30th Rencontres de Blois
June 3-8

PARTICLE PHYSICS AND COSMOLOGY
2018

High Energy Gamma-Ray Astronomy

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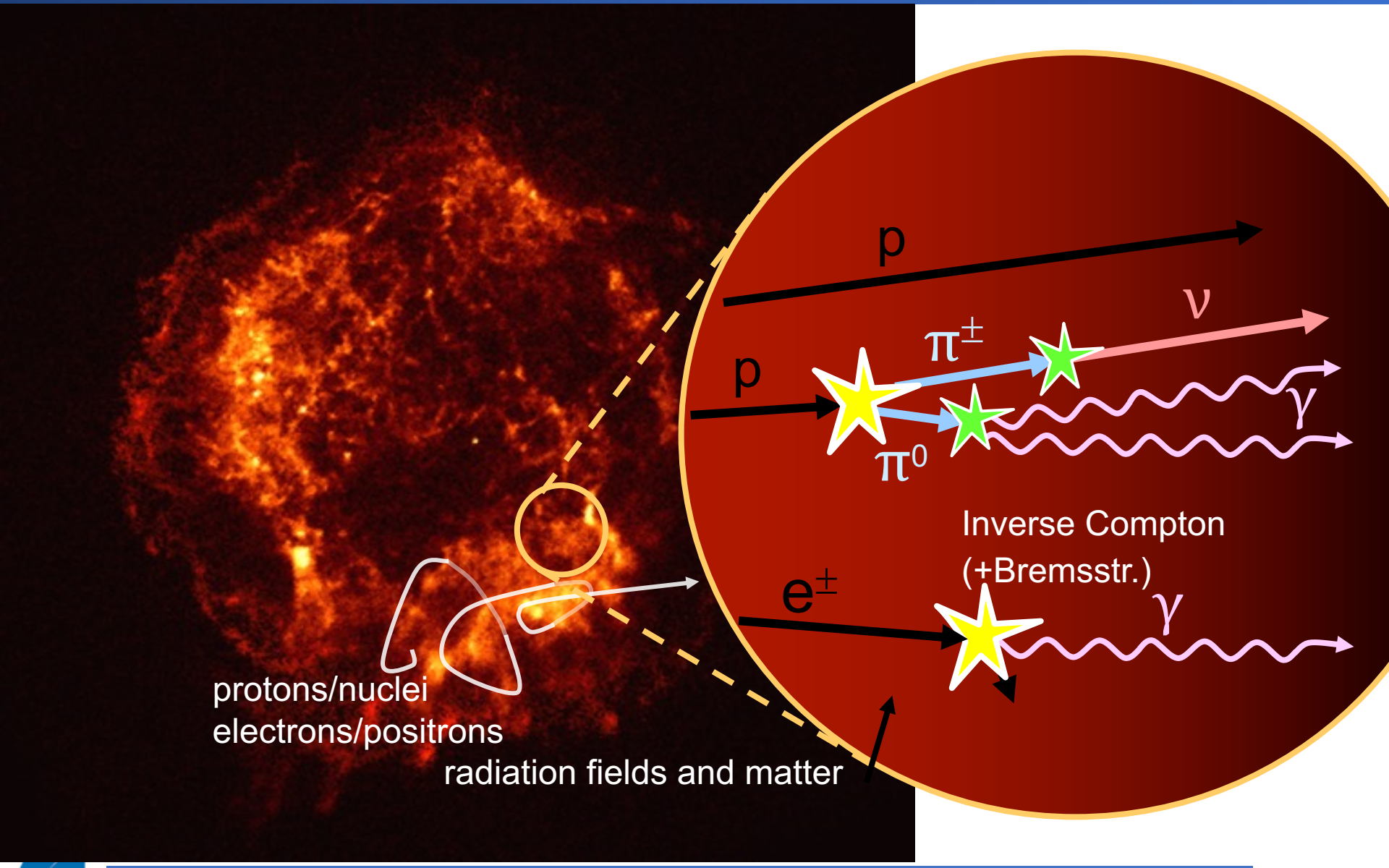
Outline

- Motivation for Gamma-Ray astronomy
- GeV-TeV telescopes
- Some selected results:
  - Galactic sky-maps
  - Search for galactic cosmic-ray sources
- Future instruments

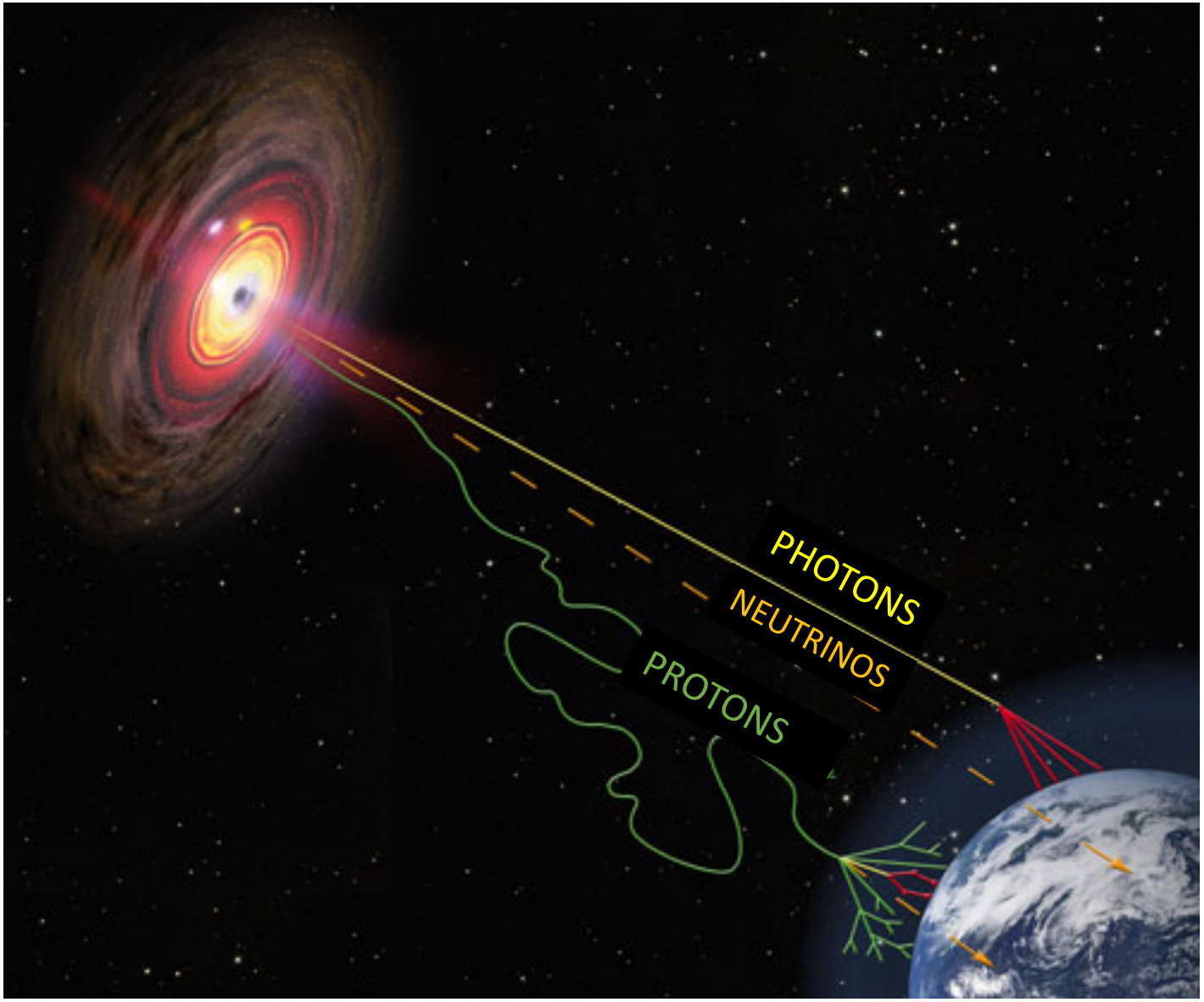
Motivation for Gamma-ray astronomy

- Understanding the Origin and Role of Relativistic Cosmic Particles:
  - Sources of Cosmic Rays
  - Acceleration mechanisms
- Probing extreme environments:
  - Characteristics of relativistic jets, winds and explosions close to neutron stars and black holes
- Exploring Frontiers in Physics:
  - Nature of dark matter
  - Cosmology
  - Quantum gravitational effects

