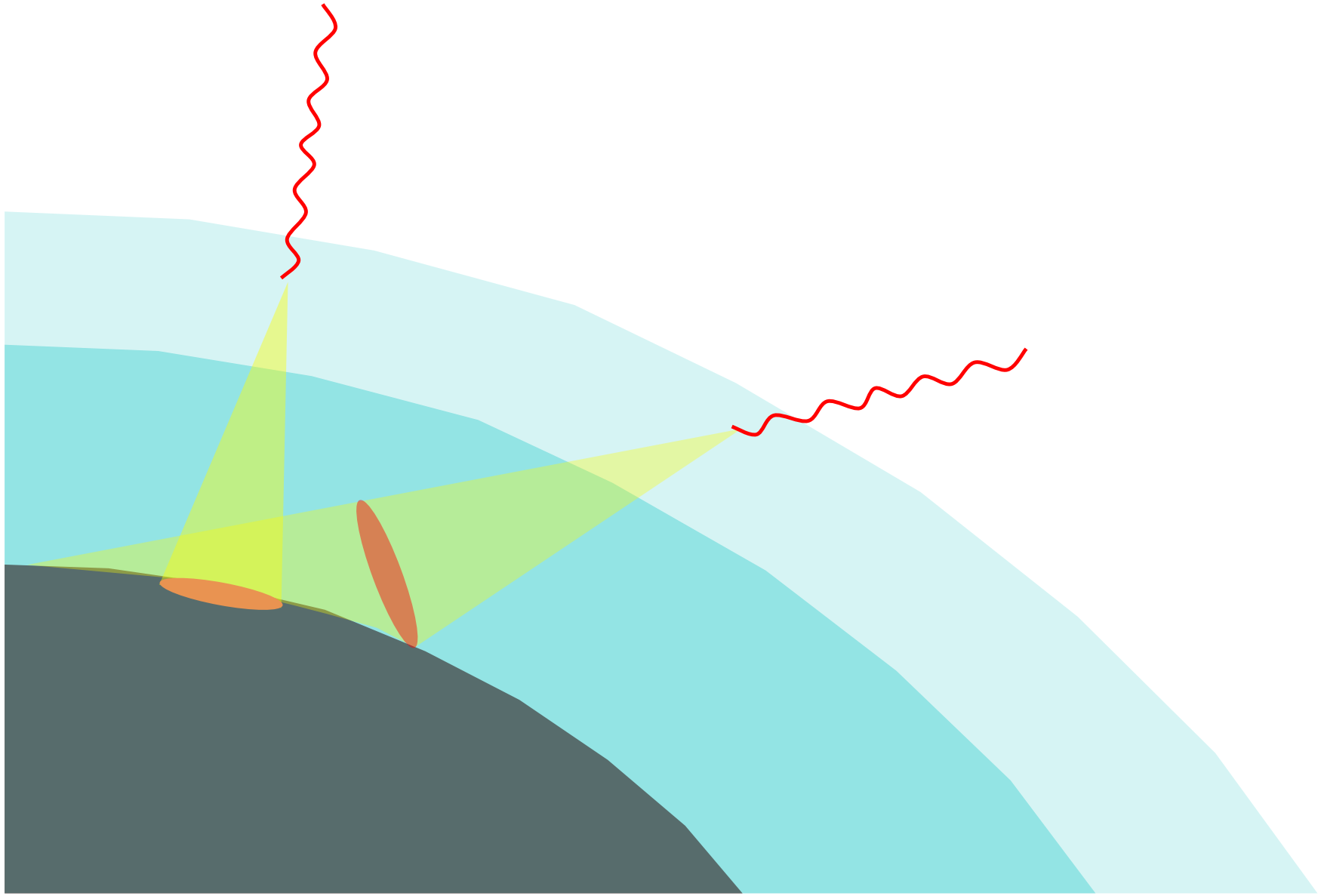
~ 40.000 m^2 , but no anticoincidence shield !

γ /hadron separation



Crab Nebula

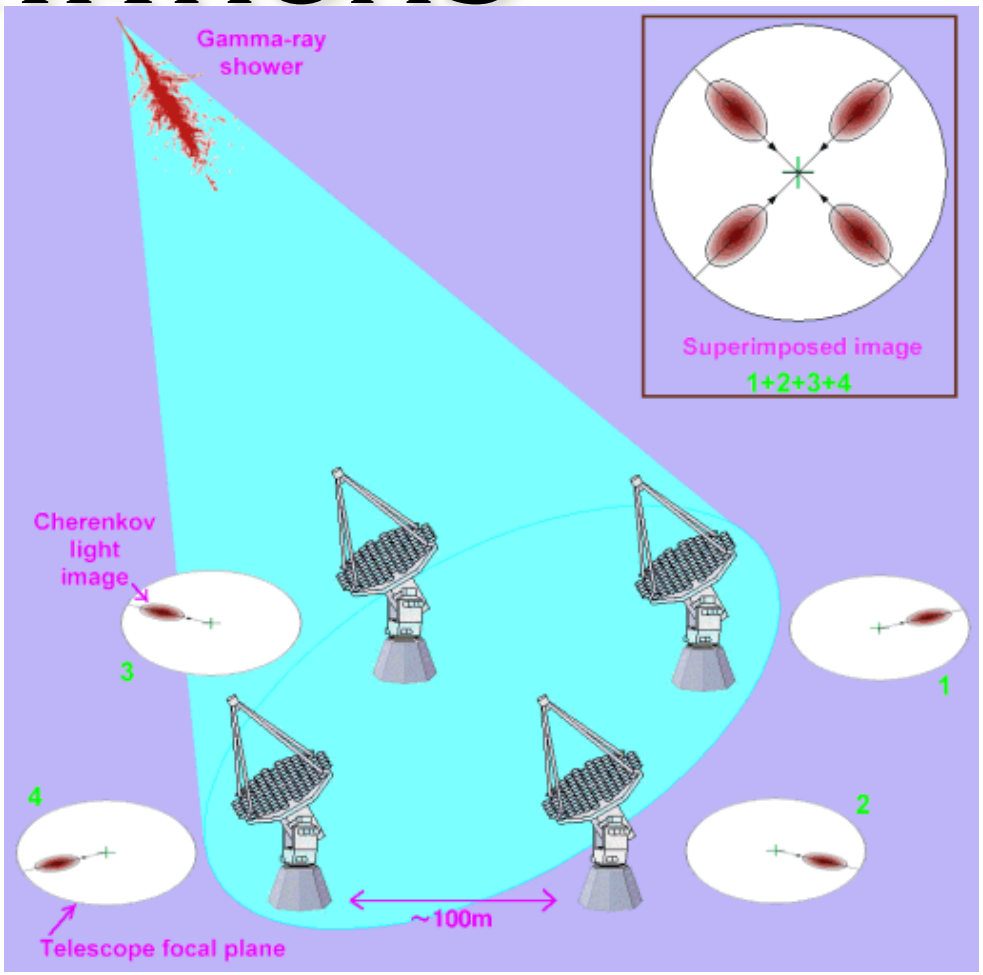
Dependence of collection area and energy threshold



Stereo Observations

Get ‘3d-Image’ from Shower:
==> improved:
+ angular resolution
+ energy resolution
+ G/H separation
(higher significance in shorter time)

But:
- need several telescopes
==> more expensive
- (trigger) threshold
~ size of single tel.

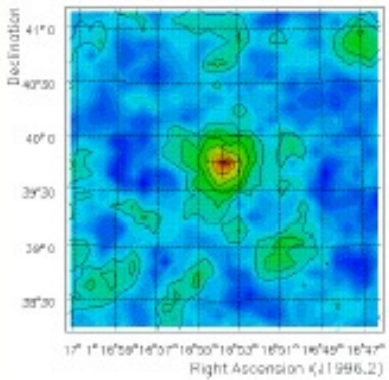


more difficult at low energies (<<100GeV)
(large intrinsic fluctuations in single shower)

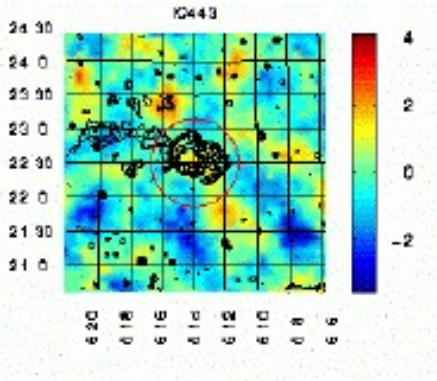
VHE Gamma-ray Detectors

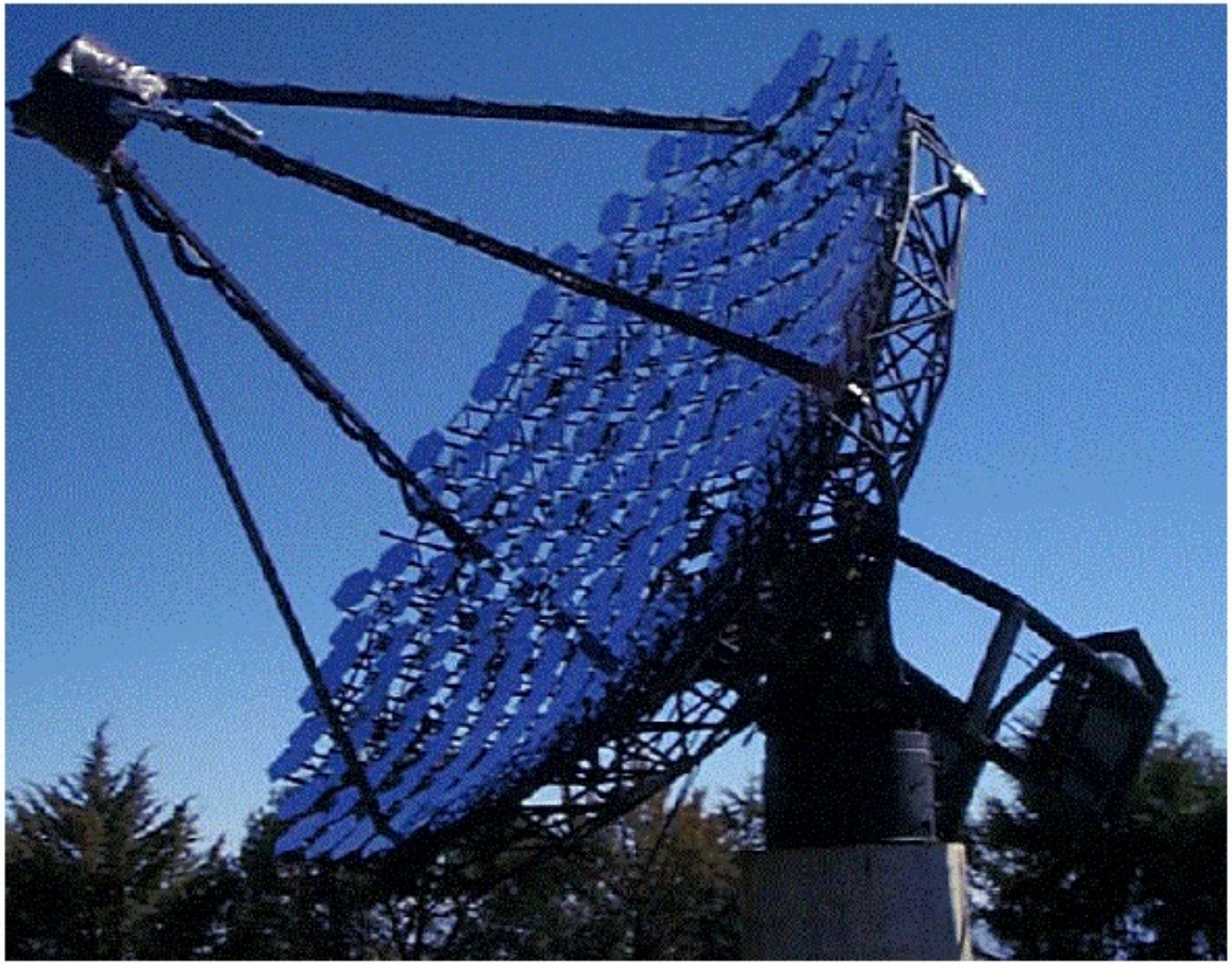
Whipple

10 m telescopes
E = >350 GeV
Location: Mt.Hopkins
in operation

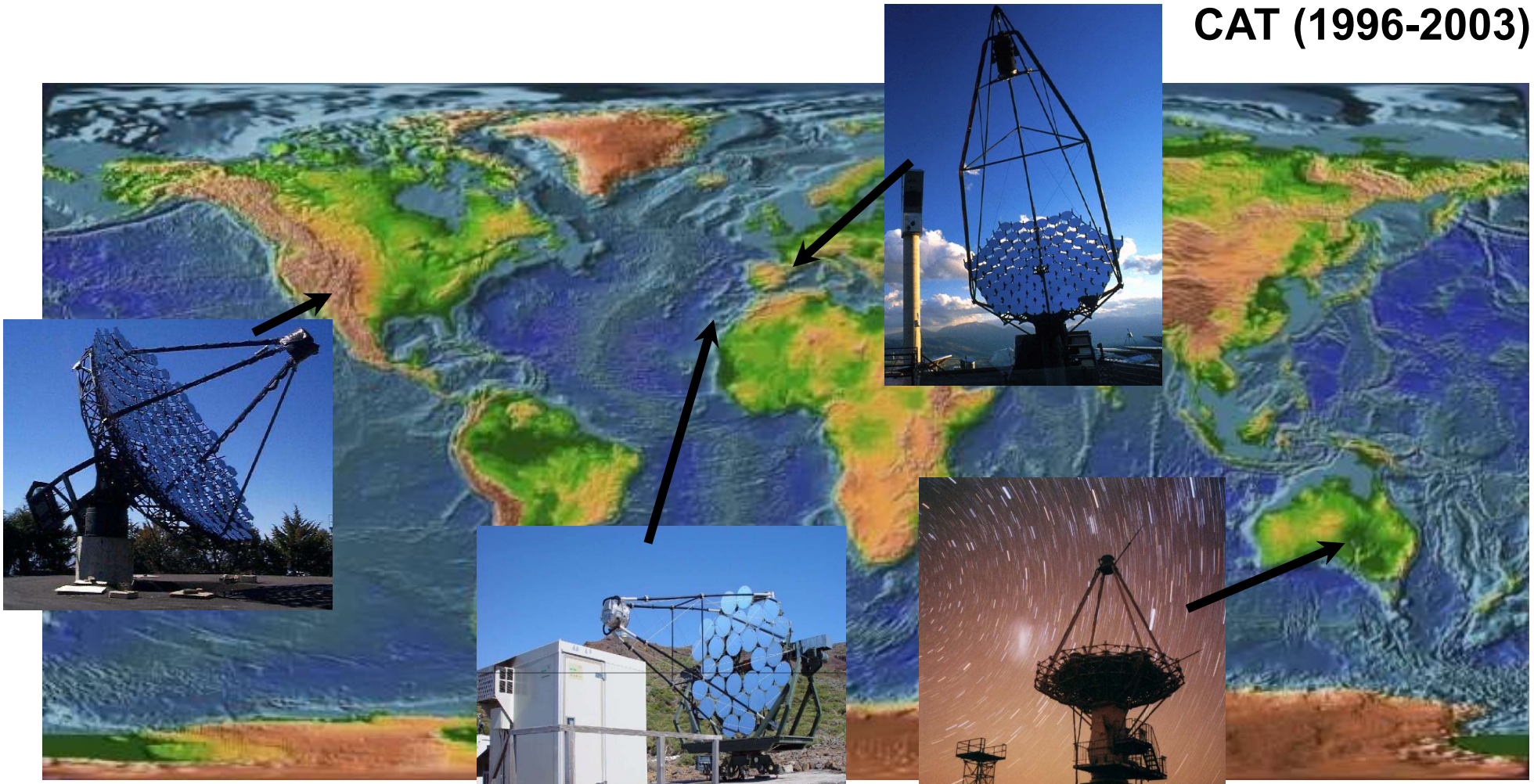


MHK501





First-generation IACTs



CAT (1996-2003)

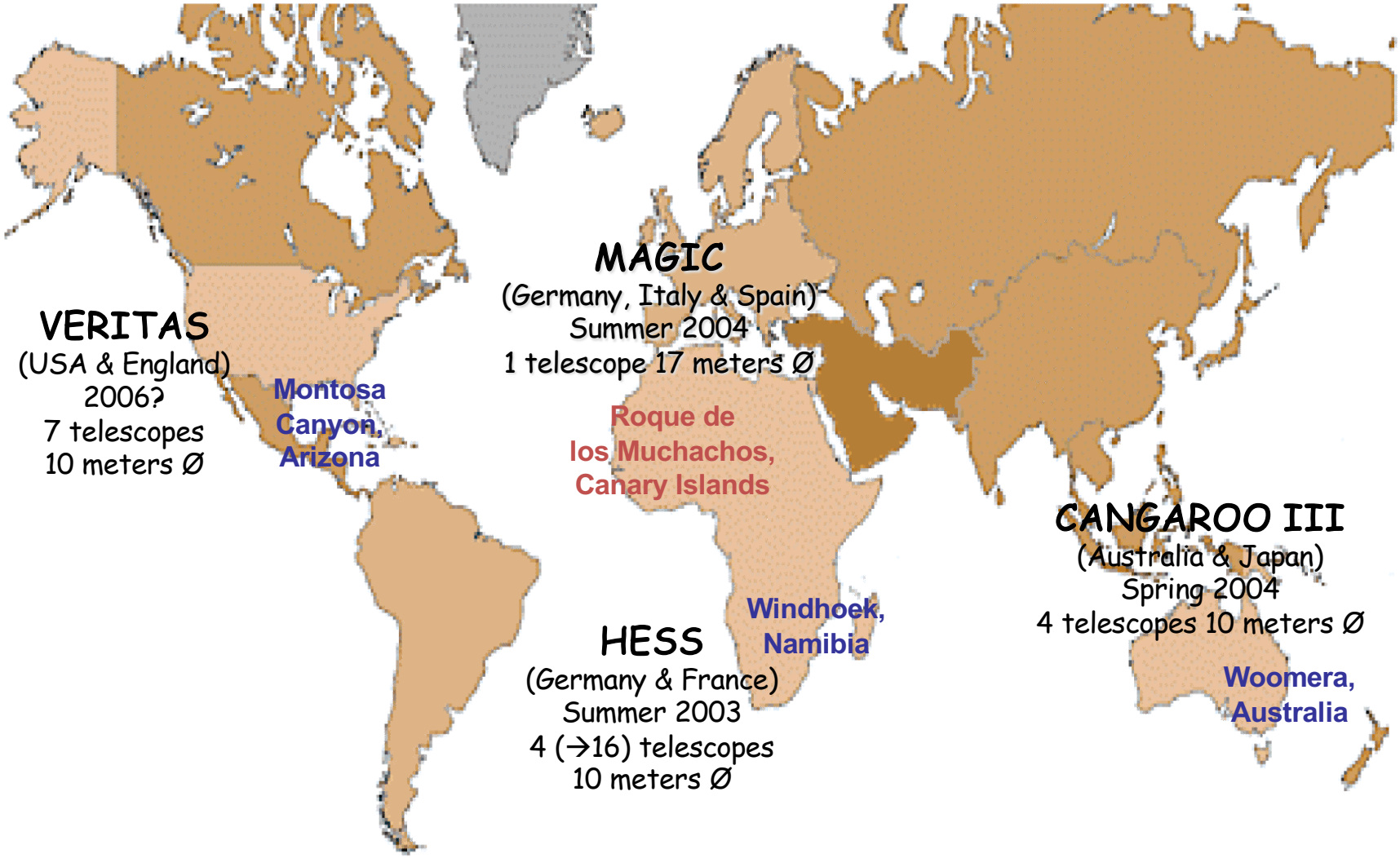
Whipple (1969!-2003)

Crab nebula (Weeke+ 1989)
Mk 421 (Punch+ 1992)

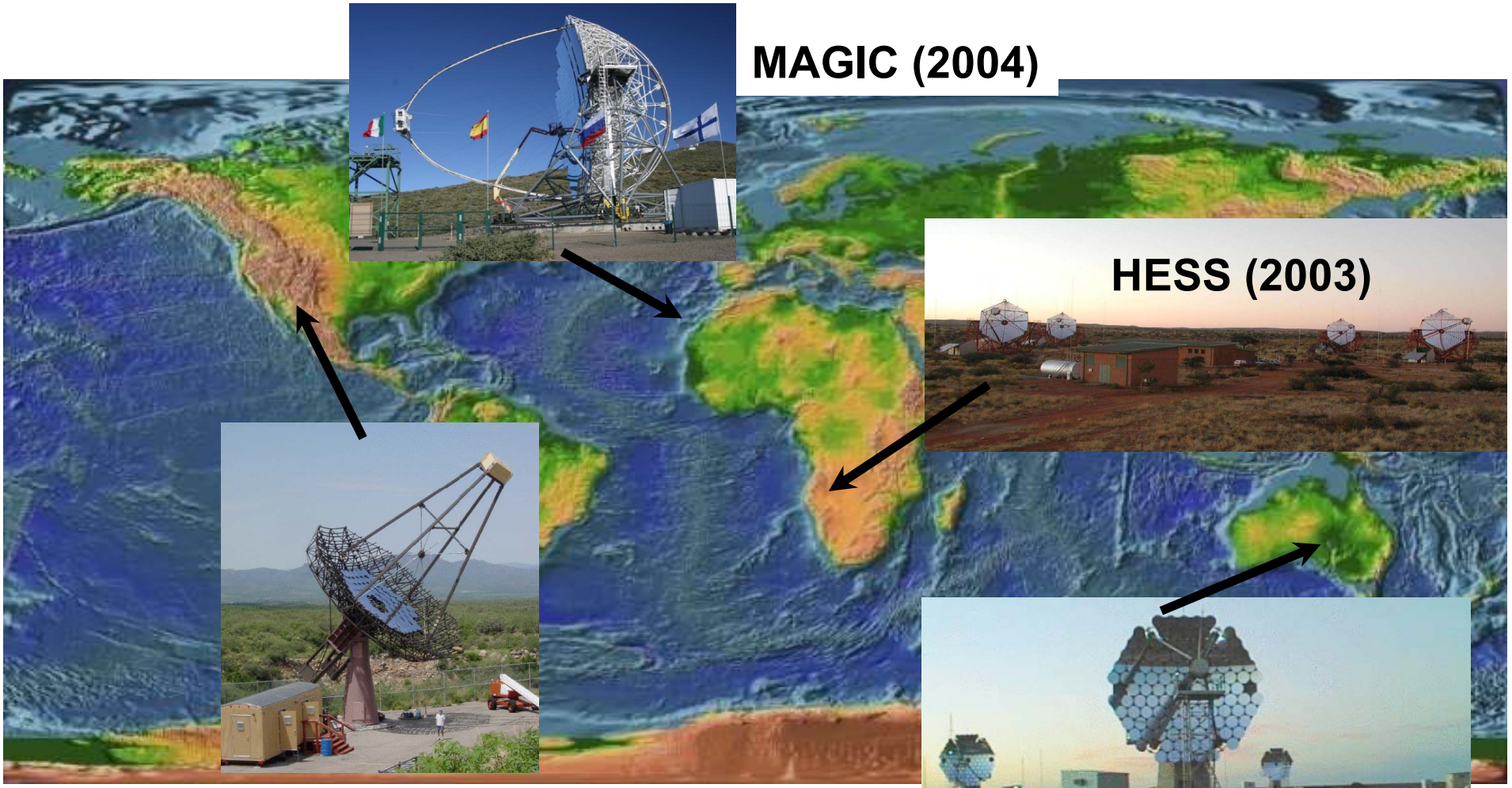
HEGRA (1993-2002)

CANGAROO (1992-2001)

Second Generation IACTs (~ 2004)



Second-generation IACTs



Exercise #6

- Find the information about the 3 major currently operating IACT telescopes
- Visit the web site of CTA

Exercise #6

- Find the information about the 3 major currently operating IACT telescopes
- Visit the web site of CTAO

H.E.S.S.

Home | About H.E.S.S. | Collaboration | Publications | Contact | Internal

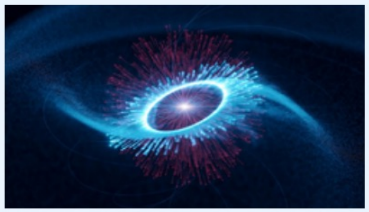
Welcome

Welcome to the webpages of H.E.S.S., one of the leading observatories studying *very high energy* (VHE) gamma-ray astrophysics. To learn more about H.E.S.S. and the high energy universe, or to view pictures from the telescopes and the site in Namibia visit the About H.E.S.S. section.

Follow H.E.S.S. on Twitter, on Facebook and on Instagramm for news regarding the H.E.S.S. instrument and its science.

News

Source of the Month



November 2023 - The Vela Pulsar - the most Highly Energetic Clock

More Info | All Sources

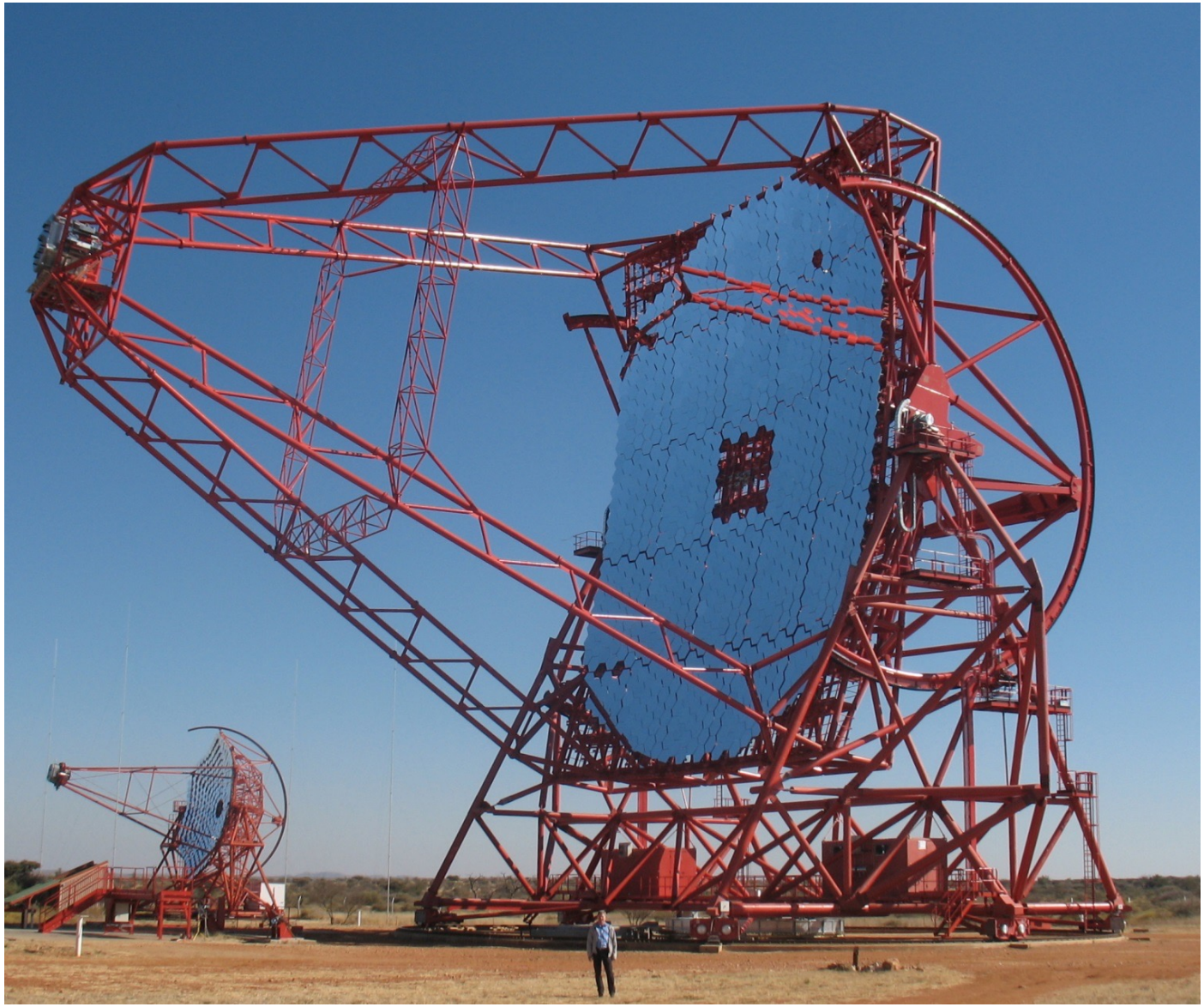
External Proposals for H.E.S.S. Observations

Requests for Observation of Targets of Opportunity with H.E.S.S.

https://www.mpi-hd.mpg.de/HESS/

HESS

HESS-II



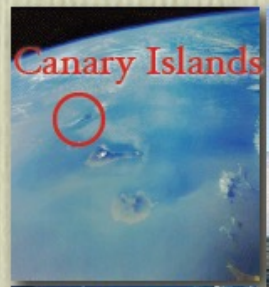
MAGIC

https://magic.mpp.mpg.de/

The MAGIC Telescope

Major Atmospheric Gamma Imaging Cherenkov telescope

Located at the Roque de los Muchachos on La Palma, Canary Islands (Spain) at ~2200 m *asl*



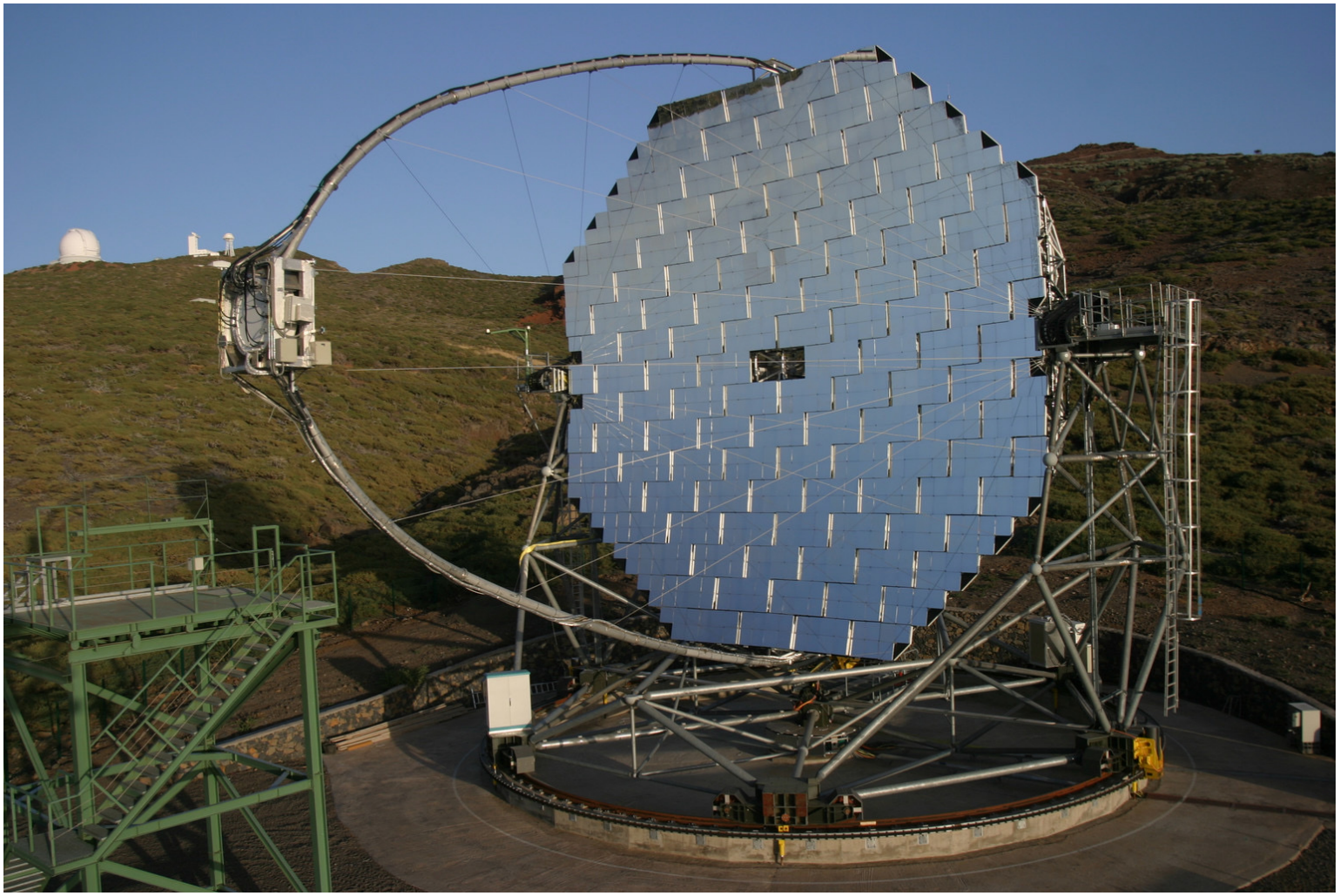
Largest imaging Cherenkov telescope for γ-ray astronomy

Designed for:

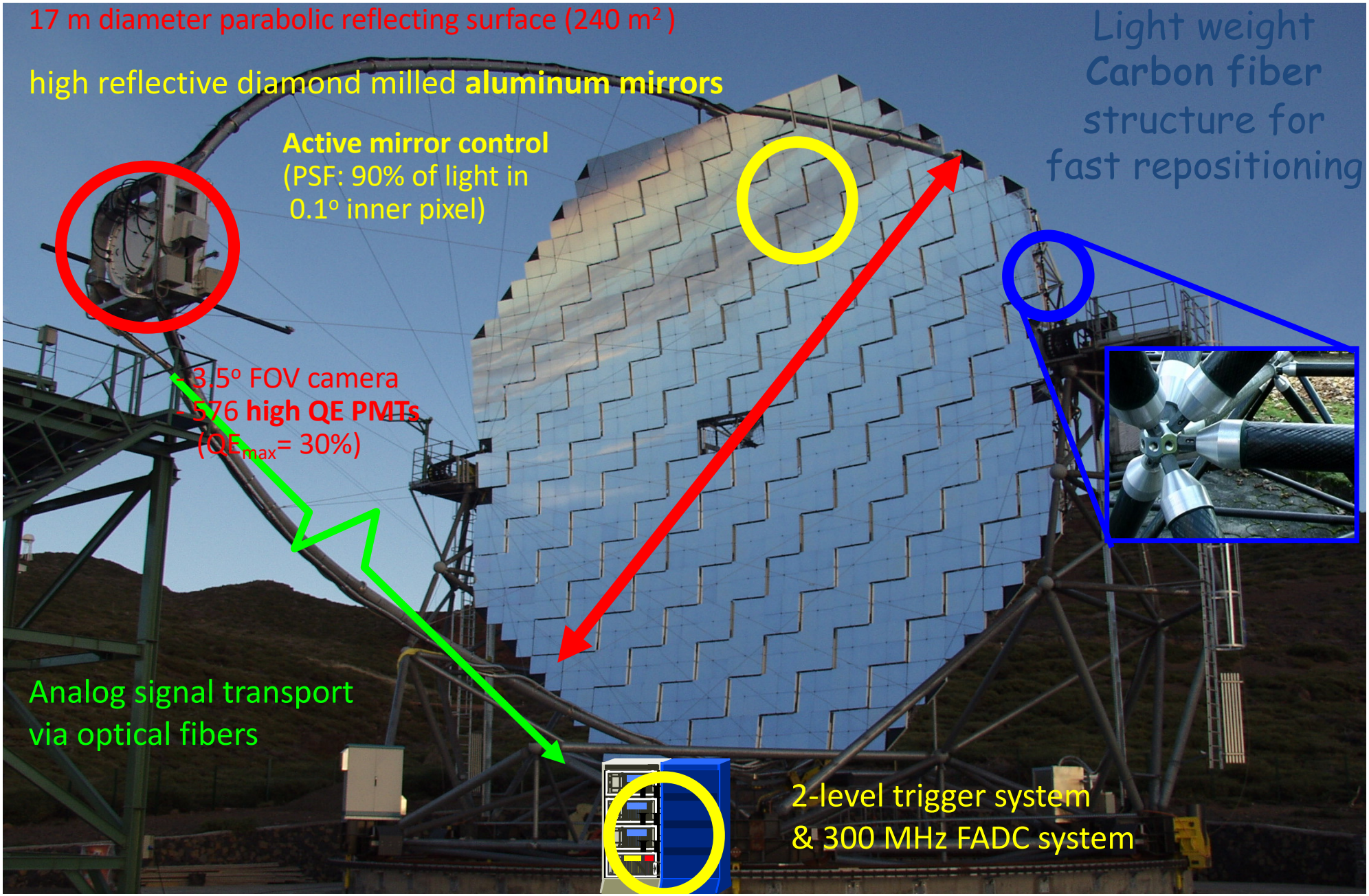
- Low energy threshold $E_{th} \approx 50$ GeV
- Fast repositioning in < 30 s

Construction 2001-2003
Inauguration 10/10/2003
Commissioning 2004
Cycle I 2005-2006

MAGIC



Key technological elements for MAGIC



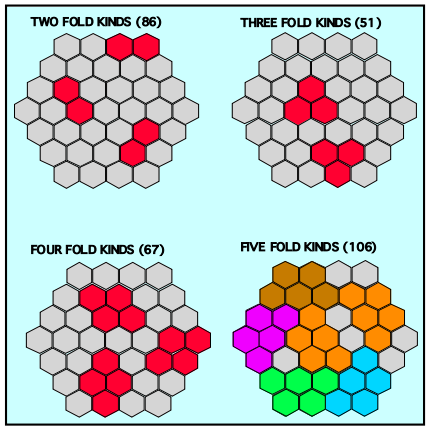
The trigger architecture

The trigger is split into two stages: level 1 (L1) and level 2 (L2). The L1 is a fast coincidence device (2-5 ns) with simple patterns (n-next-neighbor logic) while L2 is slower (50-150 ns) but can do a more sophisticated patter recognition.

Discriminators L0

Choose the **number of photoelectrons** per pixel you want to use in the trigger

Level 1 L1

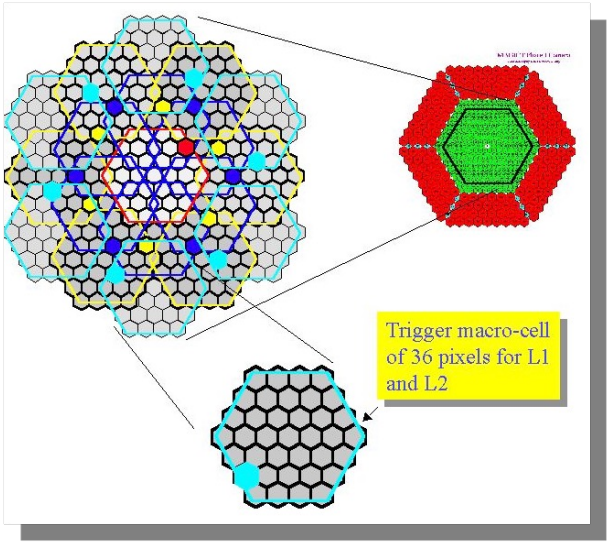


Make a **tight time coincidence** on simple pattern of compact images and **enable L2**

Level 2 L2

Make an **advanced pattern recognition** to use topological constraint:
- pixel counting in a given region of the detector
- mask hot spots like bright stars
- rough center of gravity of the image…etc…..

To FADC



MAGIC telescopes

MAGIC – II

+ The telescope(s)

Design

- Solar power-plant design
- 17-m diameter
- F/D=1
- ~500kg camera
- Signal digitization off-telescope
- 64 tons total moving weight
- Fast-movement (GRBs): 20 sec ptp

Performance

- Energy threshold ~50 GeV (~ 25 GeV with a special trigger)
- FOV 3.5deg
- Energy Resolution ~16% (E>300 GeV)
- Angular Resolution ~0.07deg (E>300 GeV)
- Sensitivity (5 σ in 50 hours) ~0.8% Crab Nebula flux (> 250 GeV)

Colin, ICRC 2009

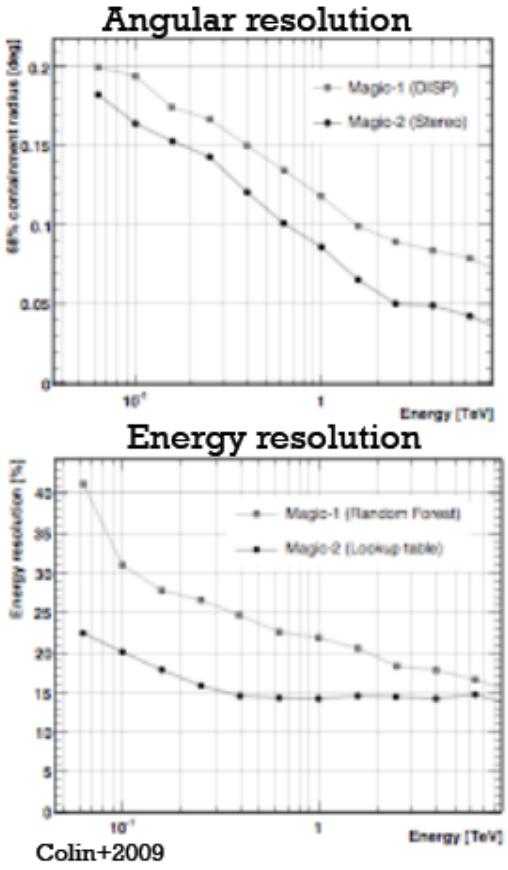
Several "firsts"

- Worldwide largest mirror dish.
- Lightweight CFRP tubes for structure
- Diamond milled light weight all-aluminum sandwich mirrors
- Active mirror control
- Low gain hemispherical PMTs with diffuse lacquer coating
- Transmission over 160 m by optical
- 2 GHz FADCs

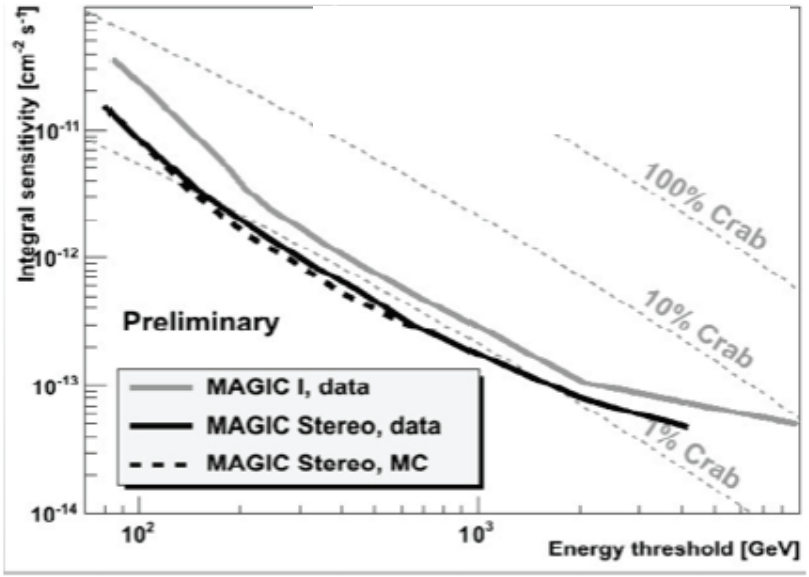
MD, ICAPTT 2008

MAGIC – II

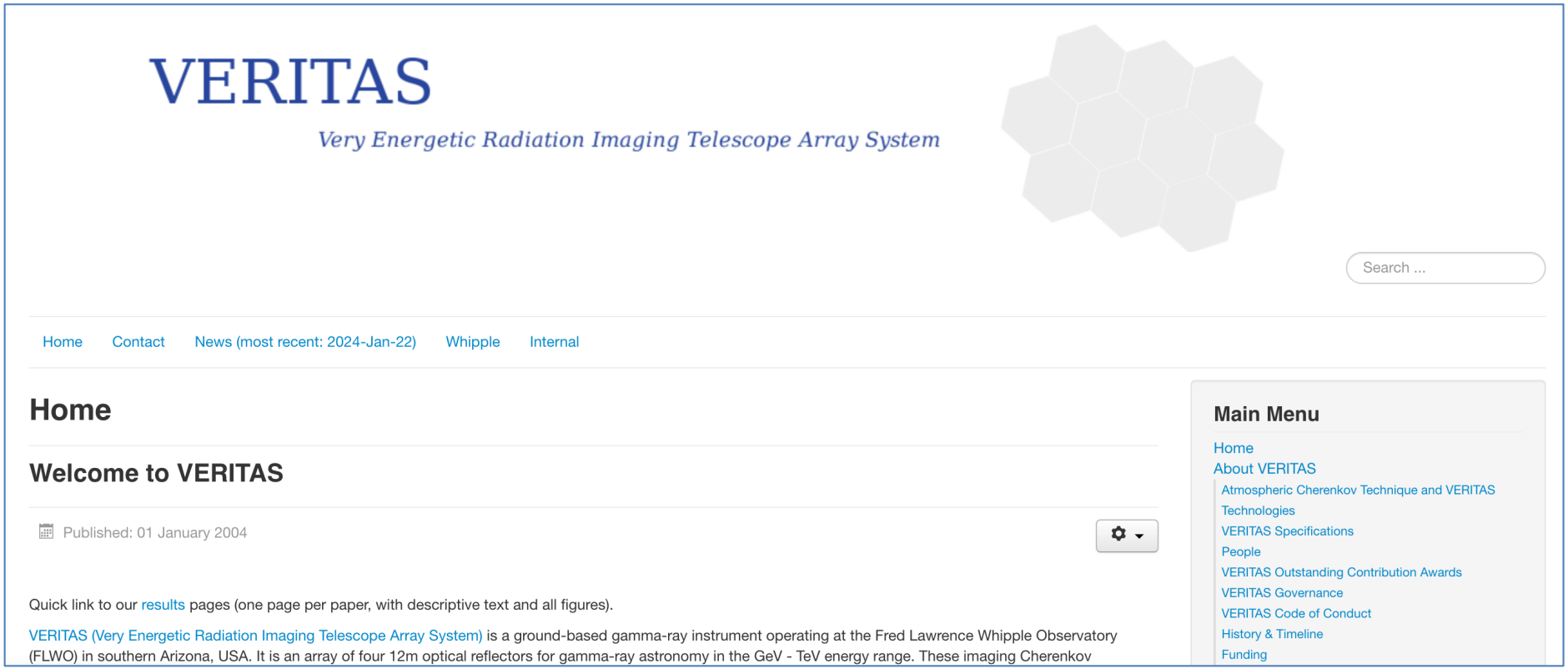
+ Improvements



- Extended sources and morphology now possible
- **Sensitivity improved of 100%** over most of the energy range
- Better performance specially at low energy (<100 GeV)