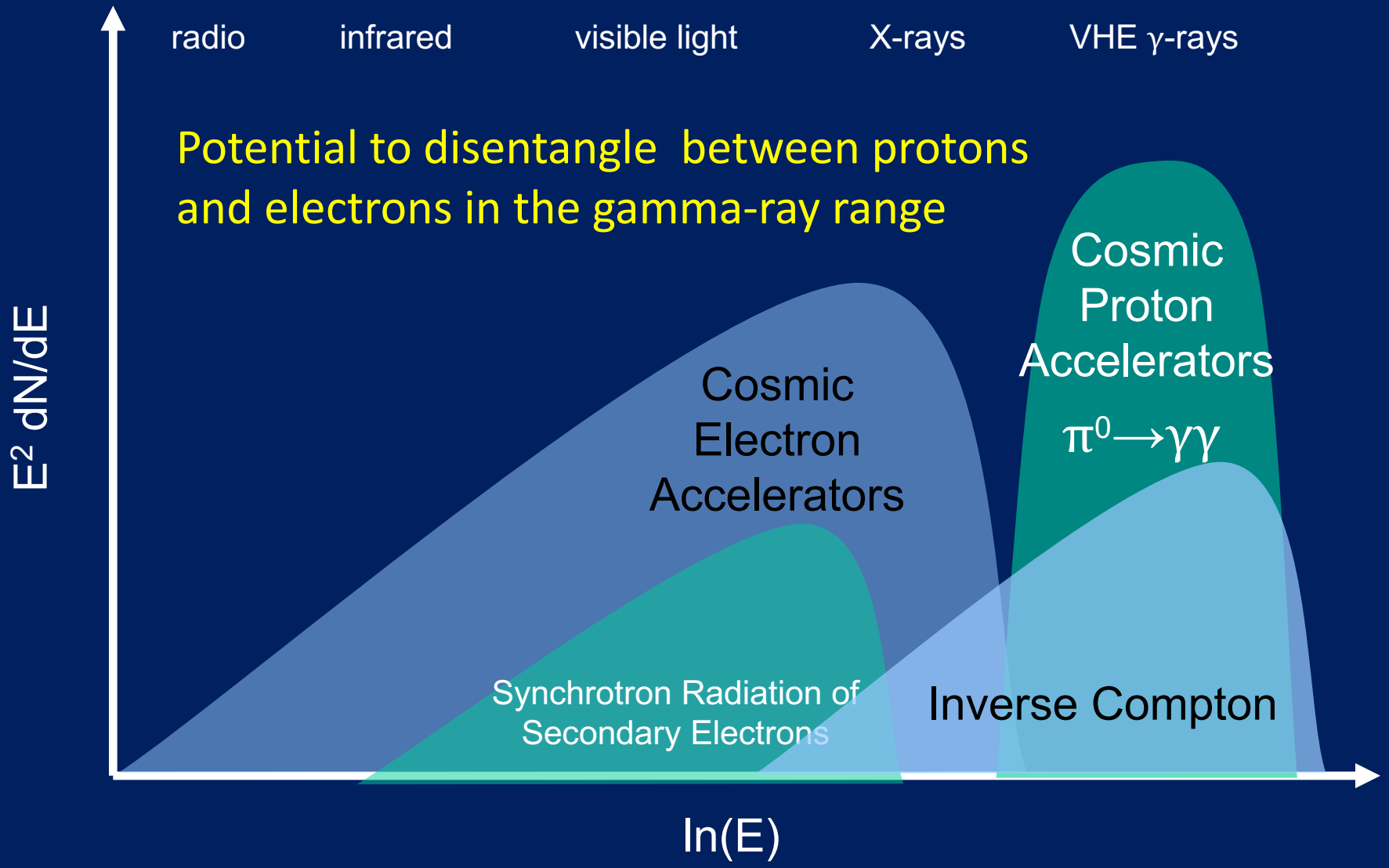
Nature of gamma ray emission



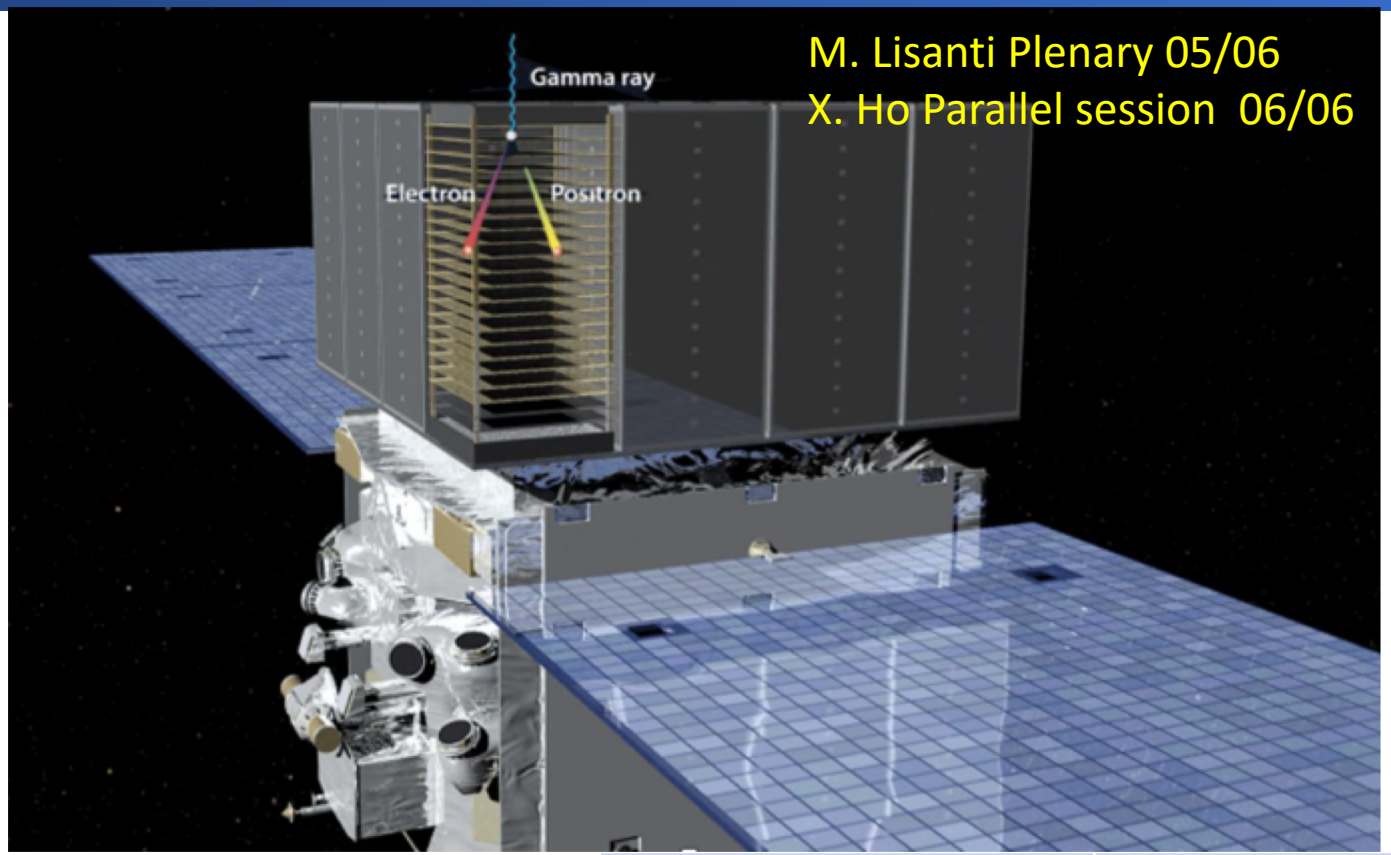
The cosmic messengers



Photon spectrum measured at Earth



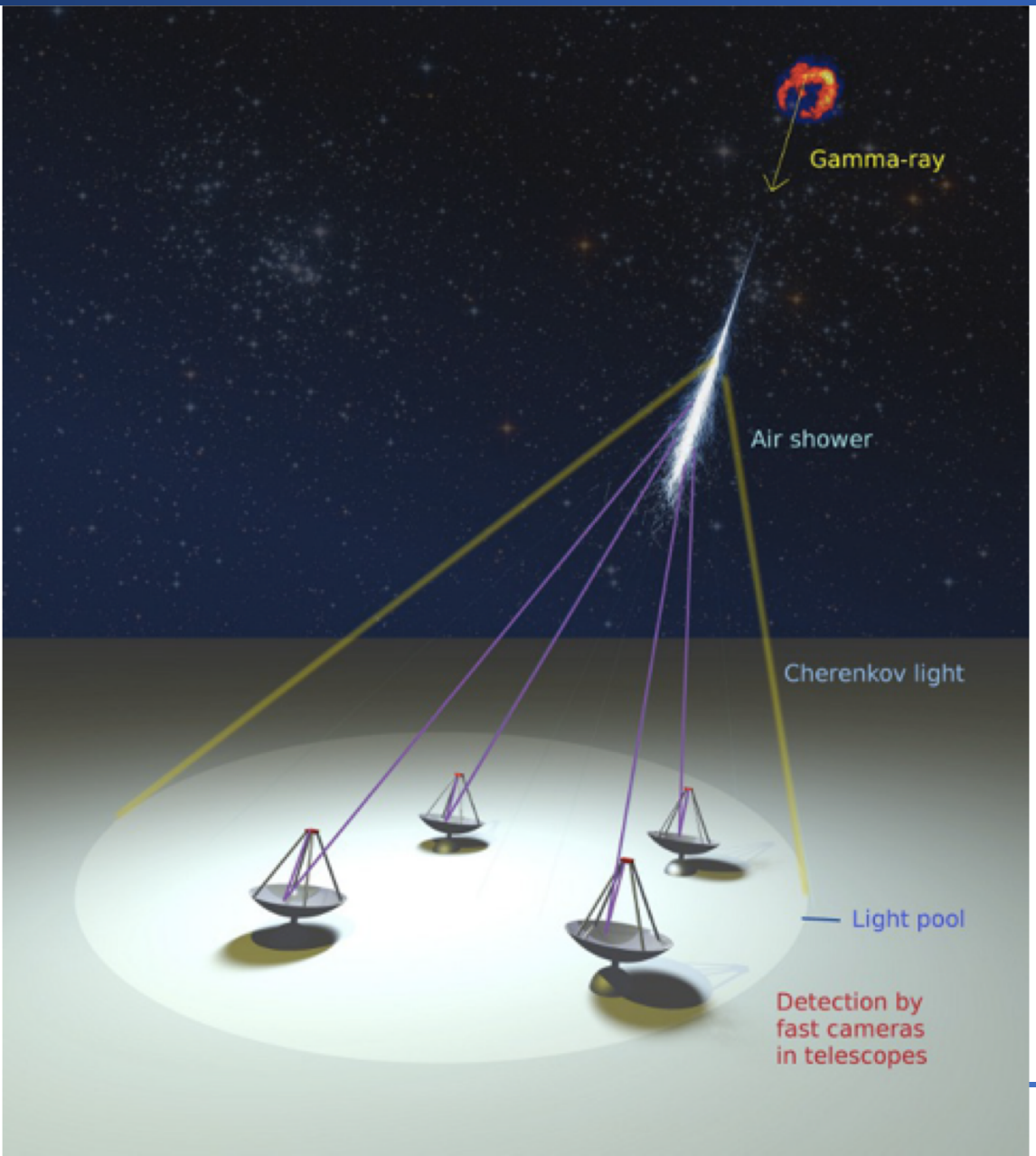
10 GeV-300 GeV: Fermi-LAT & AGILE

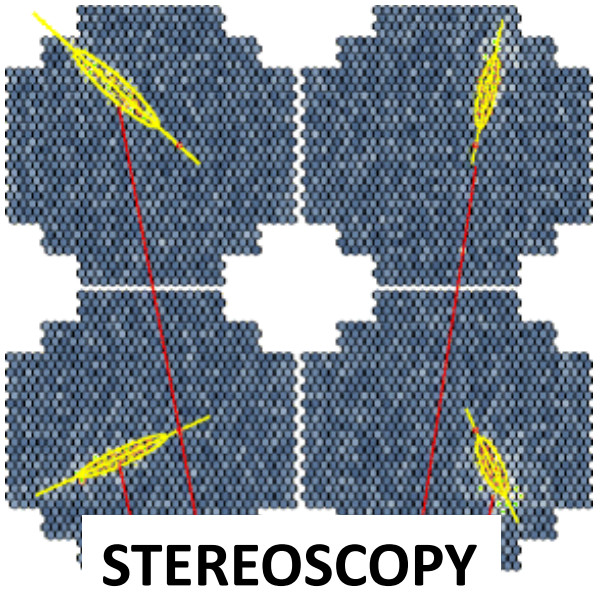


M. Lisanti Plenary 05/06
X. Ho Parallel session 06/06

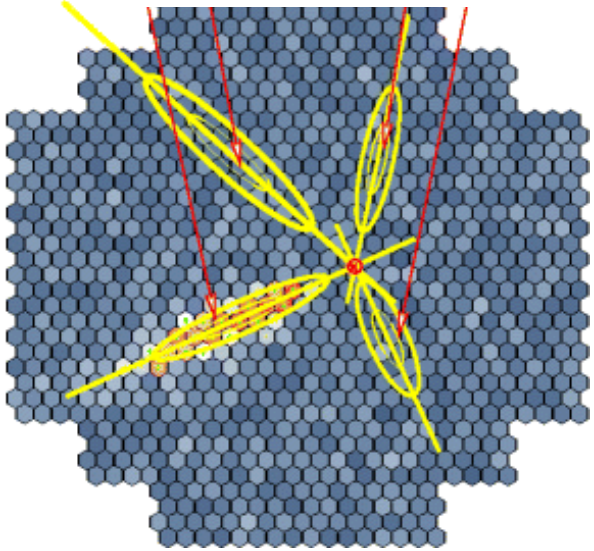
Effective area	1 m^2	Angular Res.	6^o-0.3^o
Field of view	20% of the sky	Duty cycle	Full year
Energy Res.	10%	BCK suppression	good (anticoincidence shield)

TeV: Imaging Atmospheric Cherenkov Telescopes





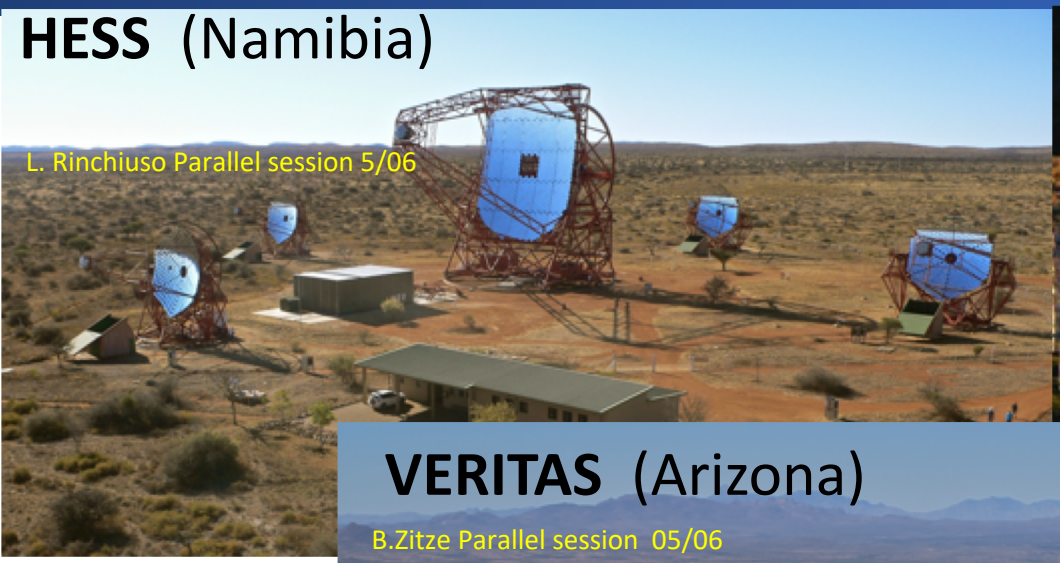
STEREOSCOPY



Present Cherenkov Telescopes

HESS (Namibia)

L. Rinchiuso Parallel session 5/06



MAGIC & FACT (La Palma)