VERITAS

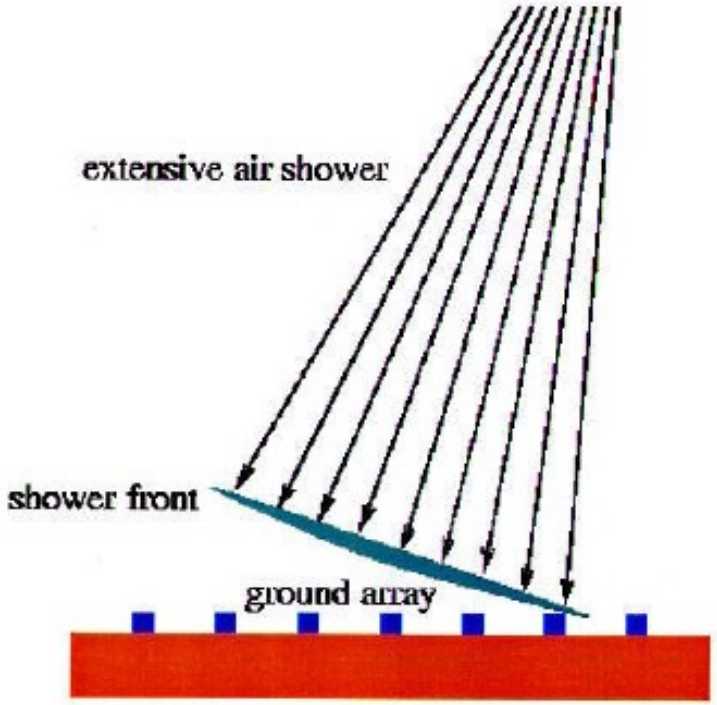


https://veritas.sao.arizona.edu/

VERITAS

TeV detectors

Air Shower Arrays



Reconstruction of the γ direction with the particles arrival times

Large field of view: ~ π sr

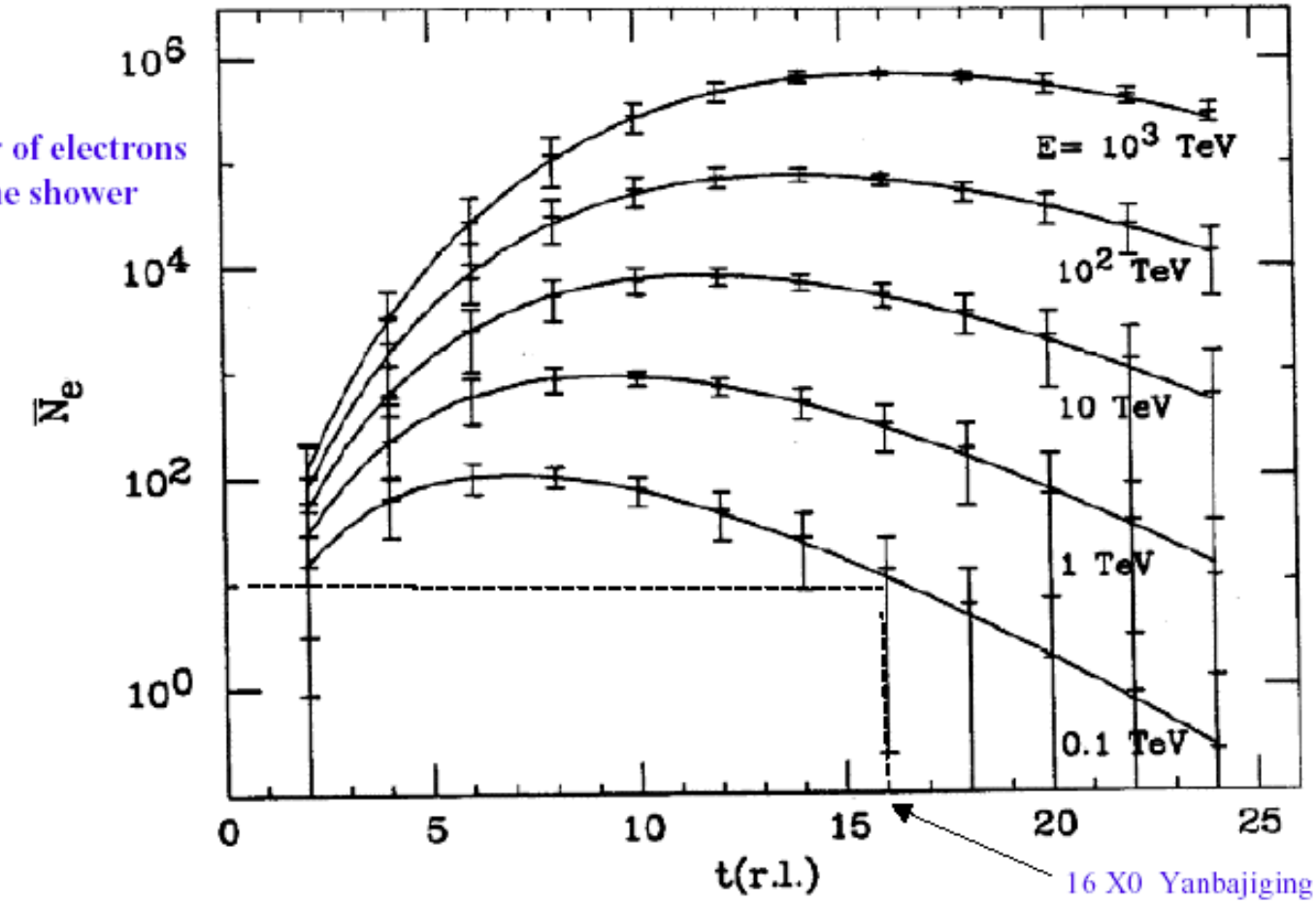
Duty cycle ~ 100%

Gamma-hadrons discrimination:

μ-poor showers

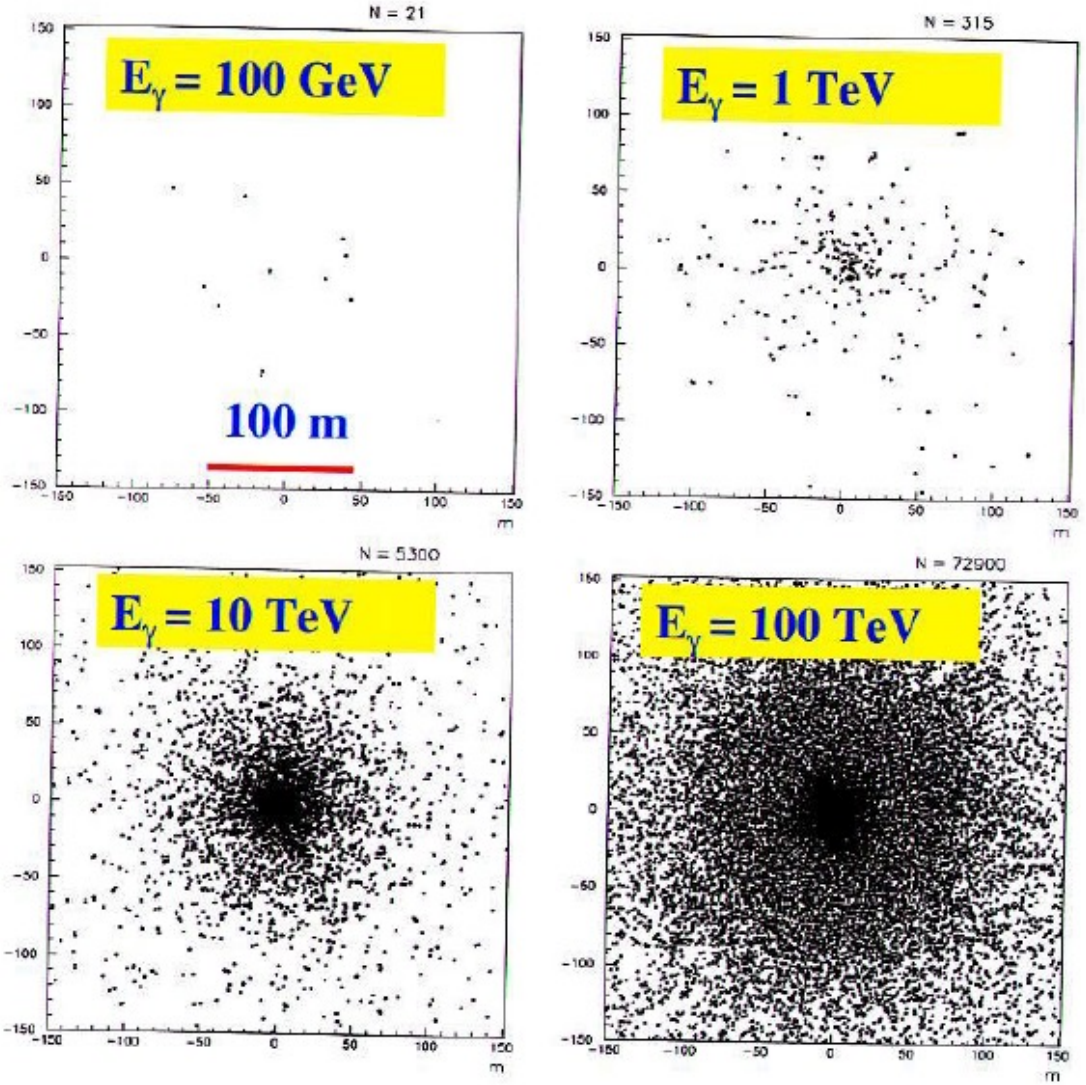
TeV detectors

Longitudinal development of the electron component of photon initiated shower
(with electron threshold energy of 5 MeV and fluctuations superimposed)

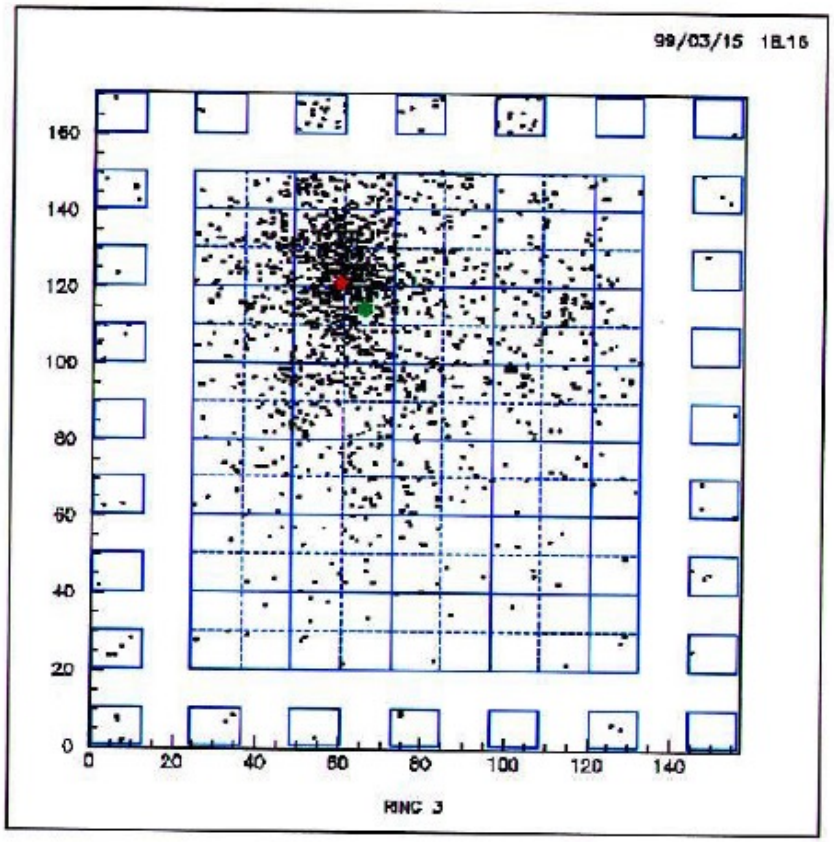


TeV detectors

EAS
at
4300 m



TeV detectors



Montecarlo simulation of a 10 TeV air shower

EAS technique

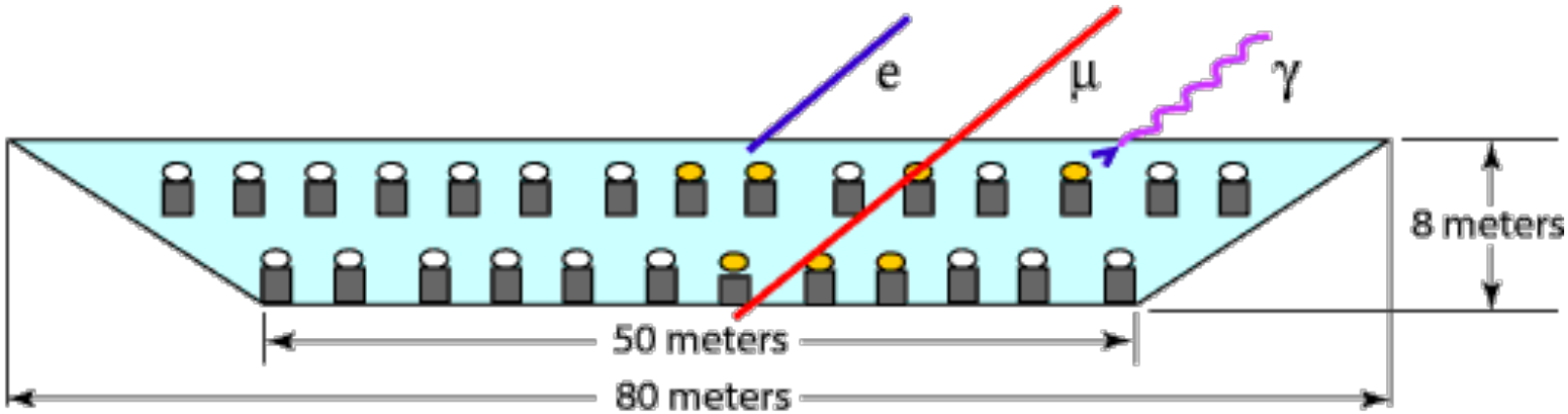
Charged particles produce Cherenkov photons in water

~1400 times more Cherenkov photons than in air per unit length track of charged particle

Cherenkov cone in water ~41° (in air: less than 1°)

Uniform sky view with an array of PMTs

Direction reconstruction through PMTs signal times



Wide Angle Telescopes

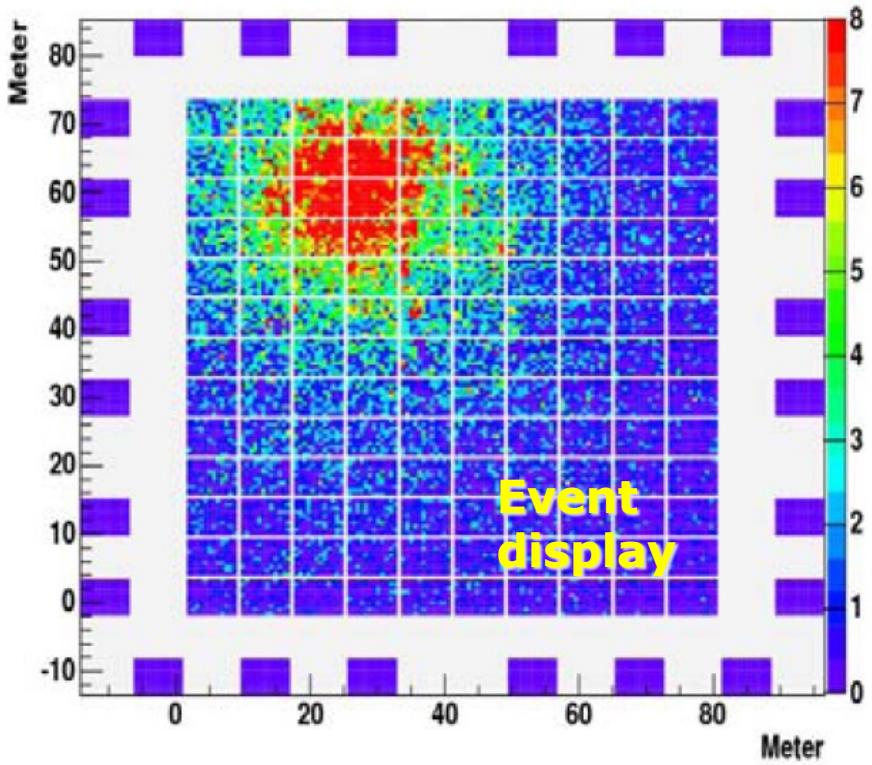
Tibet AS-γ– Air Shower Array
ARGO – Carpet array with RPC
MILAGRO – Water Cherenkov

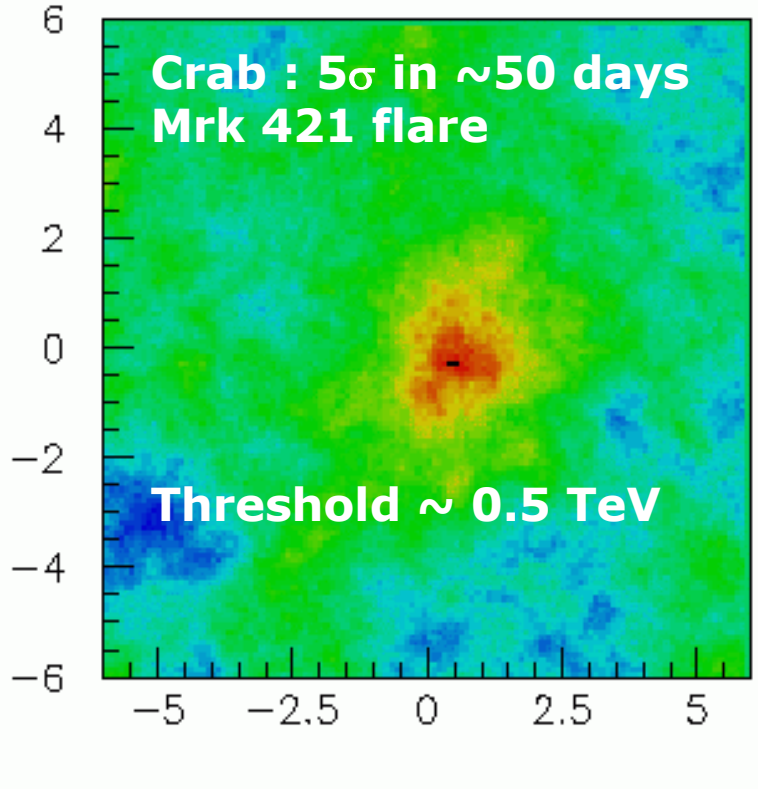
Advantage: Wide Angle 0.5π~1π
Non-bias observation

Cons: Moderate sensitivity
~5σ/yr$^{1/2}$ for Crab

ARGO-YBJ (RPC):

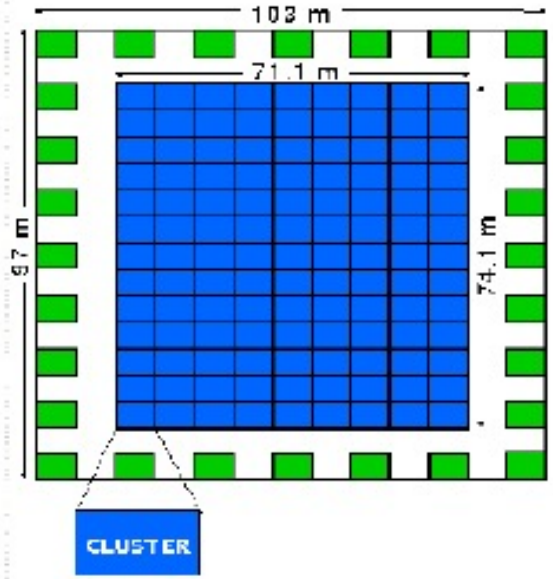

ARGO实验厅


Meter
Meter
Event display


Crab : 5σ in ~50 days
Mrk 421 flare
Threshold ~ 0.5 TeV

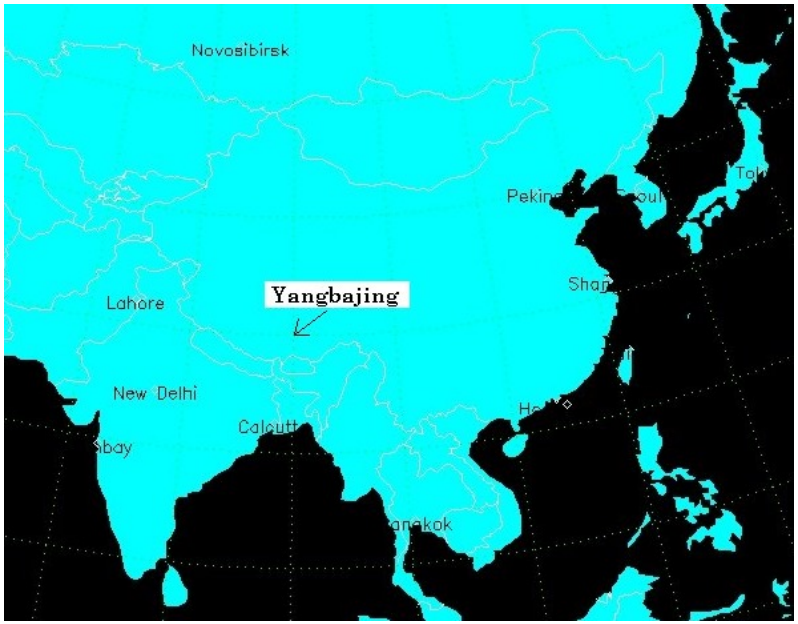
ARGO

Area 5.200 m^2 (full coverage)
(10.000 m^2 with guard ring)
Field of view ~ 1 sr
E = 50 GeV - 50 TeV
Location: Tibet 4300m alt.



17400 Pads 56 by 60 cm^2 each of Resistive Plate Chamber (RPC).
Each pad subdivided in pick-up strips 6 cm wide for the space pattern inside the pad.
The CLUSTER is made of 12 RPCs Pads

TIBET air shower array

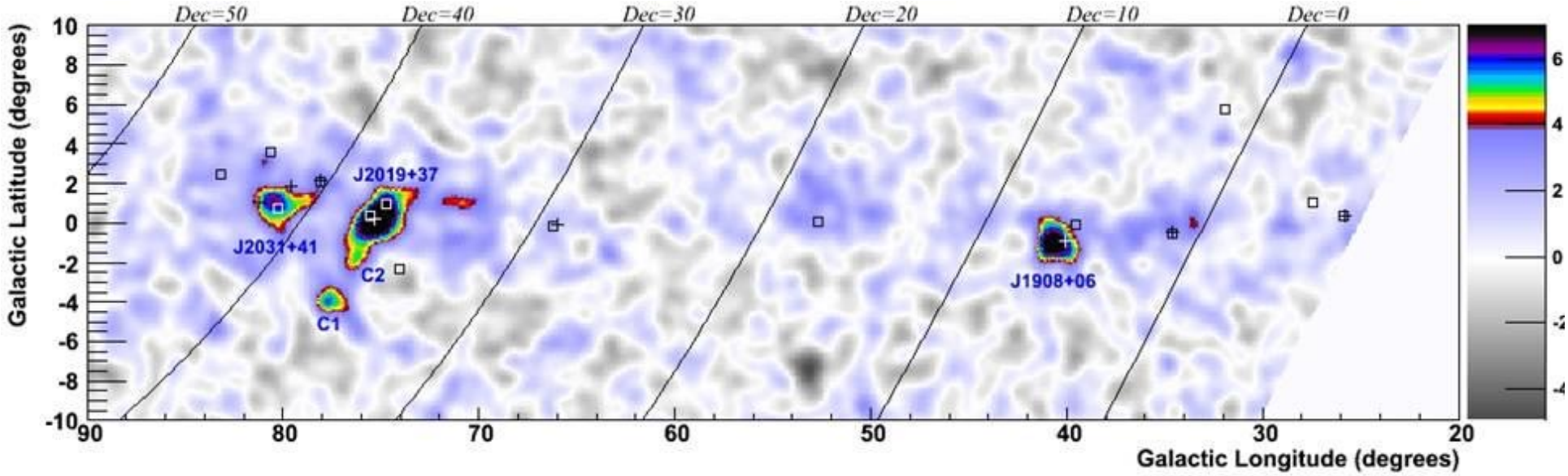


Our air shower array consists of 697 scintillation counters which are placed at a lattice with 7.5 m spacing and 36 scintillation counters which are placed at a lattice with 15 m spacing. Each counter has a plate of plastic scintillator, 0.5 m^2 in area and 3 cm in thickness, equipped with a 2-inch-in-diameter photomultiplier tube (PMT). The time and charge information of each PMT hit by an air shower event is recorded to determine its direction and energy. The detection threshold energy is approximately 3 TeV, which is the lowest one achieved by an air shower array in the world.

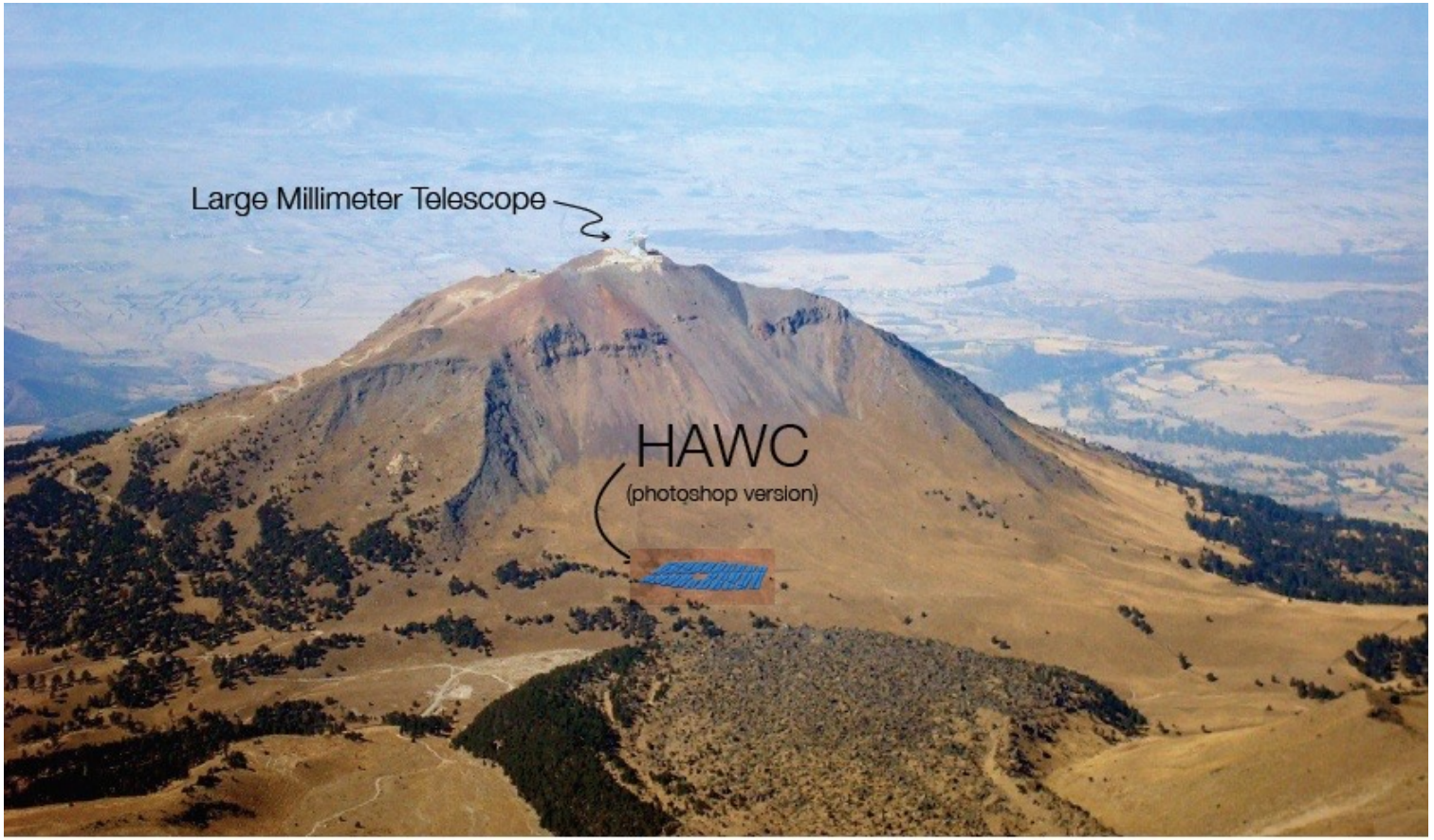
MILAGRO

Cherenkov in water, Arizona

Crab:
~5σ in 100 days
Median energy ~20 TeV



HAWC



HAWC

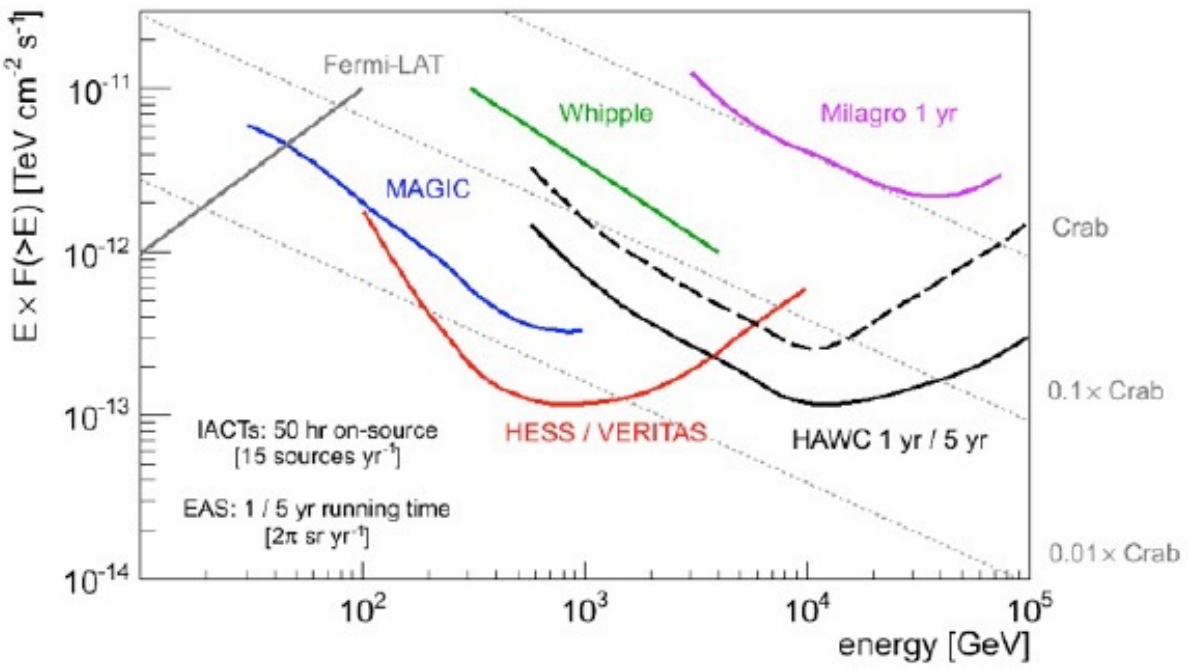
Pico de Orizaba, altitude 4100 m, latitude 18º 59' N
Two hours drive from Puebla, four from México City
Site of Large Millimeter Telescope (existing infrastructure)

HAWC

Sensitivity to Point Sources

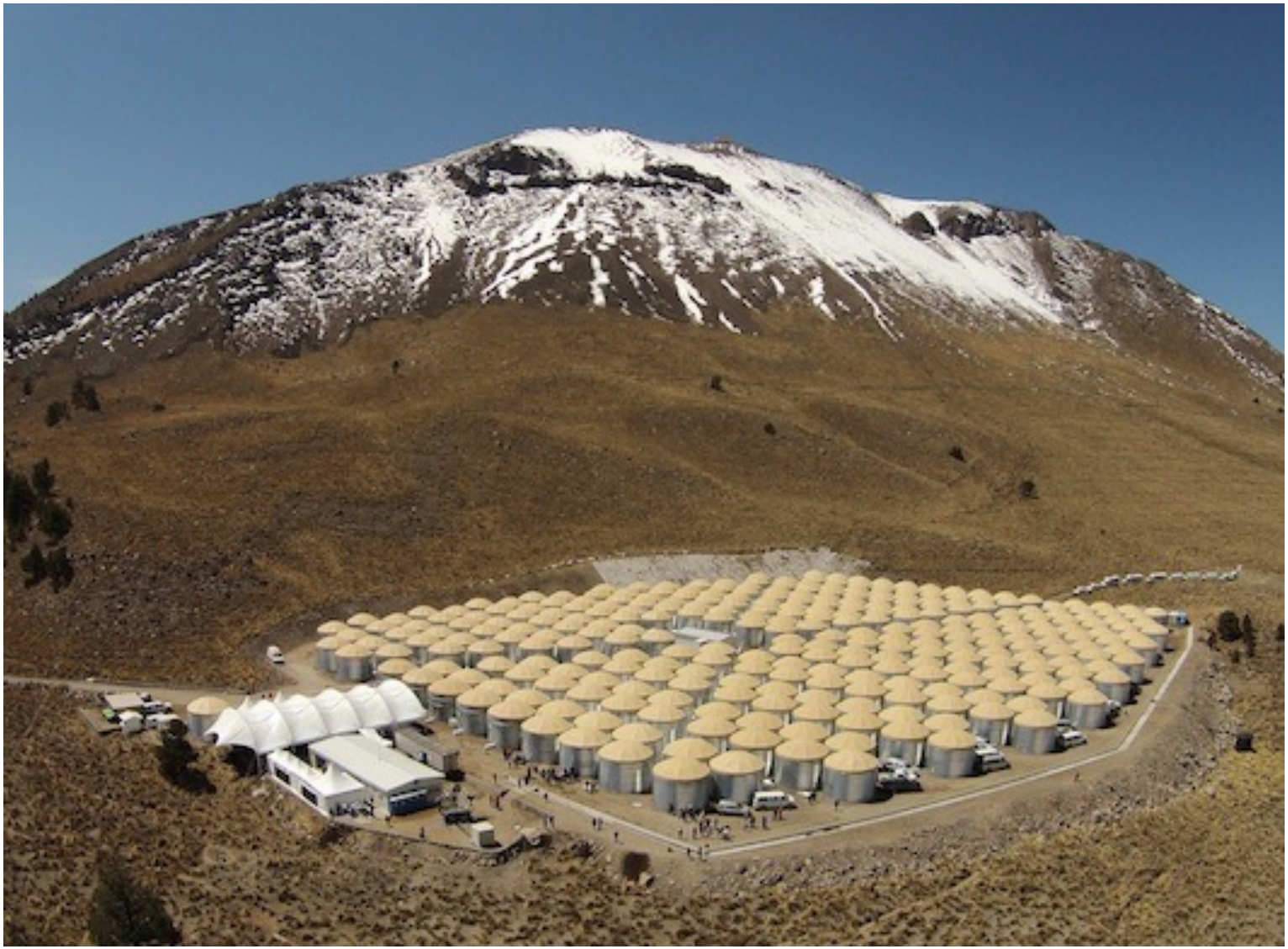
- Long integration times lead to excellent sensitivity at highest energies (> few TeV)

- 5σ sensitivity to:
  - 10 Crab in 3 min
  - 1 Crab in 5 hr
  - 0.1 Crab in ⅓ year

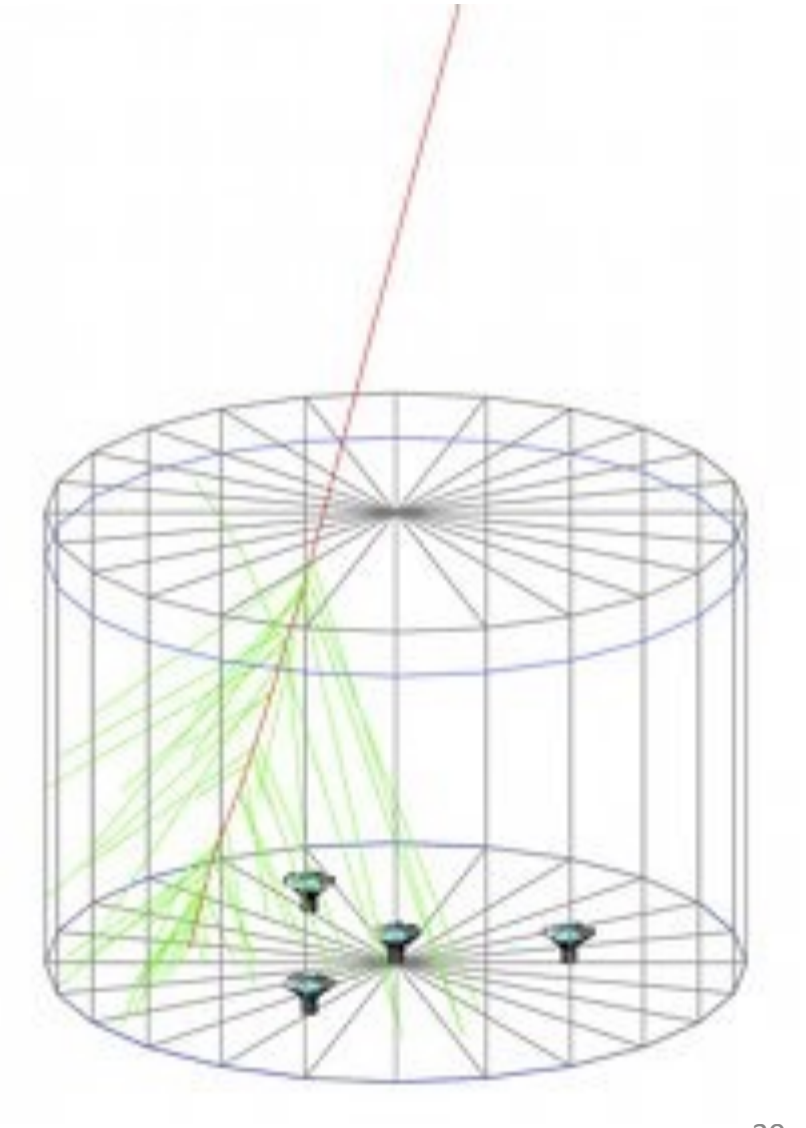


- Around 15x the sensitivity of Milagro

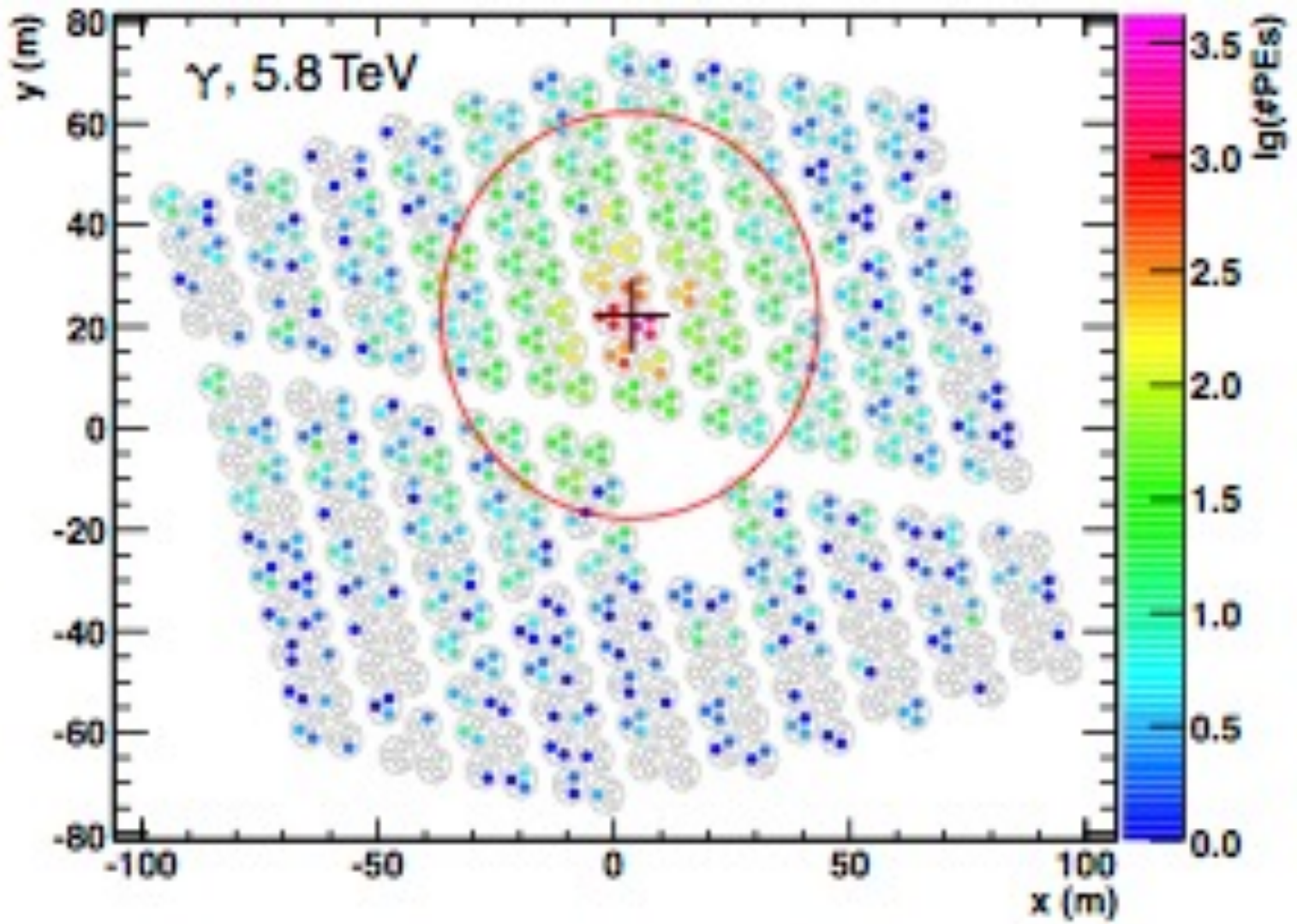
HAWC



HAWC



HAWC


γ, 5.8 TeV
y (m)
x (m)
lg(#PEs)
80
60
40
20
0
-20
-40
-60
-80
-100
-50
0
50
100
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

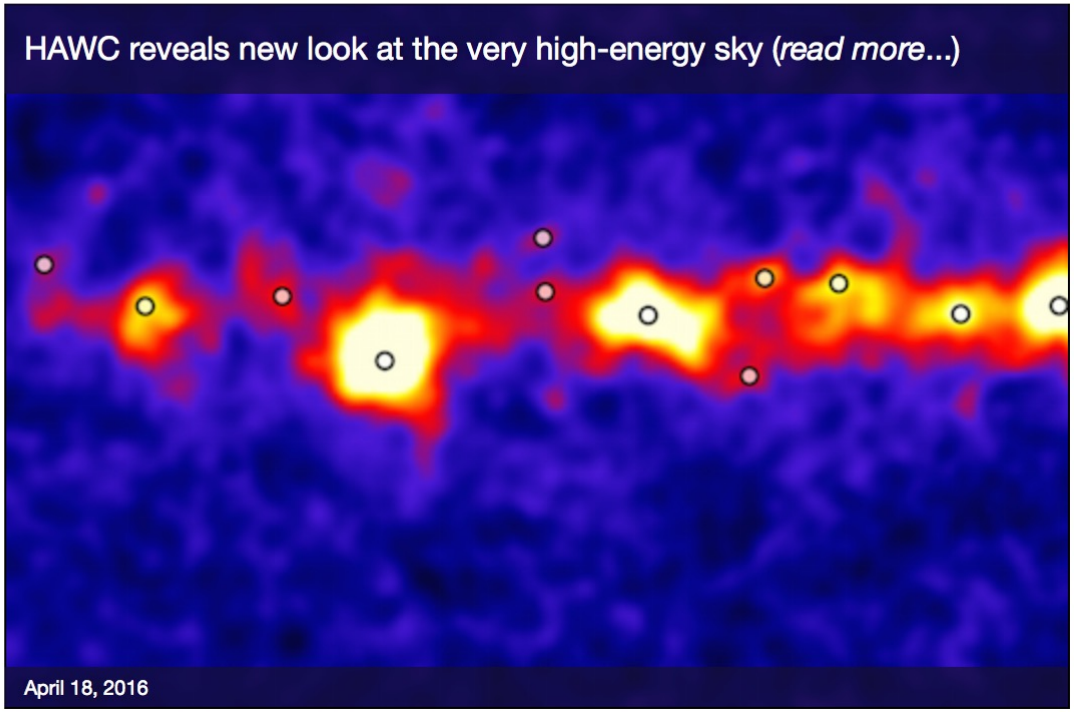
HAWC

HAWC

The High-Altitude Water Cherenkov Gamma-Ray Observatory

Home | News | Science | Observatory | Details | Publications | Collaboration | Contact | Support | Español

Latest News



HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

Quick Links:

News

- Latest news from HAWC
- Like Share
- Follow @HAWC_Obs

TeV Astronomy

- Catalog of TeV Sources
- TeV Review Papers

Milagro Links

- Milagro γ-Ray Observatory

http://www.hawc-observatory.org

LHAASO

Project Overview

Charged Particle Array

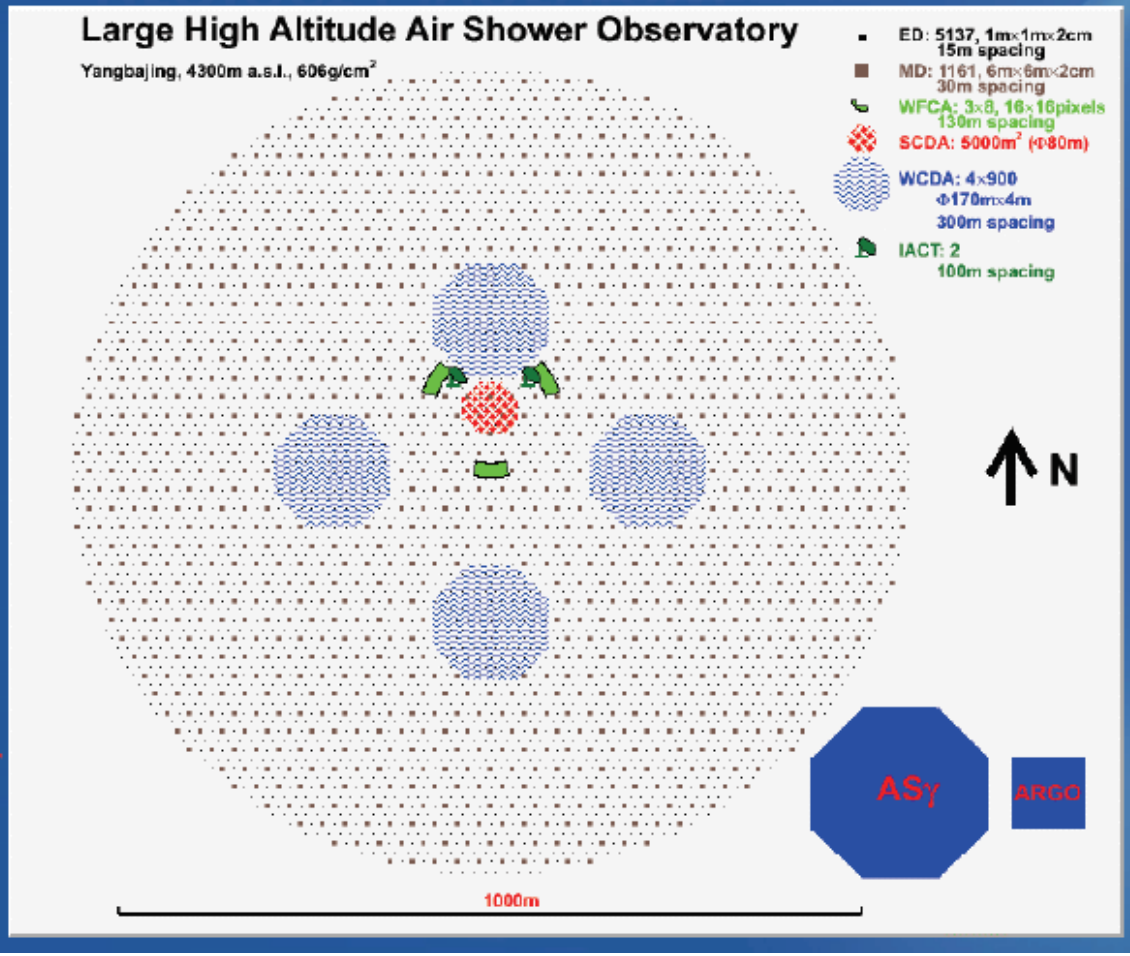
μ Detector Array

Water C Array

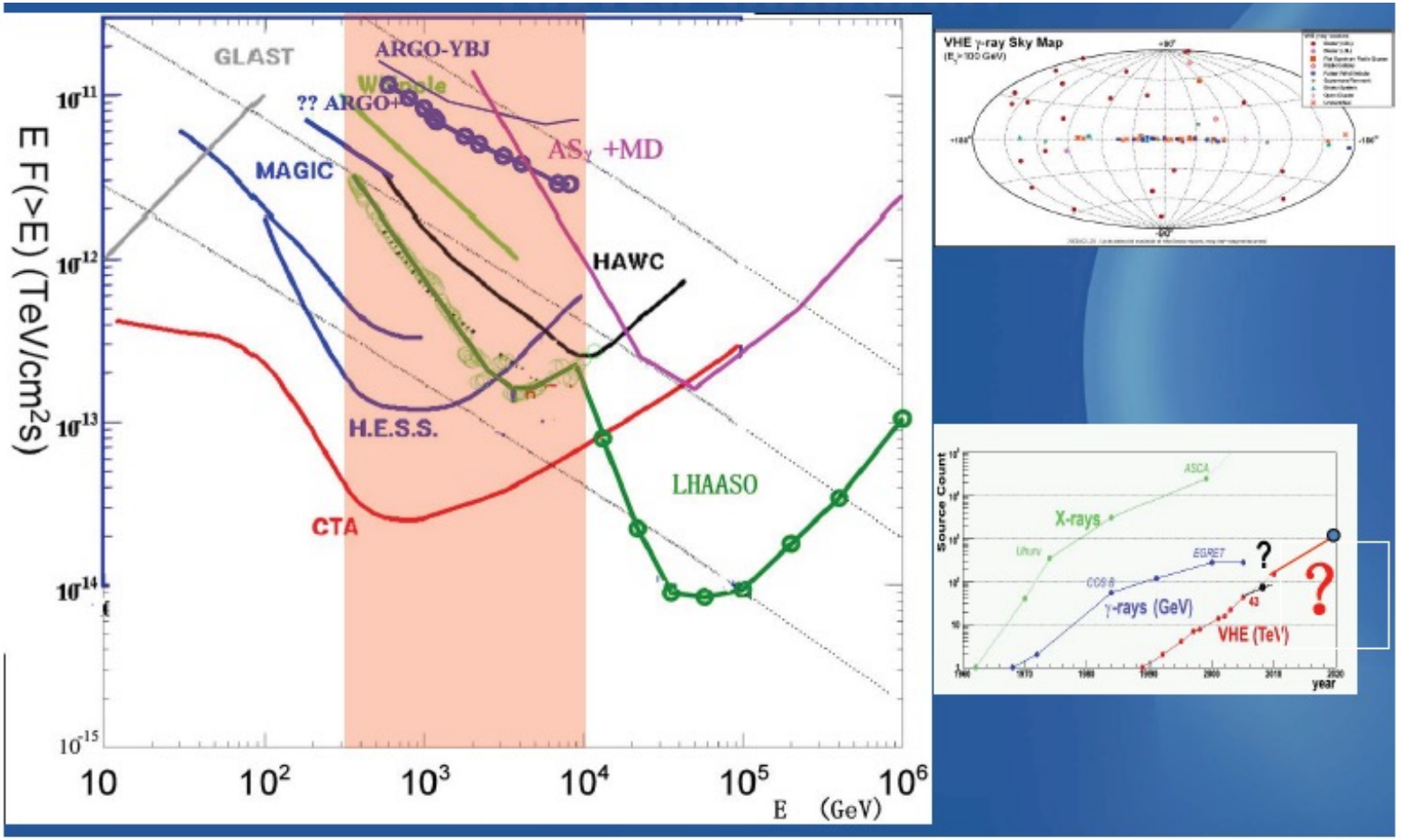
Wide FOV C-Telescope Array

&

Core Detector Array



LHAASO


GLAST
ARGO-YBJ
?? ARGO+
MAGIC
ASγ +MD
HAWC
H.E.S.S.
CTA
LHAASO
E F(<E) (TeV/cm²s)
E (GeV)
VHE γ-ray Sky Map
Source Count
X-rays
γ-rays (GeV)
VHE (TeV)
year

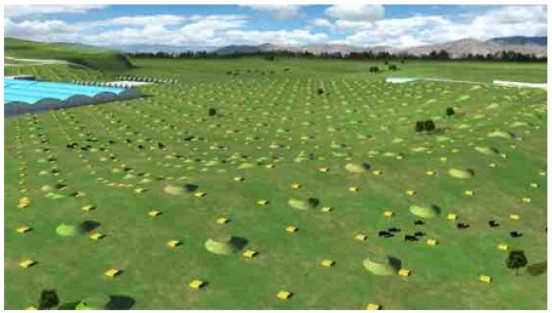
The LHAASO experiment

The Large High Altitude Air Shower Observatory (LHAASO) project is a new generation all-sky instrument to investigate the '*cosmic ray connection*' through a combined study of cosmic rays and gamma-rays in the wide energy range 10^{11} -- 10^{17} eV.

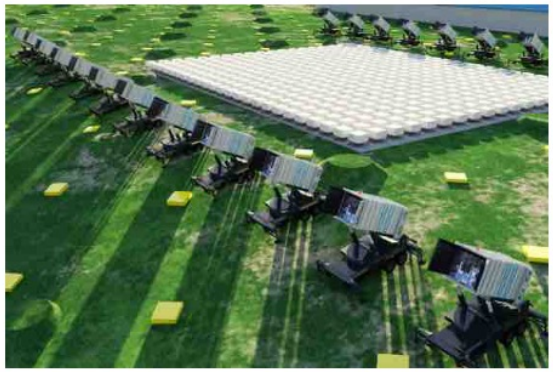
The first phase of LHAASO will consist of the following major components:

- 1 km^2 array (LHAASO-KM2A), including 5635 scintillator detectors, with 15 m spacing, for electromagnetic particle detection.
- An overlapping 1 km^2 array of 1221, 36 m^2 underground water Cherenkov tanks, with 30 m spacing, for muon detection (total sensitive area 40,000 m^2).
- A close-packed, surface water Cherenkov detector facility with a total area of 90,000 m^2 (LHAASO-WCDA), four times that of HAWC.
- 24 wide field-of-view air Cherenkov (and fluorescence) telescopes (LHAASO-WFCTA).
- 452 close-packed burst detectors, located near the centre of the array, for detection of high energy secondary particles in the shower core region (LHAASO-SCDA).

LHAASO main components



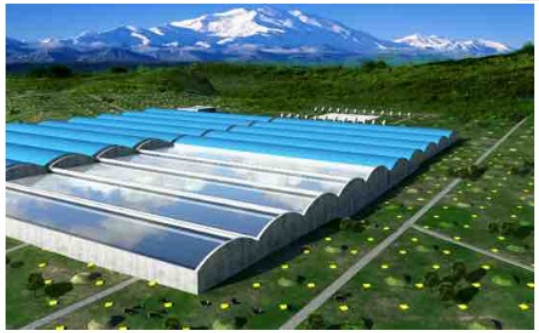
1 KM2A:
5635 EDs
1221 MDs



WFCTA:
24 telescopes
1024 pixels each

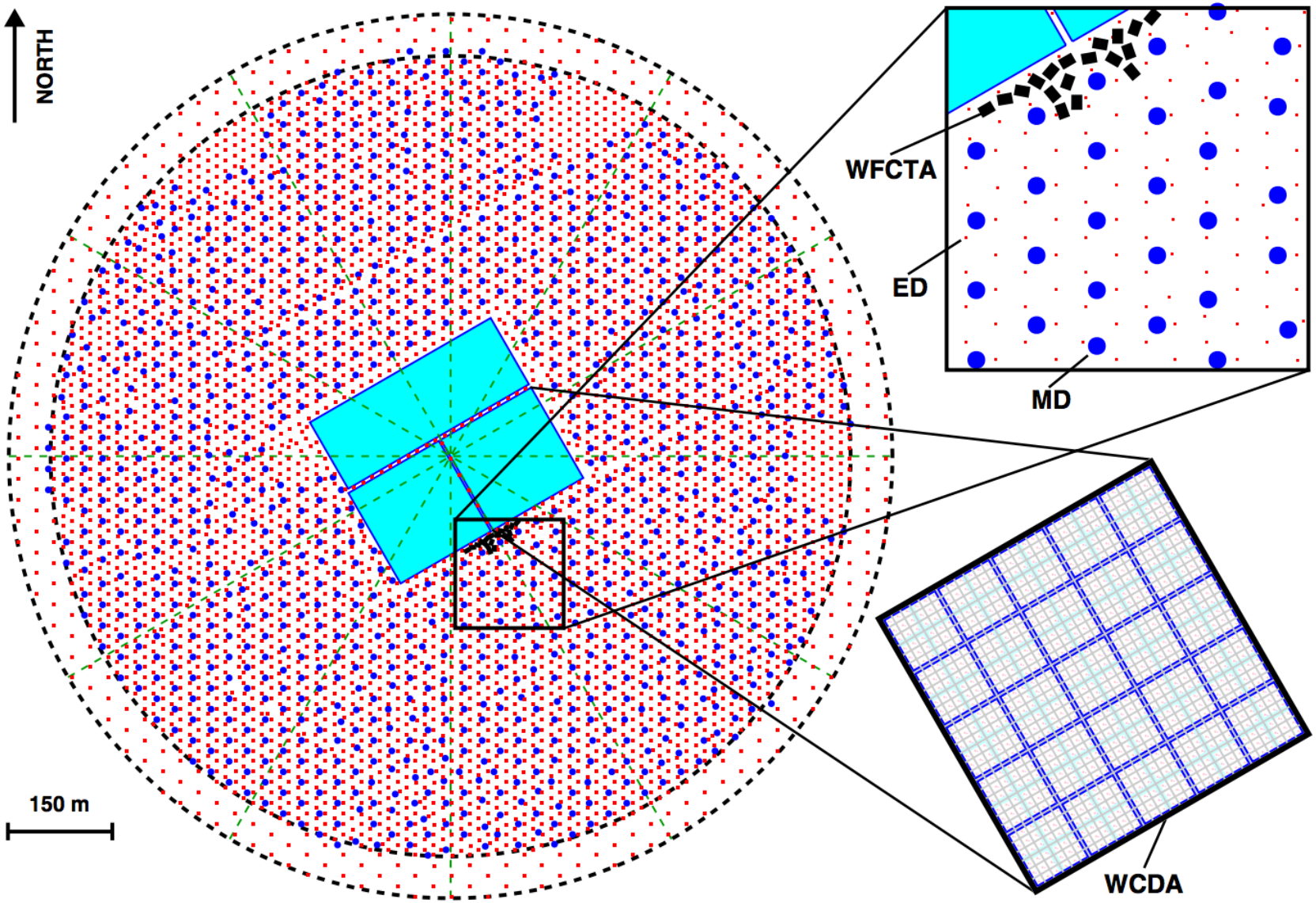
Coverage area: 1.3 km^2

WCDA:
3600 cells
90,000 m^2

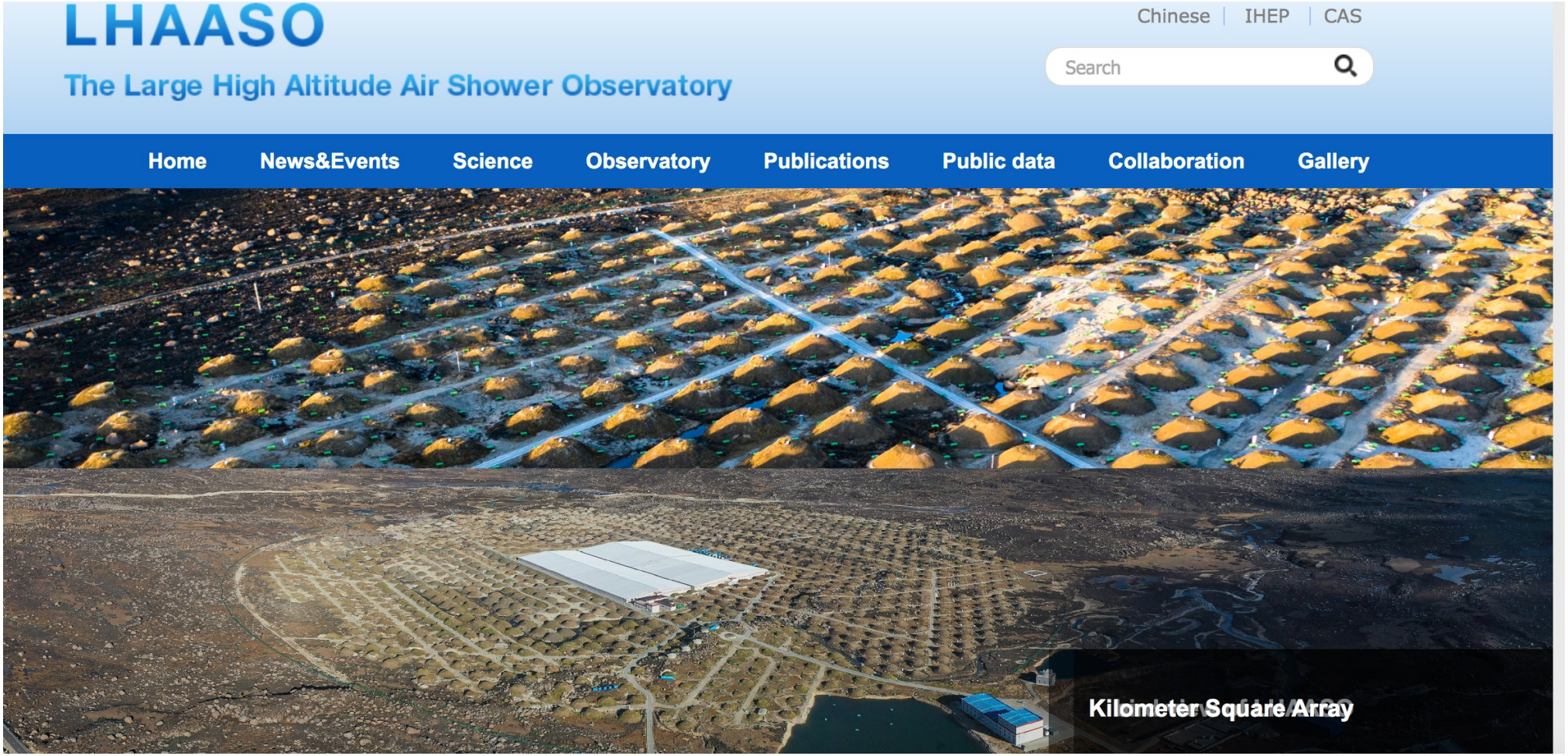


SCDA:
452 detectors

LHAASO



LHAASO



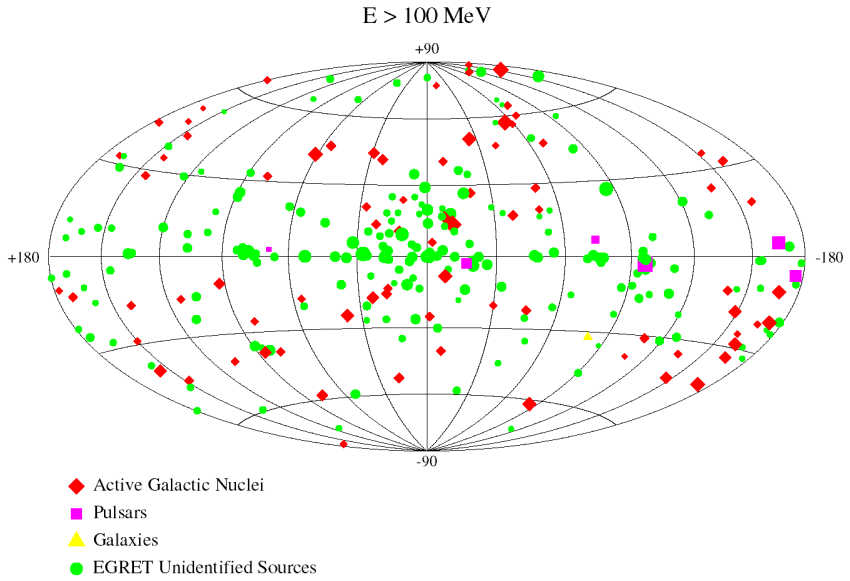
http://english.ihep.cas.cn/lhaaso/

Astrofisica Nucleare e Subnucleare

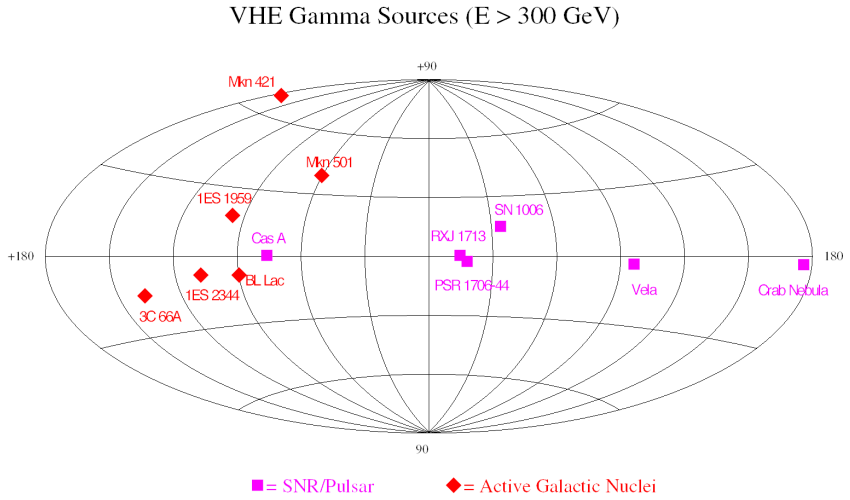
VHE Gamma Astrophysics

The unexplored spectrum gap

- Satellites give a nice crowded picture of energies up to 10 GeV.

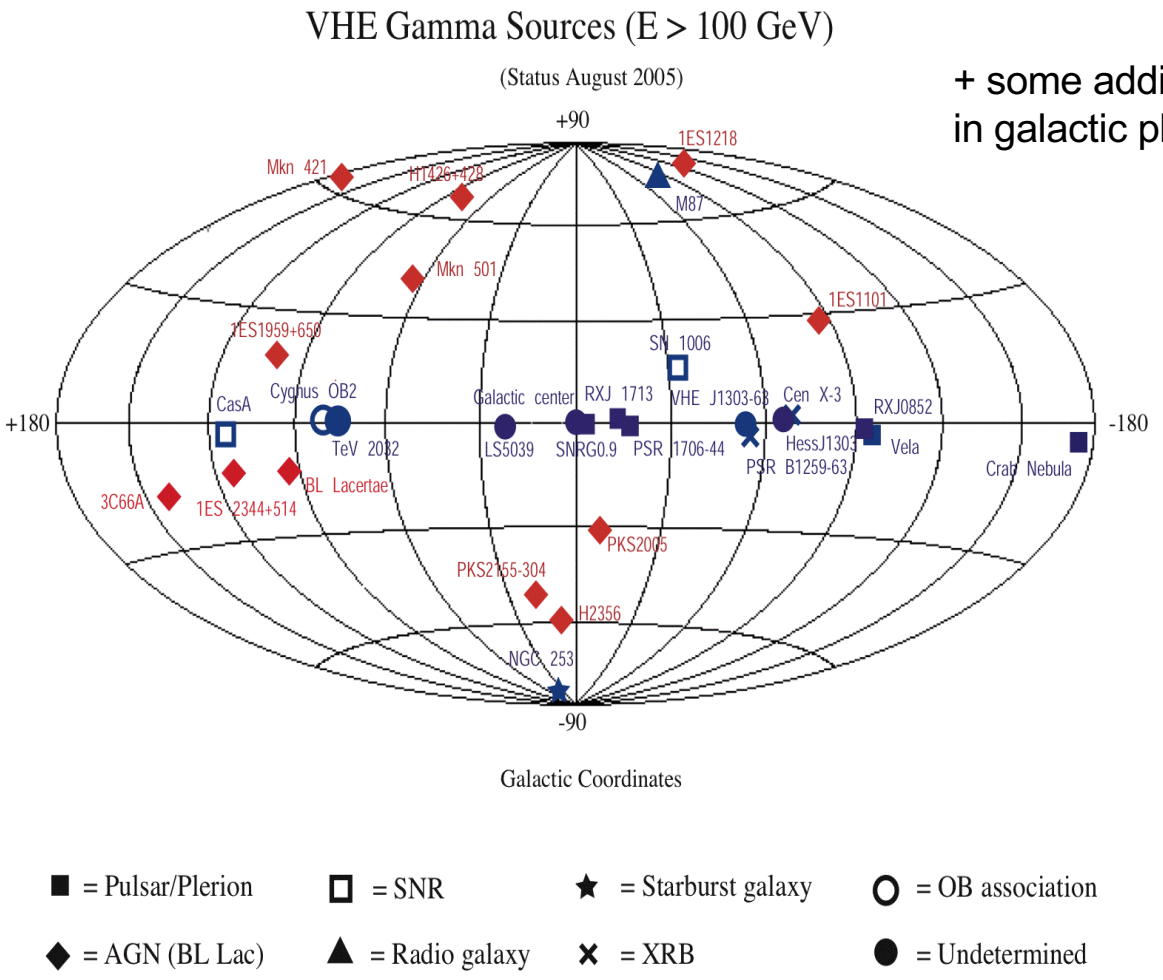


- **Ground based experiments show very few sources with energies > ~300 GeV.**



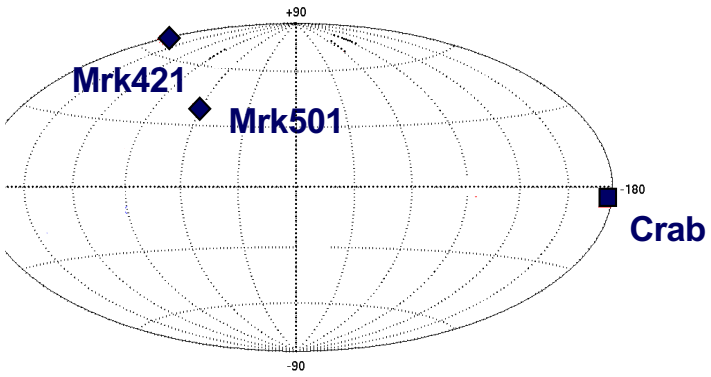
The VHE γ ray sky

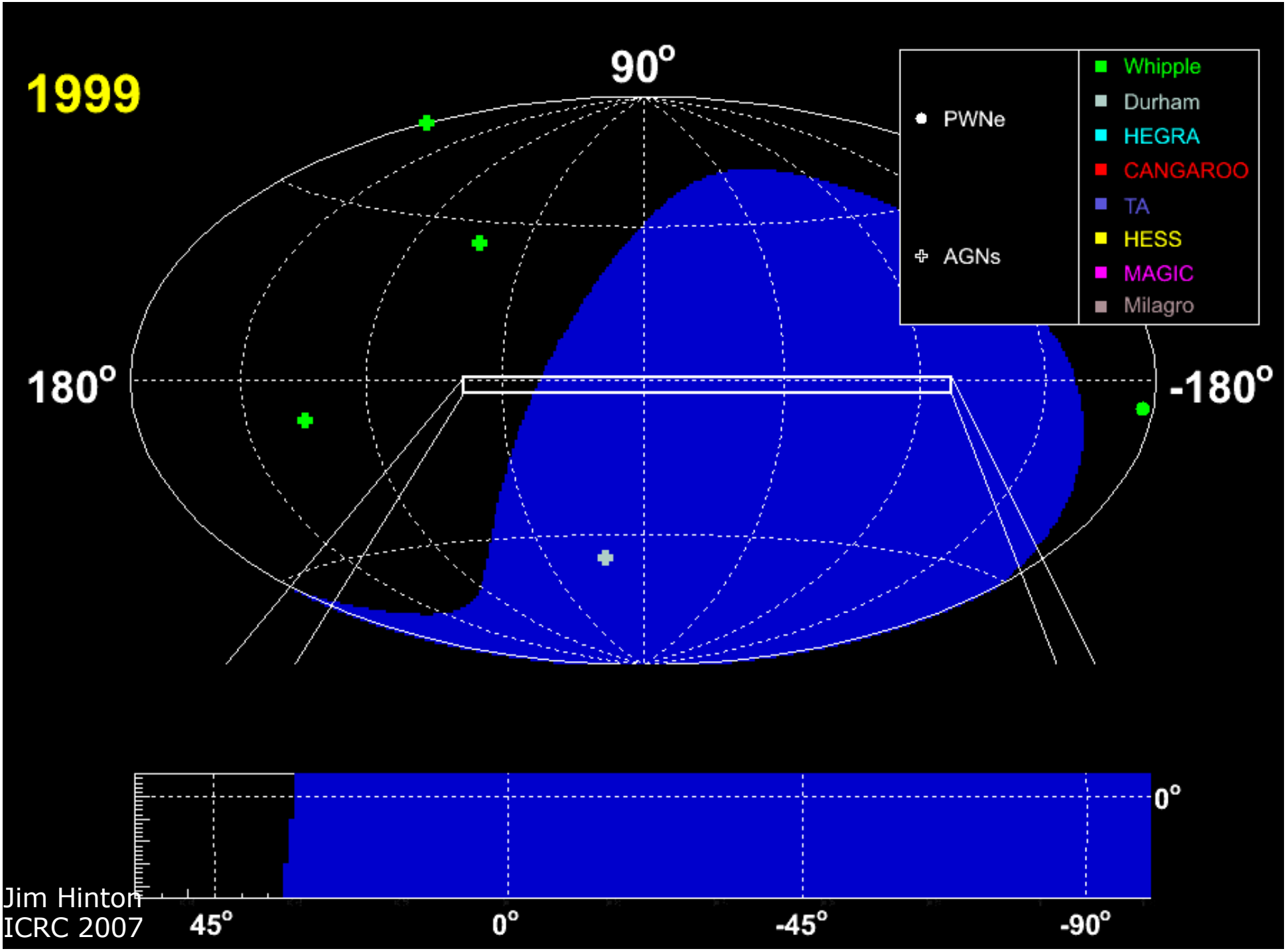
2005

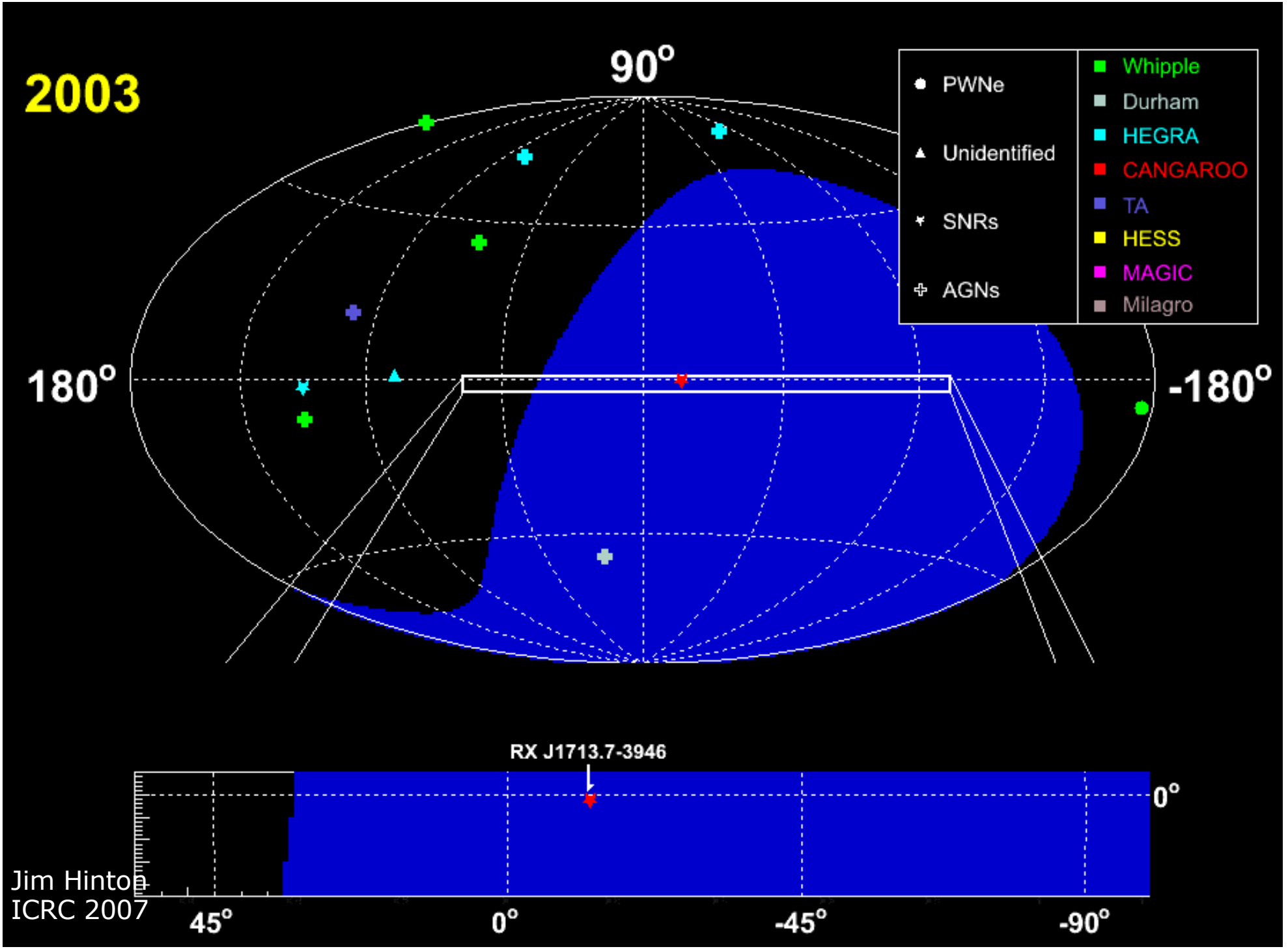


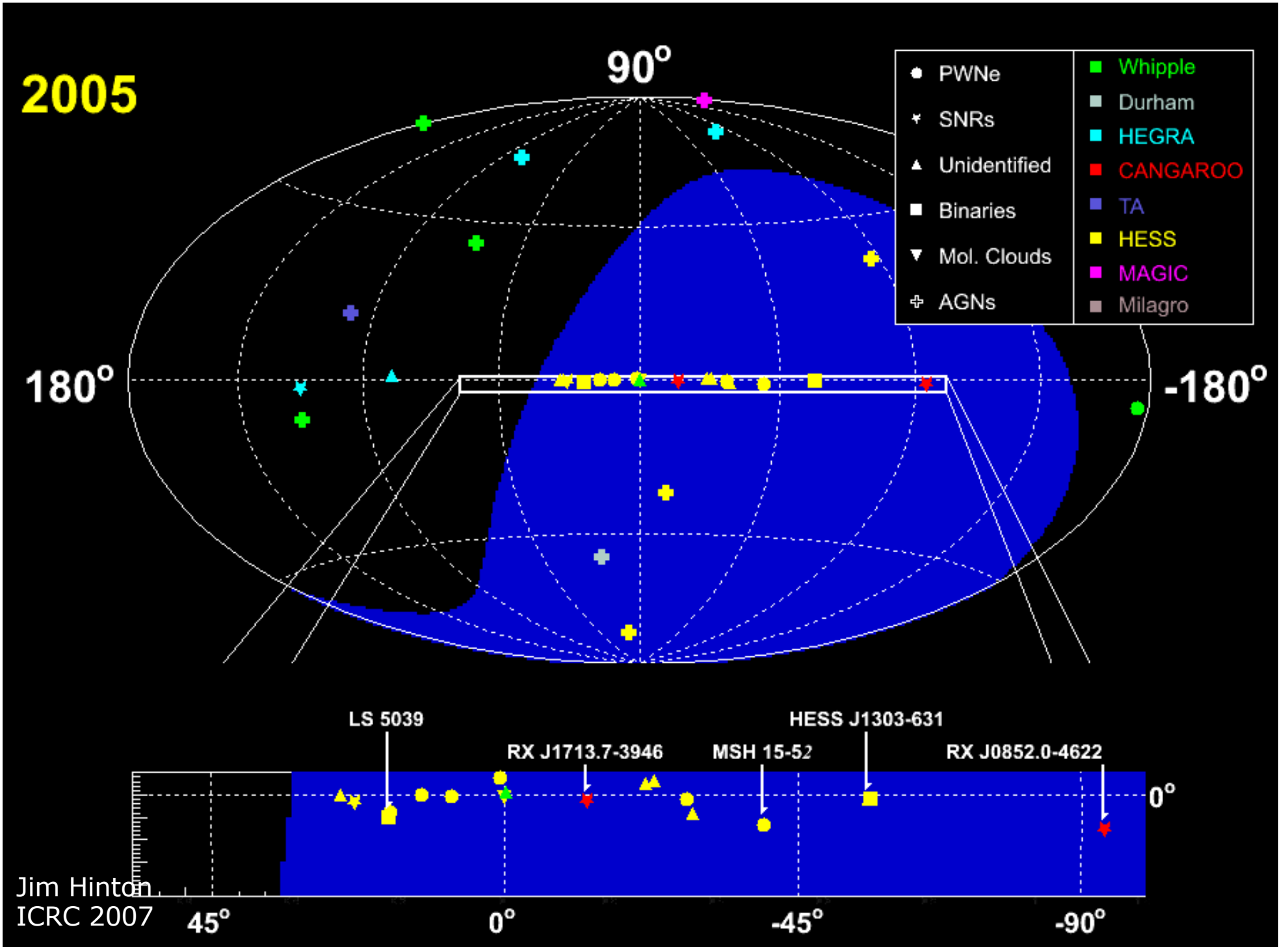
+ some additional sources in galactic plane.

1995

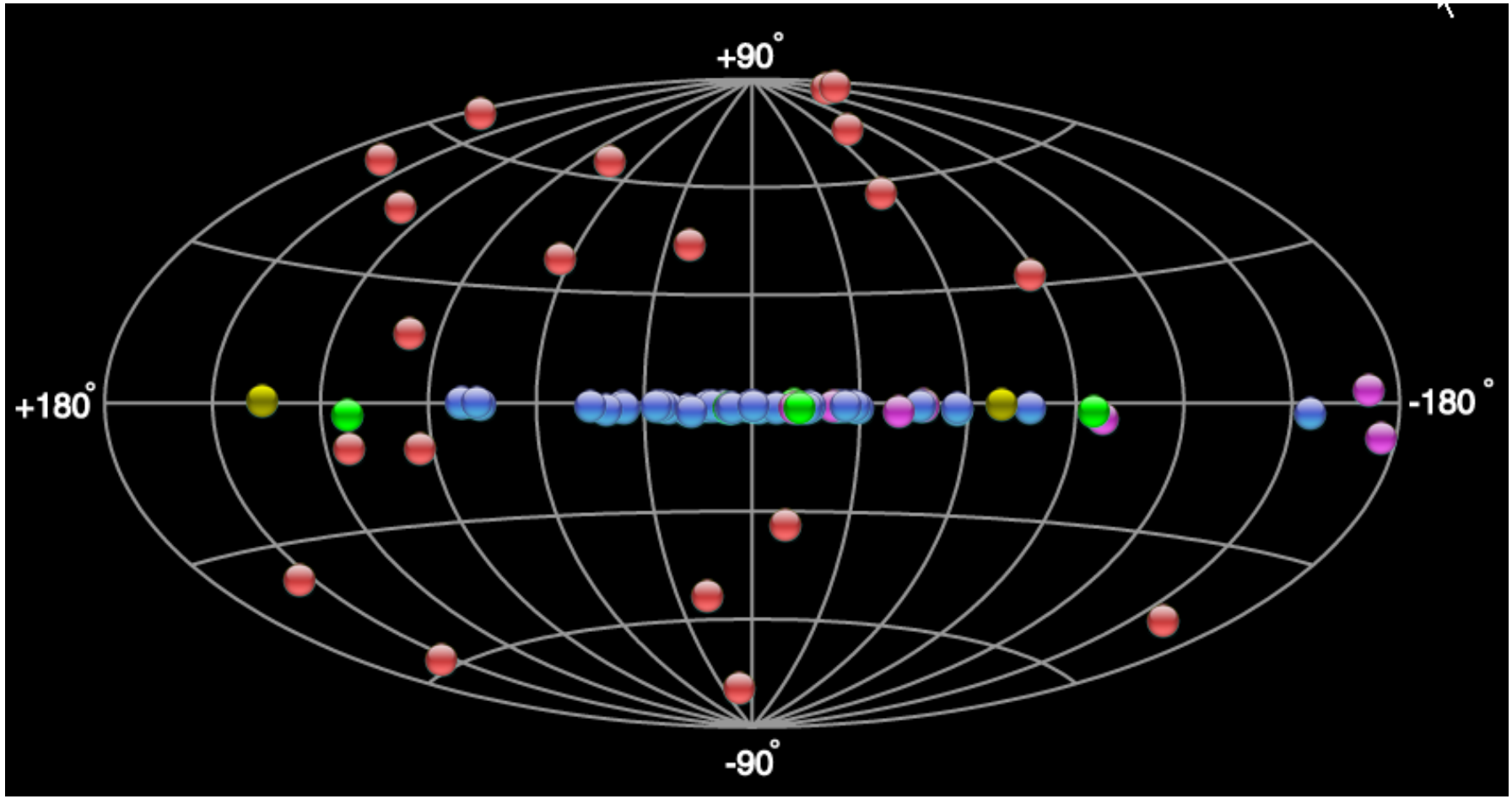



1999
90°
180°
-180°
PWNe
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007


2003
90°
180°
-180°
PWNe
Unidentified
SNRs
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
RX J1713.7-3946
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007

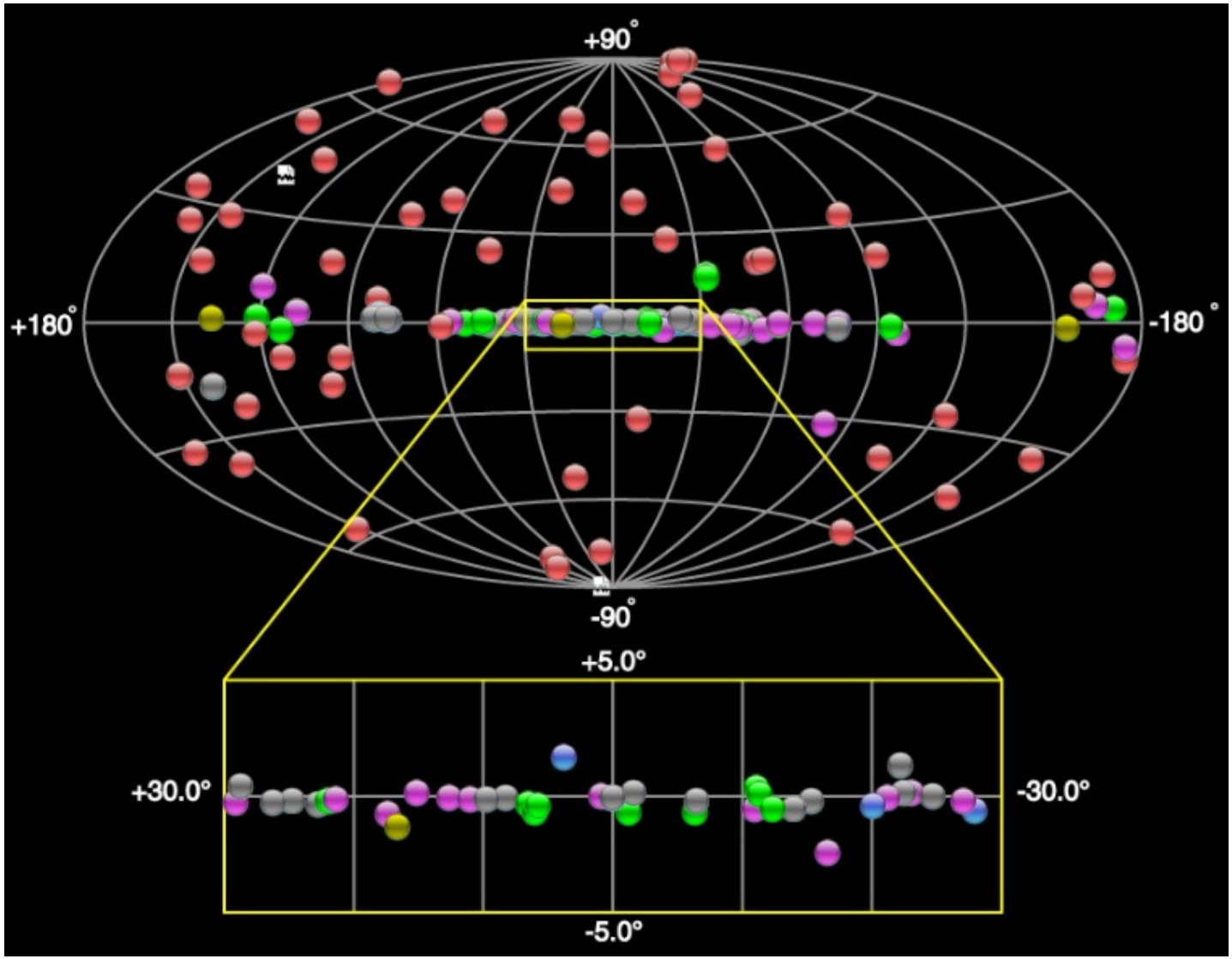

2005
90°
180°
-180°
PWNe
SNRs
Unidentified
Binaries
Mol. Clouds
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
LS 5039
RX J1713.7-3946
MSH 15-52
HESS J1303-631
RX J0852.0-4622
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007

TeV Source Catalog

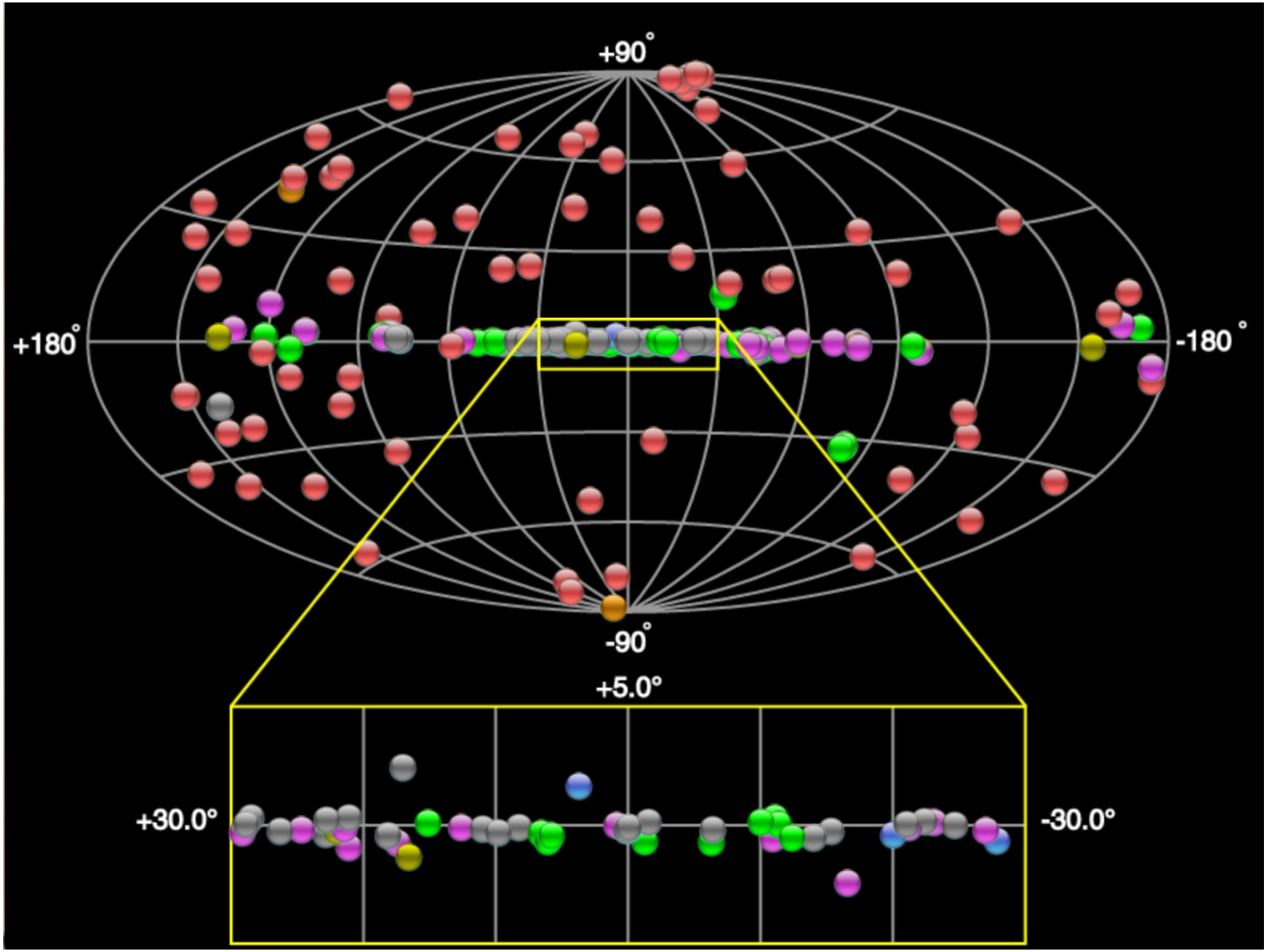


http://tevcat.uchicago.edu/

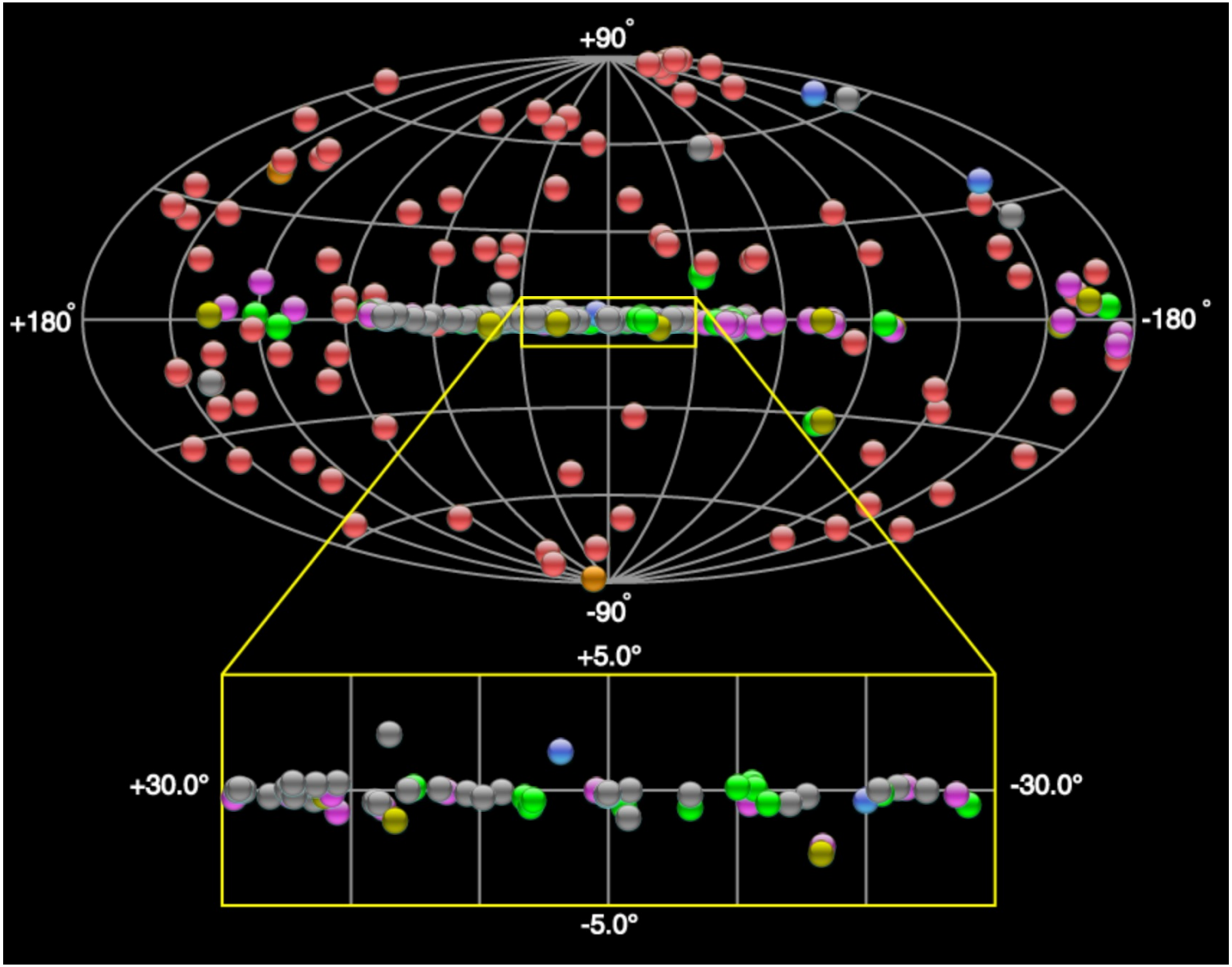
The TeV Catalog 2012



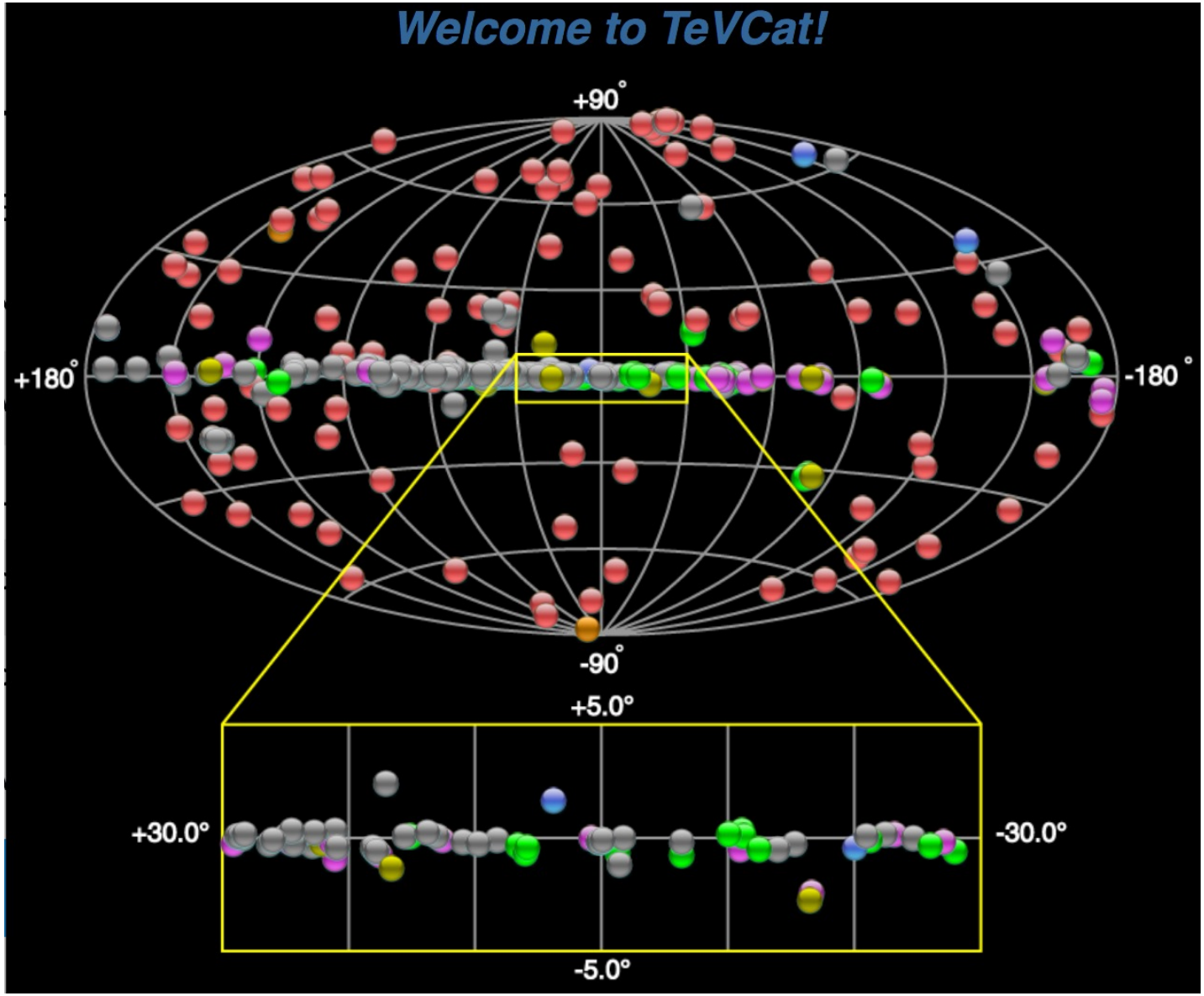
The TeV Catalog 2016



The TeV Catalog 2021

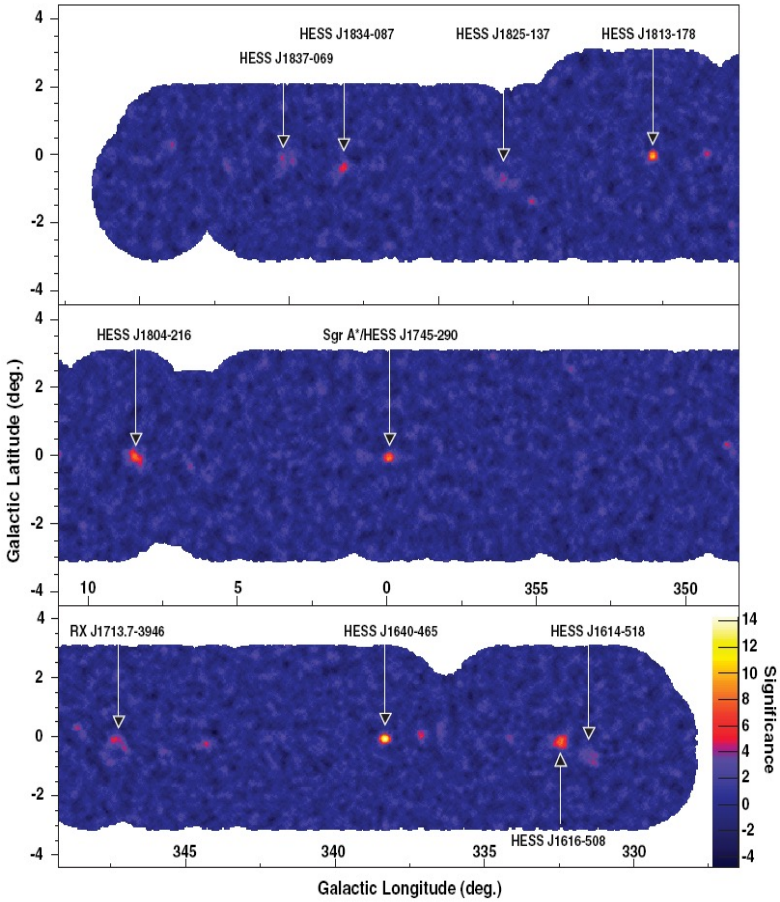


The TeV Catalog 2024

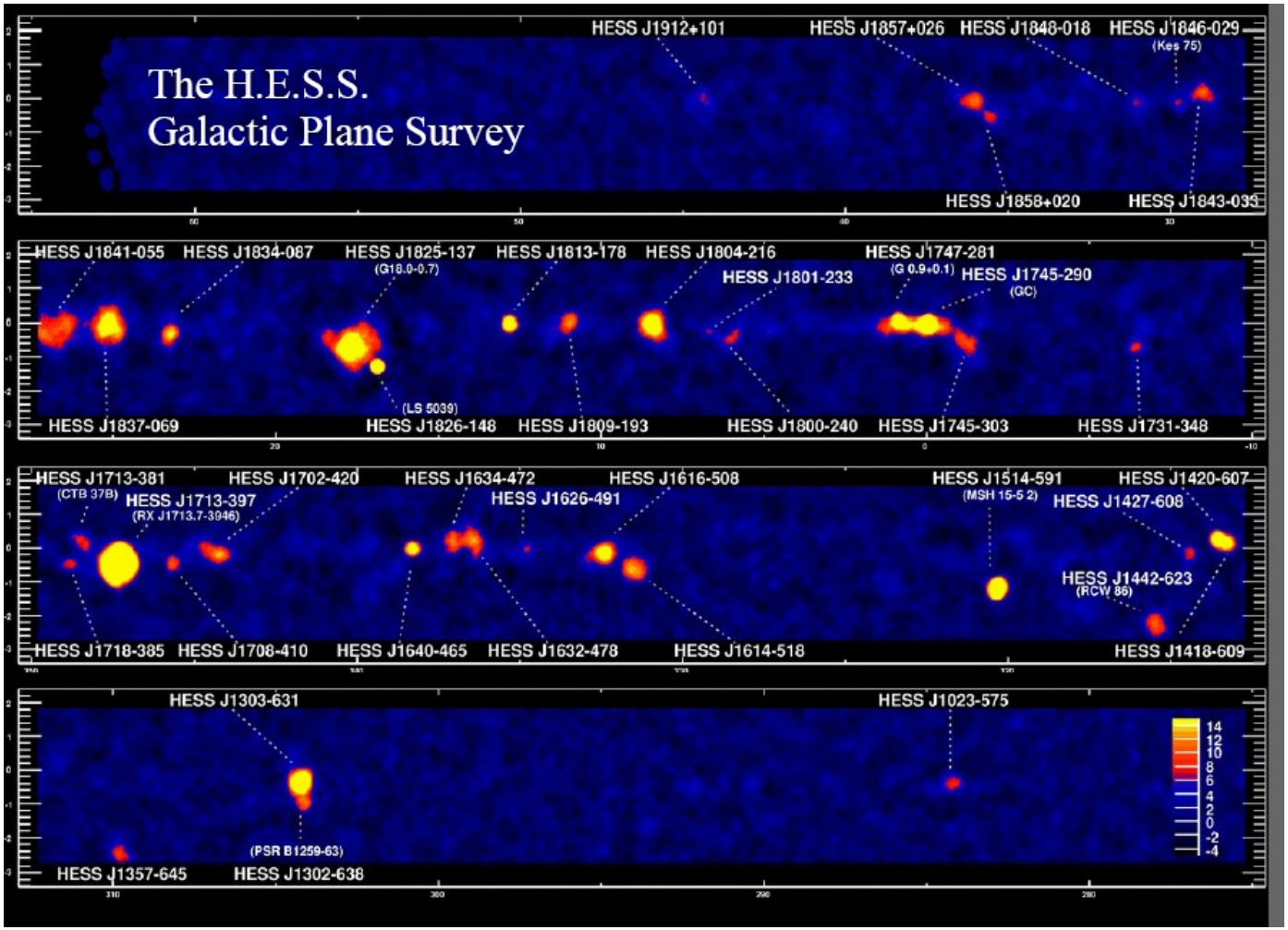


TeV Sky Survey

- HESS Galactic plane survey sees many new TeV sources (Aharonian et al. 2005)
  - This might possibly inform a detailed model of the distribution of CR sources, although the distribution is so confined to the plane that the sources (probably plerions and SNR) are at least several kpc distant