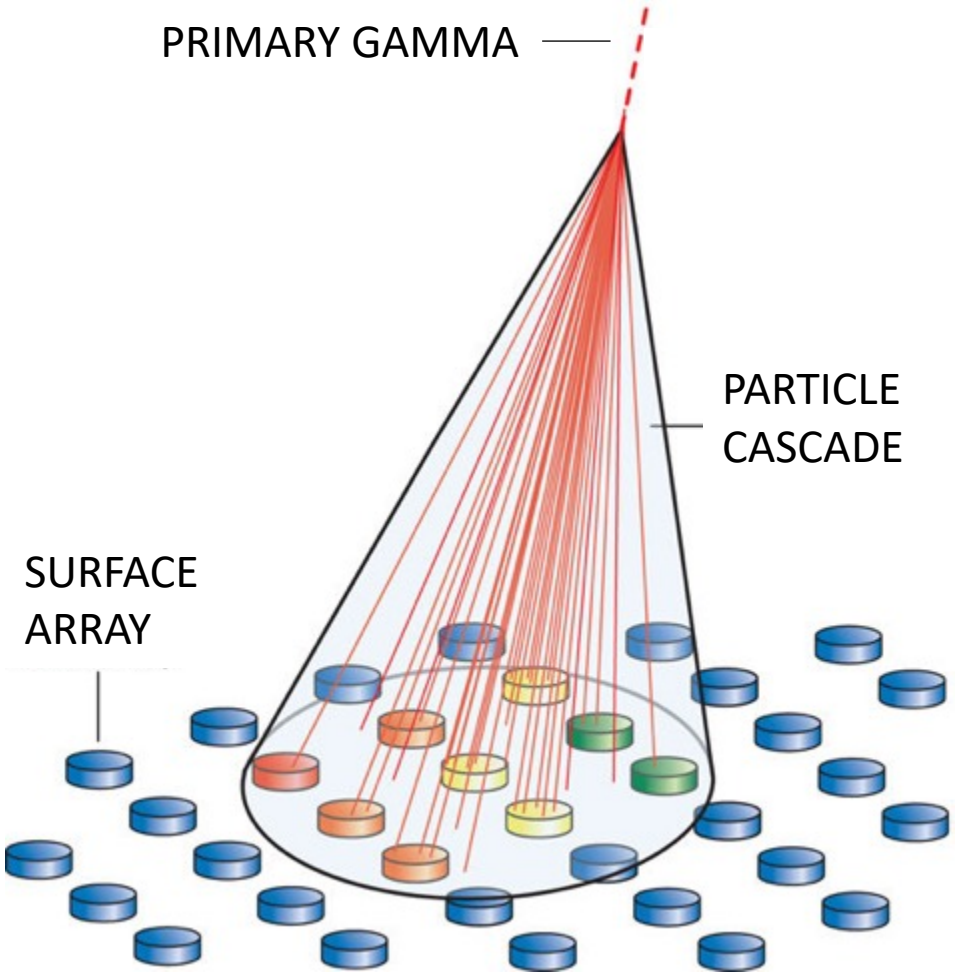
A. Berti Parallell session 06/06

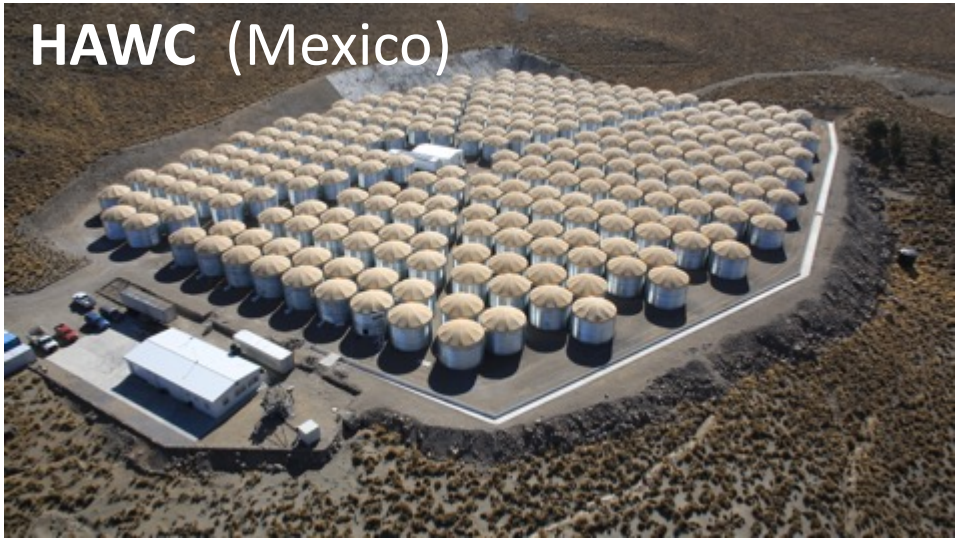
VERITAS (Arizona)

B.Zitze Parallel session 05/06
B.Zitze Parallel session 06/06

Effective area	10^5 m^2	Angular Res.	0.1º
Field of view	3º-5º	Duty cycle	1400 h/year
Energy Res.	10%	BCK suppression	good g-h discrimination

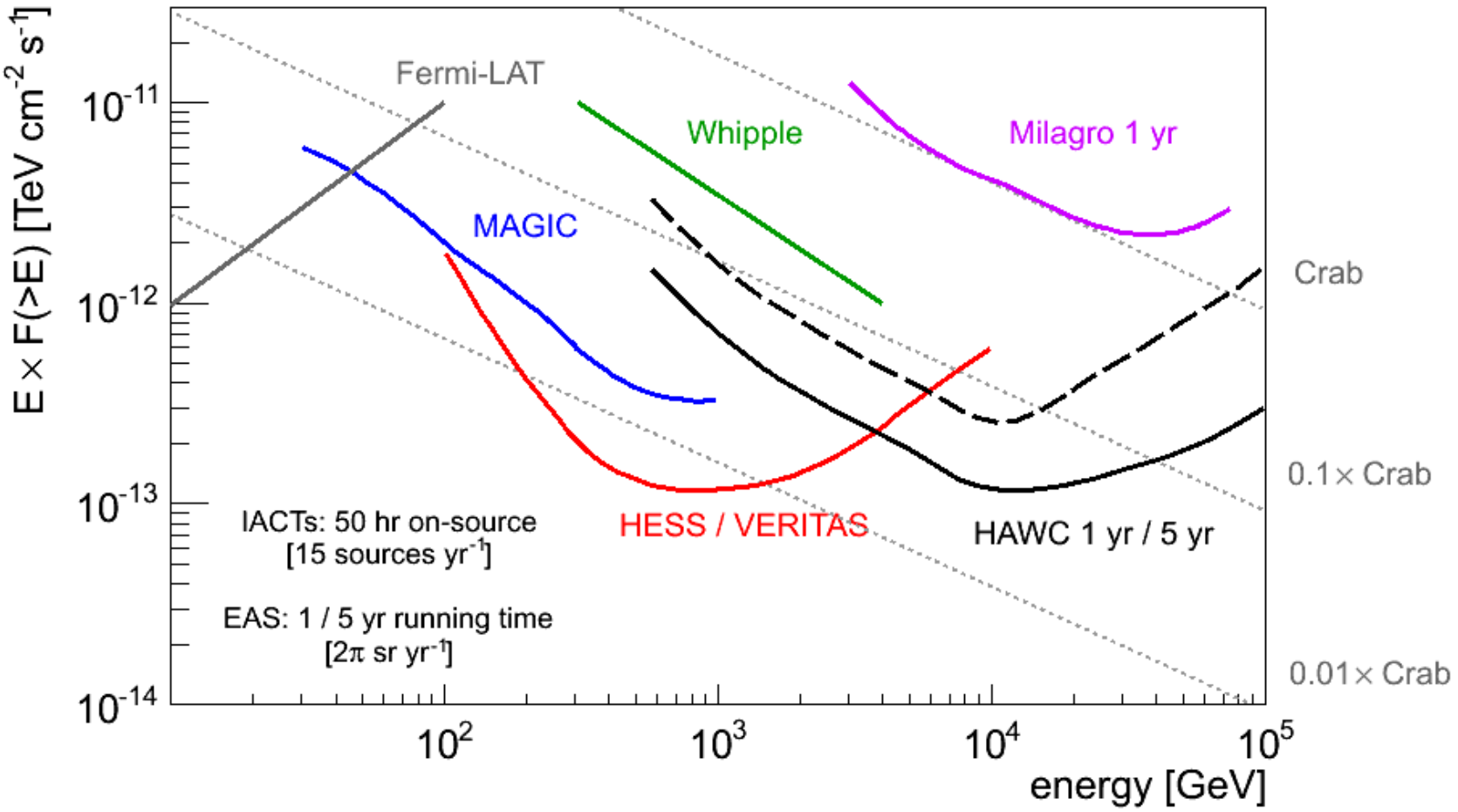
TeV domain: Extensive Air Shower Detectors





Effective area	10^5 m^2
Field of view	15% of the sky
Energy Res.	20%-100%
Angular Res.	1° -0.1°
Duty cycle	Full year
BCK suppression	poor g-h discrimination

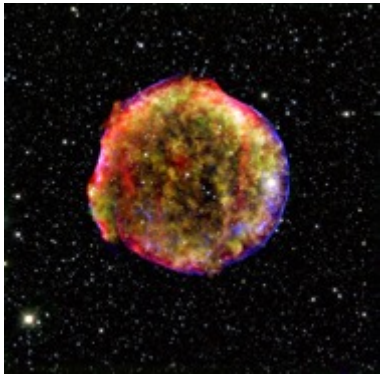
Complementarity between instruments



Which sources are detected with gammas?