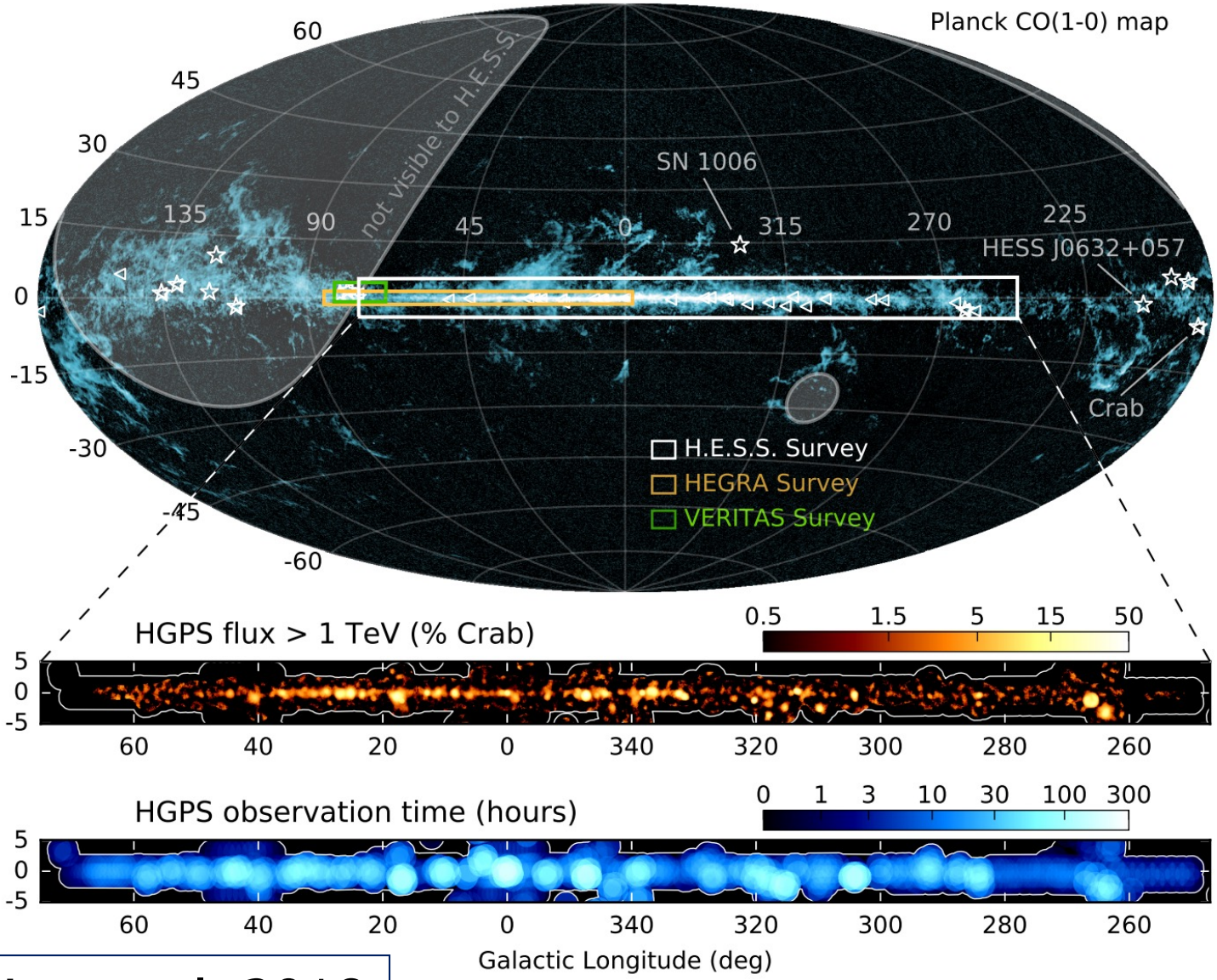


The Galactic Plane survey



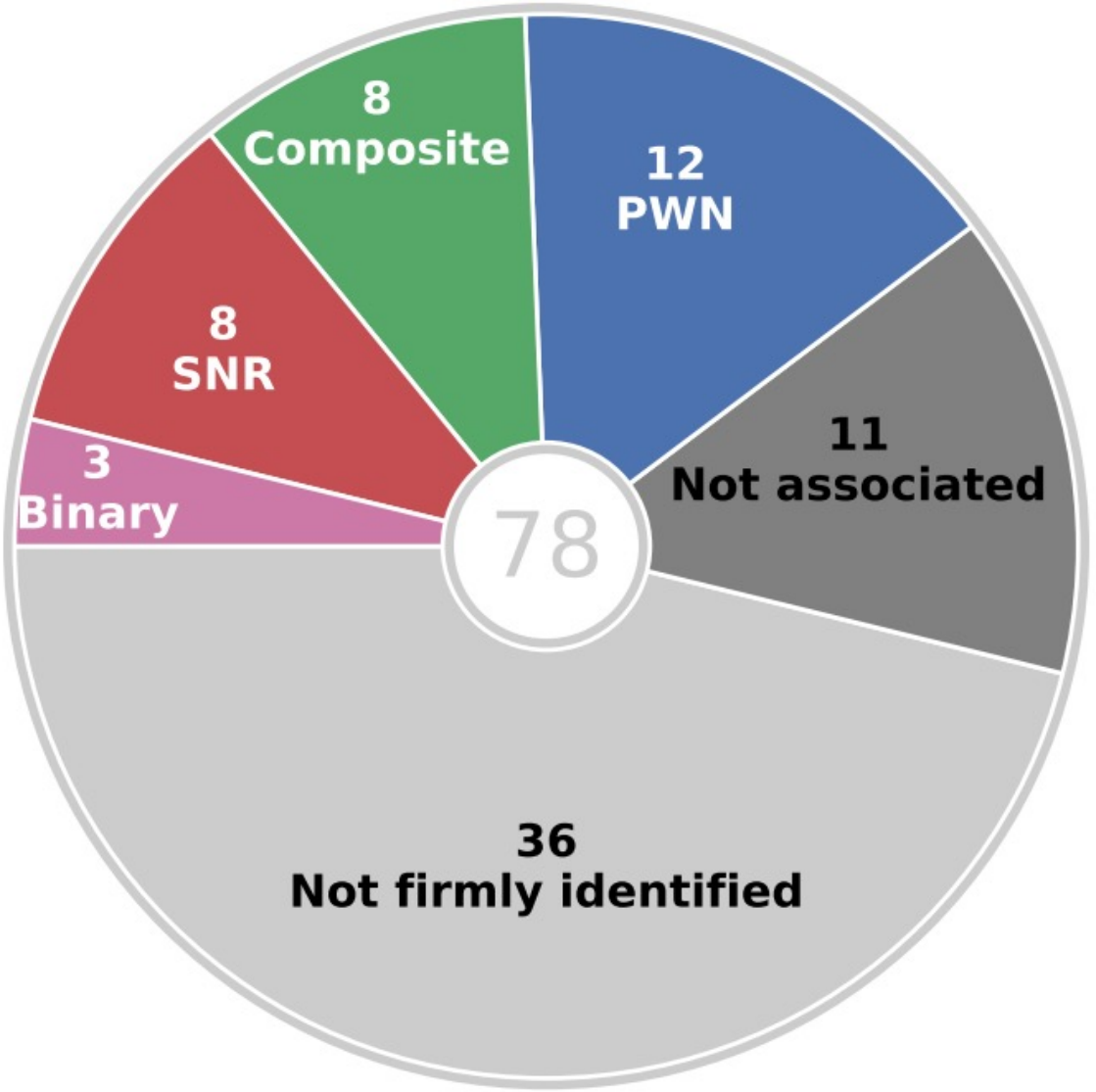
Aharonian et al. 2006

The Galactic Plane survey



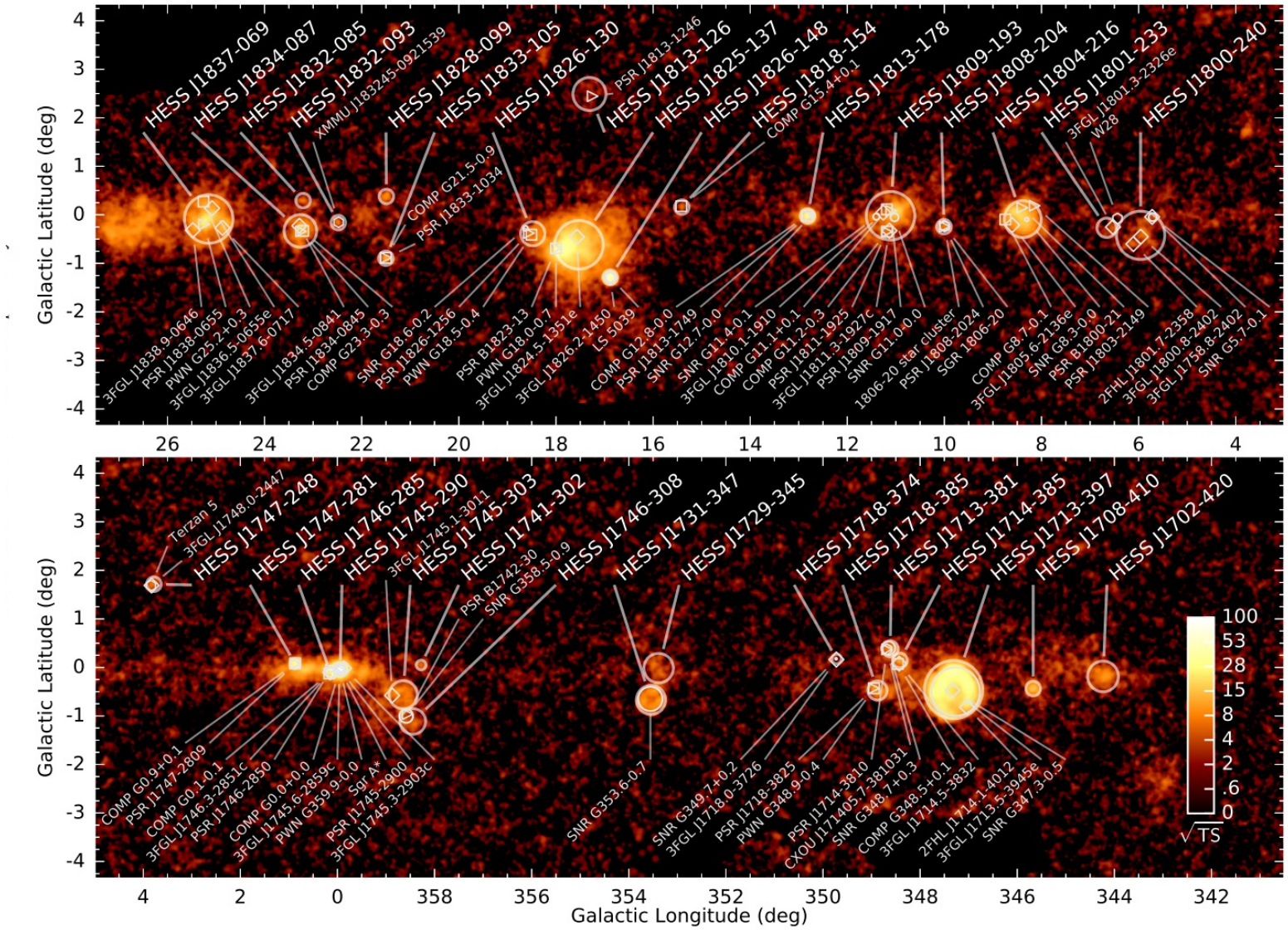
Aharonian et al. 2018

The Galactic Plane survey



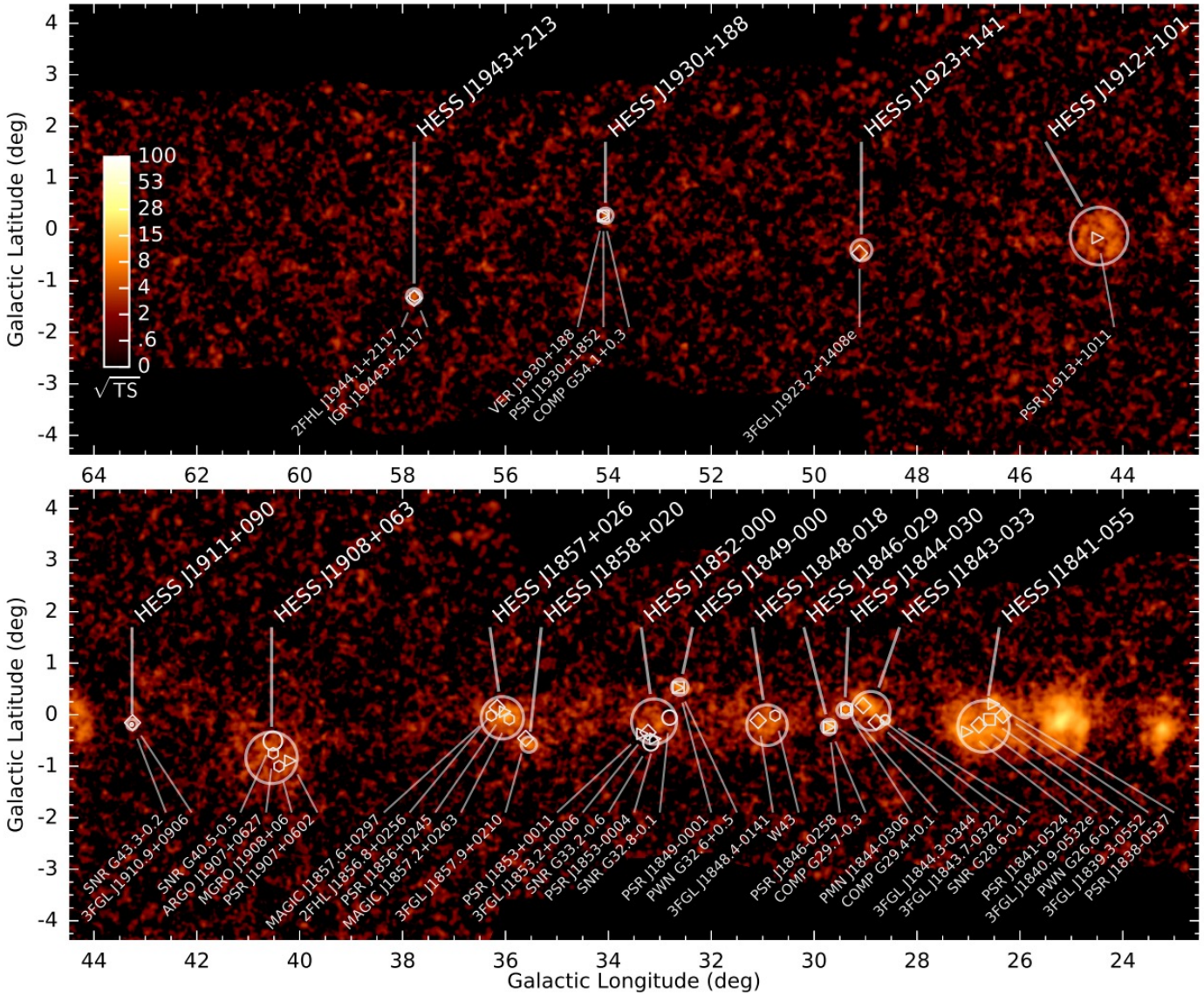
Aharonian et al. 2018

The Galactic Plane survey



Aharonian et al. 2018

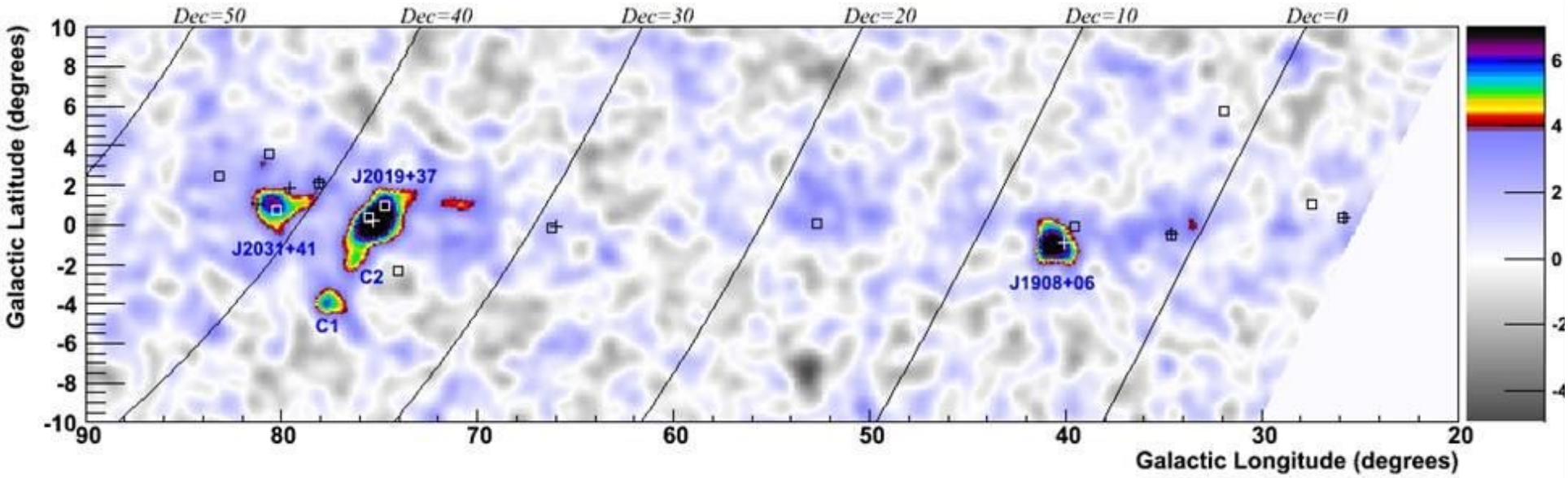
The Galactic Plane survey



Aharonian et al. 2018

MILAGRO Sky Survey

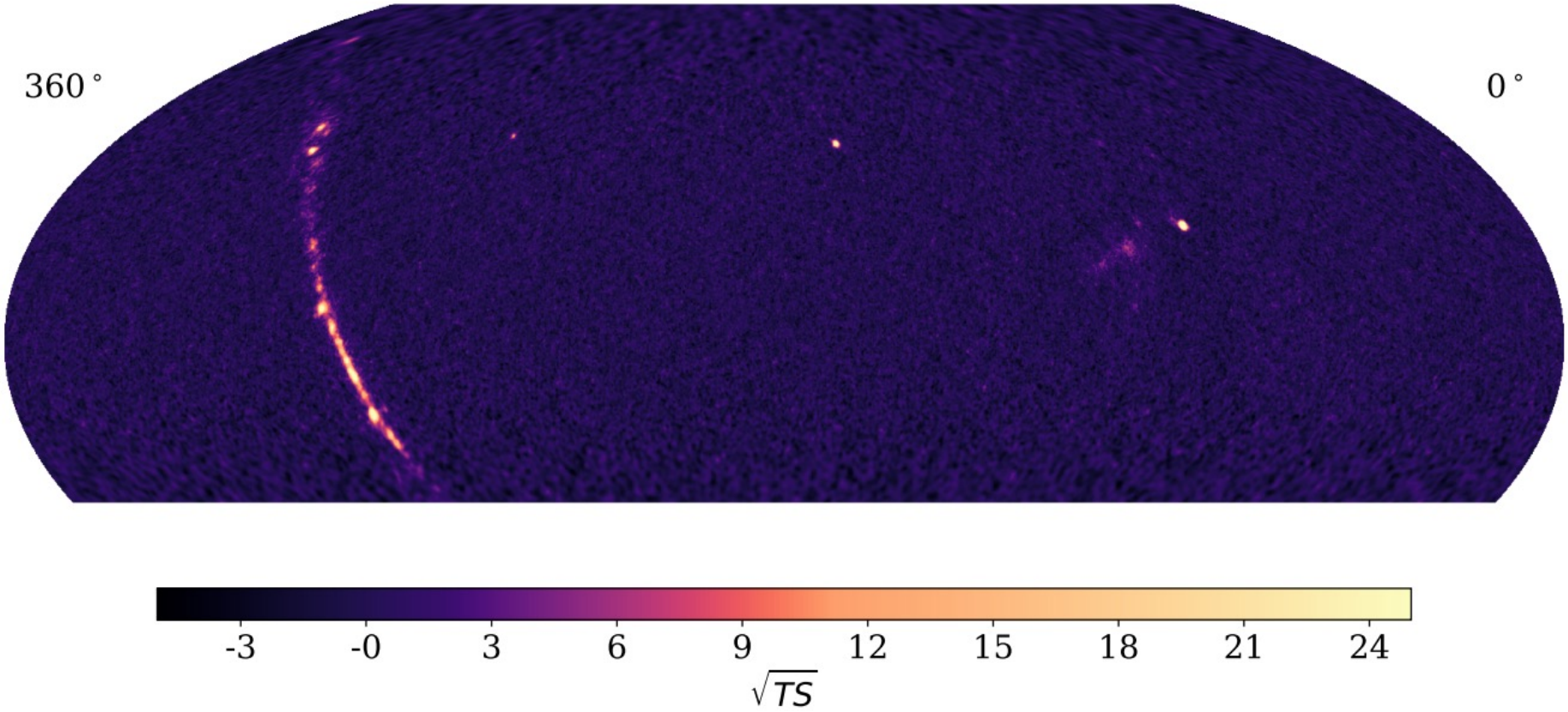
- Milagro reports detecting the diffuse emission of the Milky Way at >1 TeV energies (Abdo et al 2008)



Abdo et al. 2008

HAWC Sky Survey

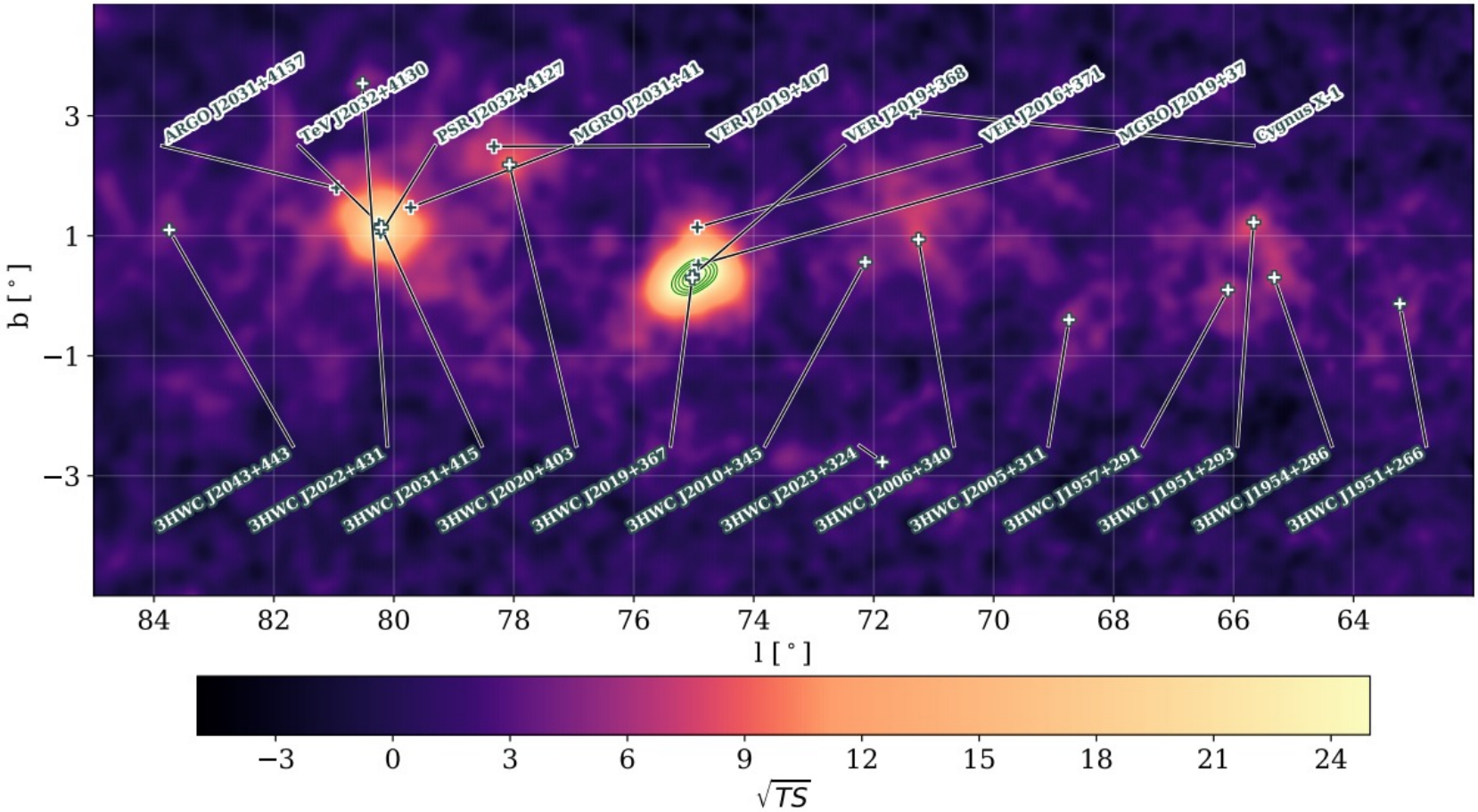
- HAWC 3rd catalog of Gamma Ray sources



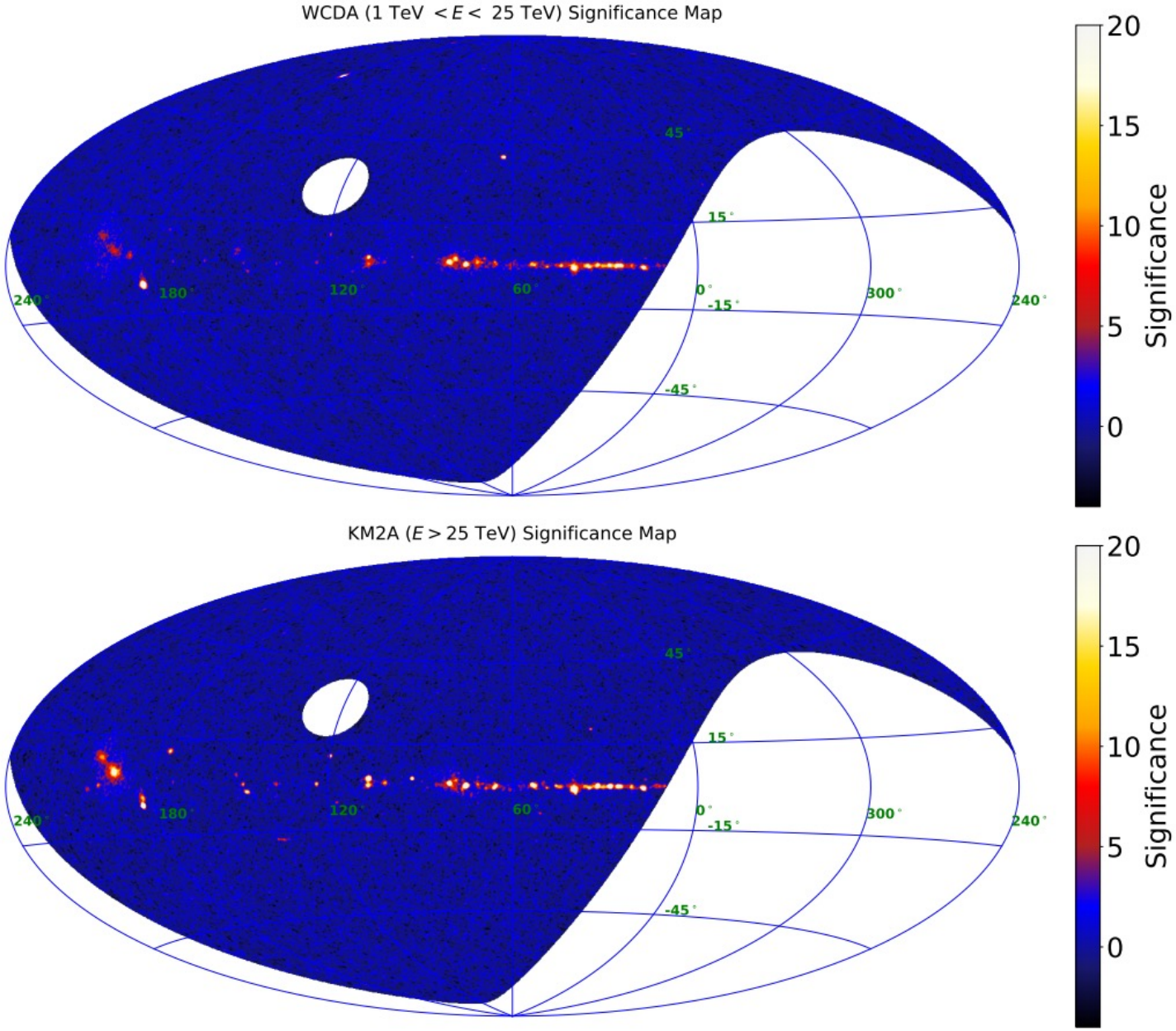
Albert et al. 2021

HAWC Sky Survey

- HAWC 3rd catalog of Gamma Ray sources



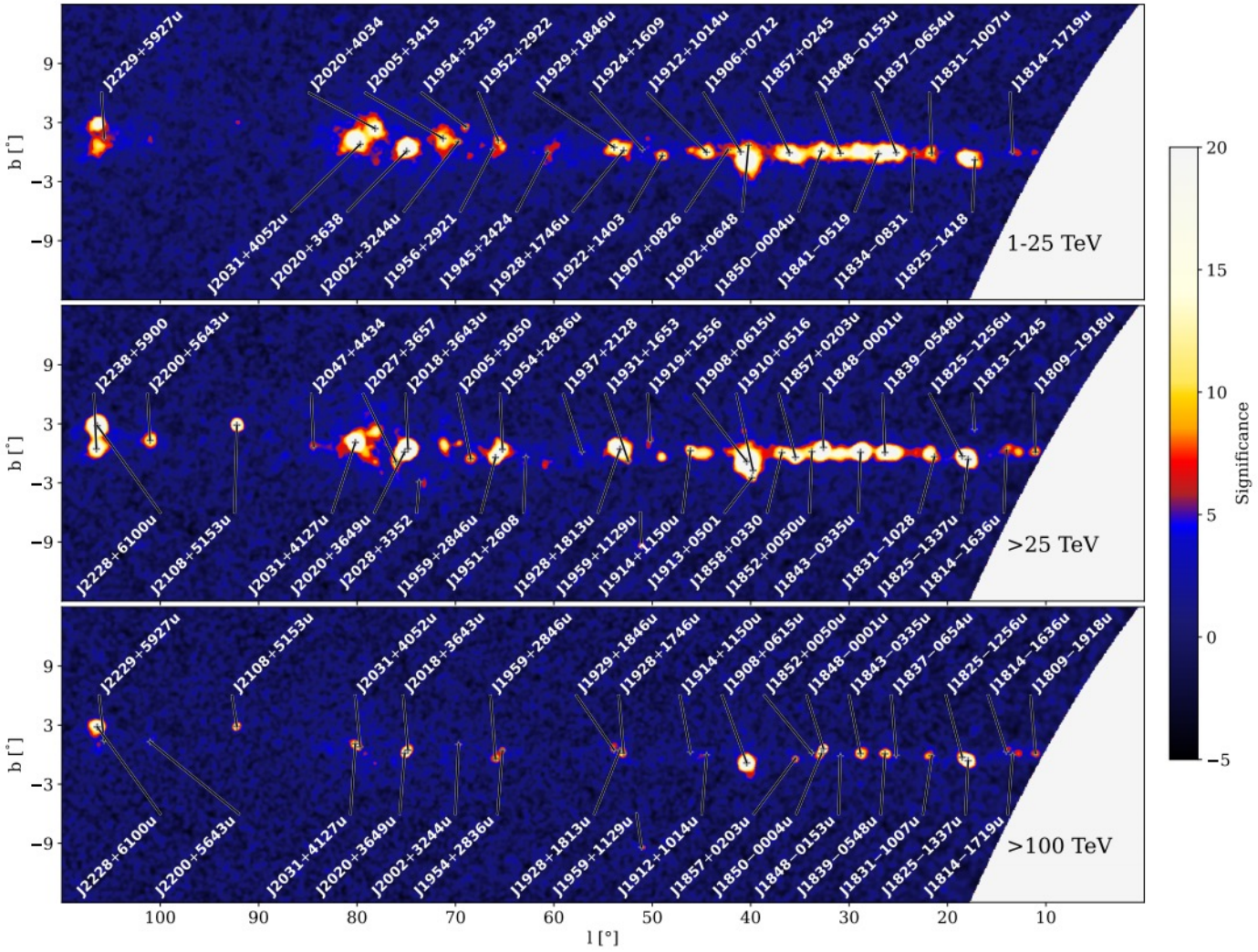
Albert et al. 2021



LHAASO Catalog

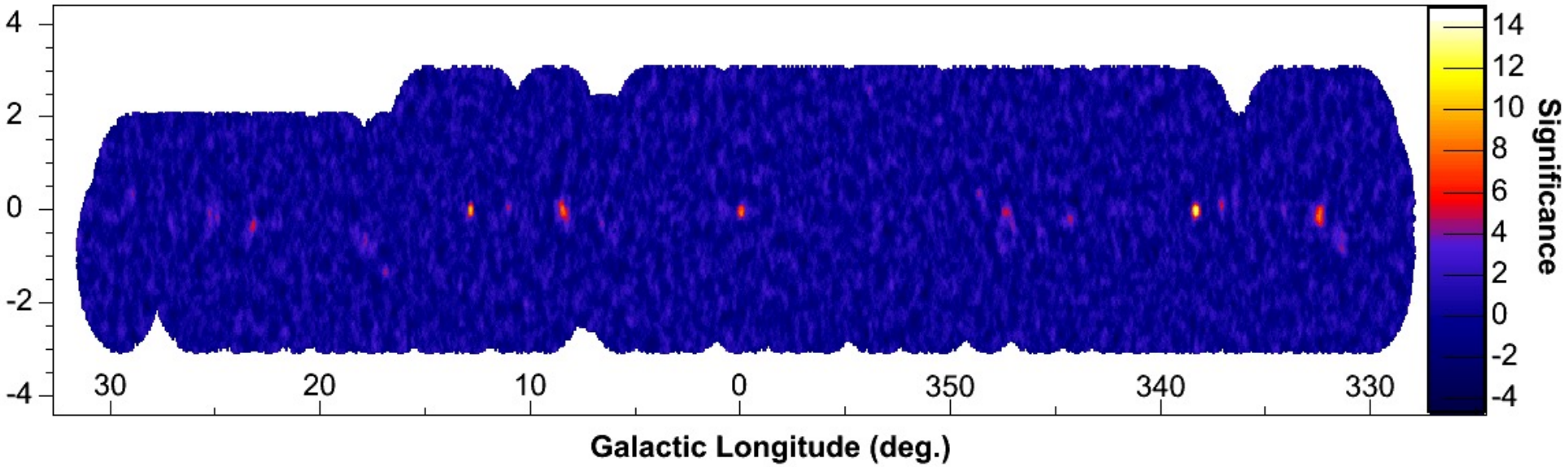
https://arxiv.org/pdf/2305.17030

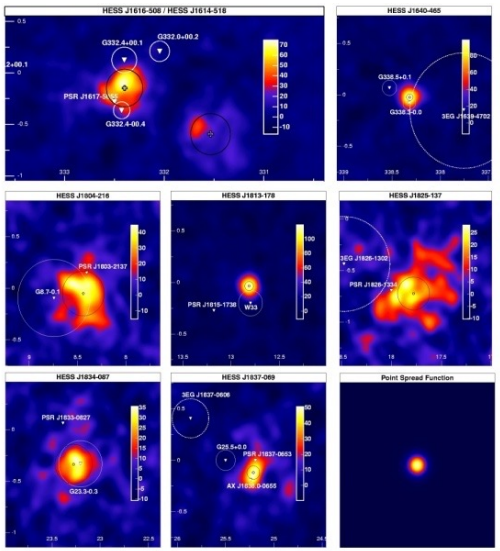
LHAASO Catalog



https://arxiv.org/pdf/2305.17030

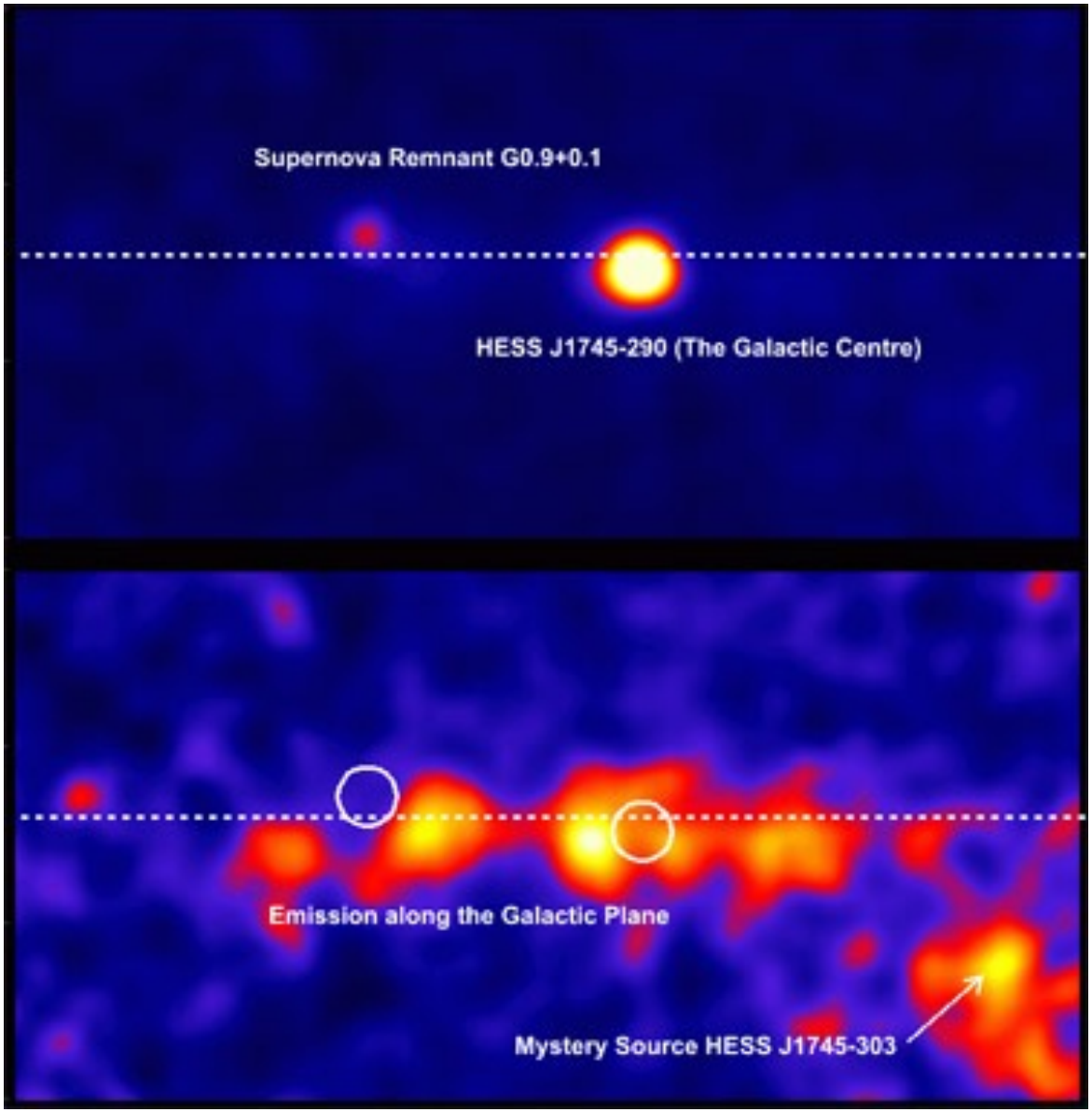
HESS “new” sources



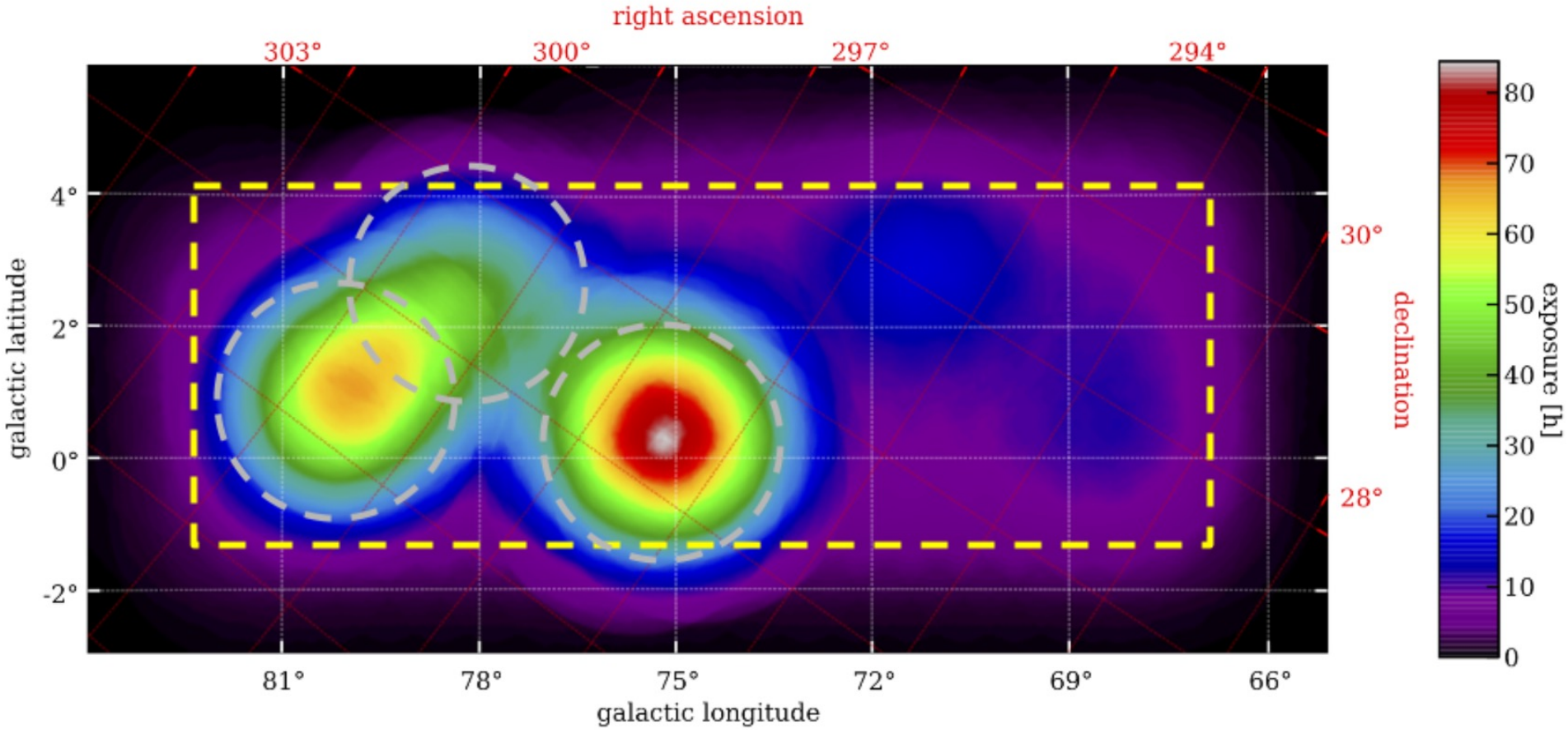


Close-up view of the new sources, discovered in the Galactic plane scan. Shown as white circles are close-by supernova remnants , that are known to be sources of very high energy gamma-rays (with the radius of the circle representing the size of the supernova remnant). Also shown in white are close-by pulsars, another class of sources of very high energy gamma-rays.

HESS Diffuse Gamma-Ray

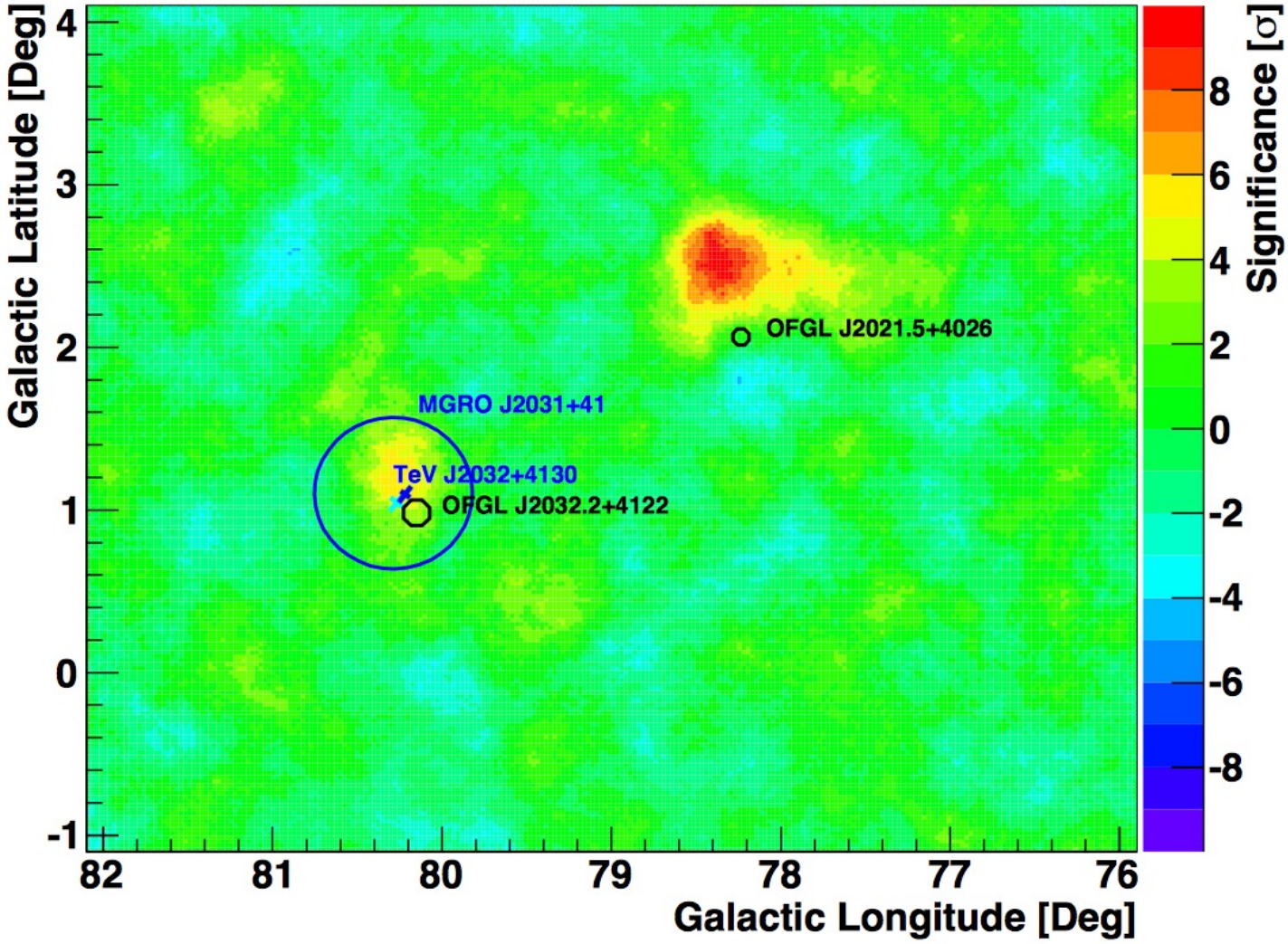


VERITAS Cygnus Survey



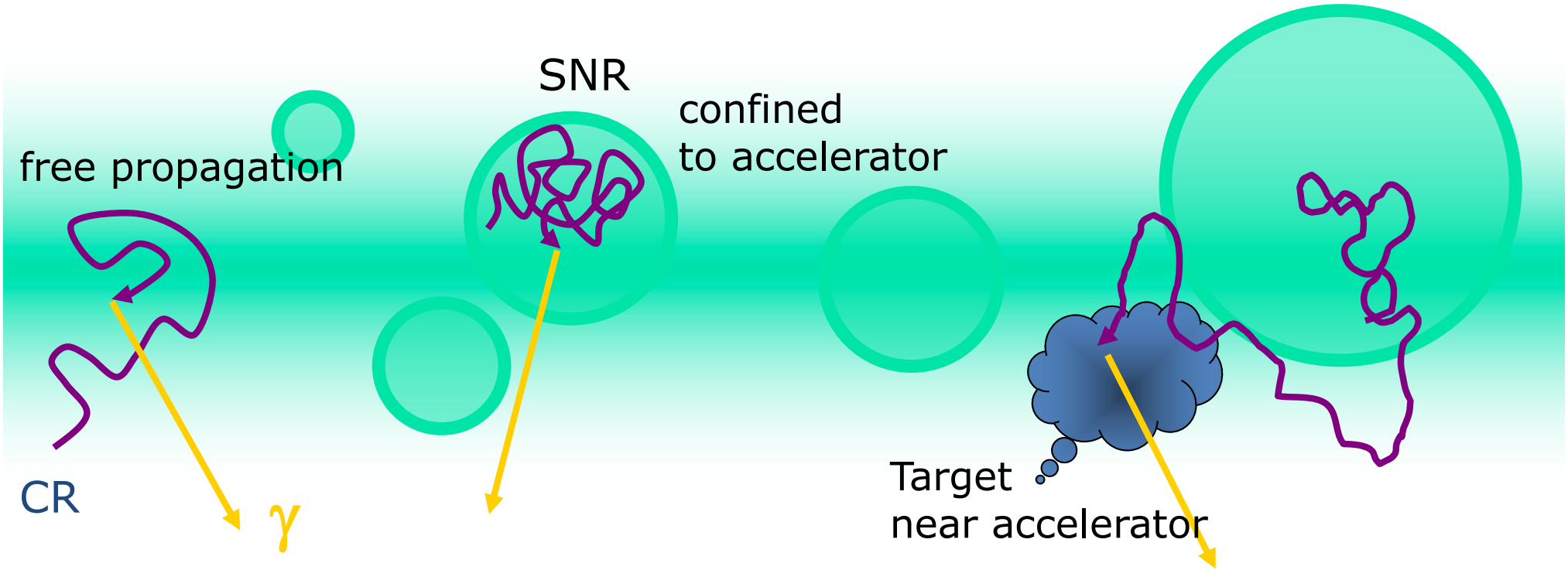
http://arxiv.org/abs/1508.06684

VERITAS Cygnus Survey



http://arxiv.org/abs/0912.4492

CR origin and propagation



VHE gamma rays from secondary interactions:

p: π^o production and decay

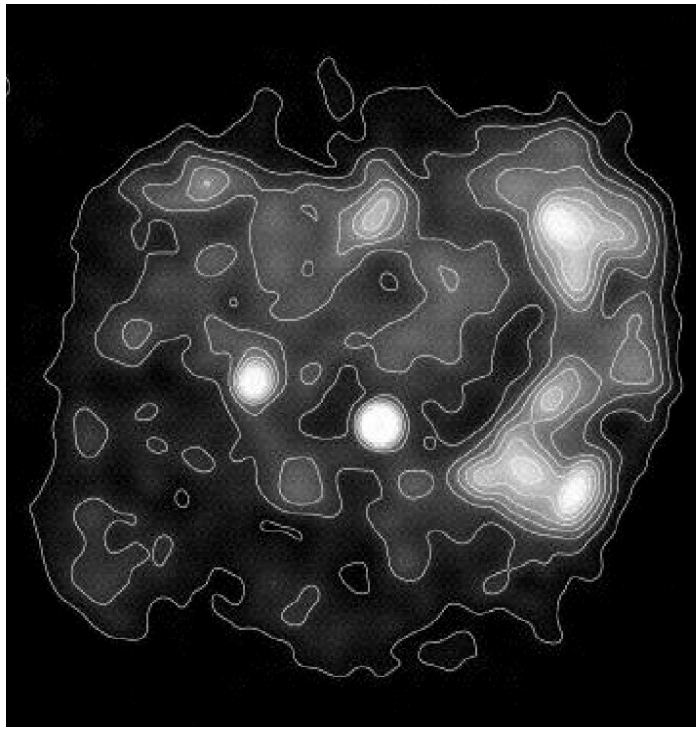
e: Inverse Compton scattering and Bremsstrahlung

Trace beam density x target density

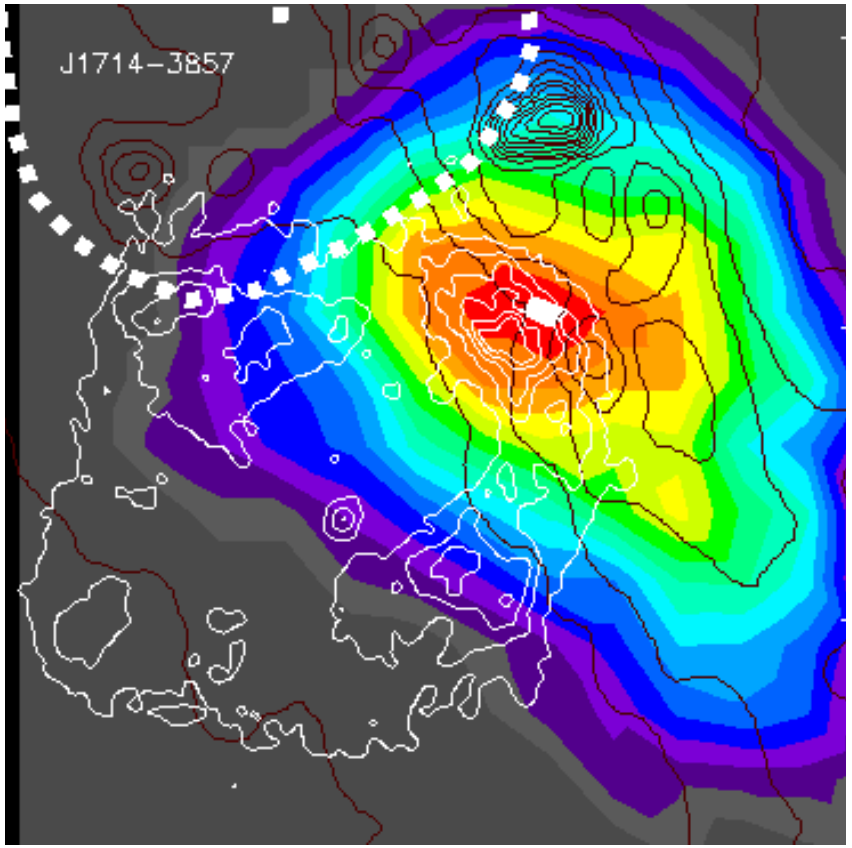
Astrofisica Nucleare e Subnucleare

VHE Galactic Sources

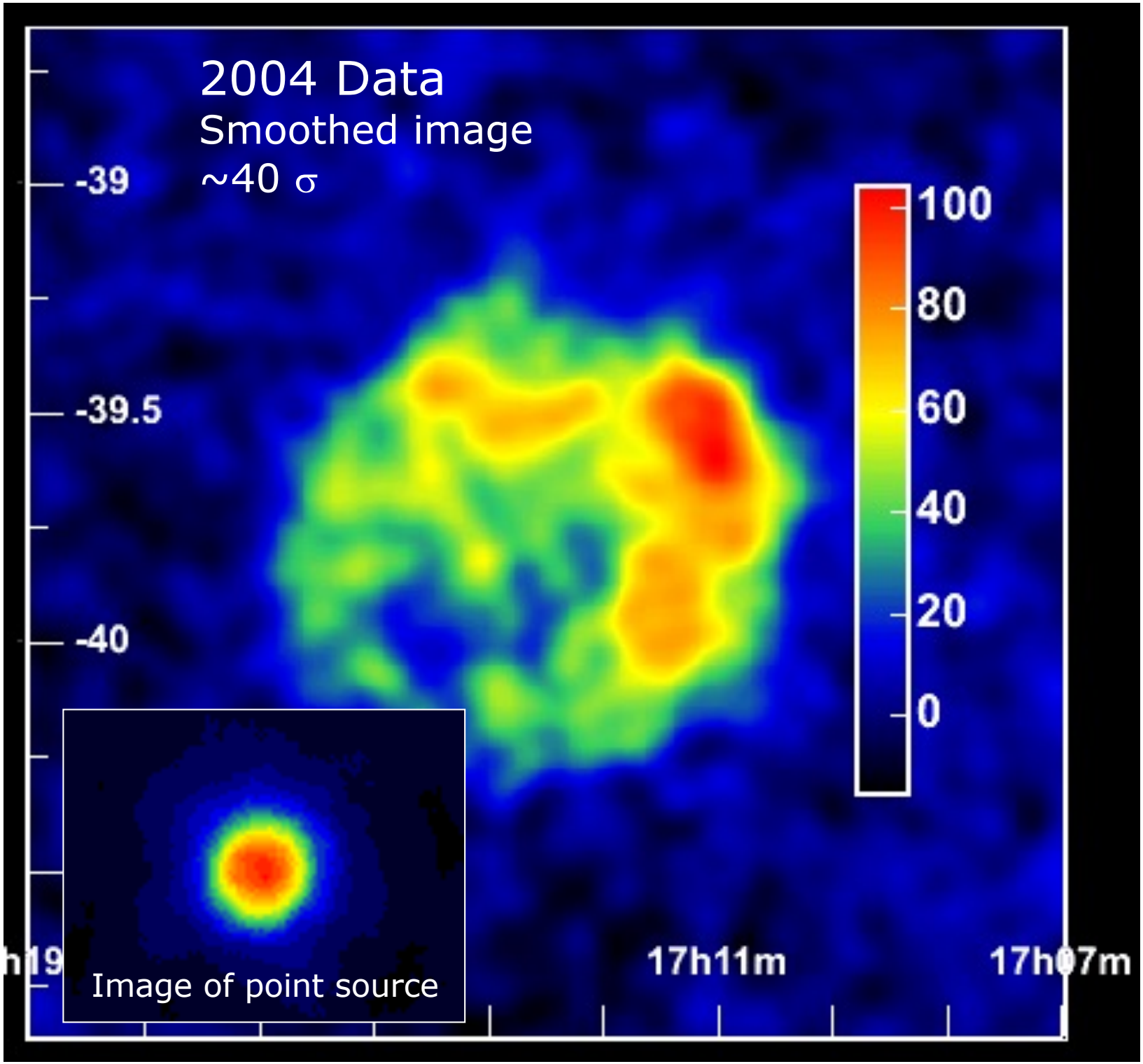
The supernova remnant G347.3-0.5 (RX J1713.7-3946)

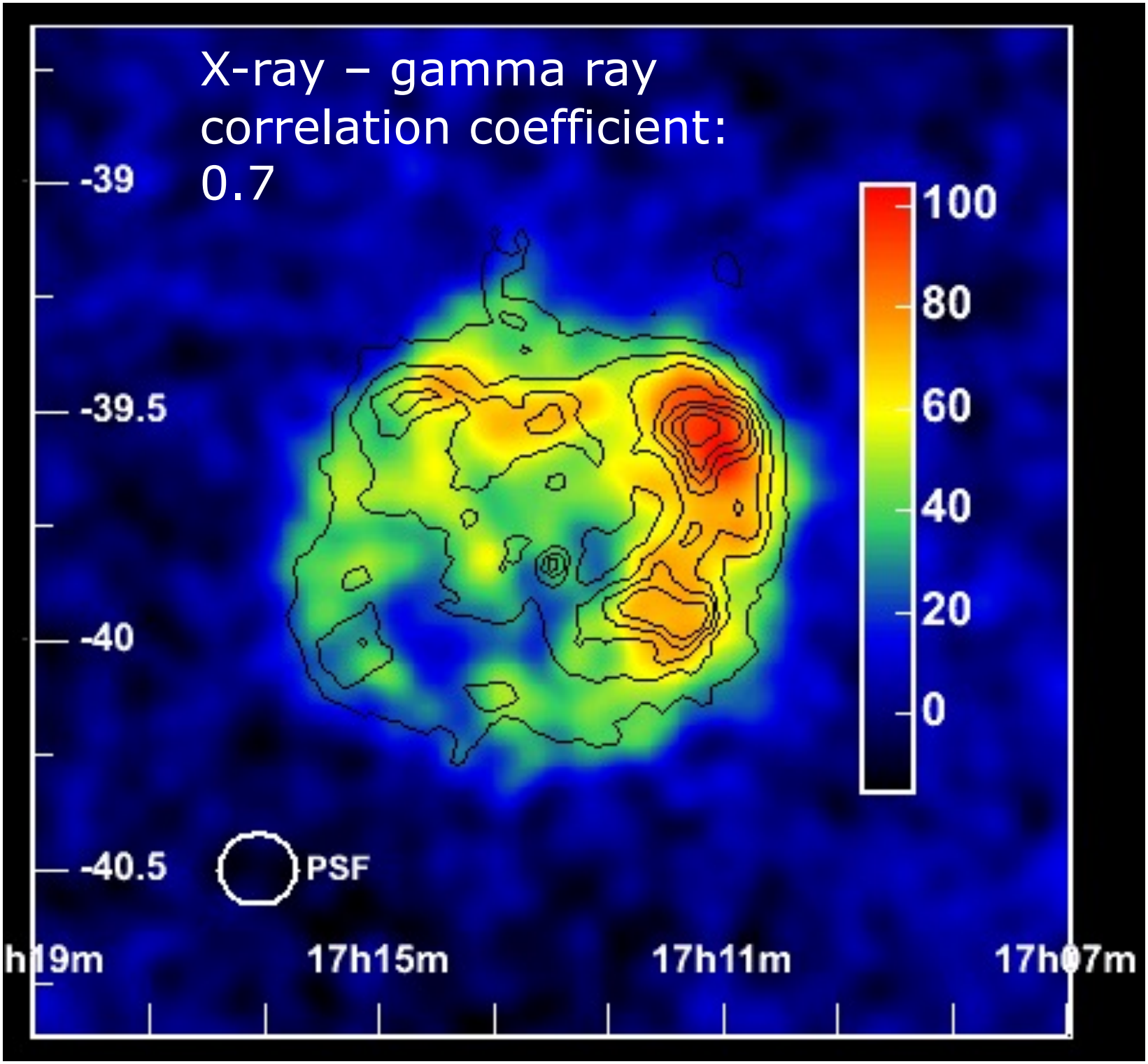


ROSAT
(keV)

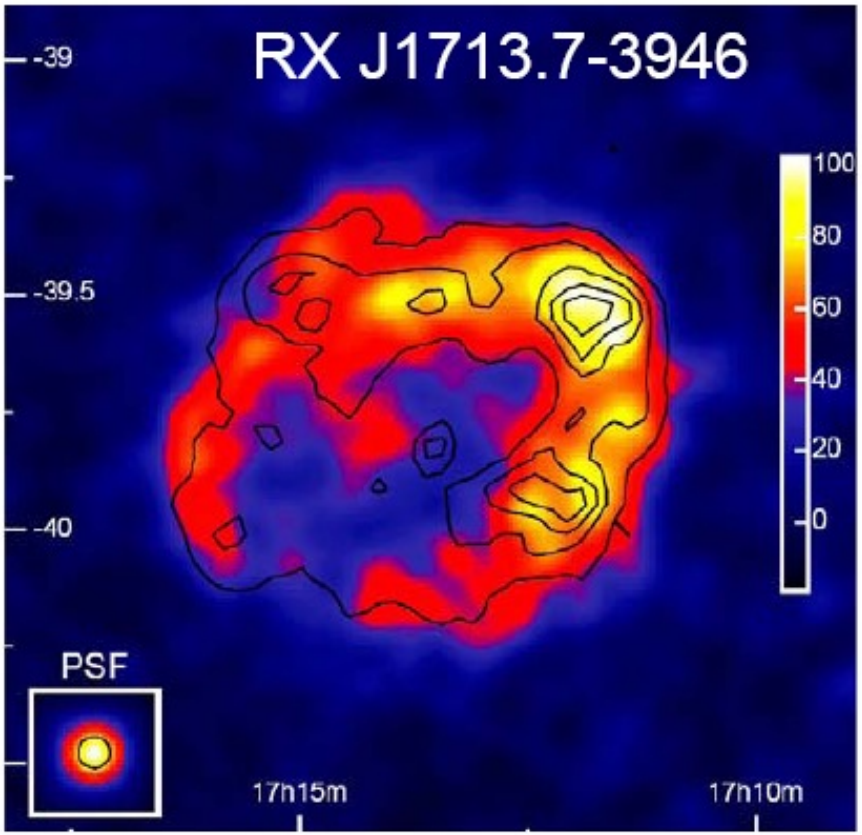


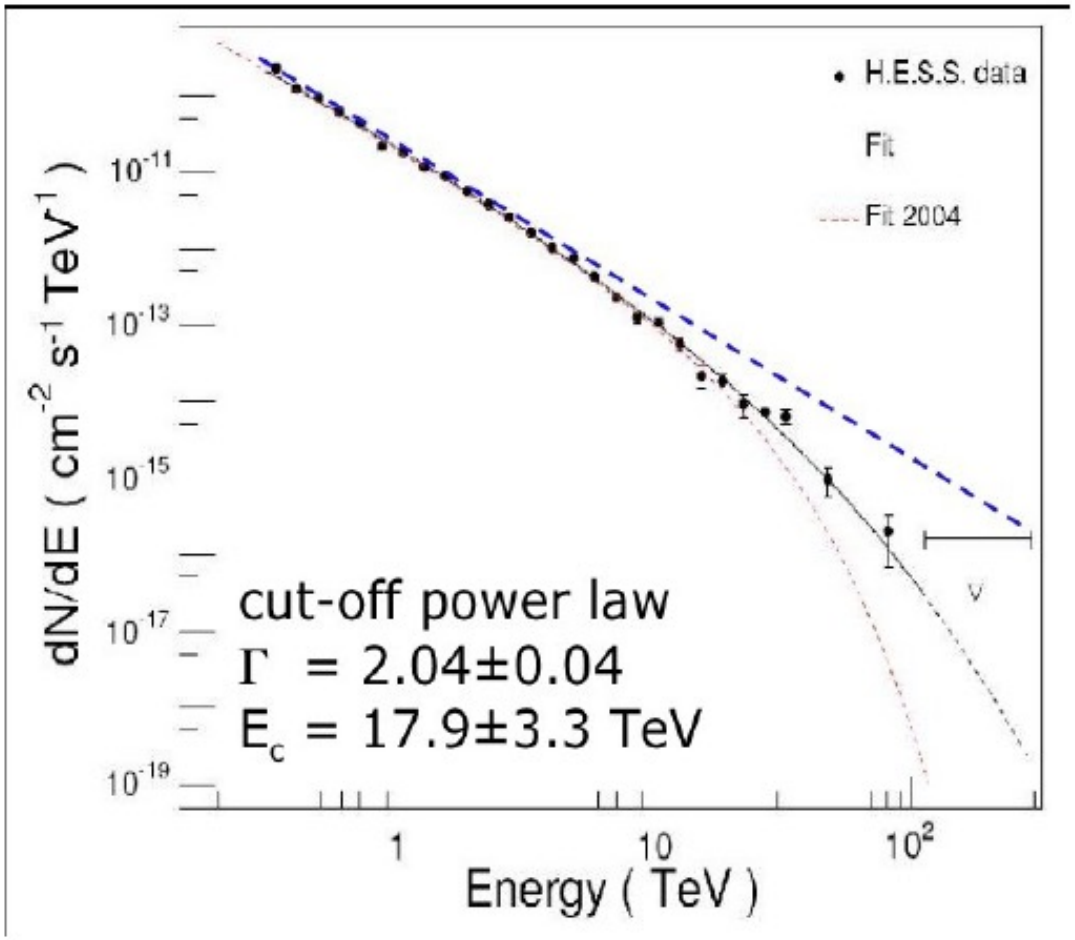
CANGAROO
(TeV)


2004 Data
Smoothed image
~40 σ
-39
-39.5
-40
100
80
60
40
20
0
17h11m
17h07m
Image of point source

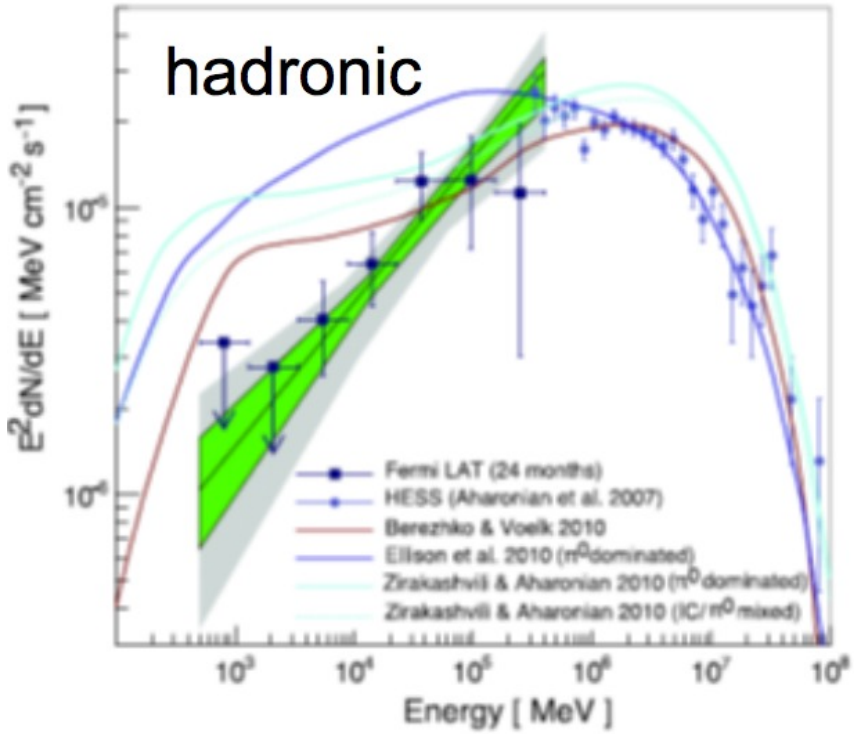

X-ray – gamma ray
correlation coefficient:
0.7
-39
-39.5
-40
-40.5
PSF
100
80
60
40
20
0
h19m
17h15m
17h11m
17h07m

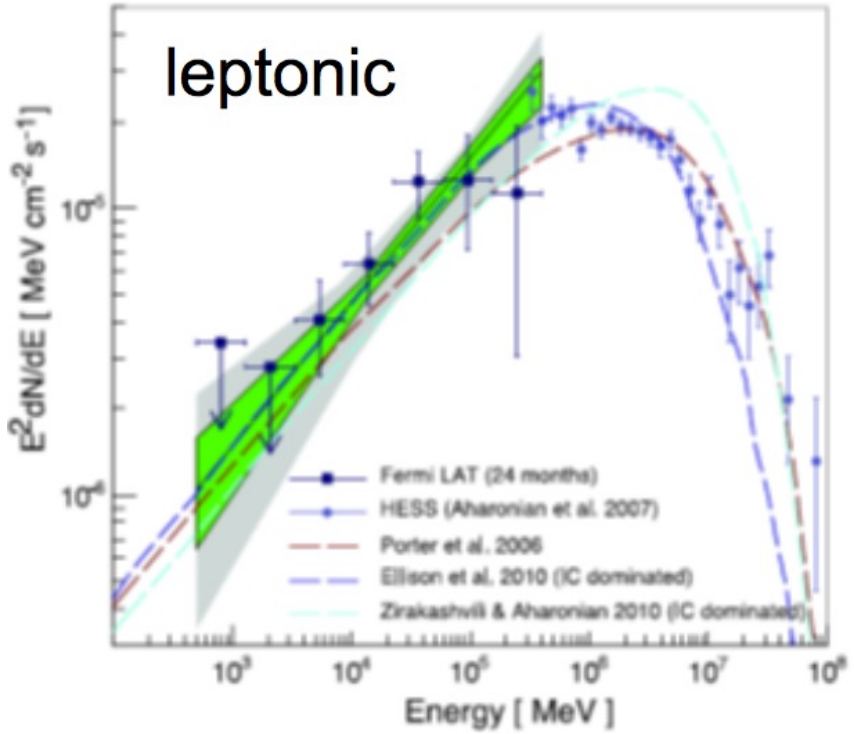
HESS – SNR in VHE gamma





Aharonian et al. 2004





Fermi LAT results on RX J1713.7-3946 (Abdo et al. 2011)

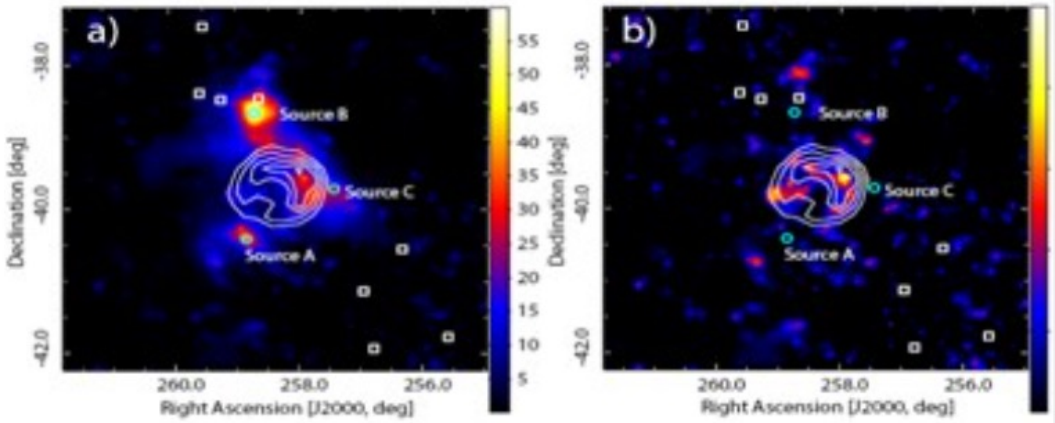
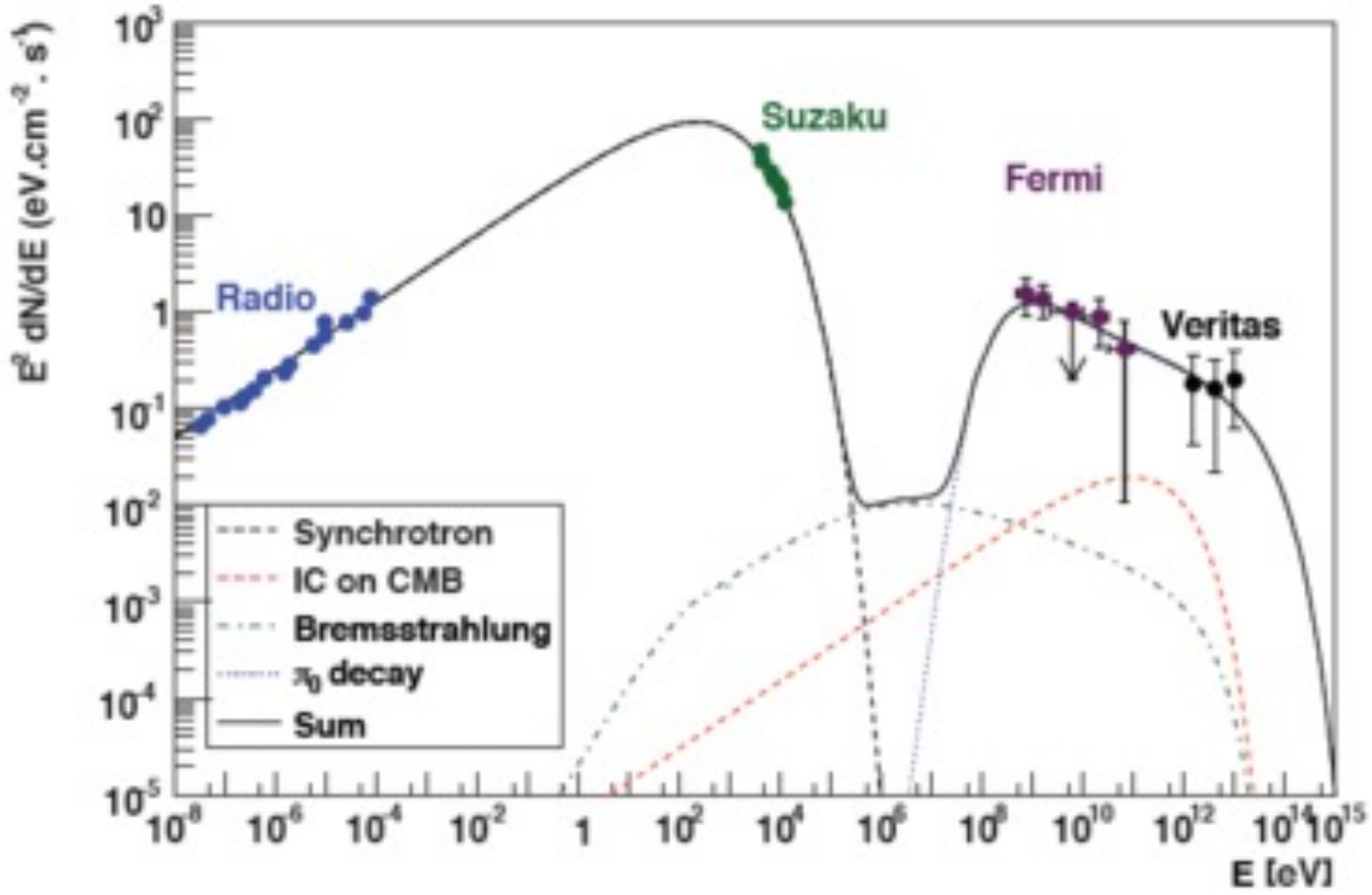


Fig. 1.— **Panel (a):** Map of the test statistic (TS) for a point source in the region around RX J1713.7−3946 obtained in a maximum likelihood fit accounting for the background diffuse emission and 1FGL catalog sources. Only events above 500 MeV have been used in this analysis. H.E.S.S. TeV emission contours are shown in white (Aharonian et al. 2007). Rectangles indicate the positions of 1FGL sources in our background model, Several TS peaks outside the SNR shell are visible. The 3 peaks marked by circles are added as additional sources to our background model (see text). **Panel (b):** Same map as panel (a), but with the 3 additional sources now considered in the background model.

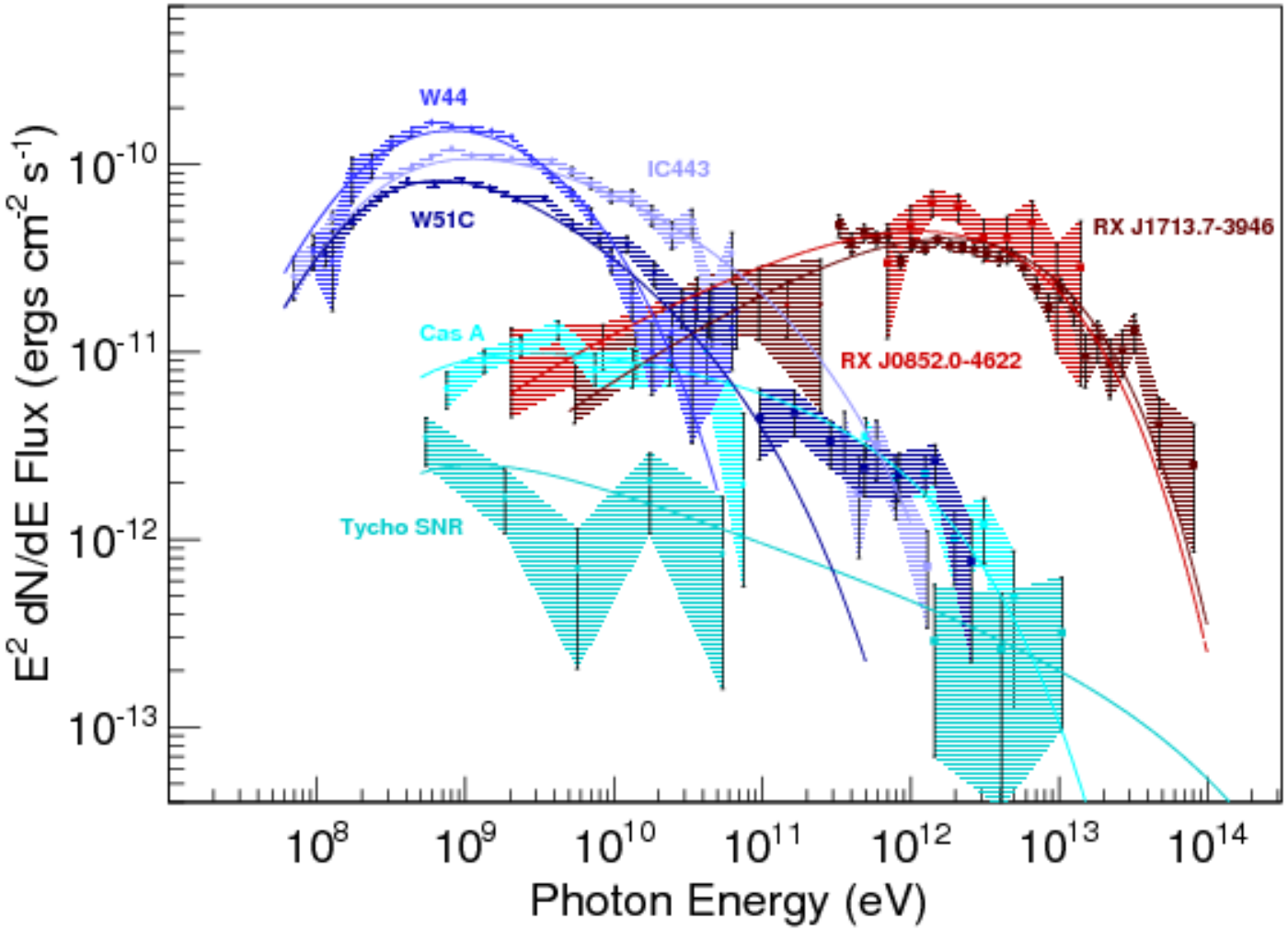
Although the leptonic model is preferable, the hadronic model is not excluded because of the possible energy dependent CR penetration in to the clouds. The main problem of the hadronic model is the absence of thermal X-rays.

… but Tycho ..



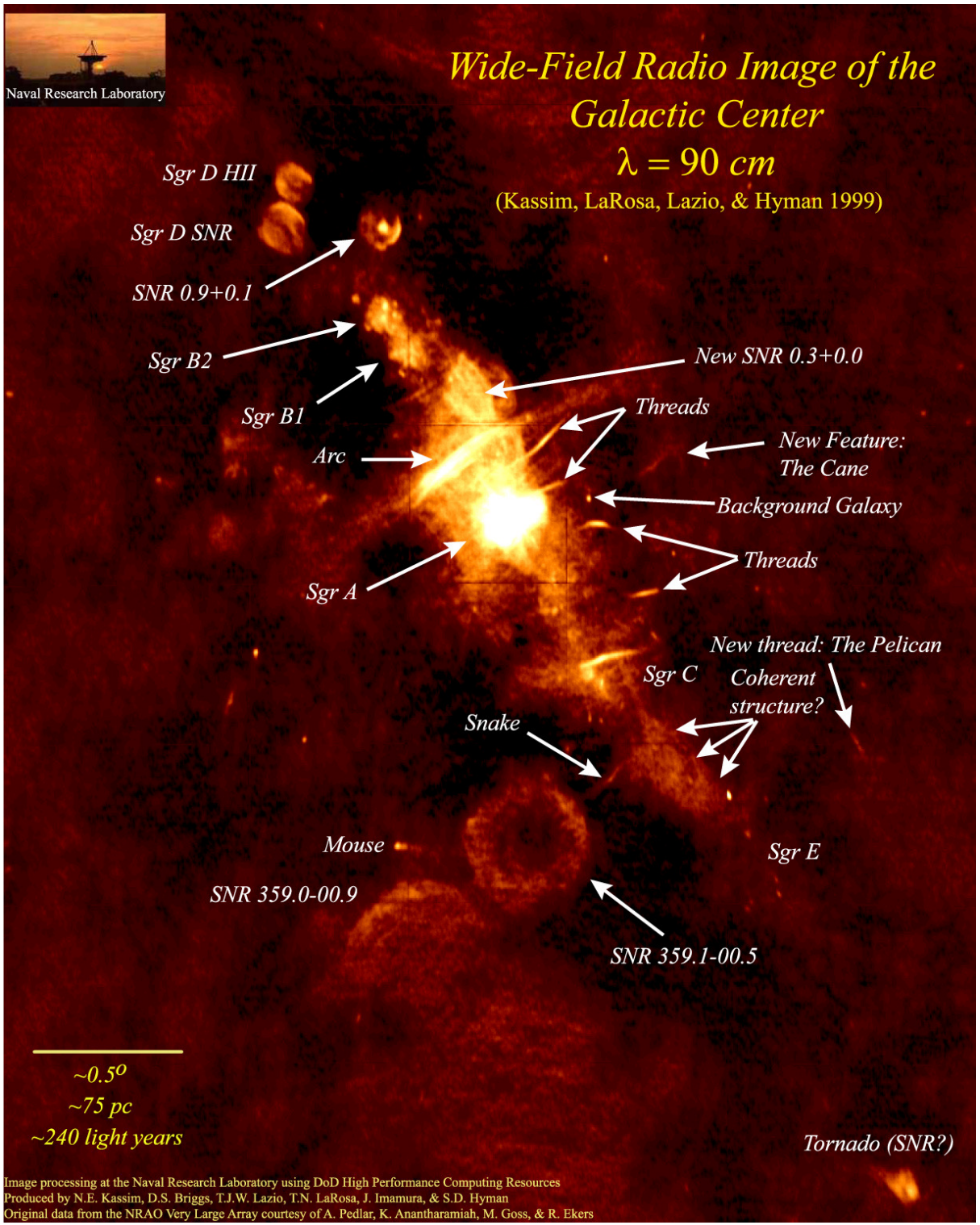
https://arxiv.org/abs/1108.0265

SNR age

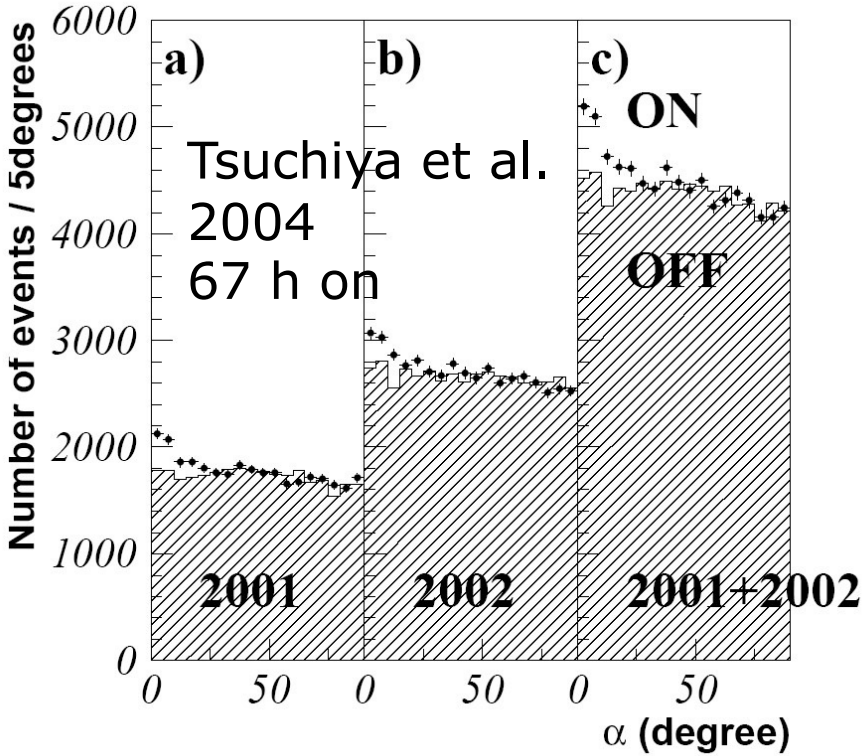


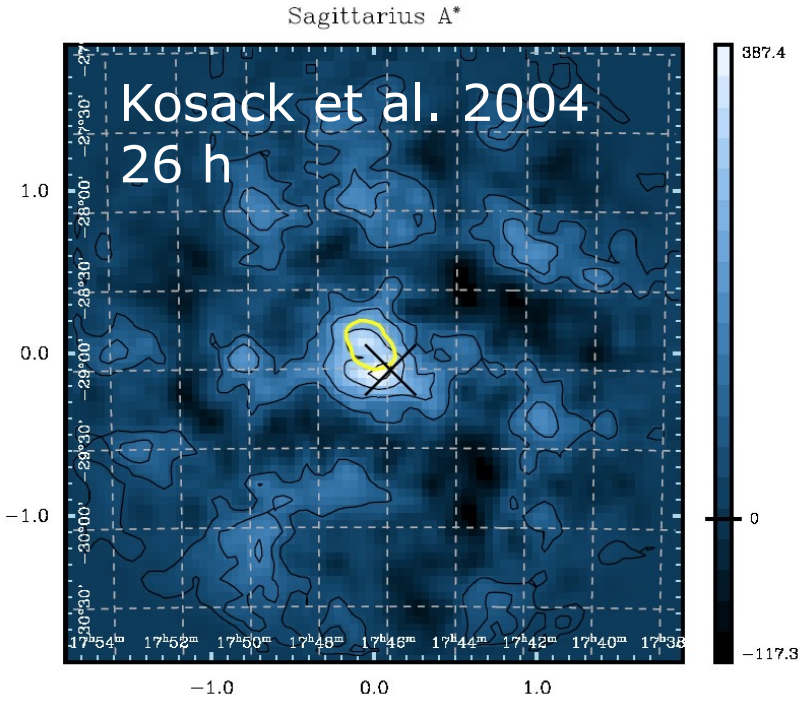
arXiv:1508.05190

The Galactic center



TeV gamma rays from GC





CANGAROO
2001/2002
> 10 σ

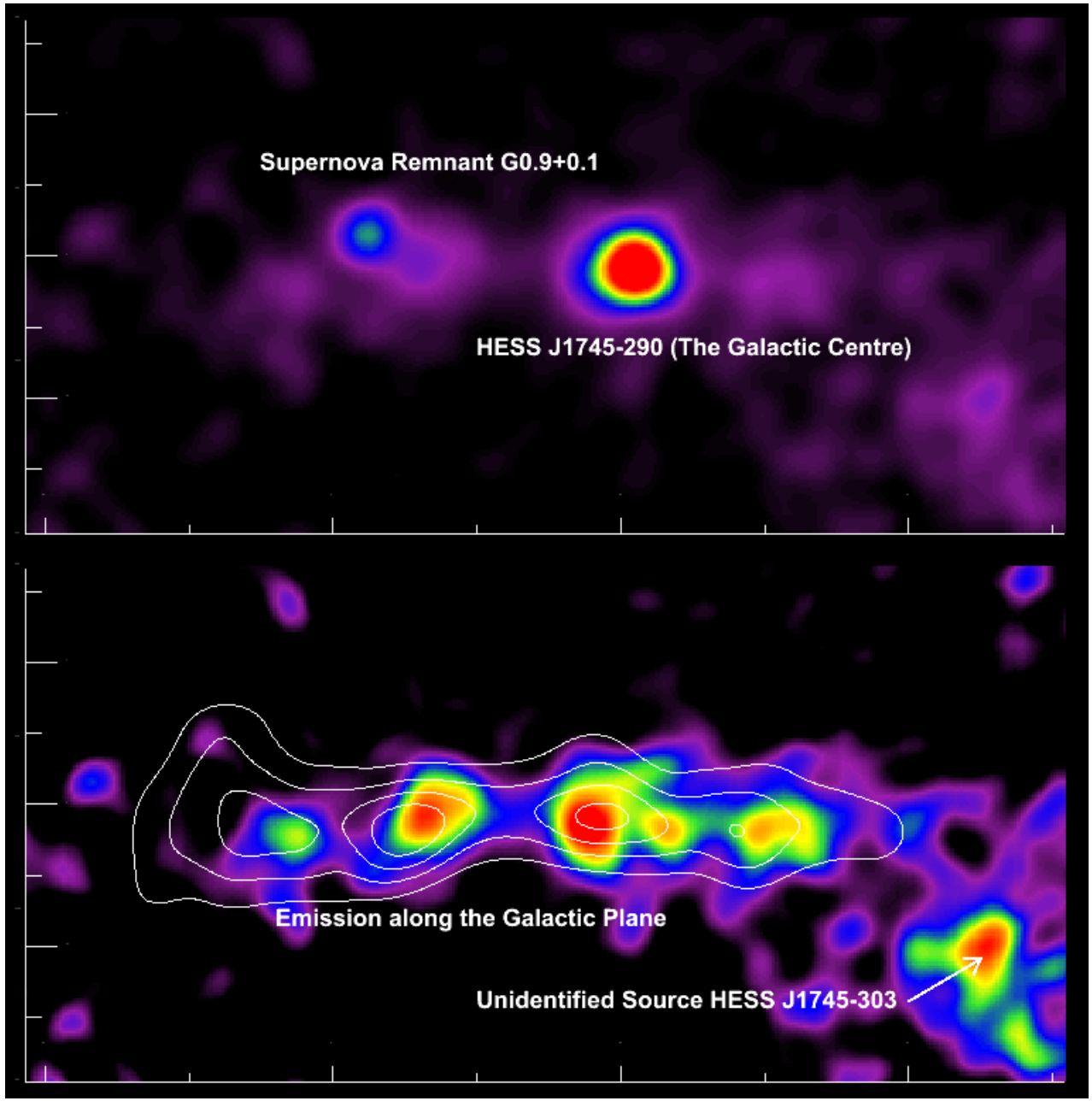
Whipple
1995 – 2003
3.7 σ

Point source (on 0.3° resolution scale)