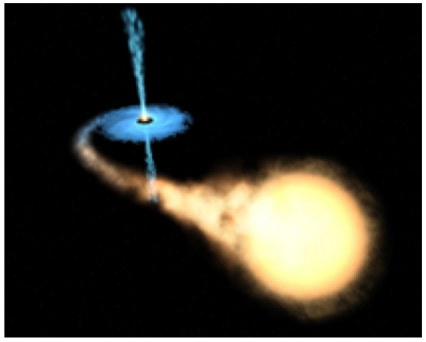
GALACTIC

Supernova Remnants



Pulsars

Microquasars

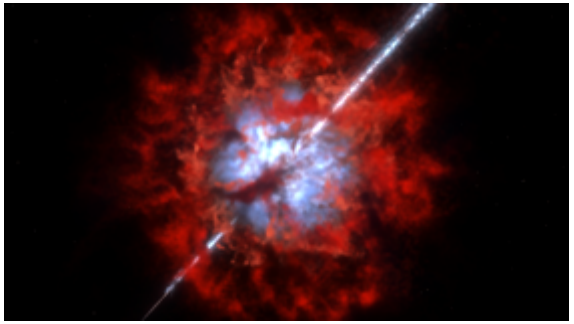


EXTRA-GALACTIC

Active Galactic Nuclei

Starburst galaxies

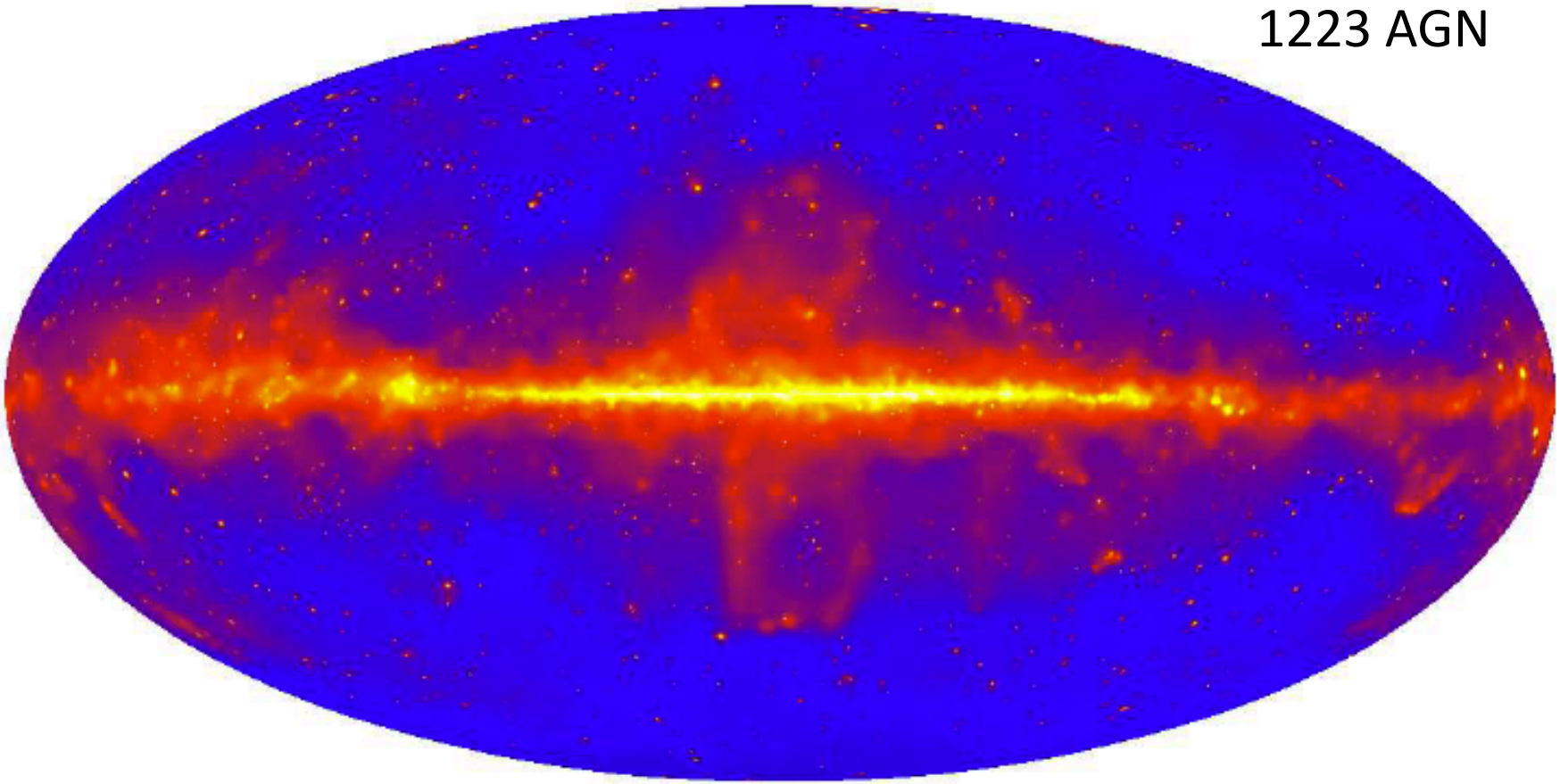
Gamma Ray Bursts



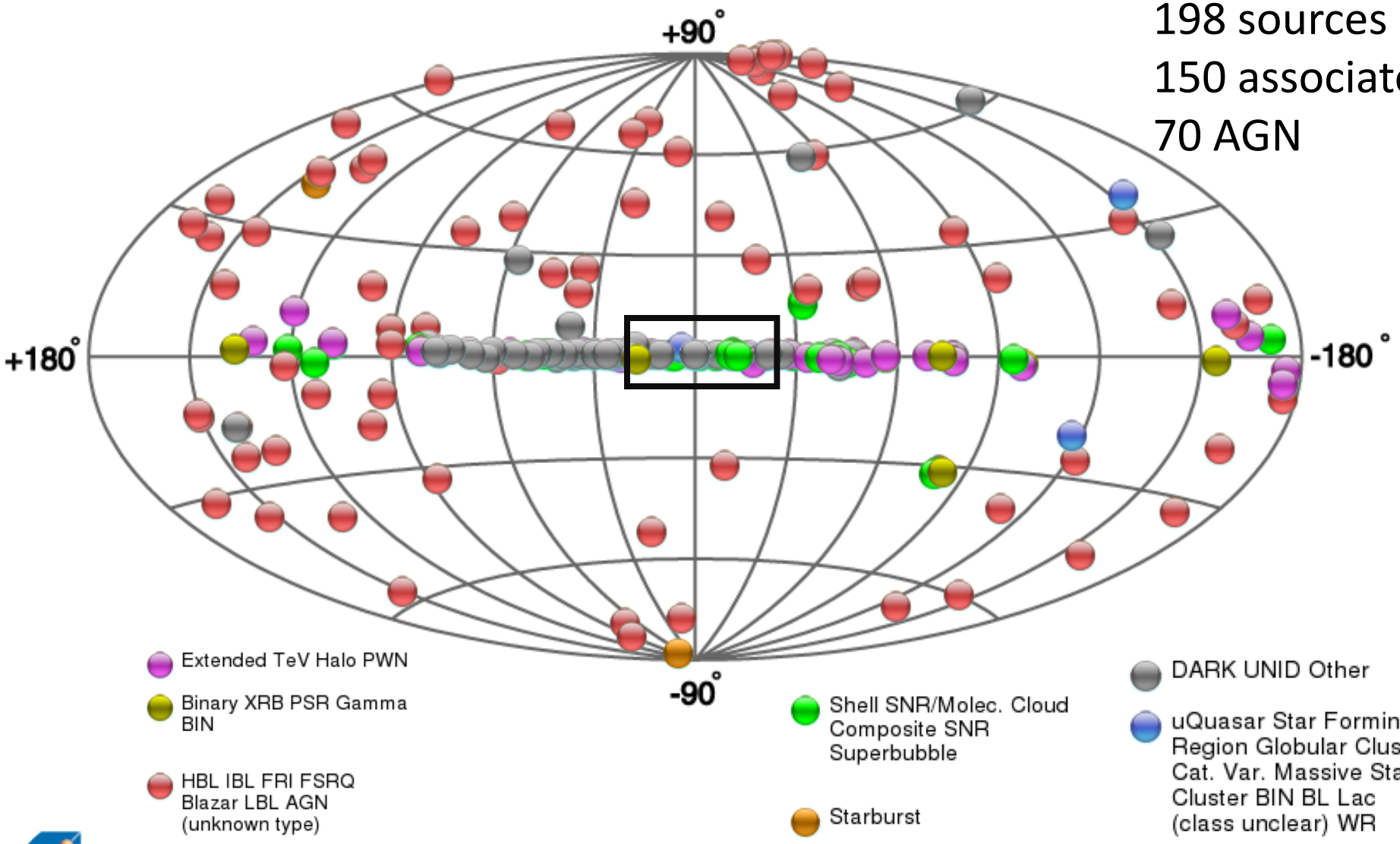
Fermi-LAT Sky E>10 GeV

3rd Catalog 3FHL : arXiv:1702.0066

1558 sources
1242 associated
1223 AGN