Galactic Center

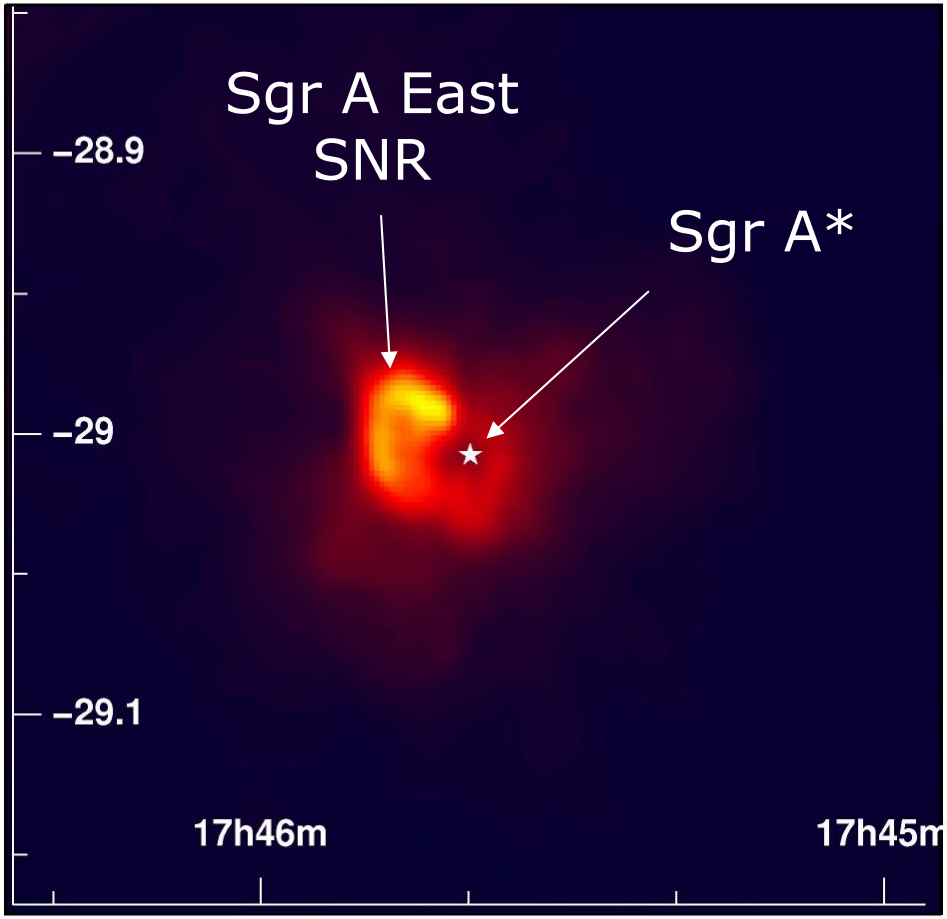
Sgr A

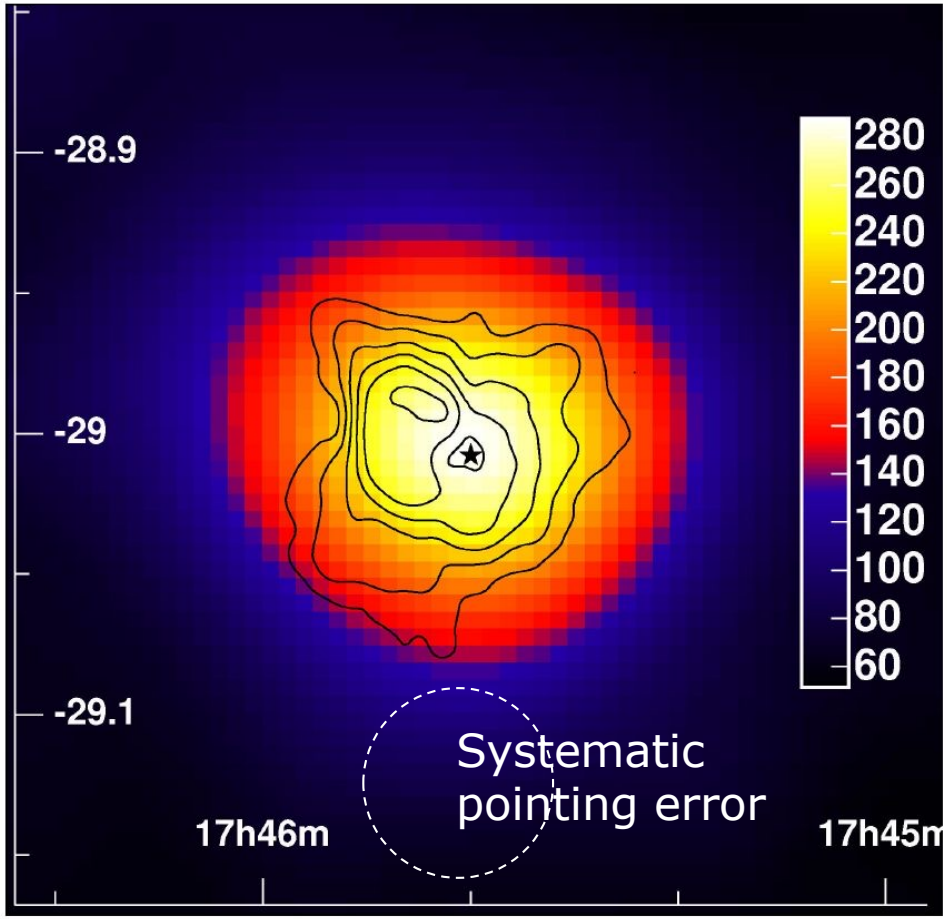
Diffuse emission



Nature, Feb. 9th 2006

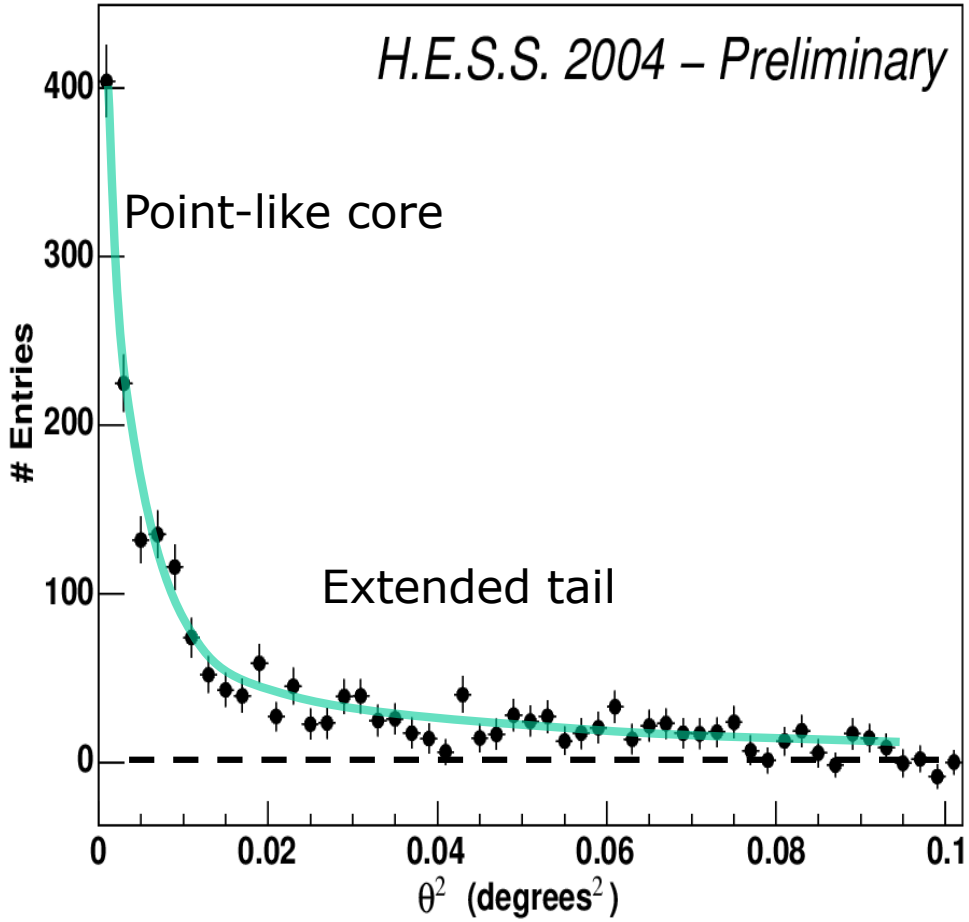
Sagittarius A

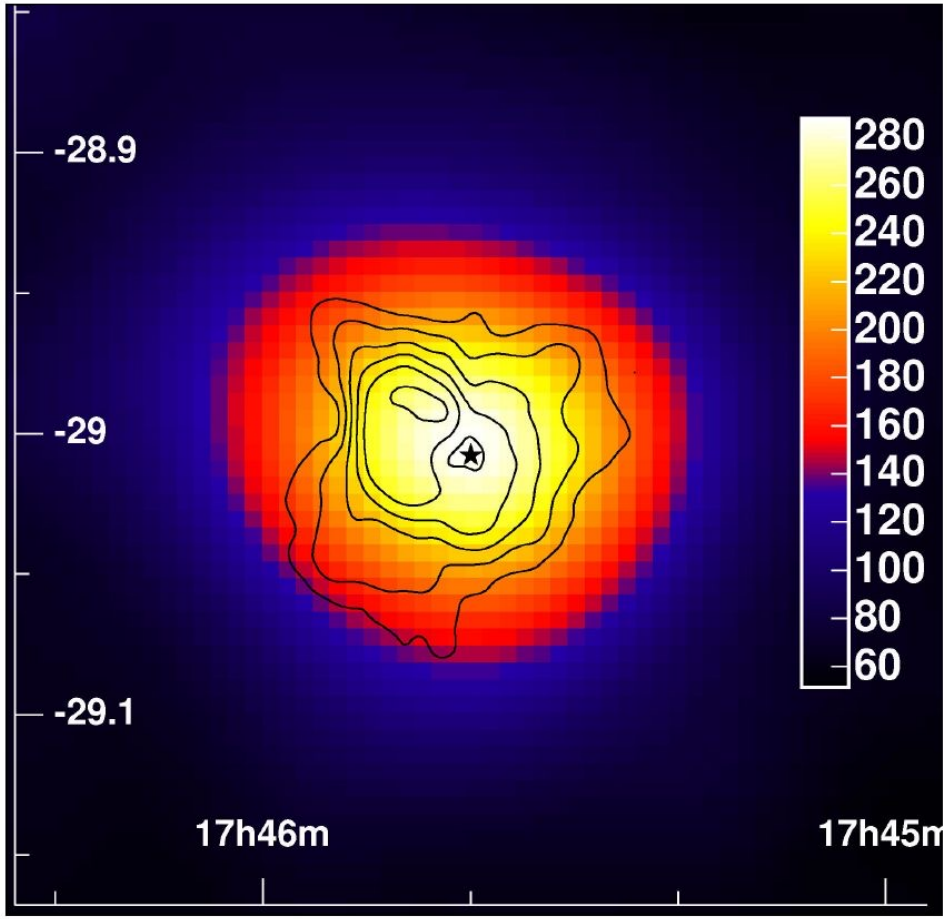




TeV H.E.S.S.

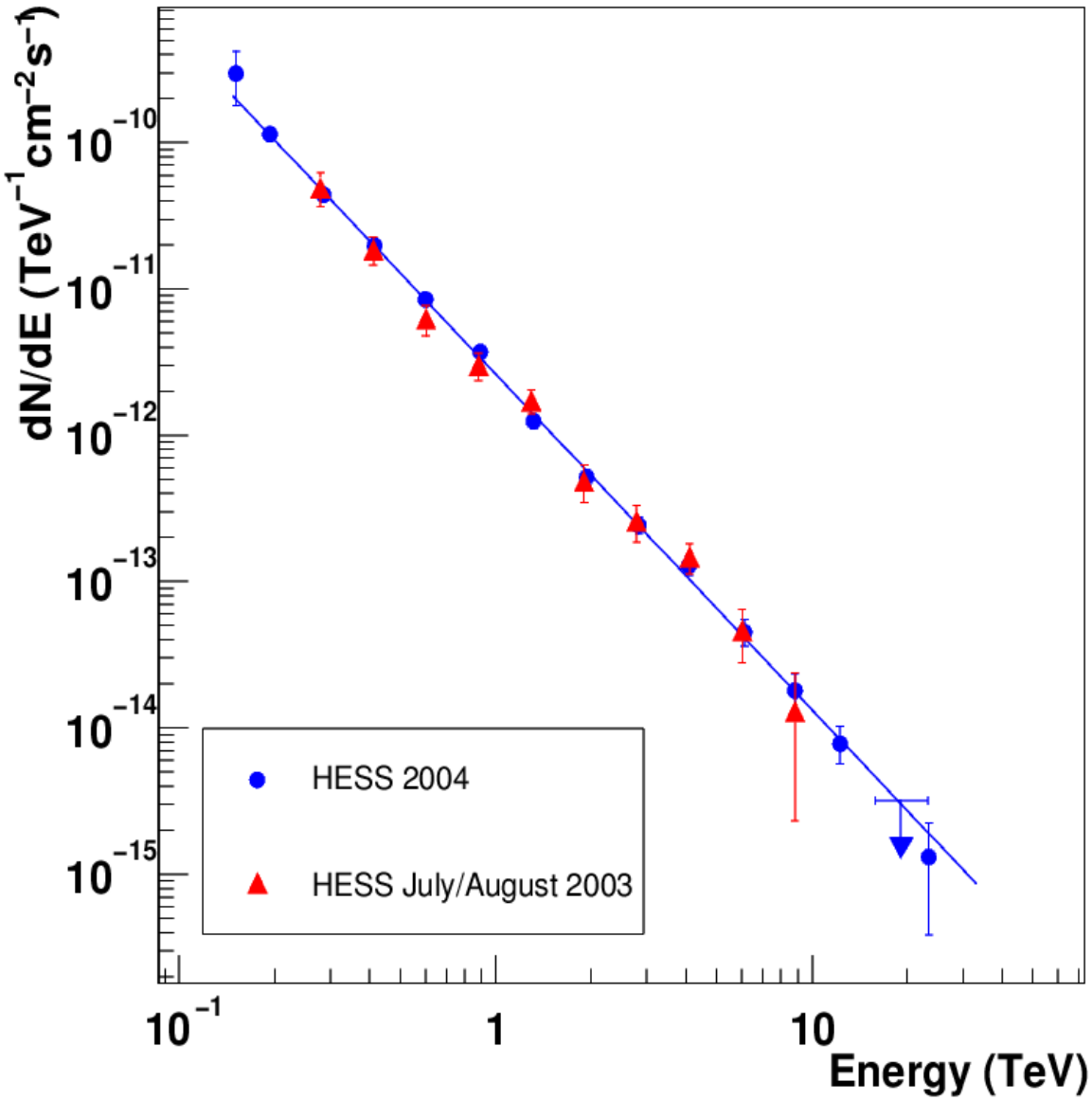
Sagittarius A





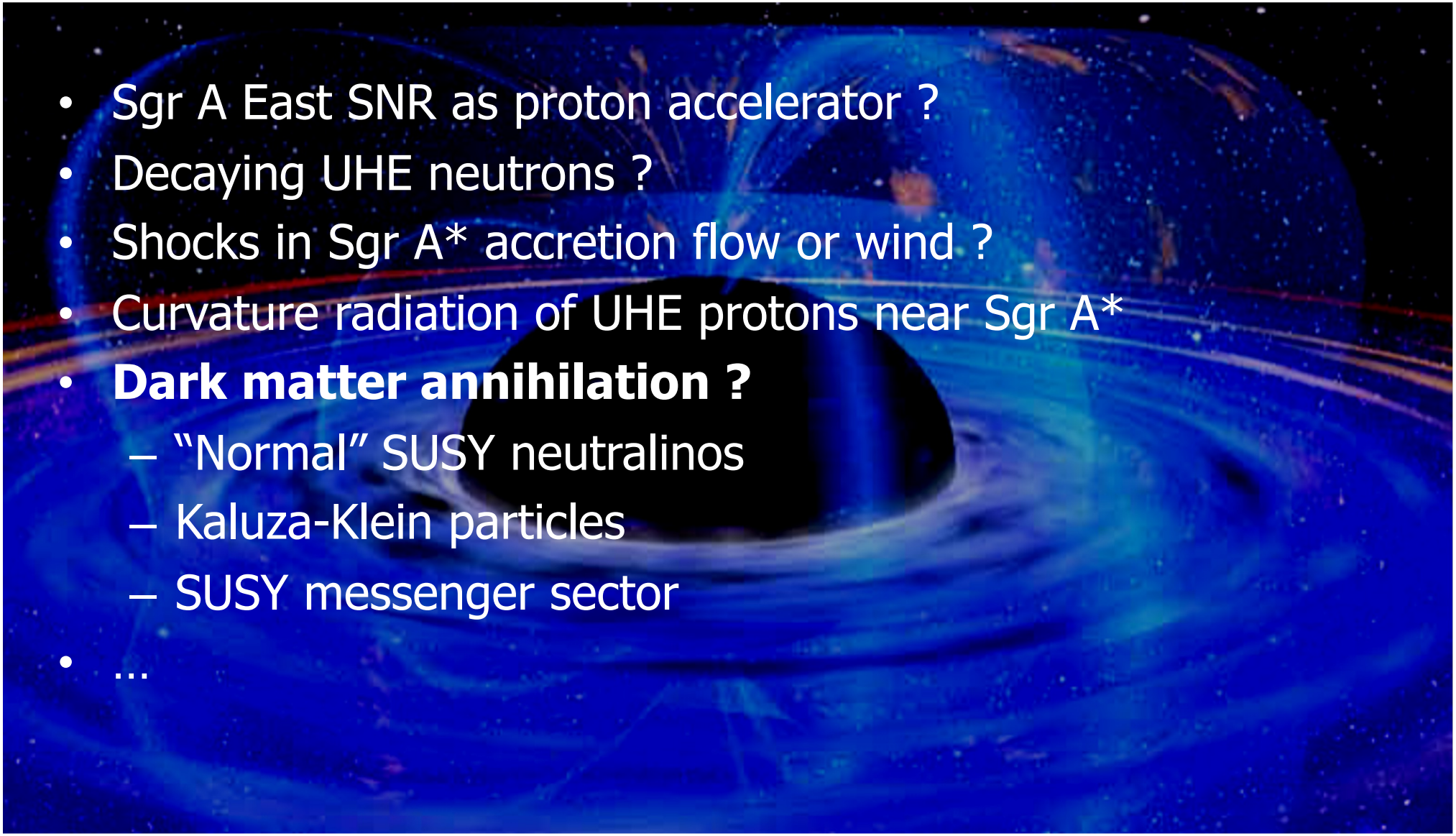
TeV H.E.S.S.

Gamma ray spectrum



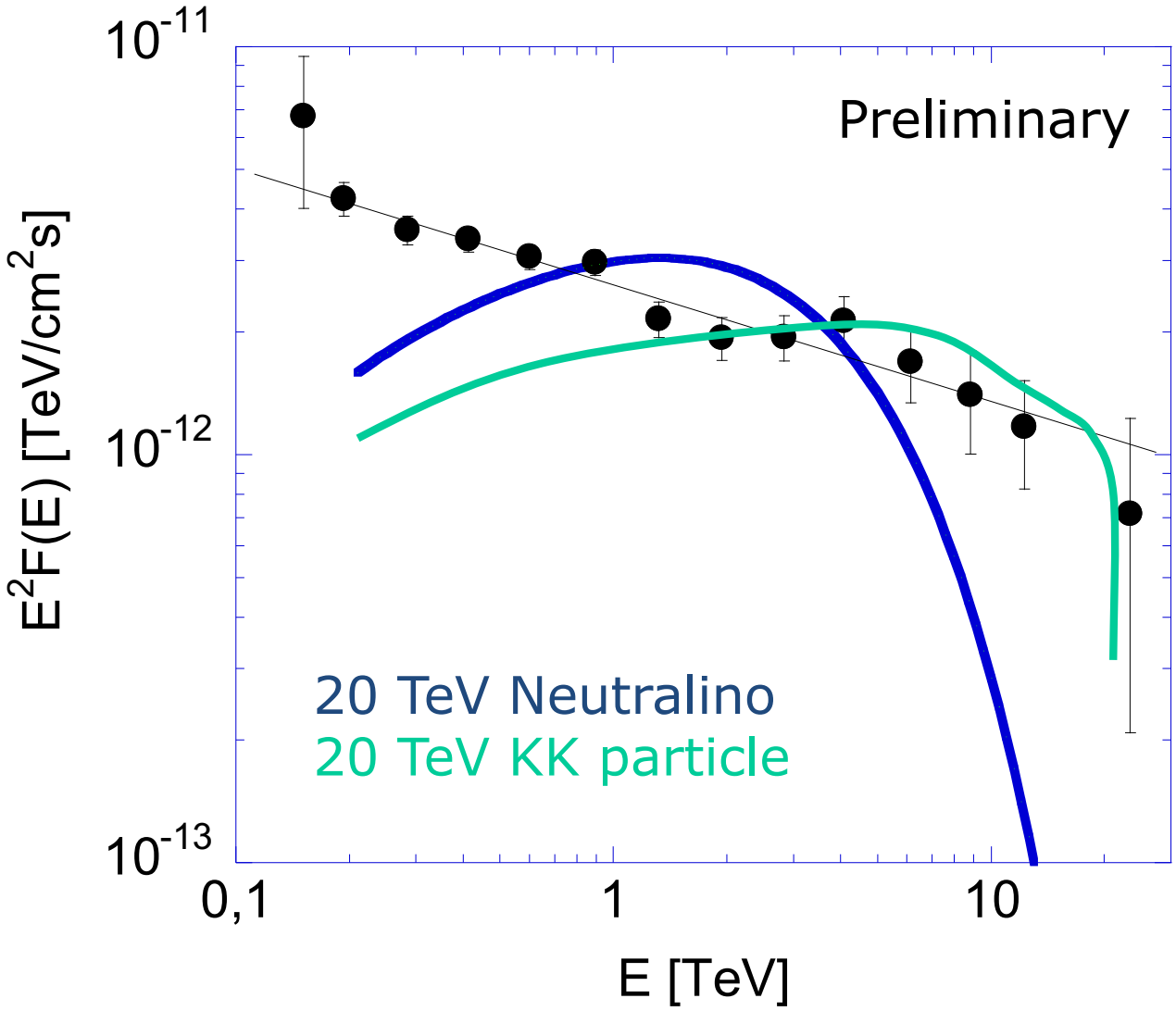
- Power law, index 2.3
- No significant variability
  - on year scale
  - on month scale
  - on day scale
  - on hour scale
  - on minute scale

Origin ?



- Sgr A East SNR as proton accelerator ?
- Decaying UHE neutrons ?
- Shocks in Sgr A* accretion flow or wind ?
- Curvature radiation of UHE protons near Sgr A*
- **Dark matter annihilation ?**
  - "Normal" SUSY neutralinos
  - Kaluza-Klein particles
  - SUSY messenger sector
- …

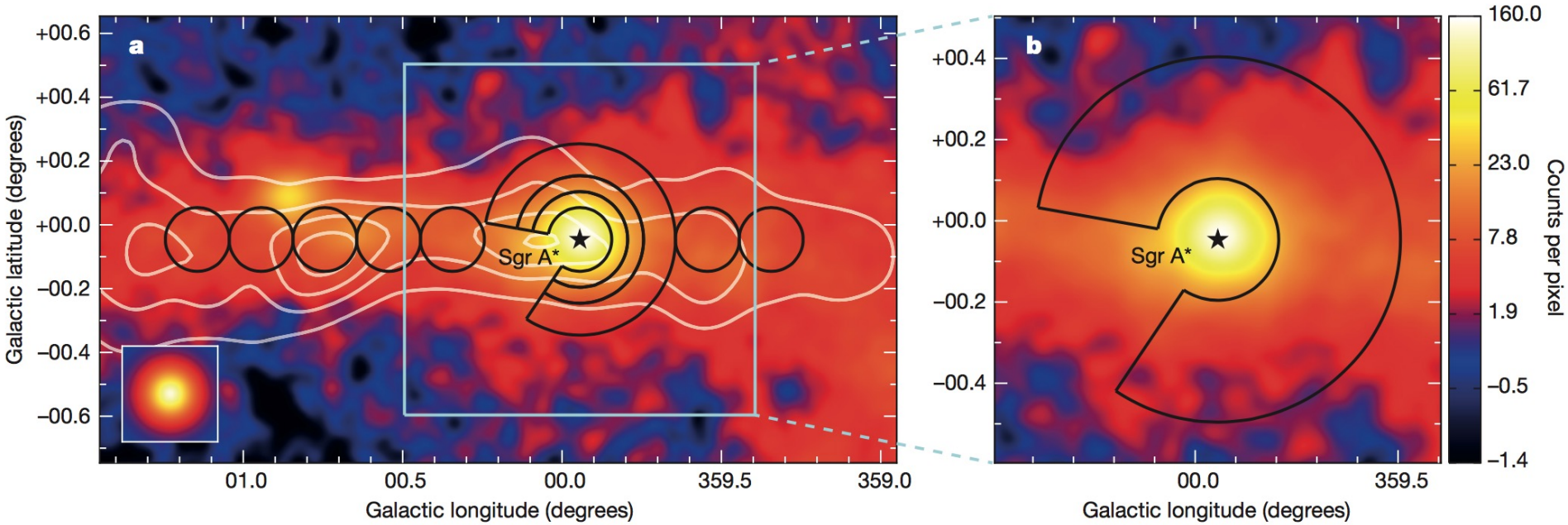
Dark matter annihilation ?



For pure DM origin

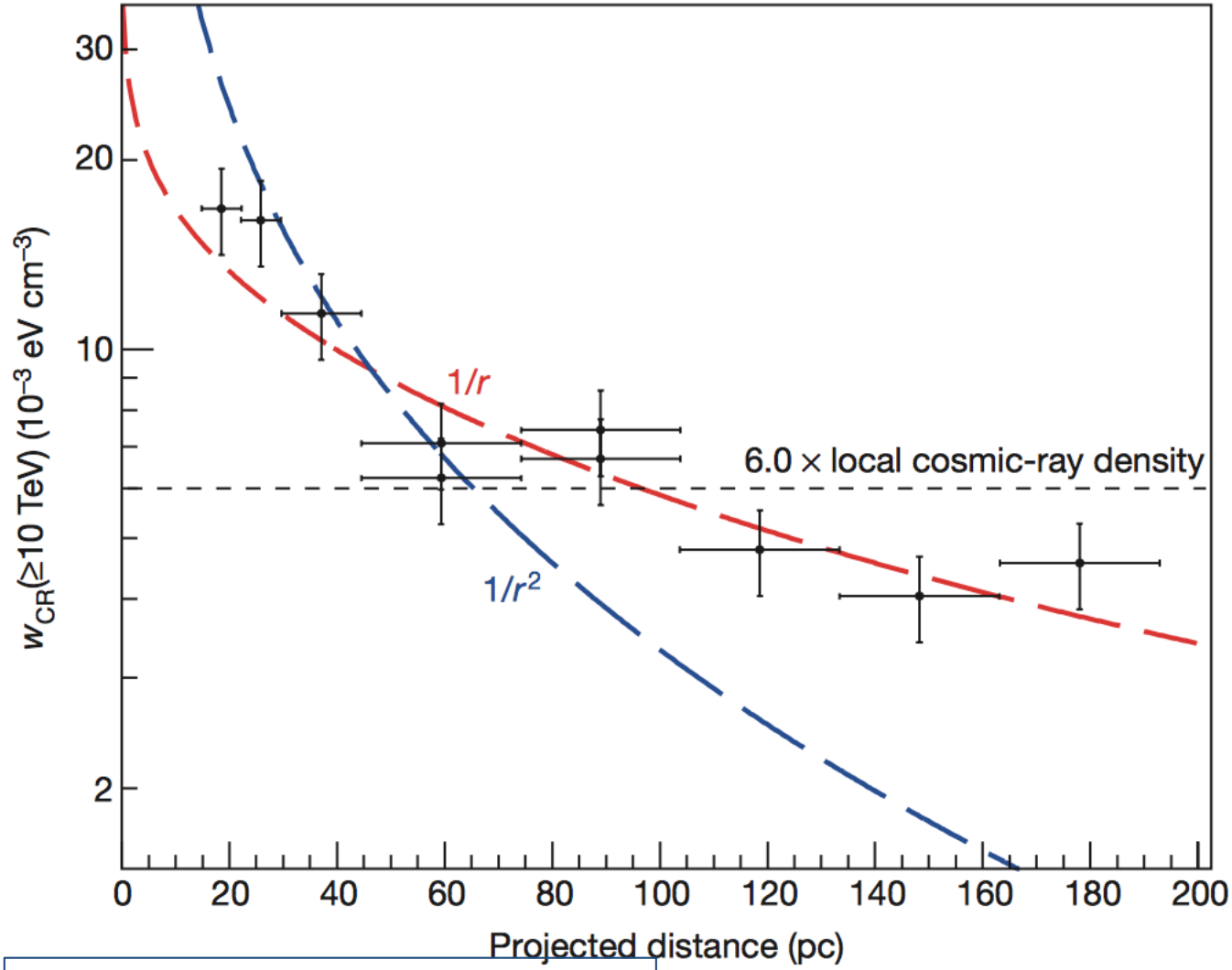
- rather large mass
- large x-section or density
- unusual spectrum or superposition of spectra

The “Pevatron”



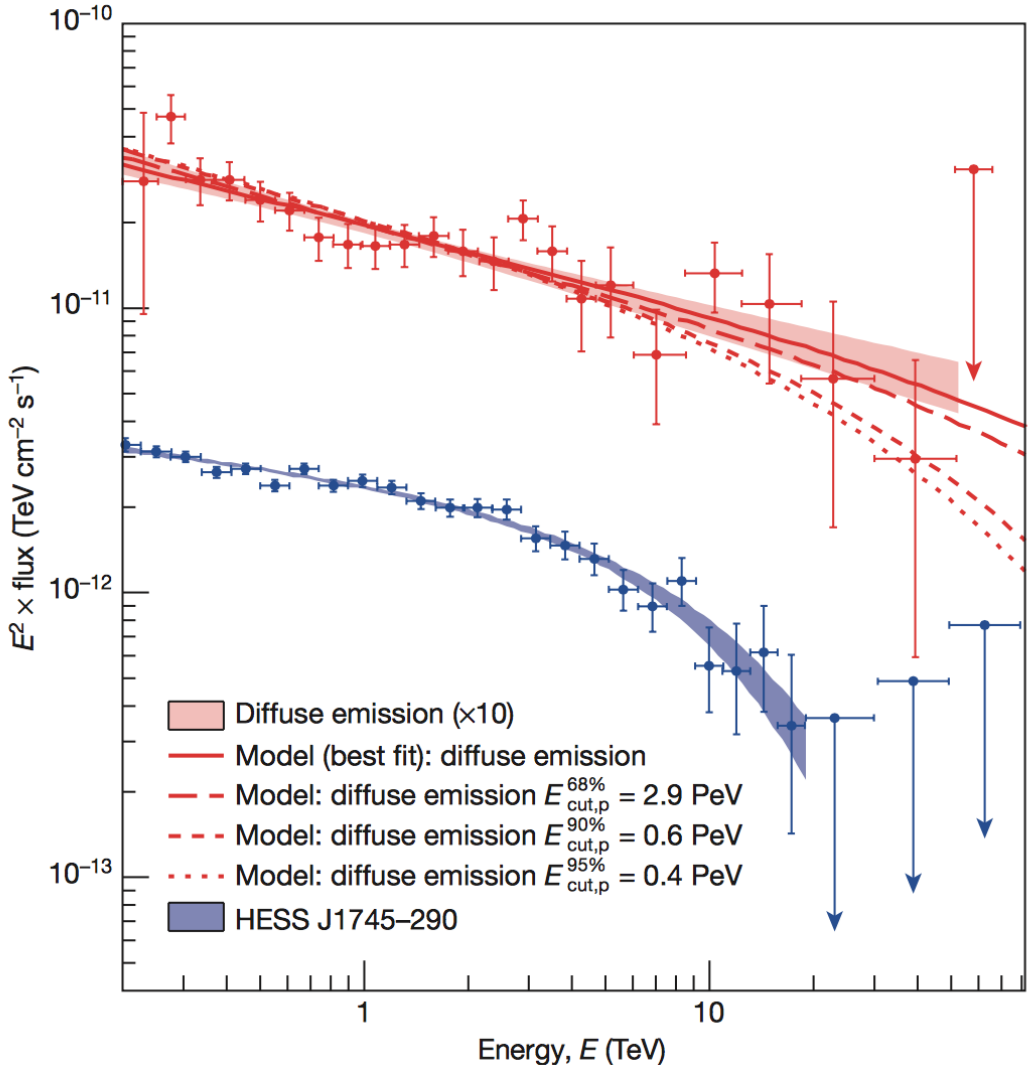
Abramovski et al. (2016)

The “Pevatron”



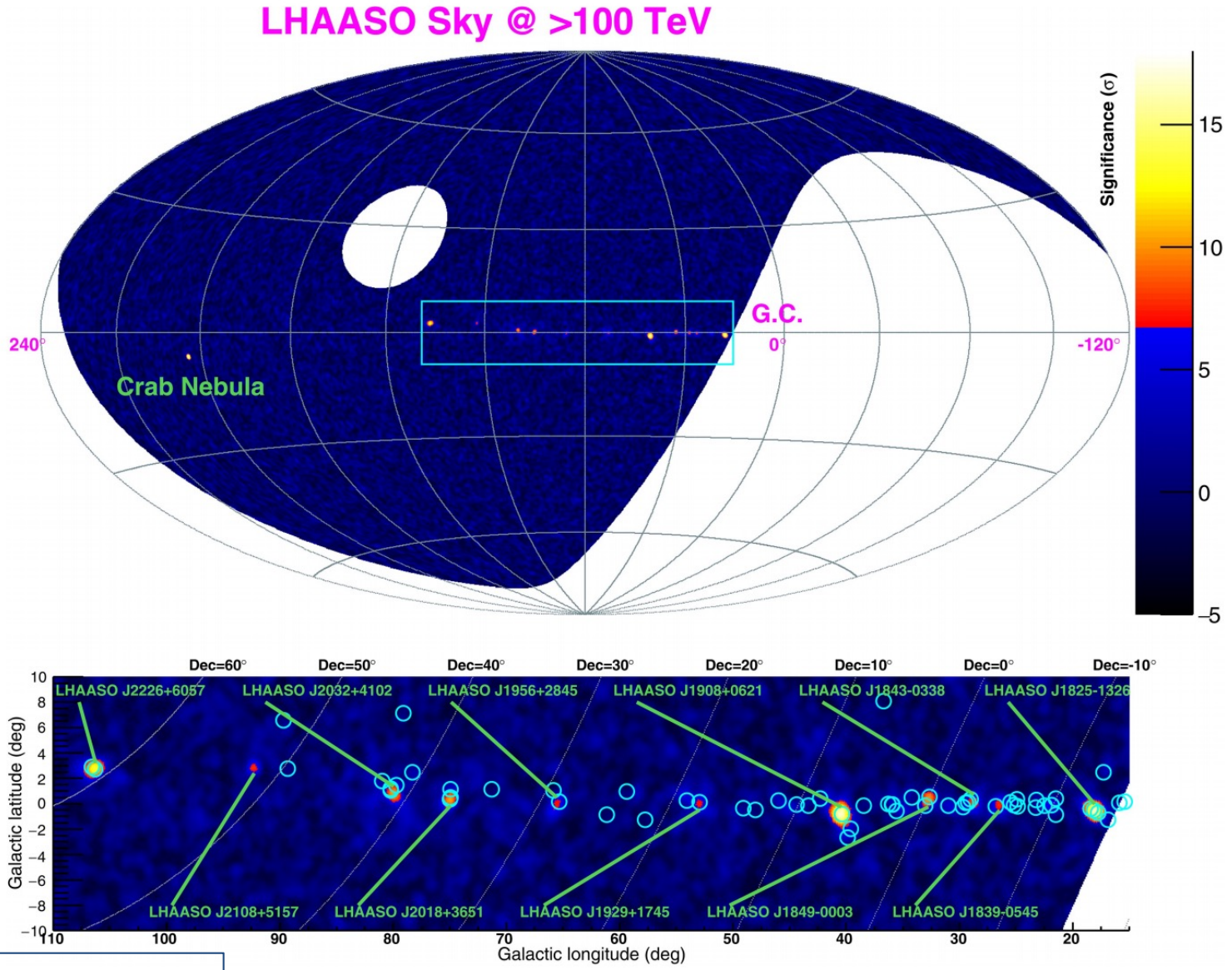
Abramovski et al. (2016)

The “Pevatron”



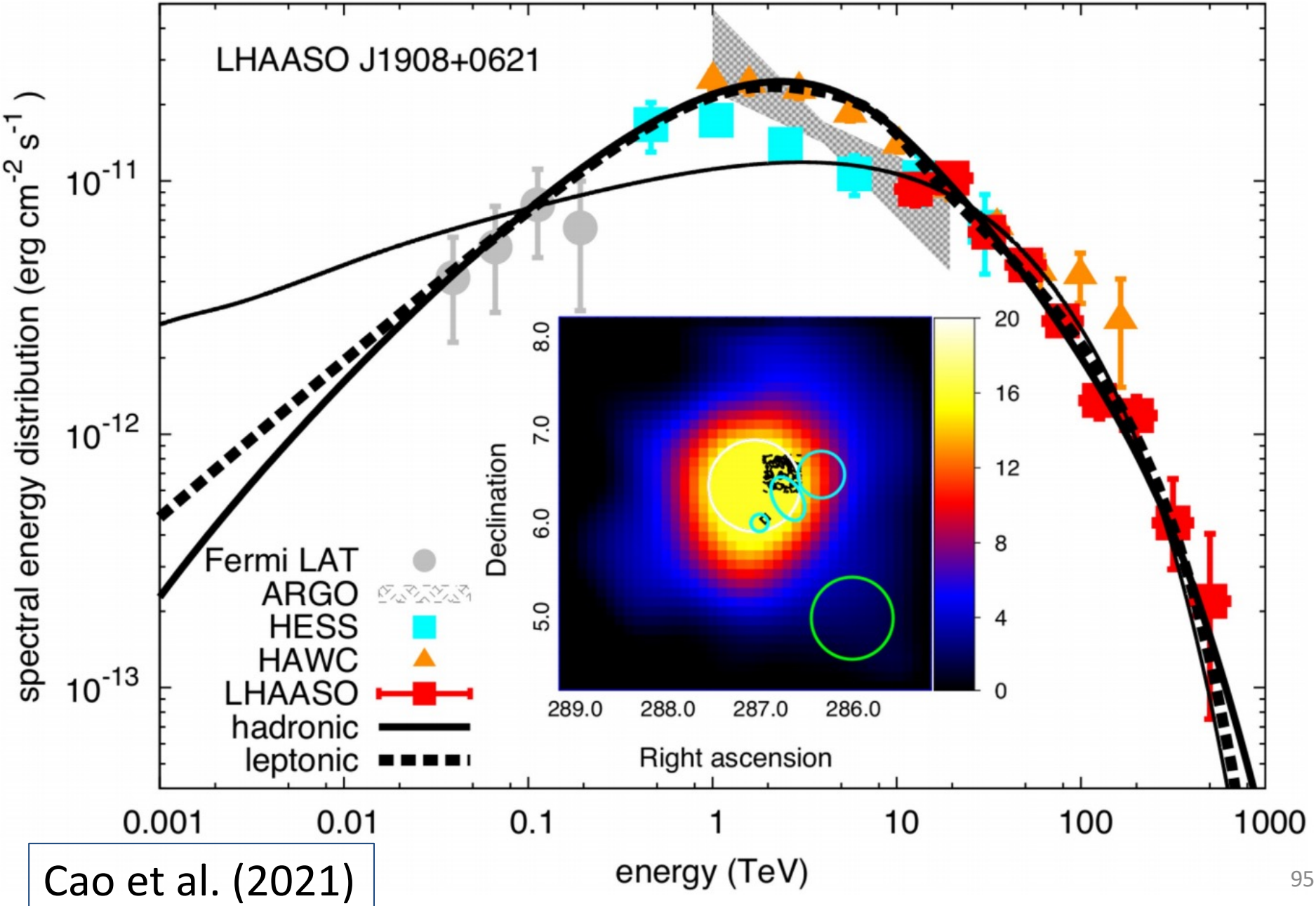
Abramovski et al. (2016)

LHAASO Pevatrons



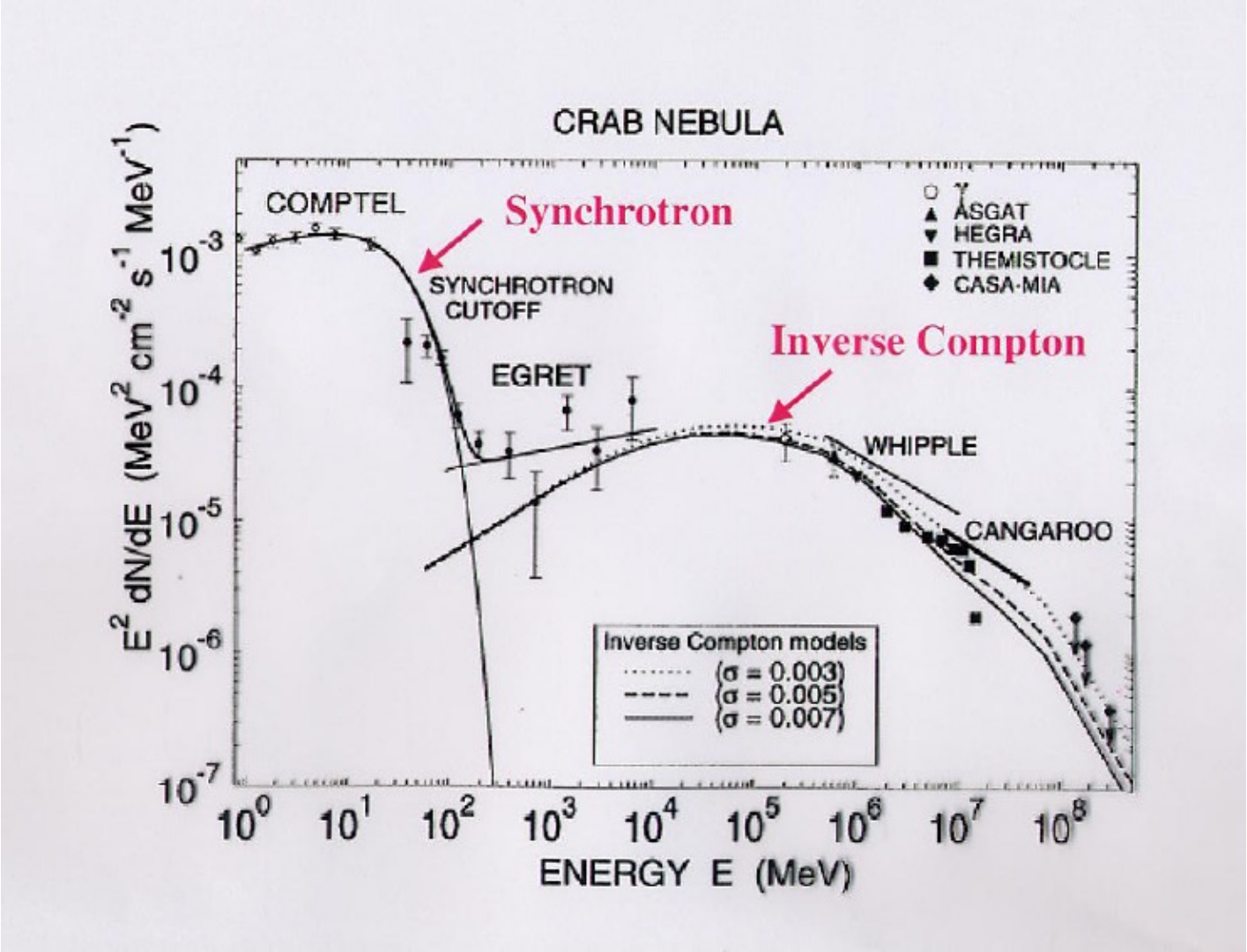
Cao et al. (2021)

LHAASO Pevatrons



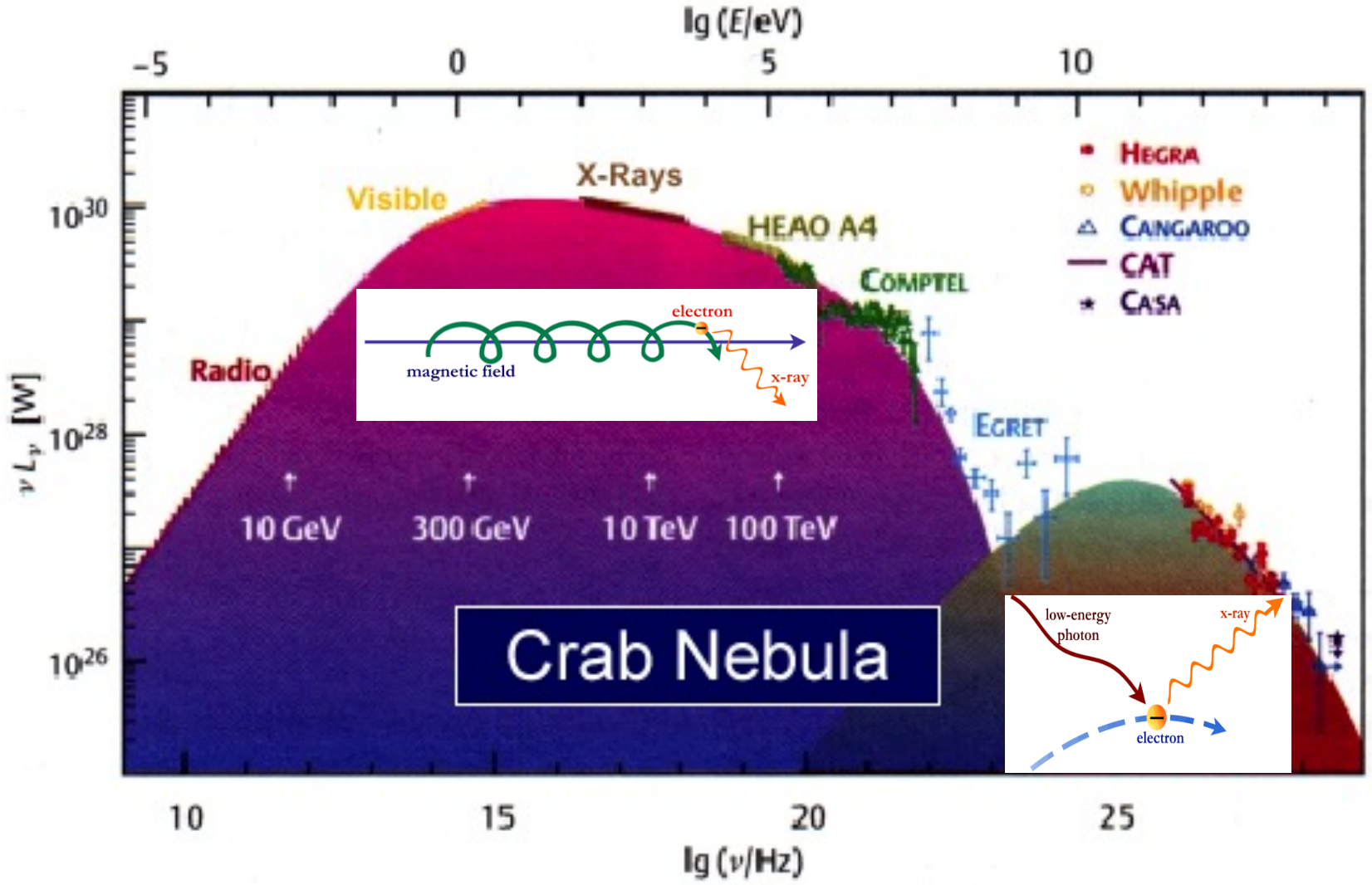
Cao et al. (2021)

Crab Nebula


CRAB NEBULA
COMPTEL
Synchrotron
SYNCHROTRON CUTOFF
EGRET
Inverse Compton
WHIPPLE
CANGAROO
ASGAT
HEGRA
THEMISTOCLE
CASA-MIA
Inverse Compton models
(σ = 0.003)
(σ = 0.005)
(σ = 0.007)
E² dN/dE (MeV² cm⁻² s⁻¹ MeV⁻¹)
ENERGY E (MeV)

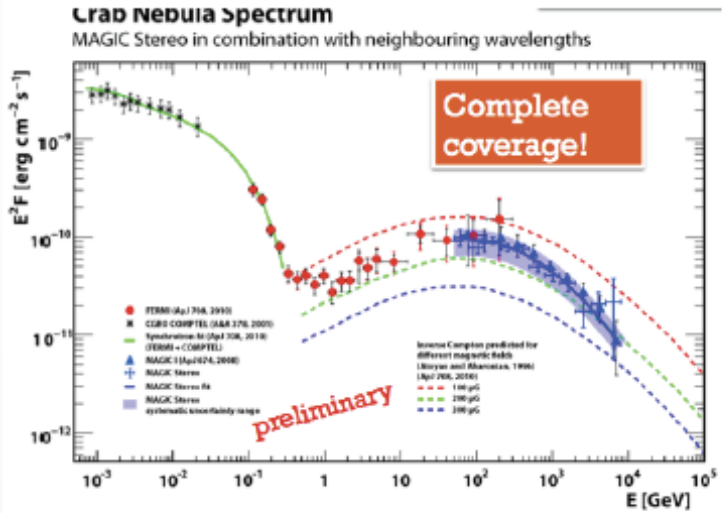
A (minimal) standard model: what do we expect?