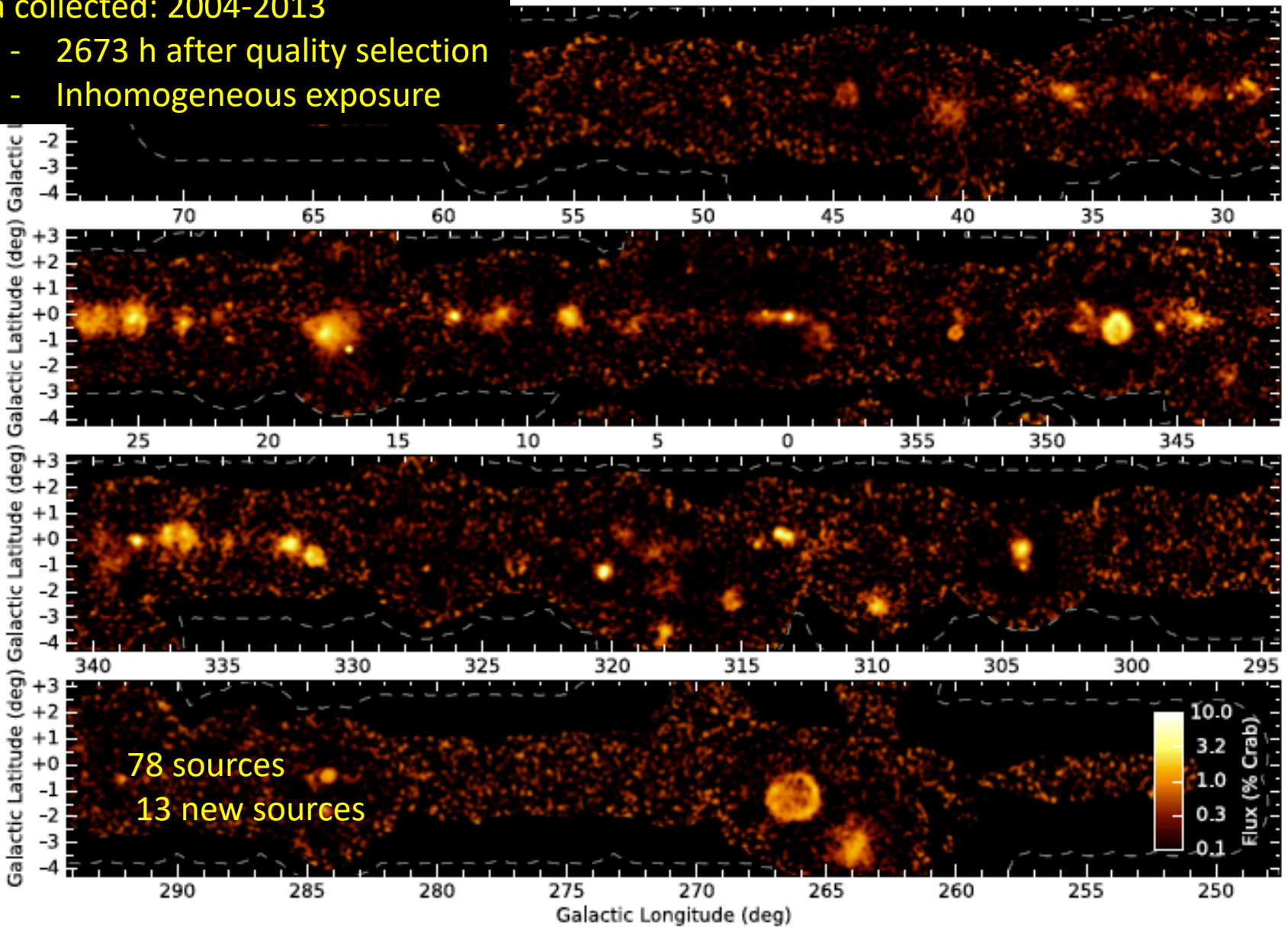
TeV sources: TeVCAT



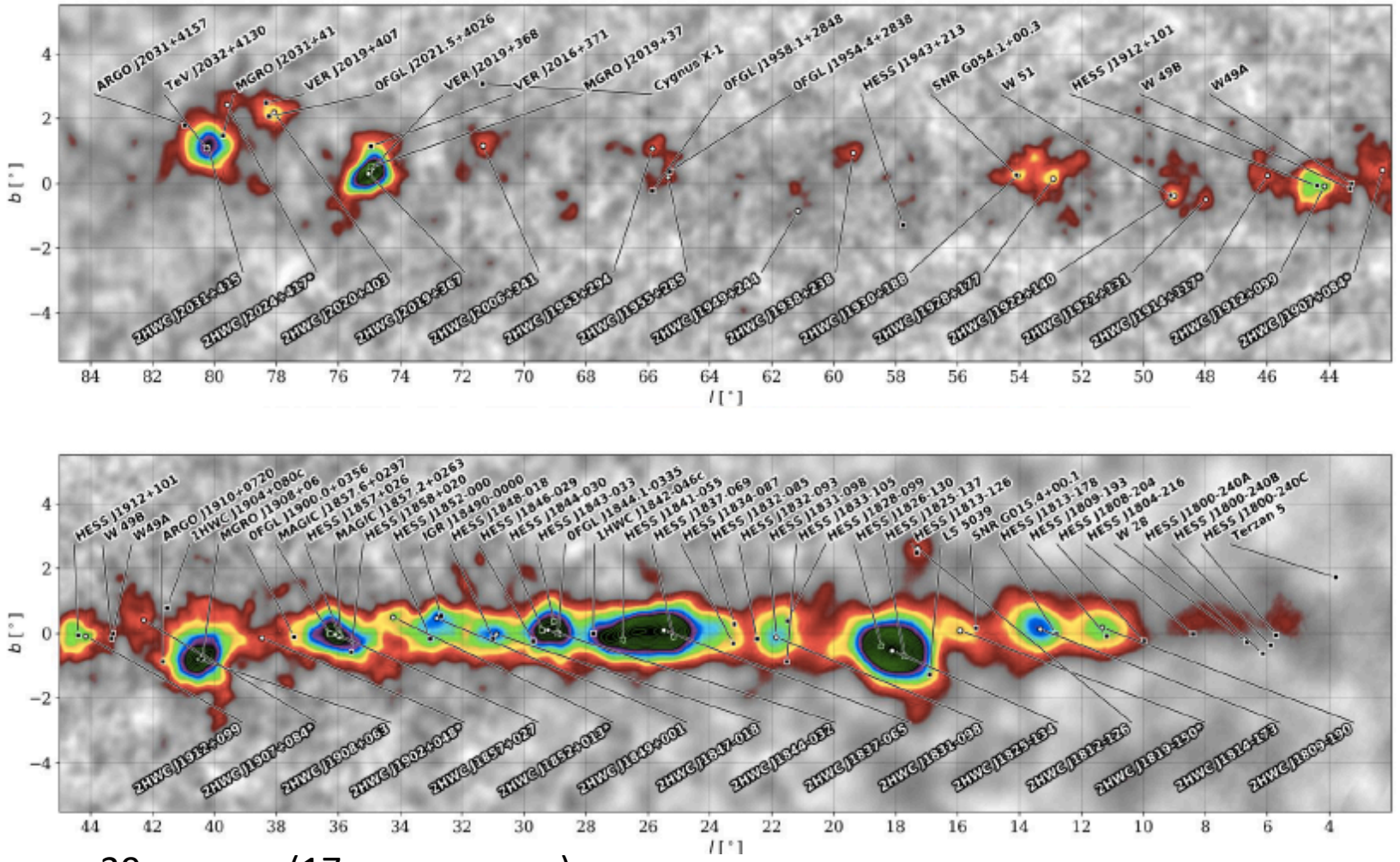
HESS Galactic Plane Survey: A&A Special Issue 2018

Data collected: 2004-2013

- 2673 h after quality selection
- Inhomogeneous exposure

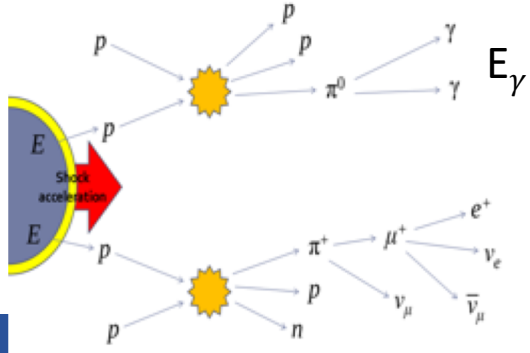


HAWC Galactic Plane Survey



- 39 sources (17 new sources)
- Some new sources with no counterpart
- Galactic Latitude <4°

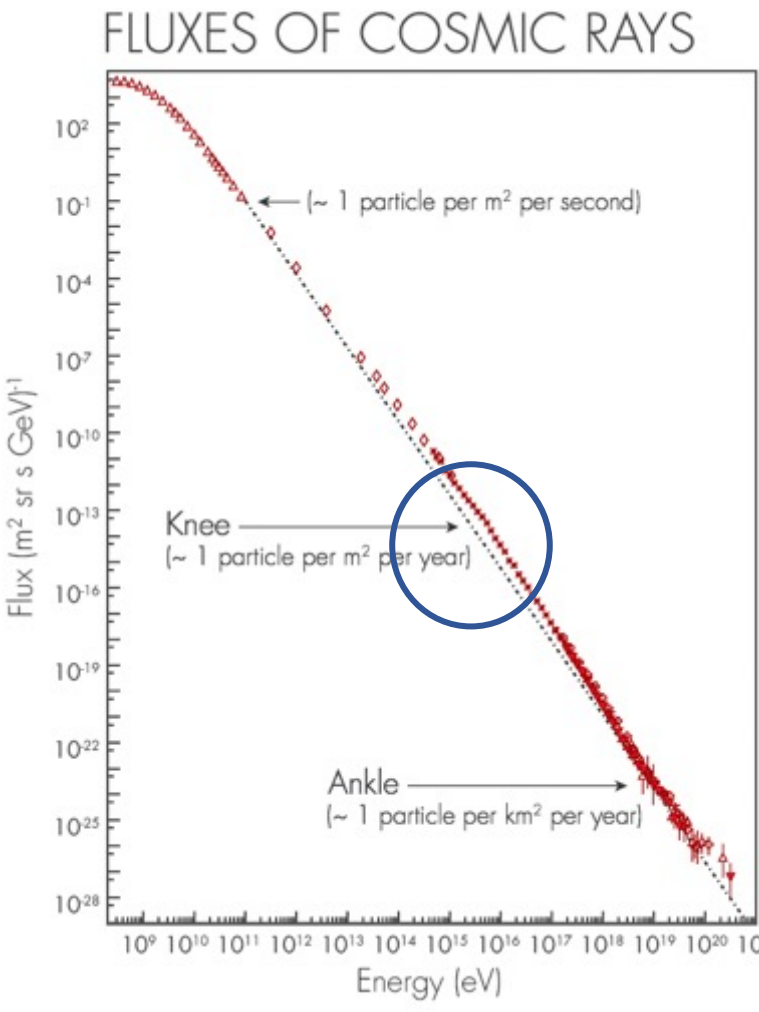
HAWC Collaboration: A.U. ApJ **843** (2017), 40.



$E_\gamma \sim 0.1\ E_p$

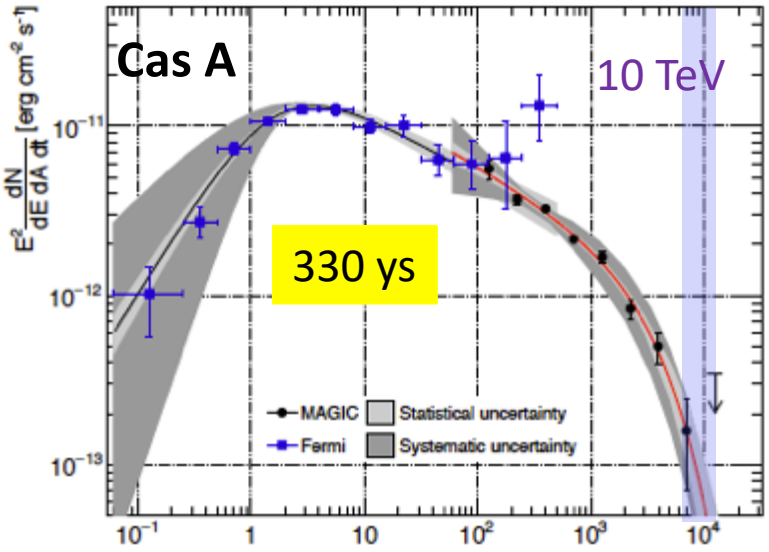
Cosmic ray sources in the Galaxy

- PeVatrons: source accelerating at $E_p > 10^{15}$ eV
- Are SNRs PeVatrons?
- Where are the PeVatrons?
- Looking for $E_\gamma > 100$ TeV ($E_\gamma \sim 0.1\ E_p$)

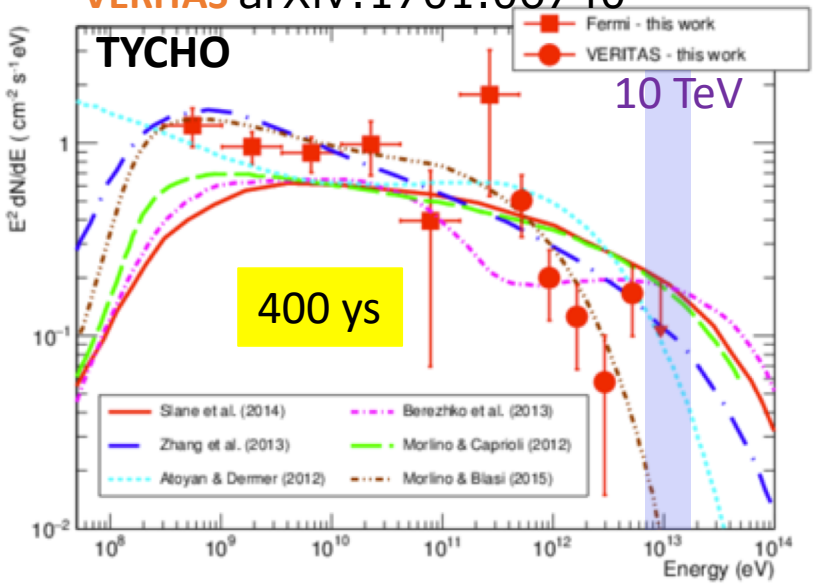


Are SNRs PeVatrons?

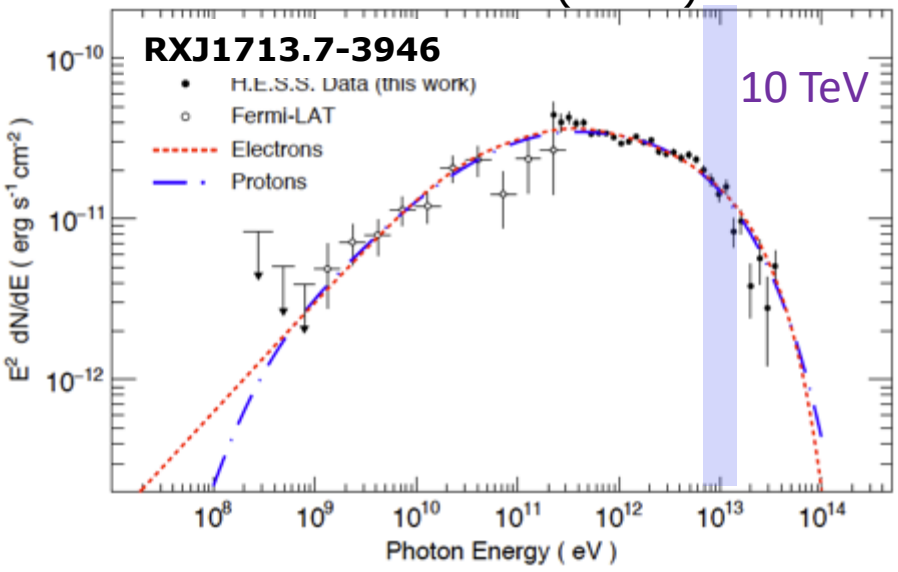
MAGIC arXiv:1707.01583v1



VERITAS arXiv:1701.06740



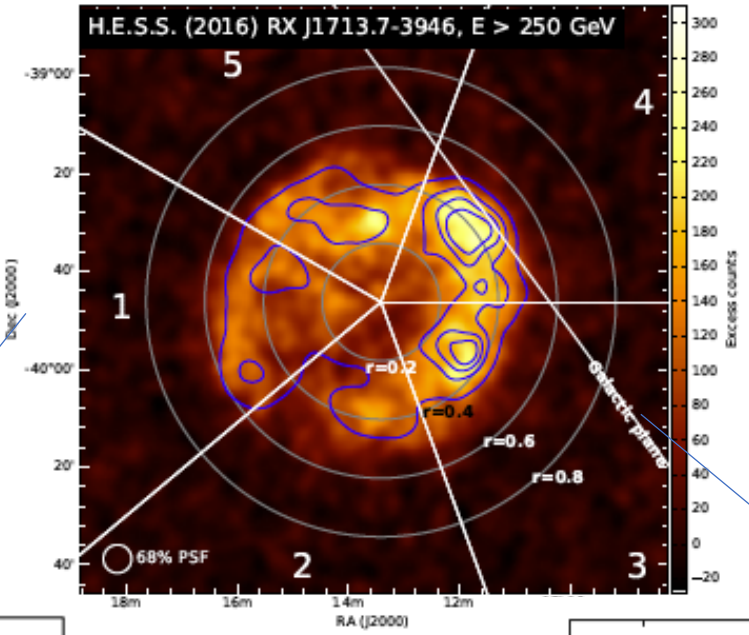
HESS A&A Vol. 612 (2018)