Explains most of the observations, not necessarily the most interesting…



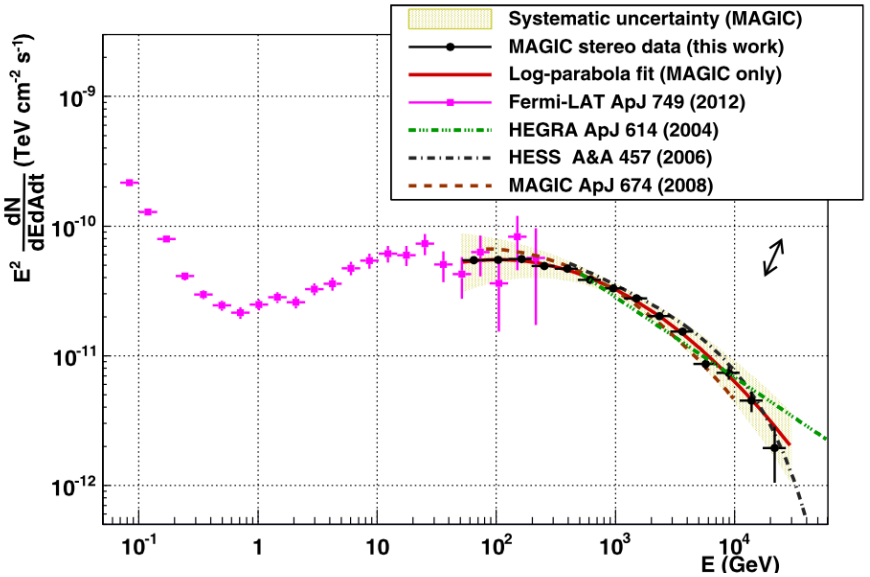
The Crab PWN

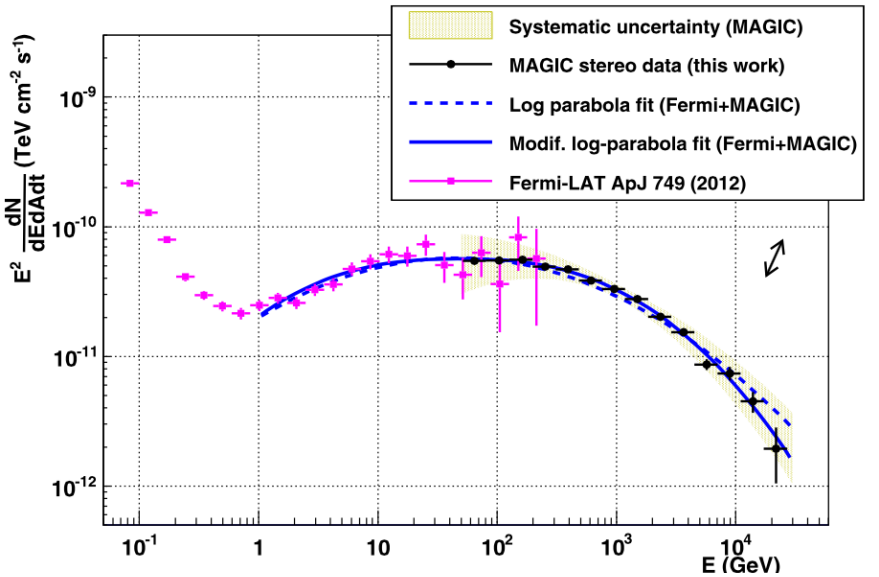
+ Crab Nebula HE-VHE coverage

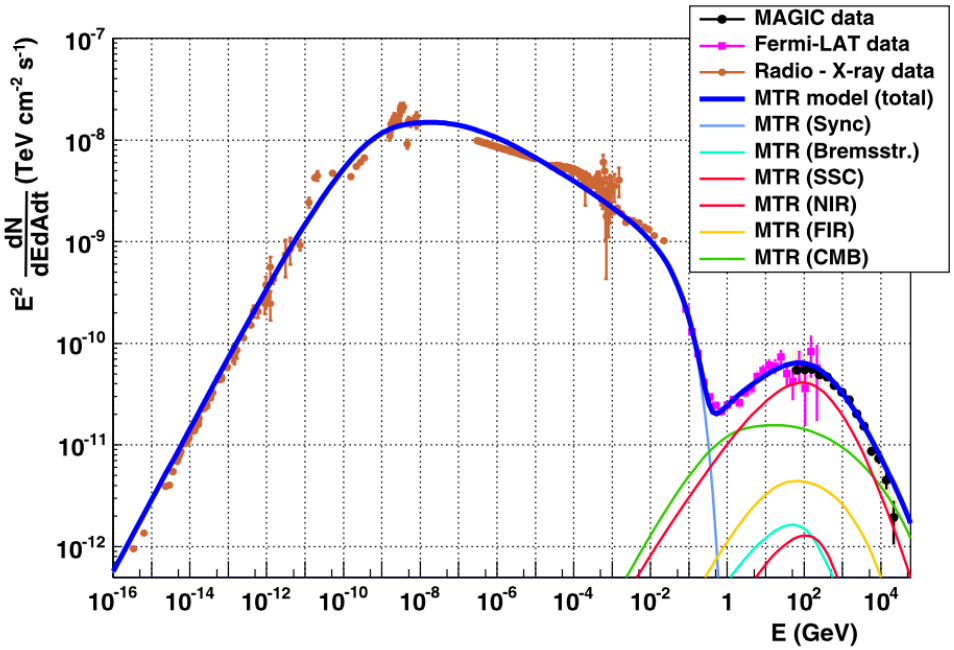


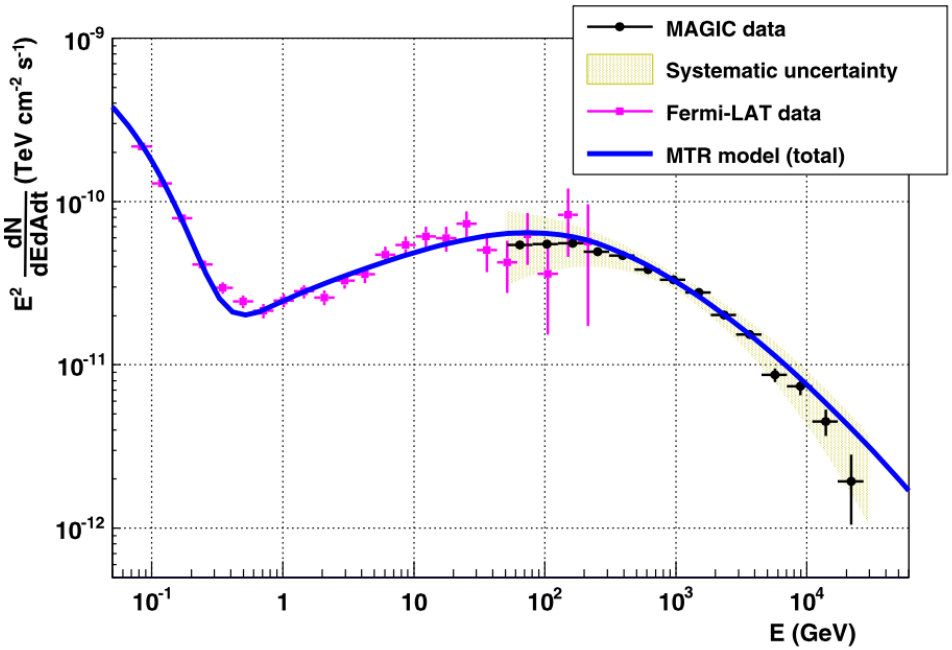
- 3.2 h of good data in Nov. 2010
- Complete overlap with Fermi
- Spectrum measured from 40-50 GeV to 30-40 TeV
- Test source for M-stereo
  - Technical Crab paper in prep.
  - Physics Crab paper in prep.
- Improved estimation of HE bump will be provided
- Regarding first HE flare (Agile, Fermi), MAGIC-stereo did not detect significant VHE flares (ATEL#2967, sep.2010)
- We monitor Fermi data for flares

The Crab Nebula



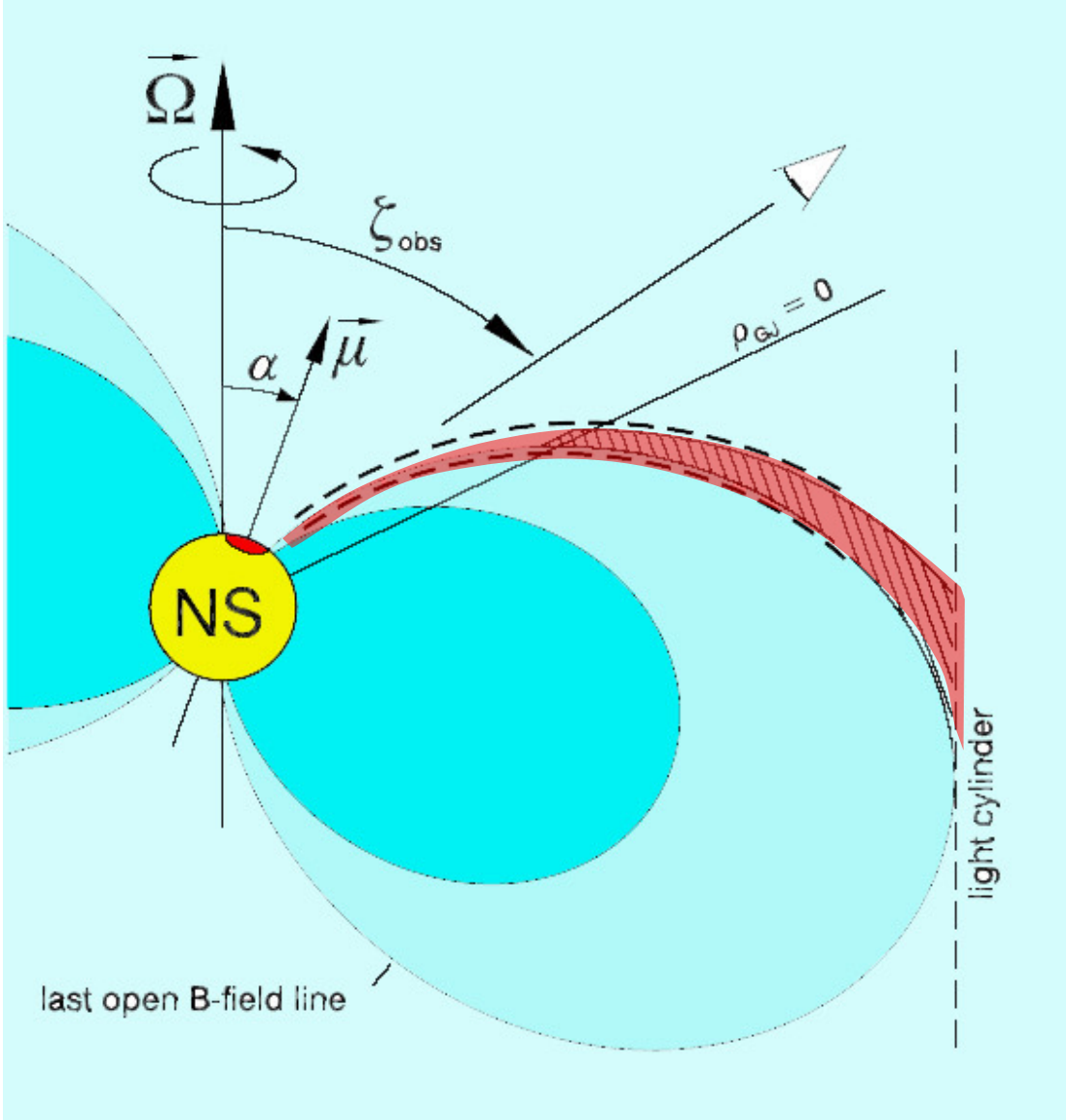






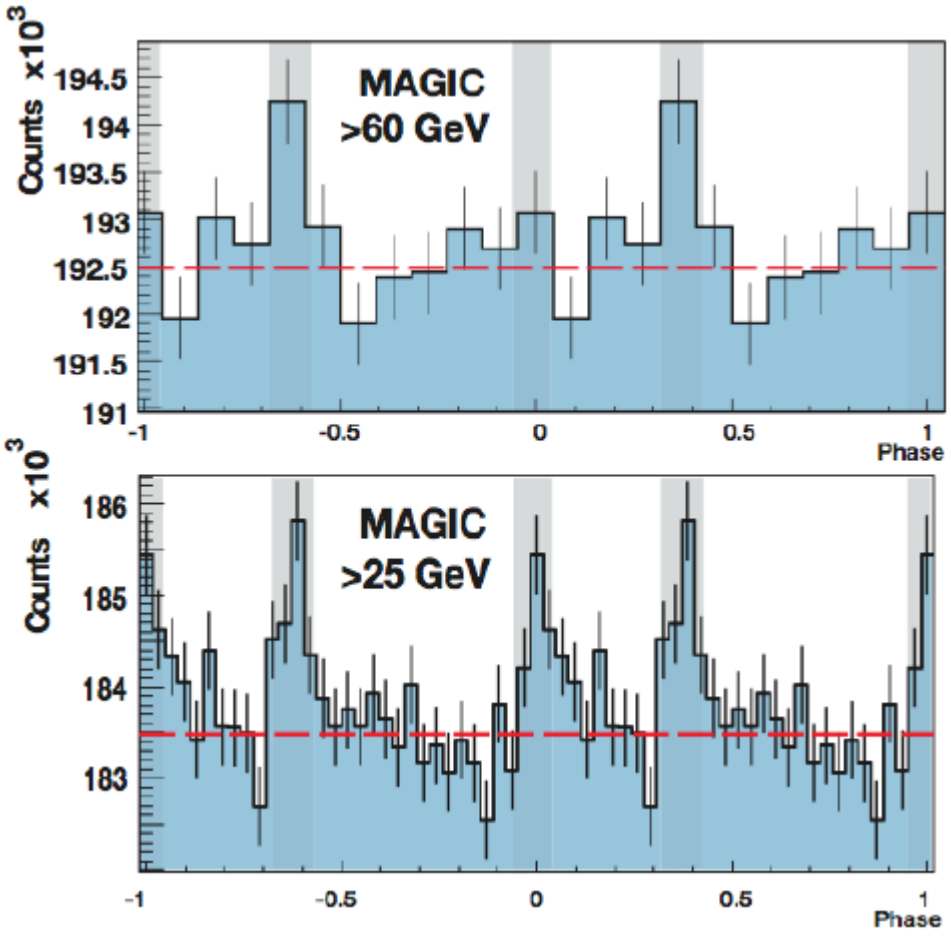
Aleksic et al. (2015)

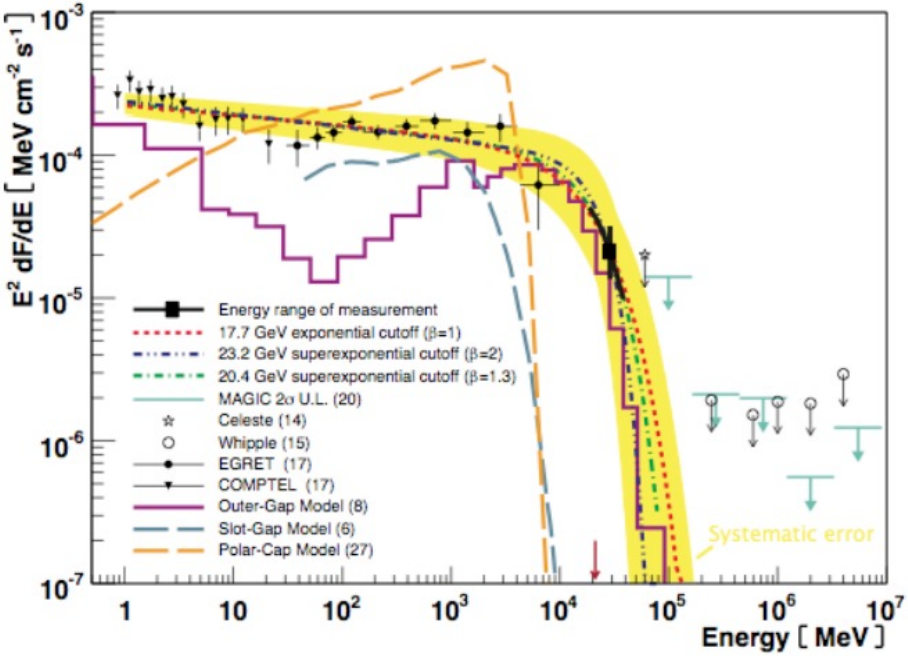
Pulsars: GR & Electrodynamics



from J. Dyks et al.

MAGIC – the Crab PSR

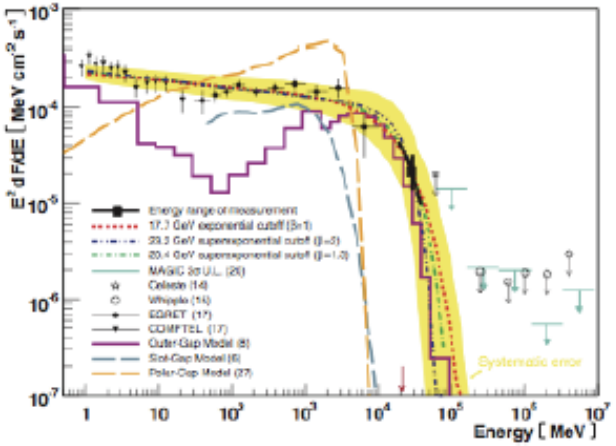


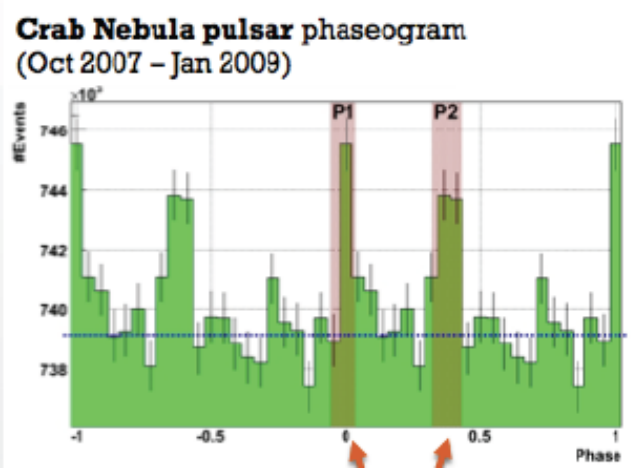


Albert et al. 2008

The Crab PSR

+ The Crab still beats.

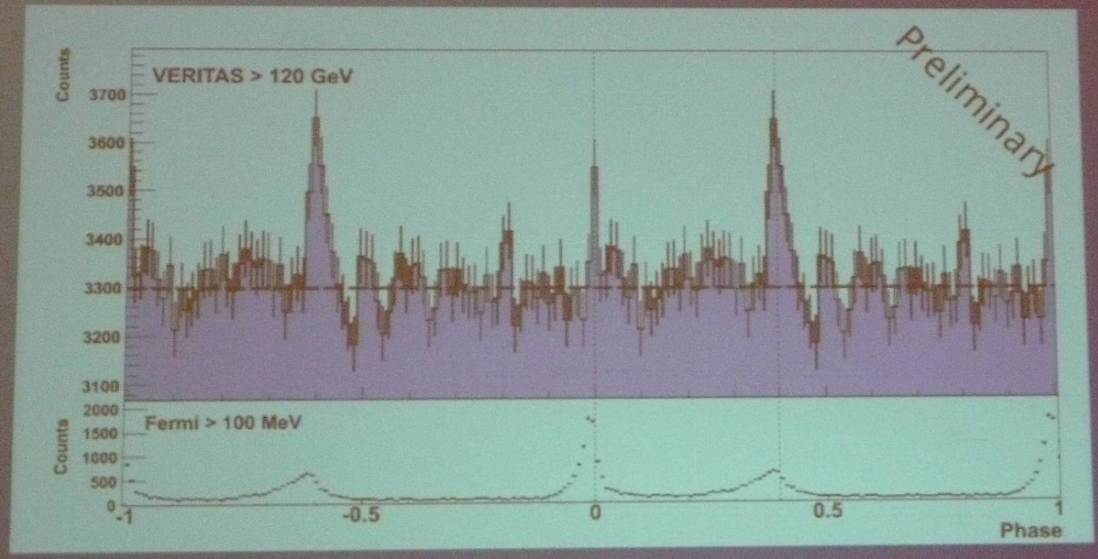




- To reach energy as low as 25 GeV special "sumtrigger" used
- In 2008, Crab pulsar detected at VHE (Science 322 (2008) 21)
- Again observed with M-stereo: publication in draft
  →see next ICRC
- Now used Fermi phaseogram rather than EGRET one
- Veritas showed here the detection above 100 GeV → see Ragan's talk

The Crab with VERITAS

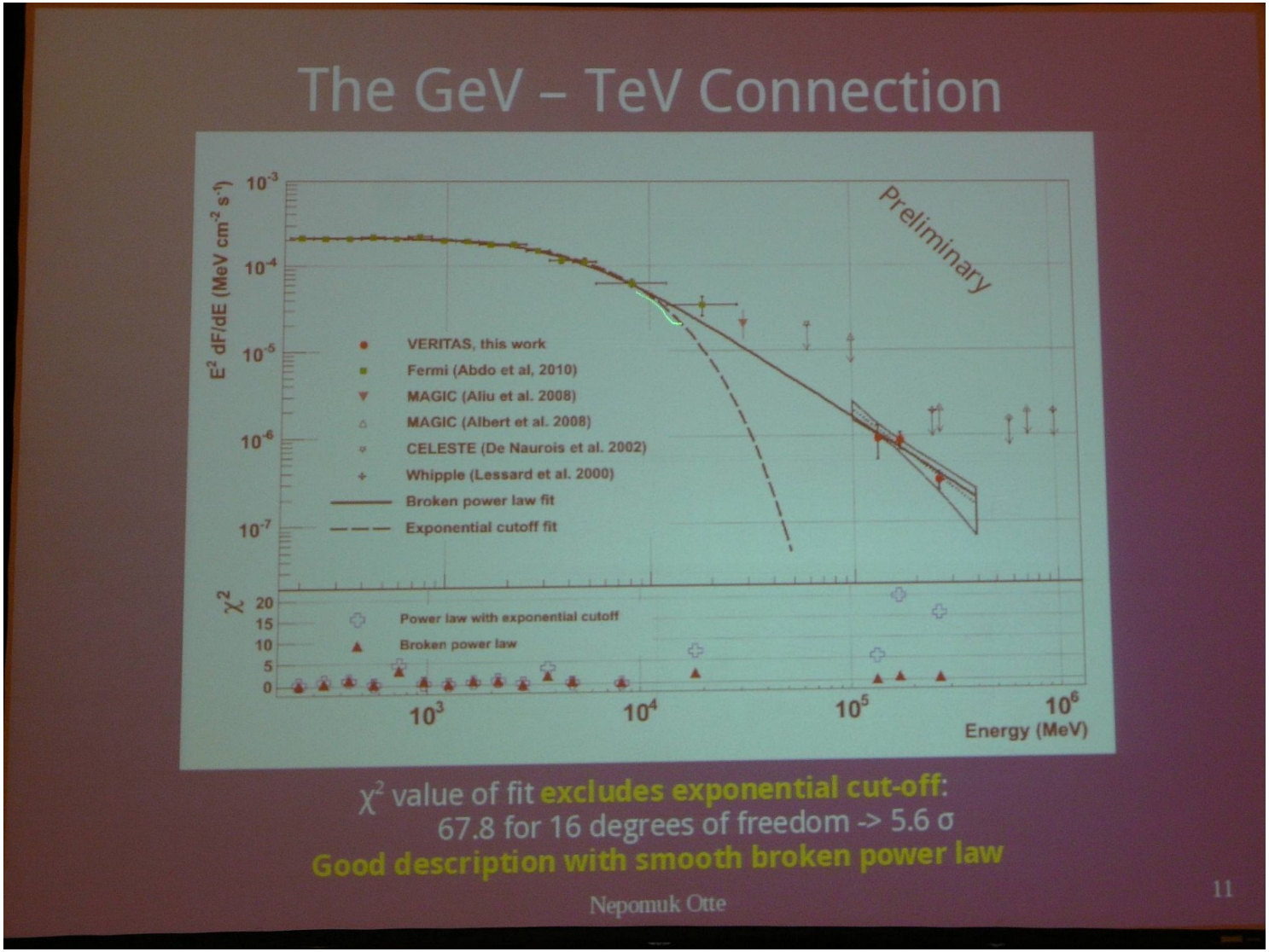
Pulsed Signal



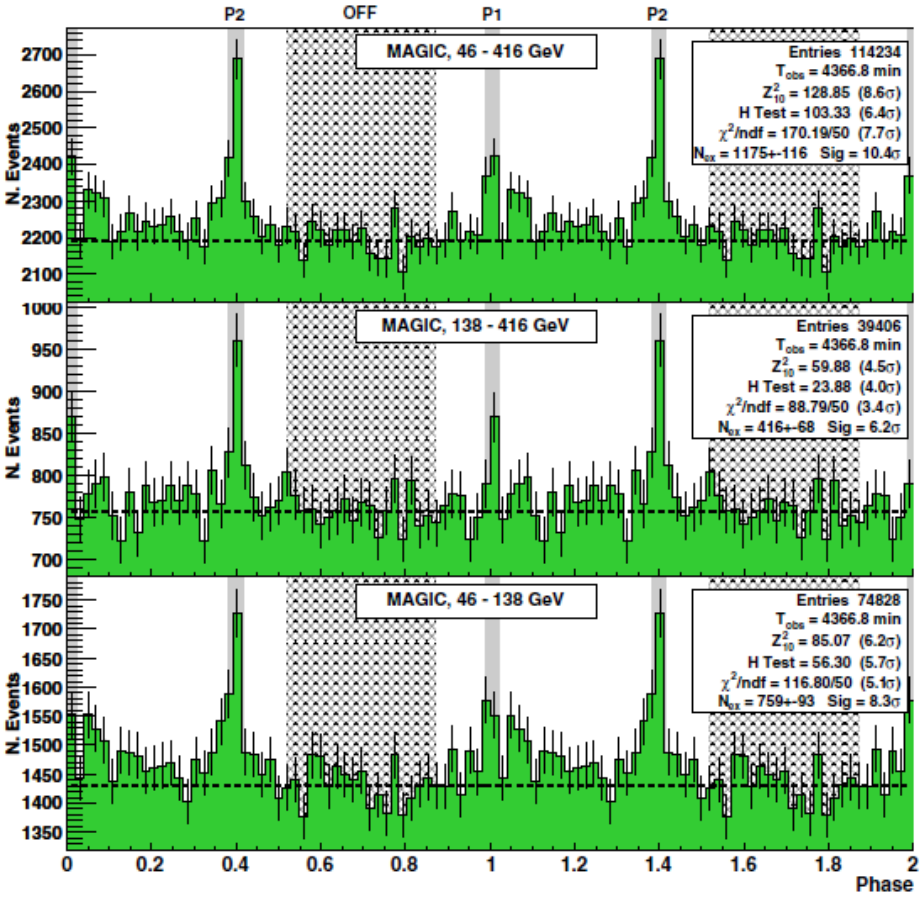
- Event time barycentering with tempo2 and custom codes
- Phase folding using Jodrell Bank ephemerides

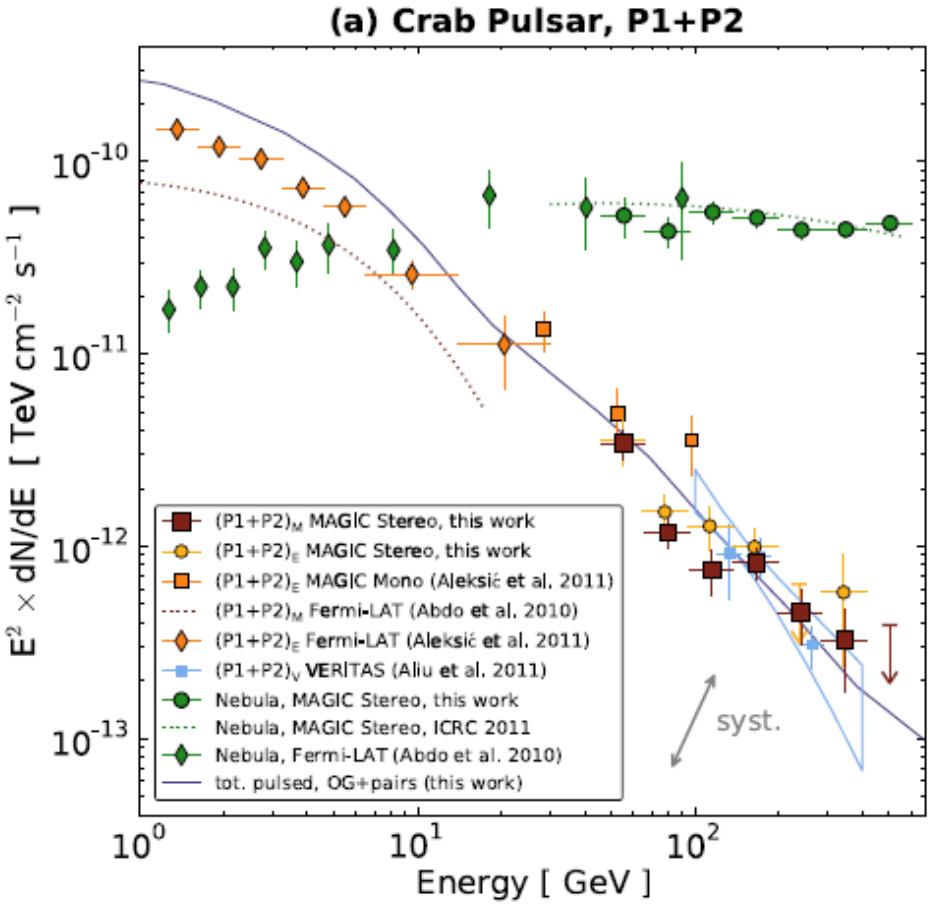
Statistical significance of pulsed signal:
H-Test: 50, i.e. 6.0 σ

The Crab with VERITAS

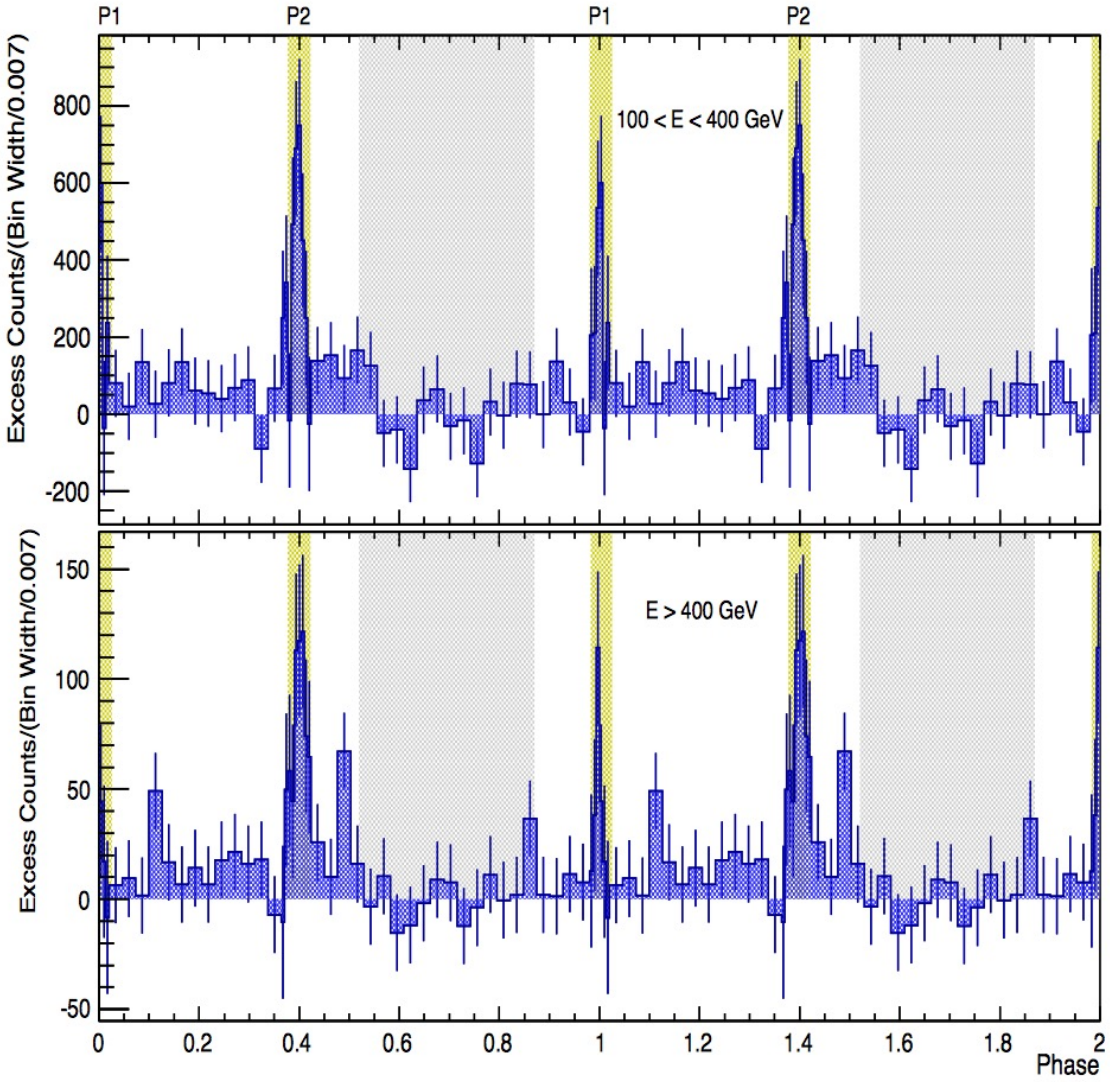


Crab PSR


P2
OFF
P1
P2
MAGIC, 46 - 416 GeV
Entries 114234
T_obs = 4366.8 min
Z²₁₀ = 128.85 (8.6σ)
H Test = 103.33 (6.4σ)
χ²/ndf = 170.19/50 (7.7σ)
N_ex = 1175+-116 Sig = 10.4σ
MAGIC, 138 - 416 GeV
Entries 39406
T_obs = 4366.8 min
Z²₁₀ = 59.88 (4.5σ)
H Test = 23.88 (4.0σ)
χ²/ndf = 88.79/50 (3.4σ)
N_ex = 416+-68 Sig = 6.2σ
MAGIC, 46 - 138 GeV
Entries 74828
T_obs = 4366.8 min
Z²₁₀ = 85.07 (6.2σ)
H Test = 56.30 (5.7σ)
χ²/ndf = 116.80/50 (5.1σ)
N_ex = 759+-93 Sig = 8.3σ
N. Events
Phase

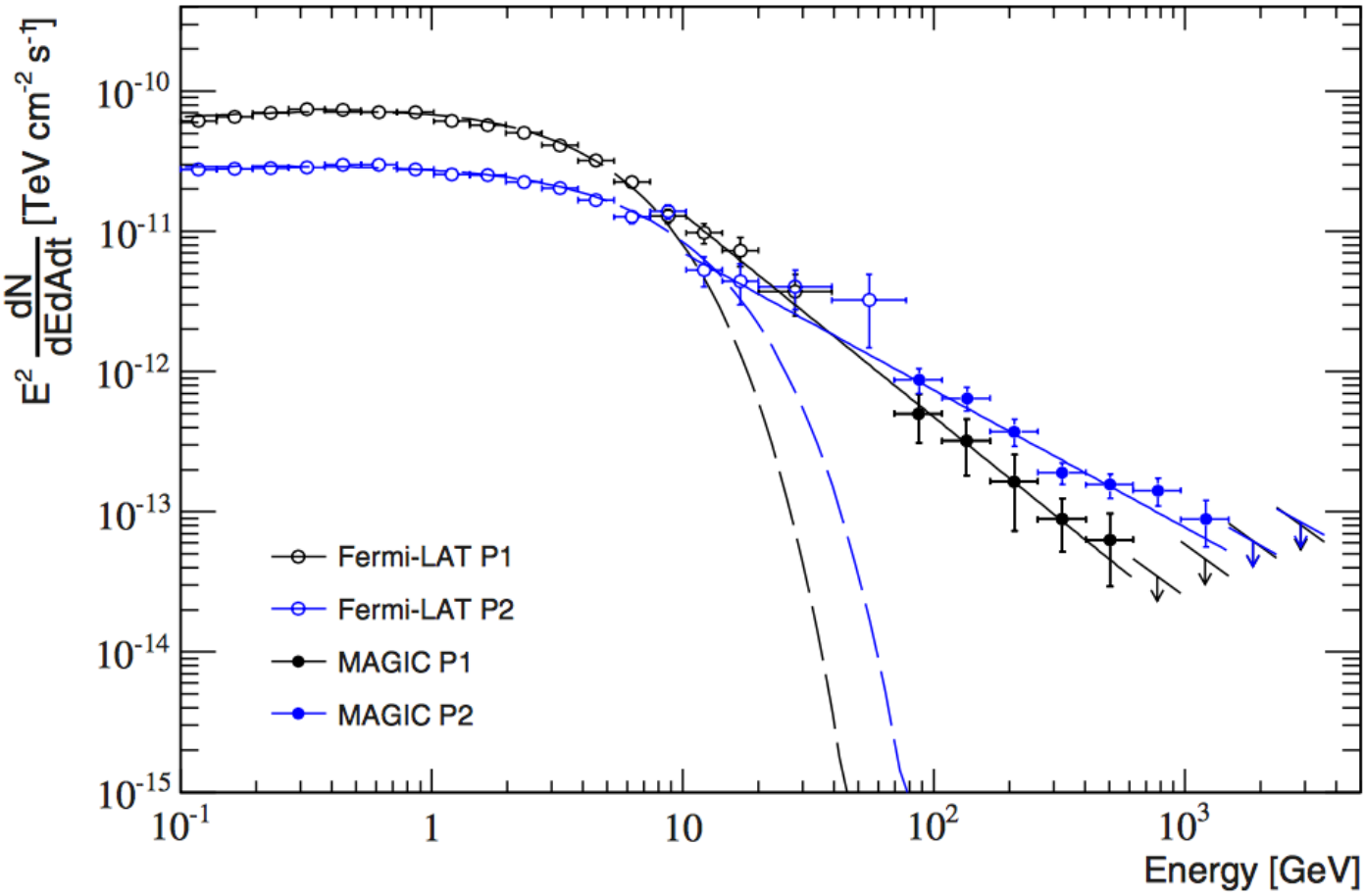

(a) Crab Pulsar, P1+P2
E² × dN/dE [TeV cm⁻² s⁻¹]
Energy [GeV]
(P1+P2)_M MAGIC Stereo, this work
(P1+P2)_E MAGIC Stereo, this work
(P1+P2)_E MAGIC Mono (Aleksić et al. 2011)
(P1+P2)_M Fermi-LAT (Abdo et al. 2010)
(P1+P2)_E Fermi-LAT (Aleksić et al. 2011)
(P1+P2)_V VERITAS (Aliu et al. 2011)
Nebula, MAGIC Stereo, this work
Nebula, MAGIC Stereo, ICRC 2011
Nebula, Fermi-LAT (Abdo et al. 2010)
tot. pulsed, OG+pairs (this work)
syst.

Crab PSR



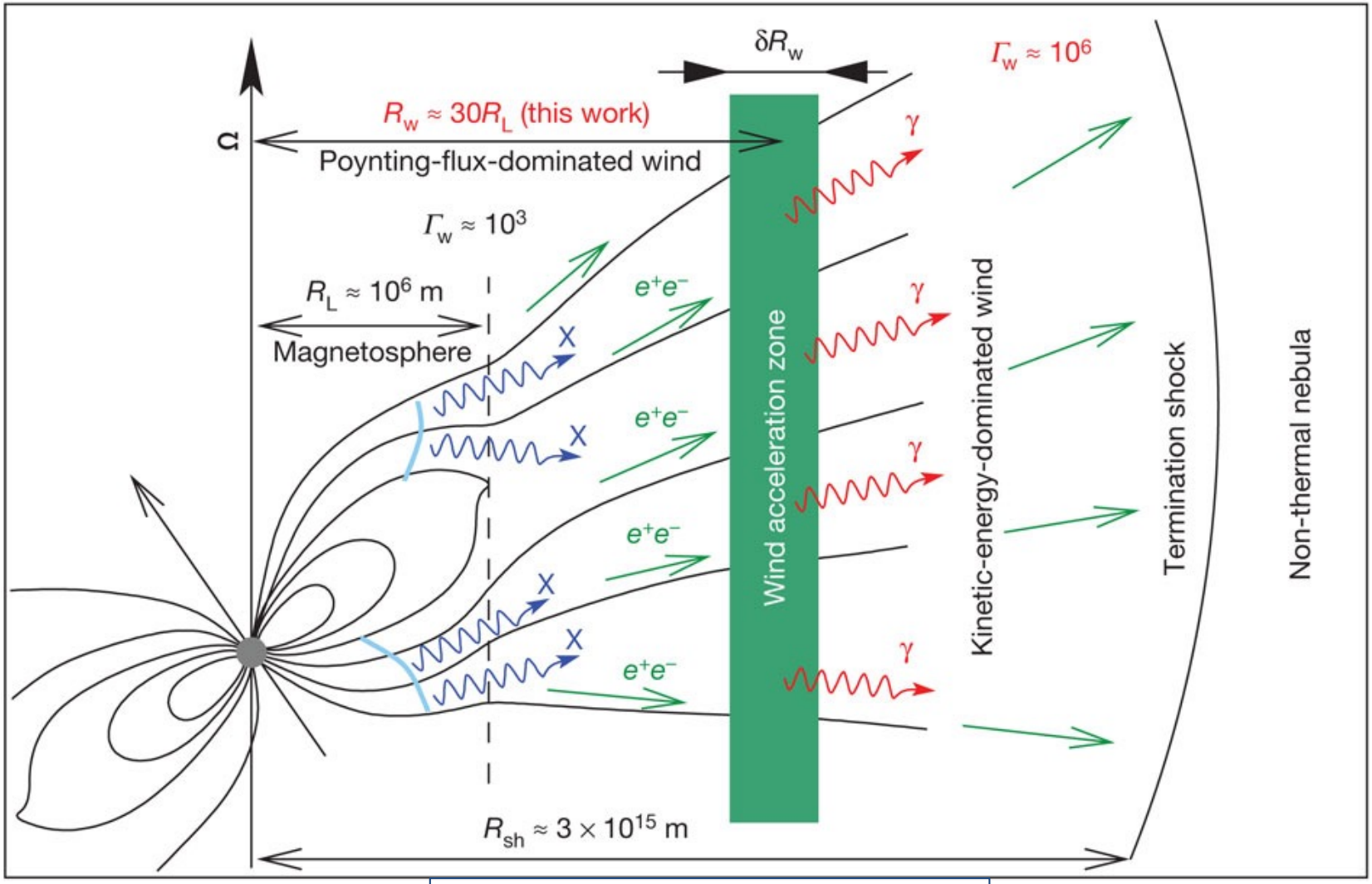
Ansoldi et al. (2016)

Crab PSR



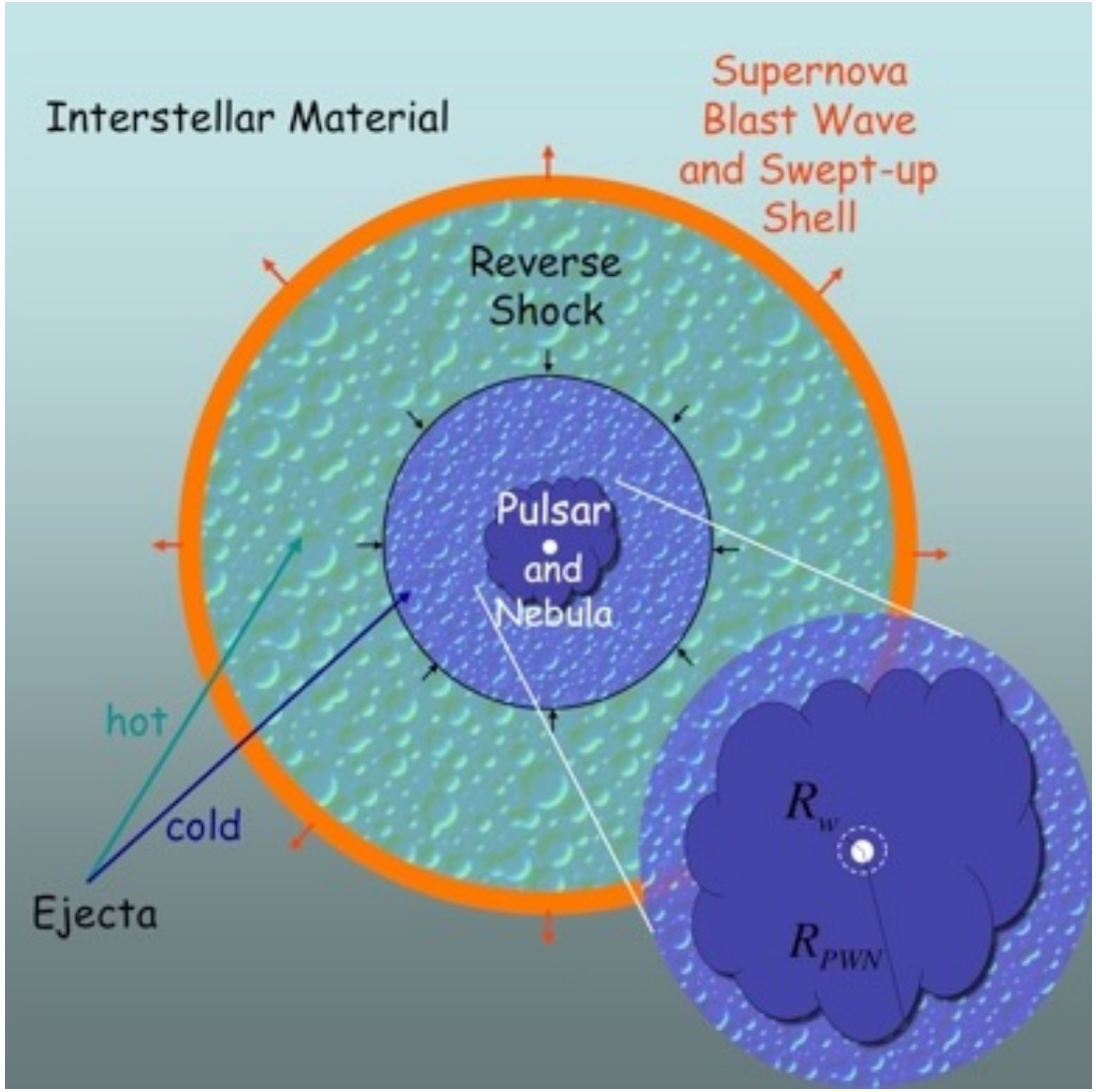
Ansoldi et al. (2016)

Crab PSR

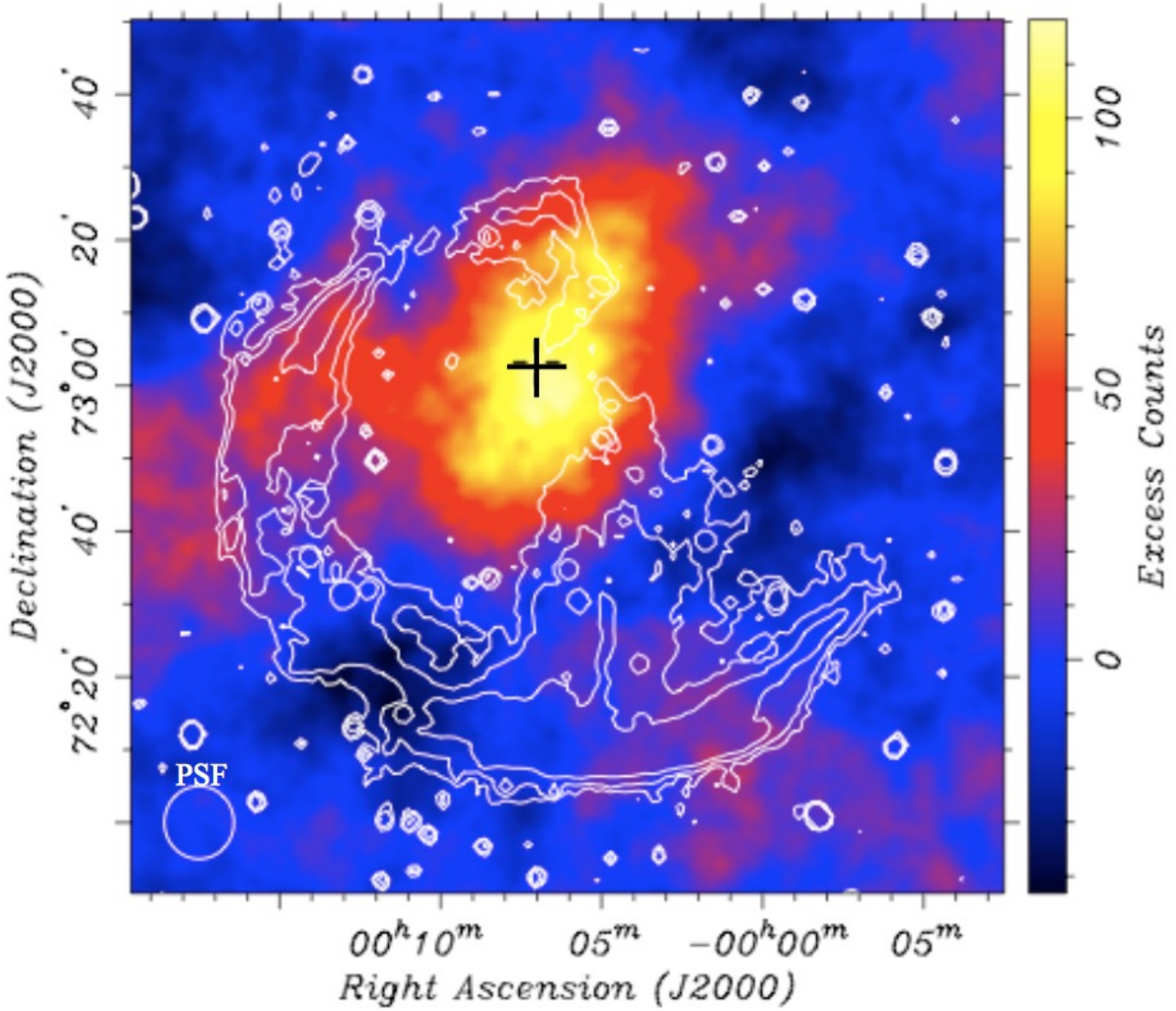


Aharonian et al. (2012)

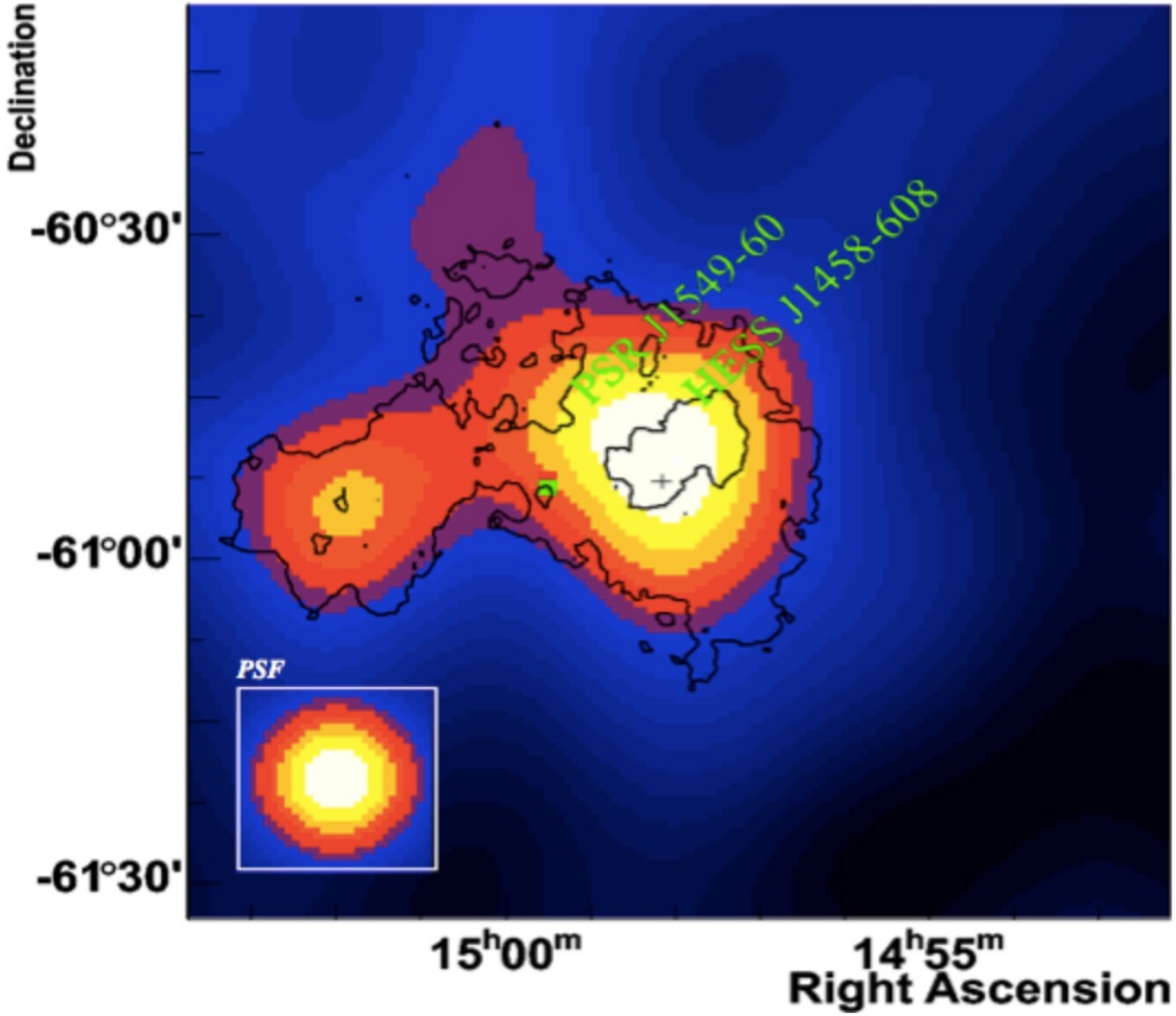
Pulsar Wind Nebulae



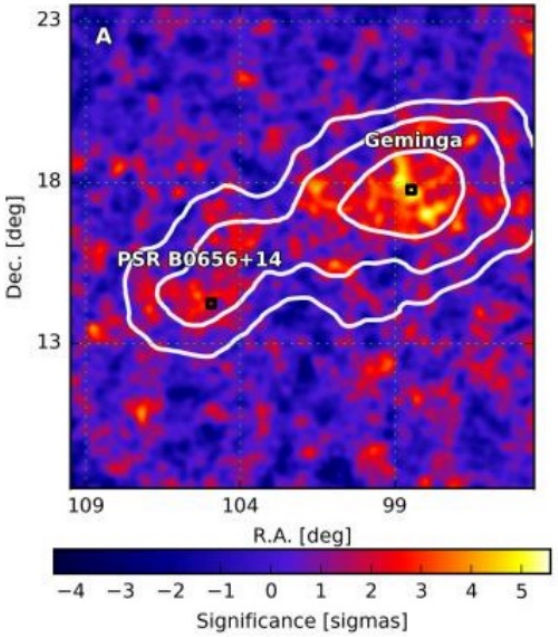
CTA1 PWN

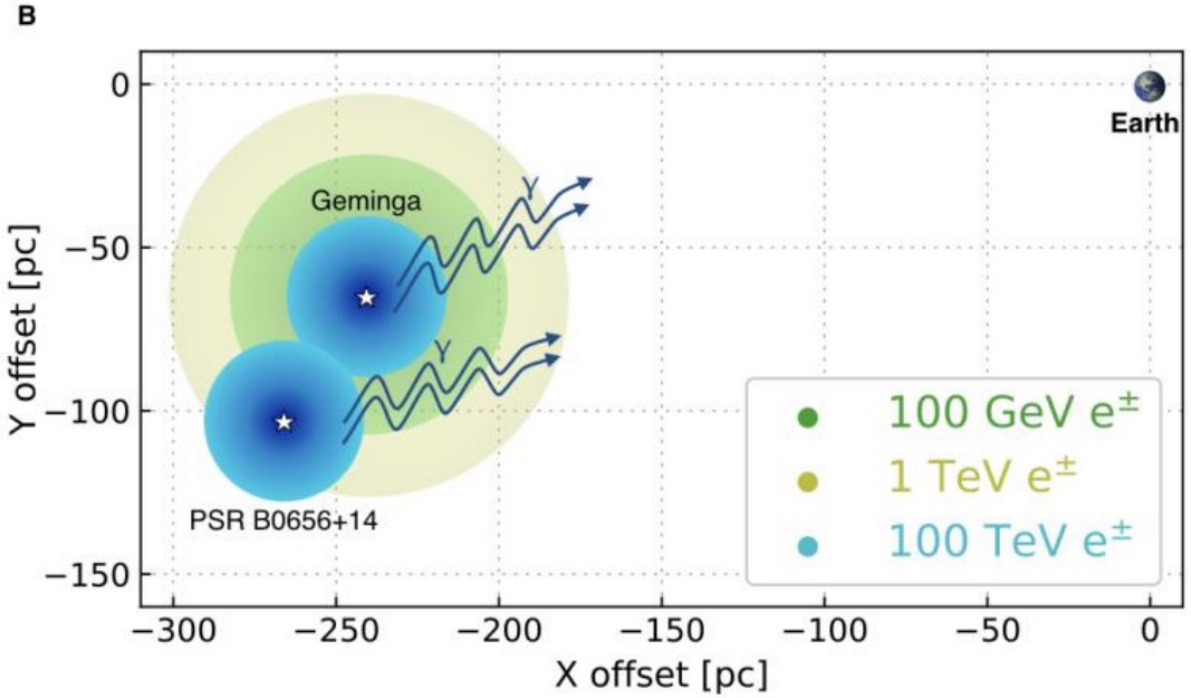

Declination (J2000)
72°20′
40′
73°00′
20′
40′
PSF
00h10m
05m
−00h00m
05m
Right Ascension (J2000)
Excess Counts
100
50
0

Pulsar Wind Nebulae



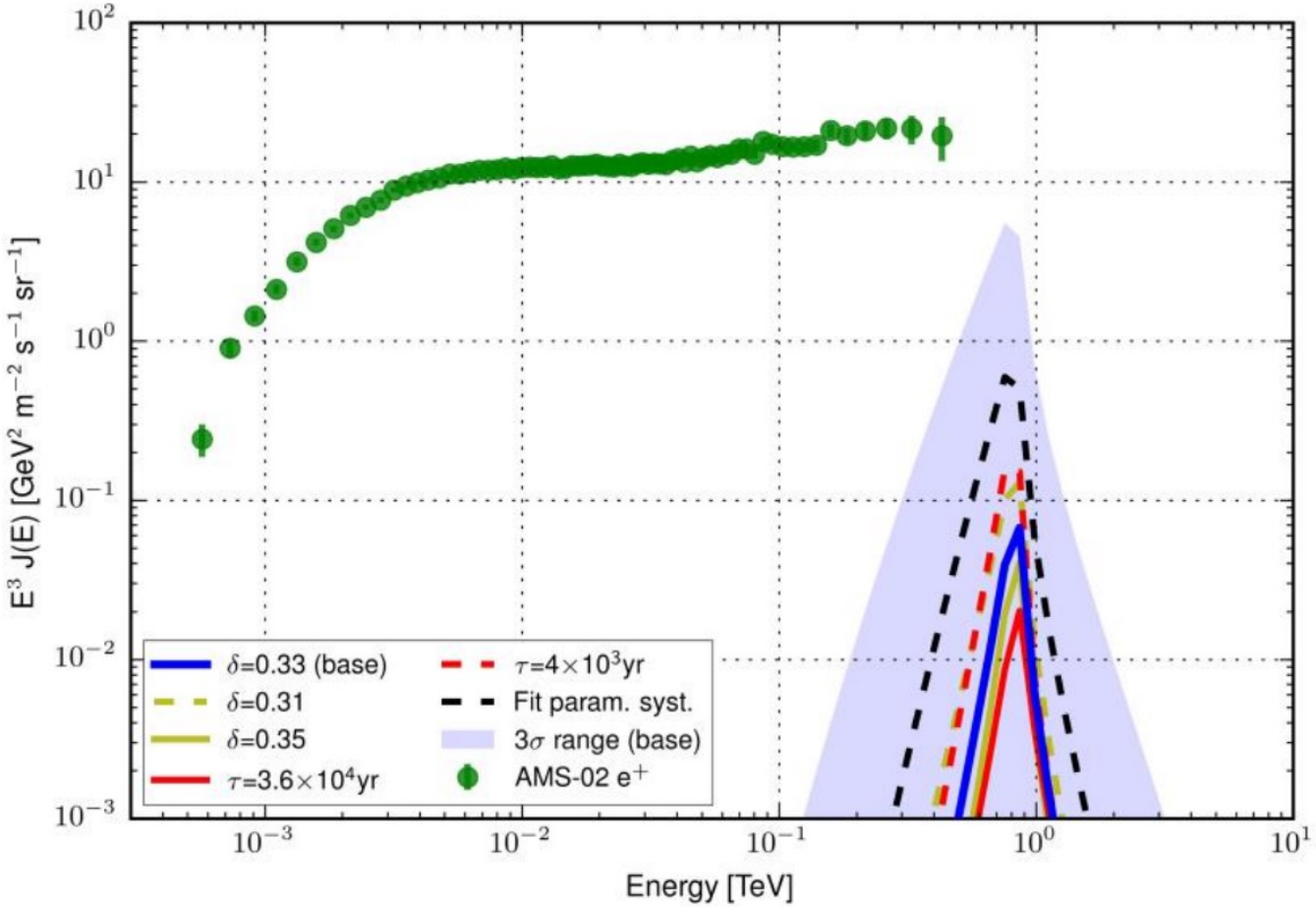
Pulsar Wind Nebulae





https://arxiv.org/pdf/1711.06223

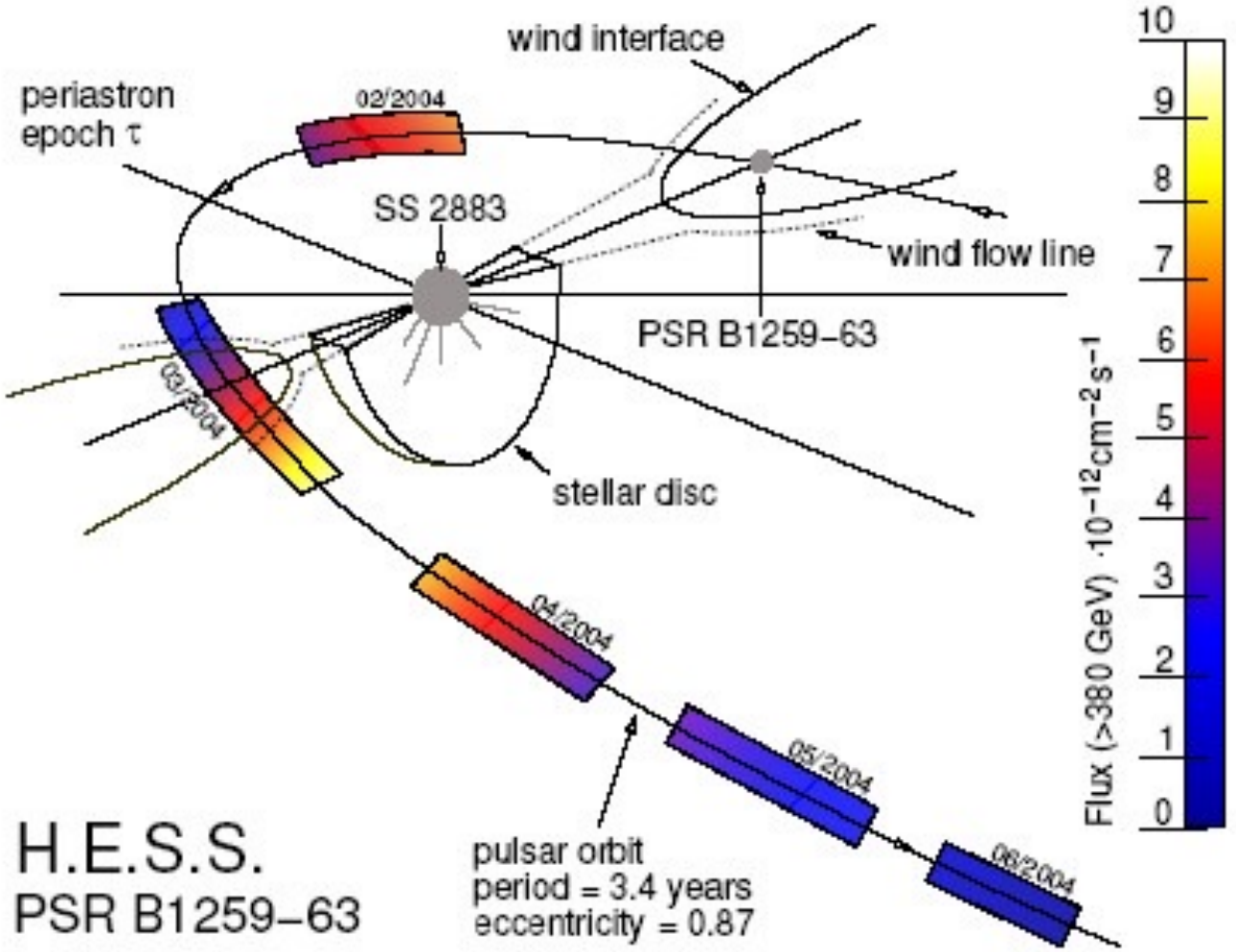
Pulsar Wind Nebulae



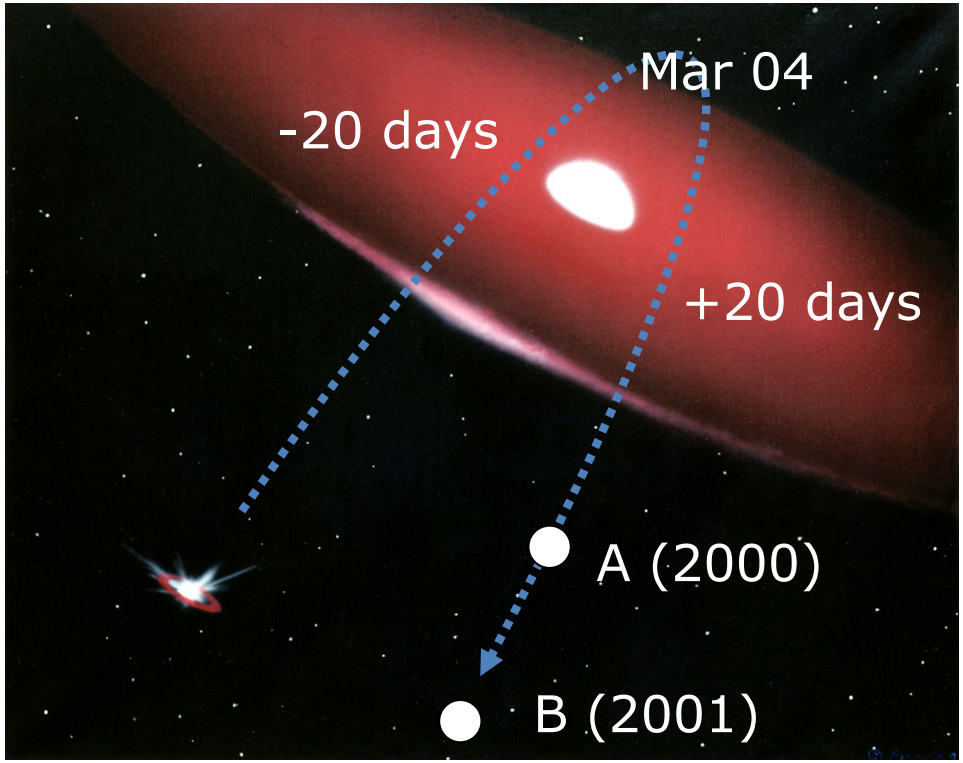
https://arxiv.org/pdf/1711.06223

PSR B1259-63

- **Binary system**
- **Strong stellar wind**
- **Shock at wind-pulsar interaction**

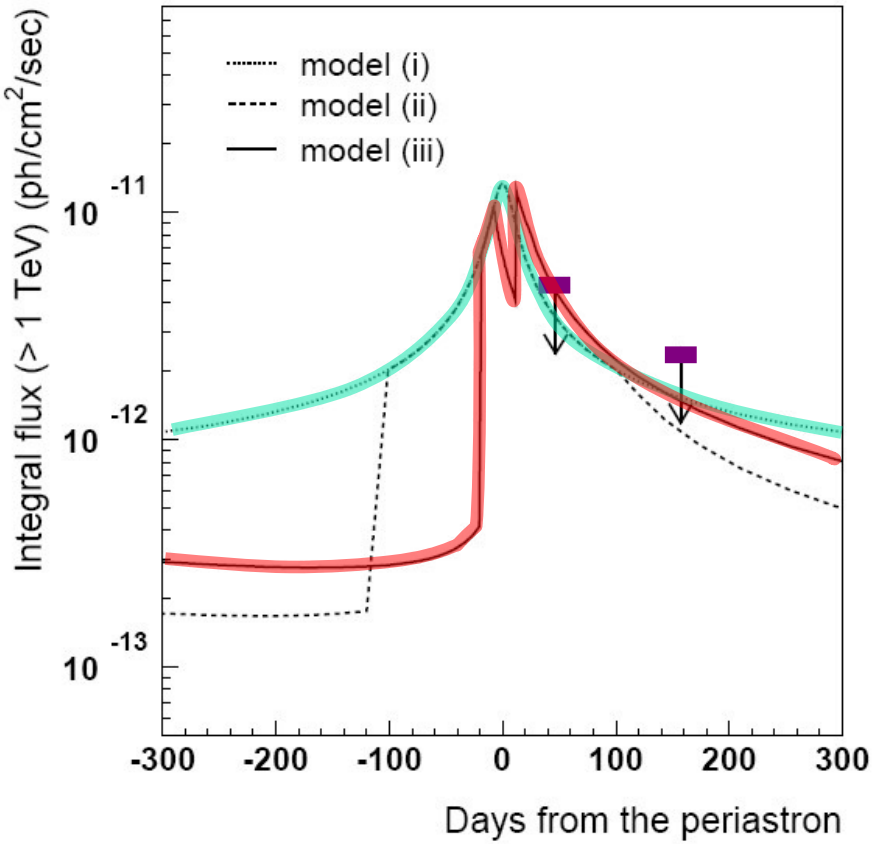


PSR B1259-63



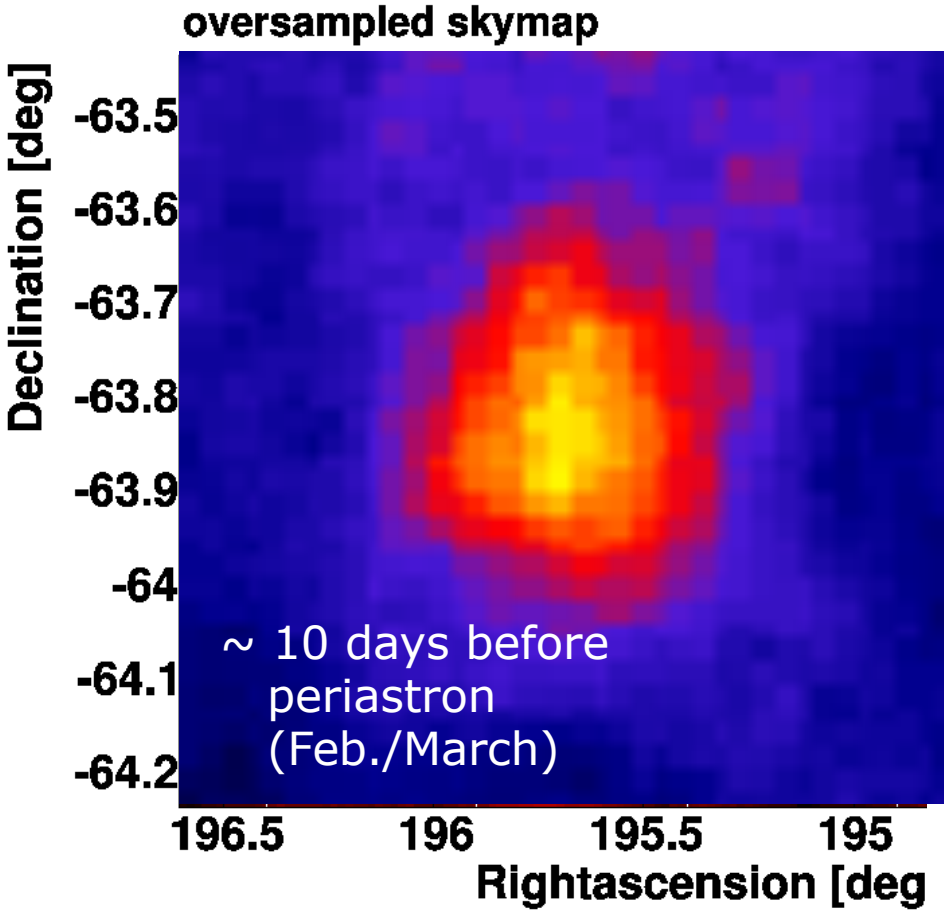
Model: Ball & Kirk 2000

CANGAROO
Kawachi et al. 2004

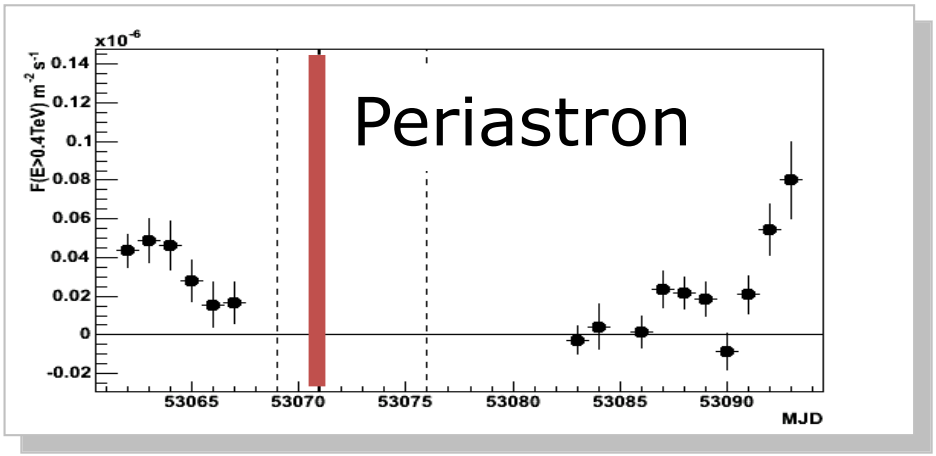


Complex structure depending on alignment of pulsar and stellar wind

PSR B1259-63

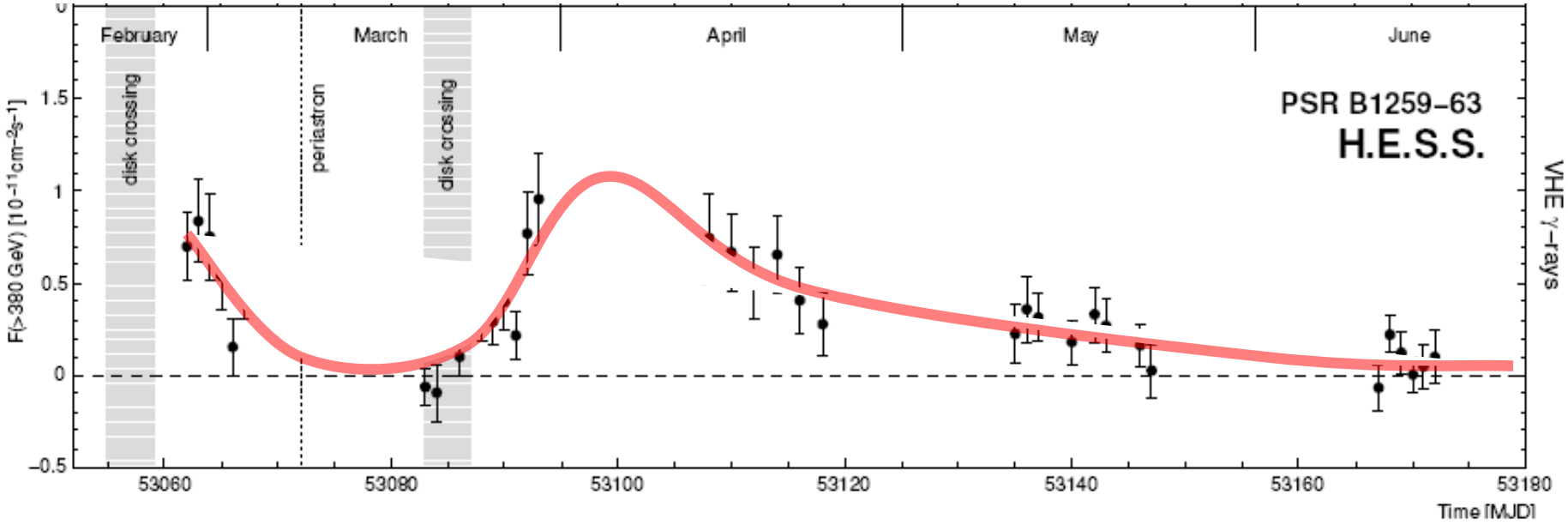


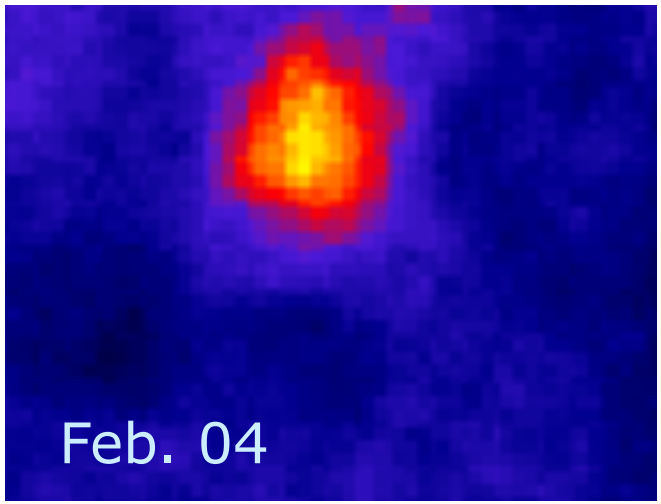
~ 9 σ pre-periastron
~ 6 σ post-periastron
Flux ~5% Crab
Index 2.8±0.3(stat)

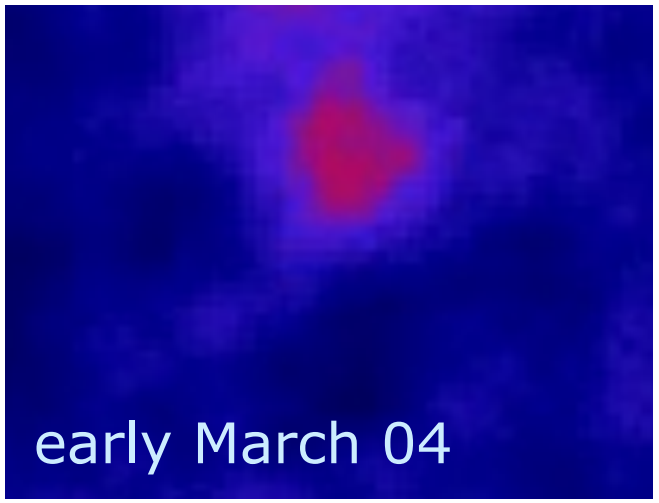


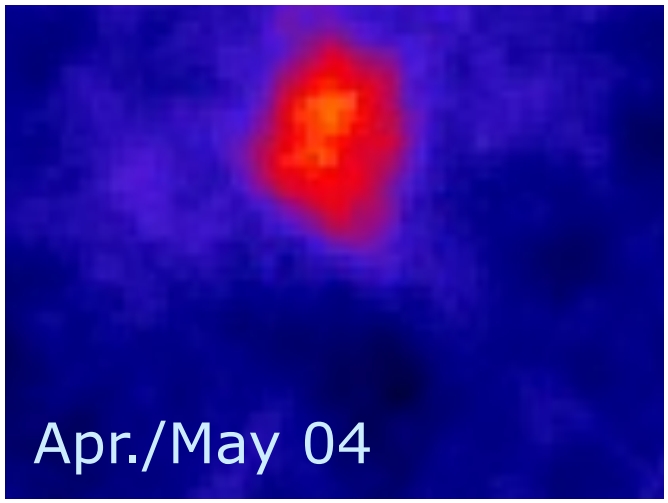
H.E.S.S.

The B1259-63 field of view



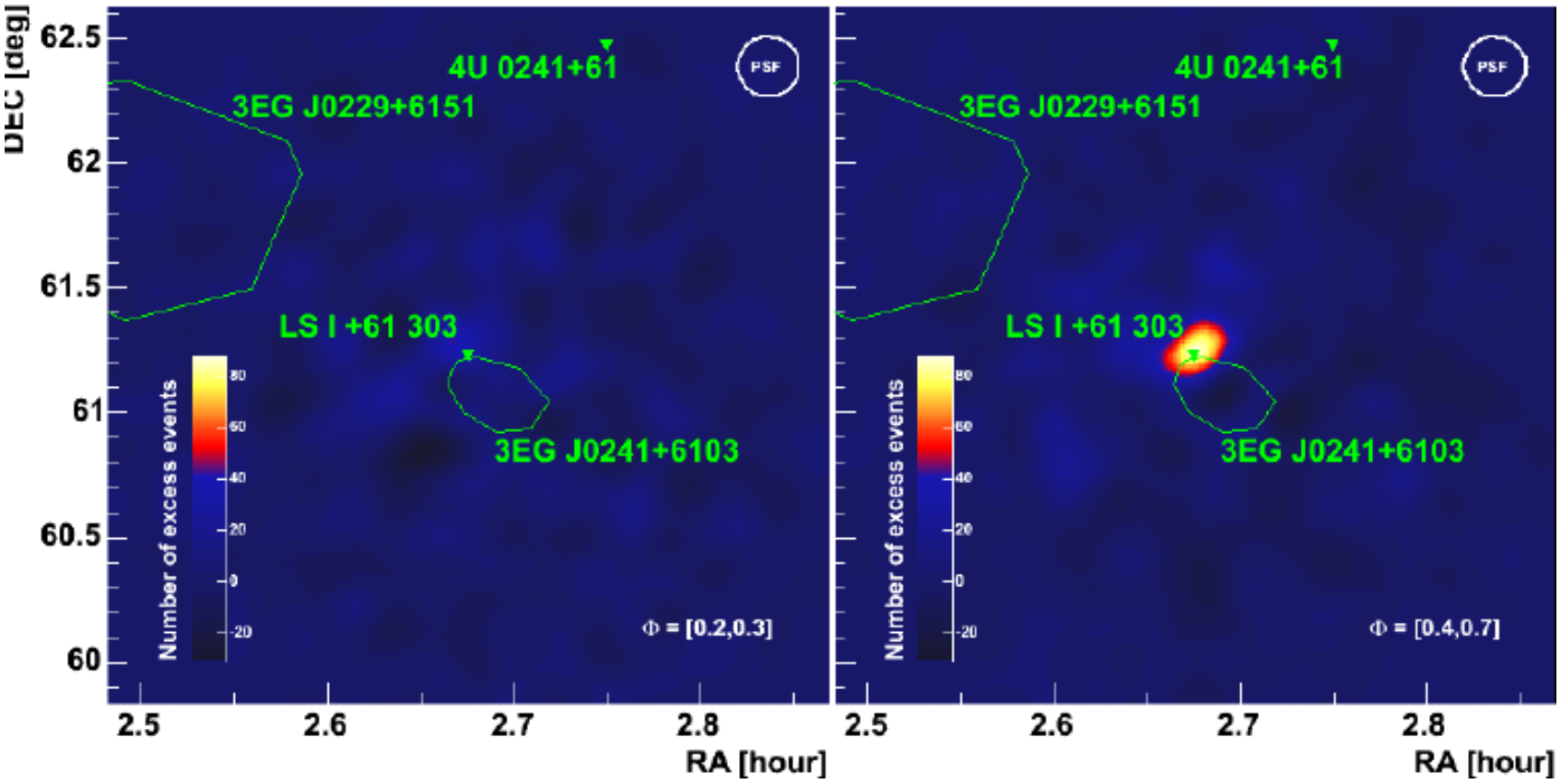




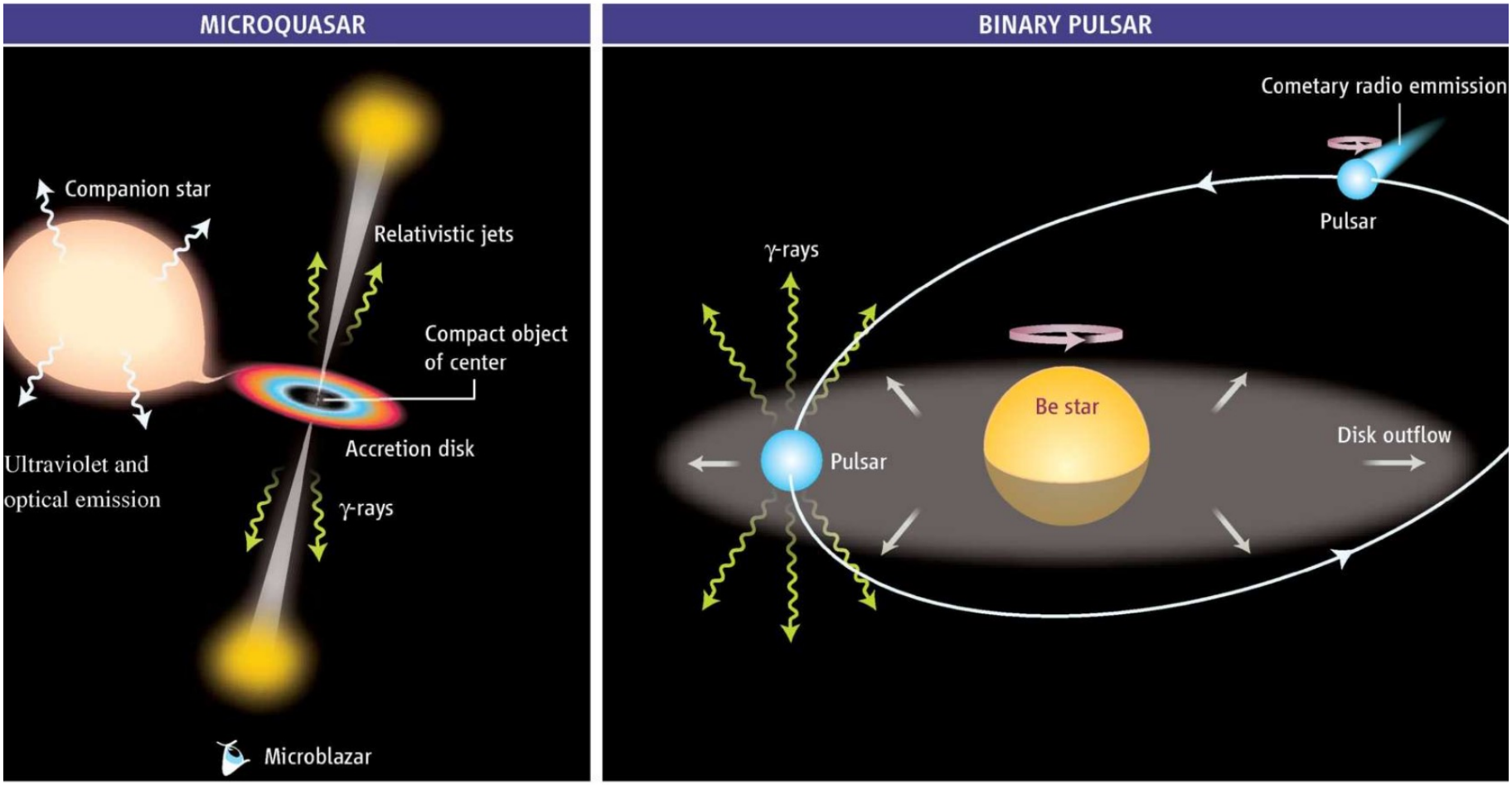


First variable galactic TeV source

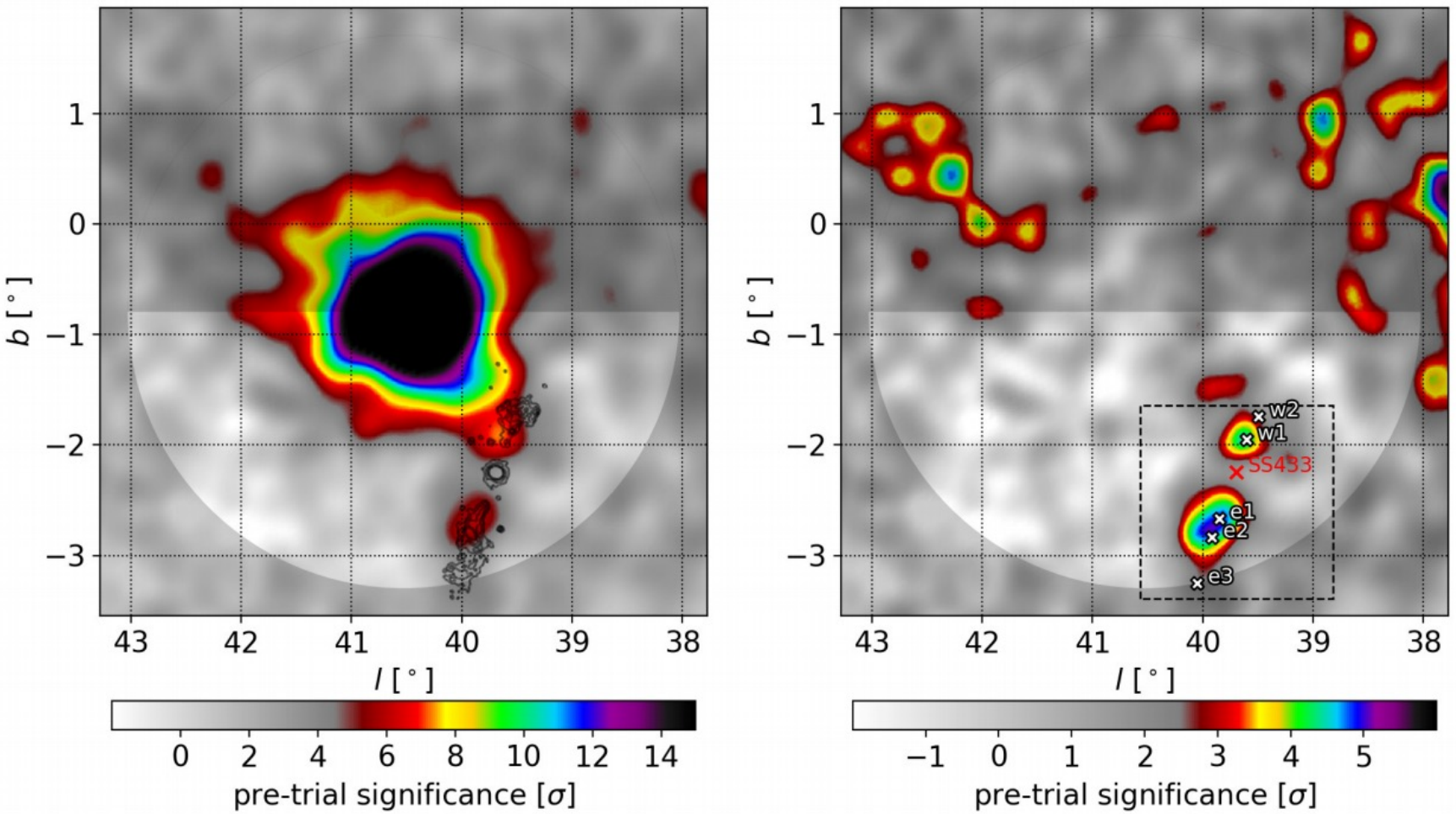
LSI 61+303 binary source



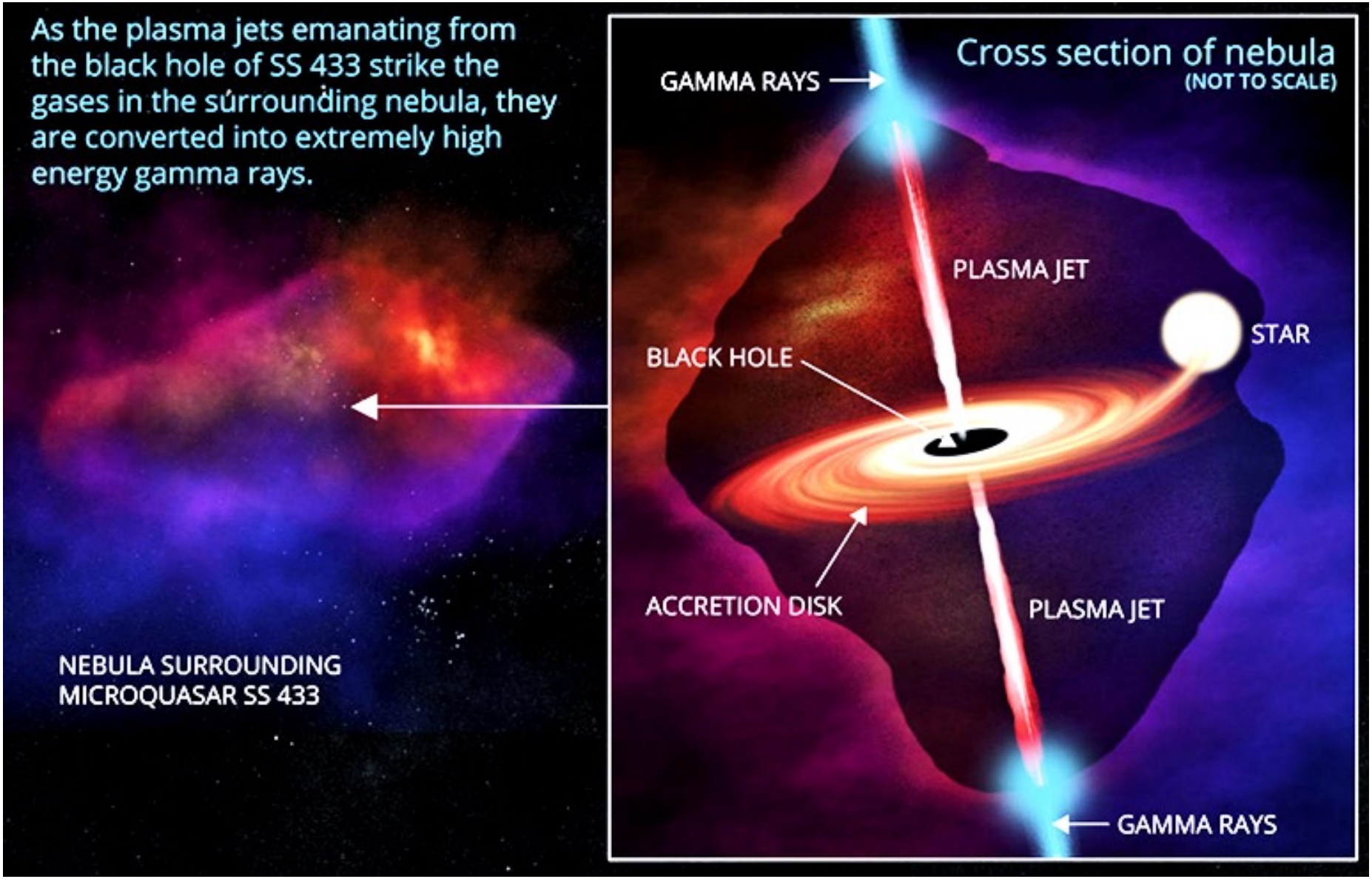
VHE Binary Sources



SS433 HAWC



SS433 HAWC


As the plasma jets emanating from the black hole of SS 433 strike the gases in the surrounding nebula, they are converted into extremely high energy gamma rays.
NEBULA SURROUNDING MICROQUASAR SS 433
Cross section of nebula
(NOT TO SCALE)
GAMMA RAYS
PLASMA JET
STAR
BLACK HOLE
ACCRETION DISK
PLASMA JET
GAMMA RAYS