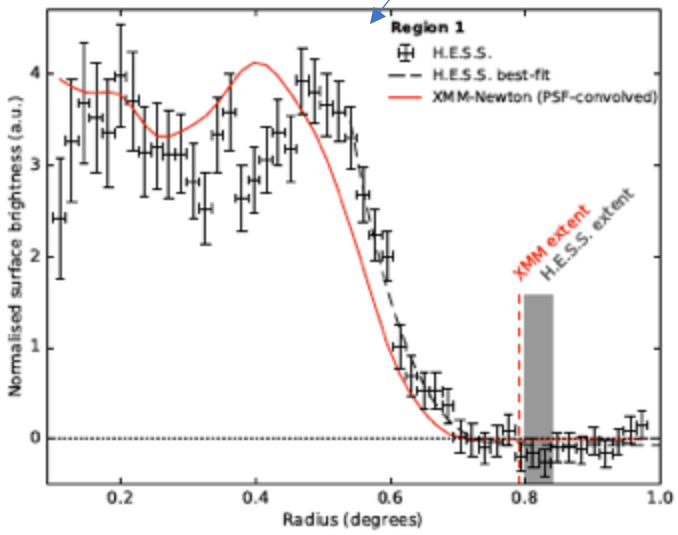
No SNRs detected as PeVatron up to now

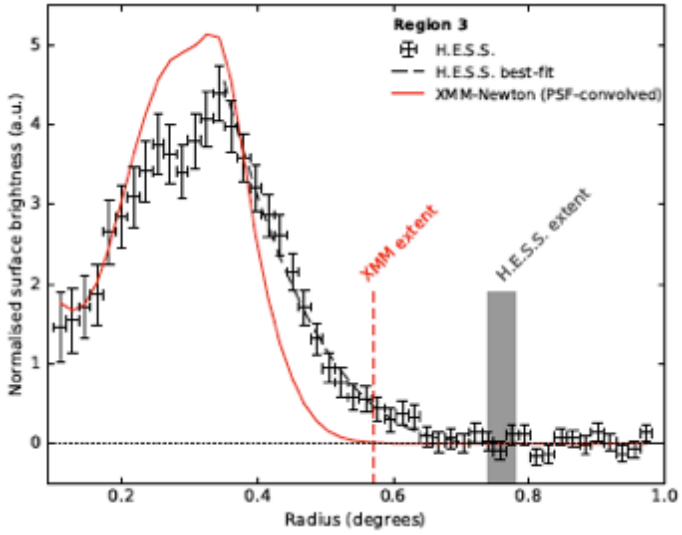
RXJ1713.7-3946

- Escape of HE particles from SNRs
- Only young SNRs can contain PeV cosmic rays ?

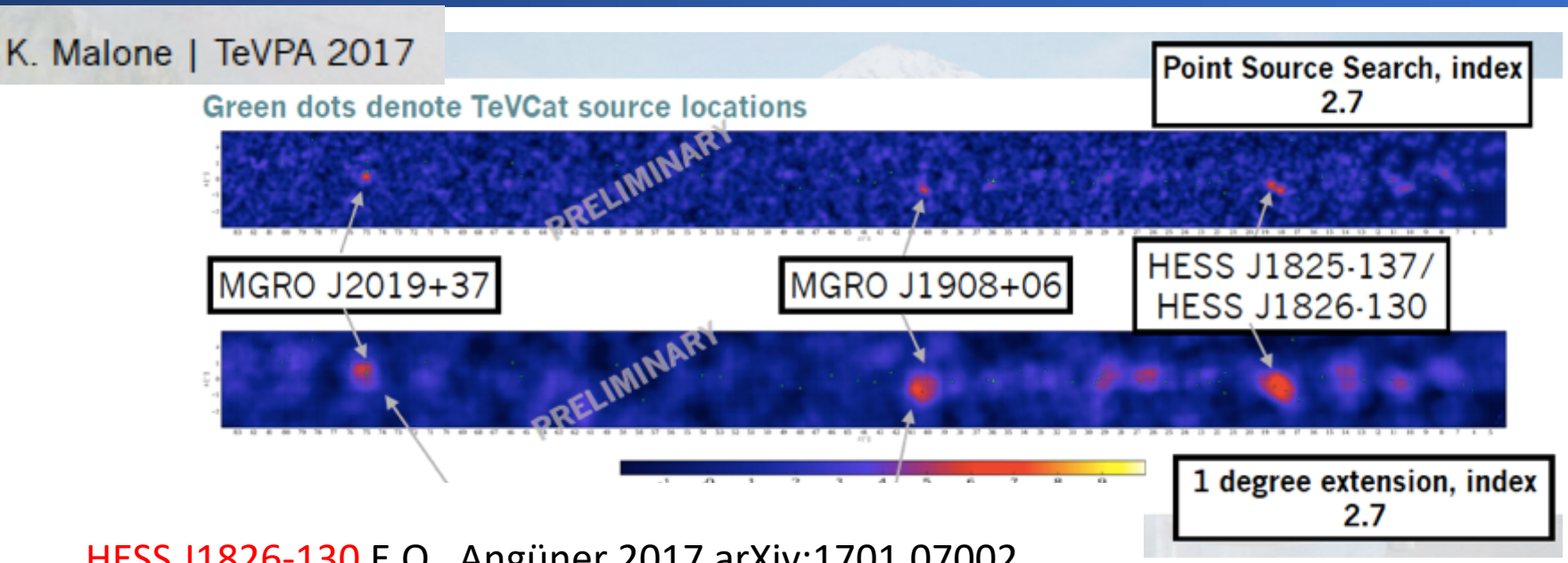


HESS A&A Vol. 612 (2018)

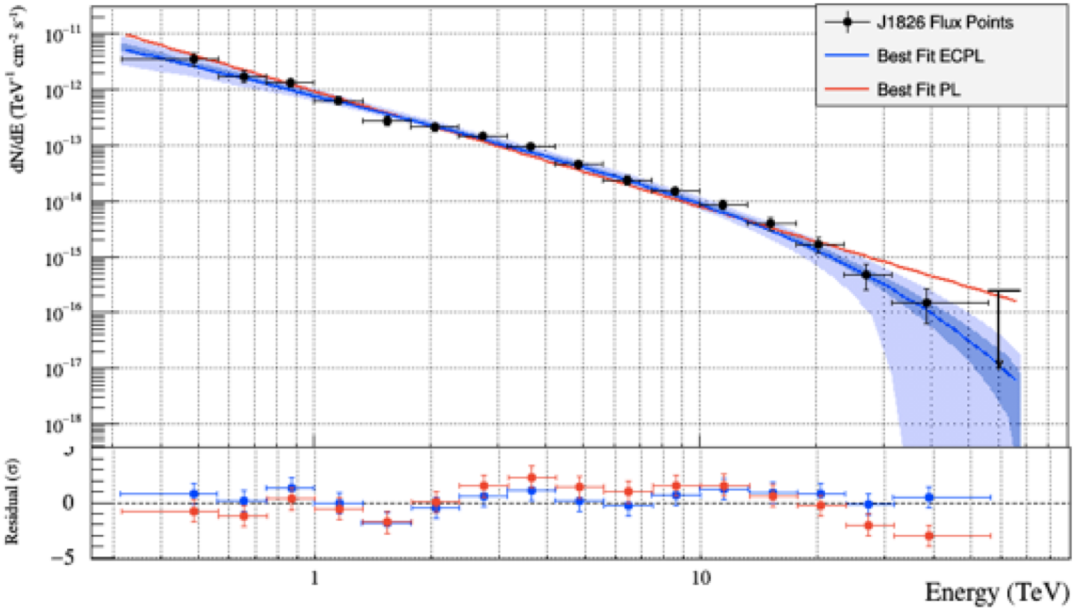




HAWC Galactic plane for E>56 TeV



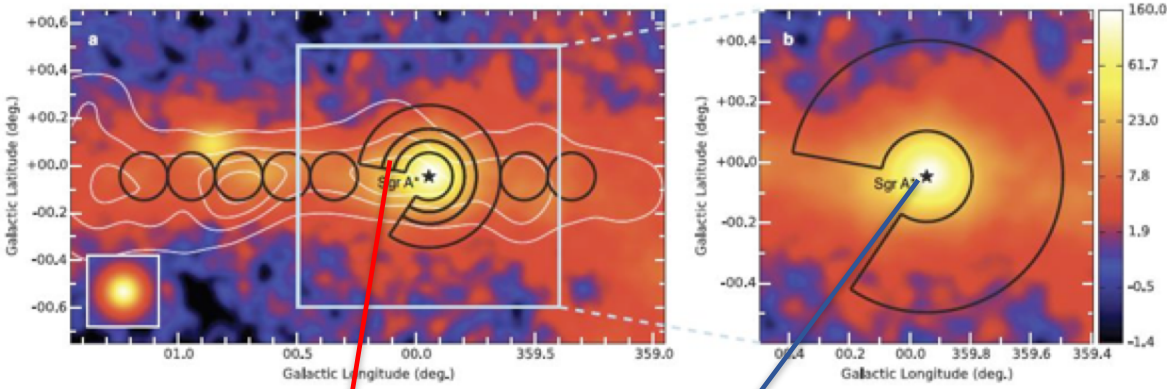
HESS J1826-130 E.O. Angüner 2017 arXiv:1701.07002

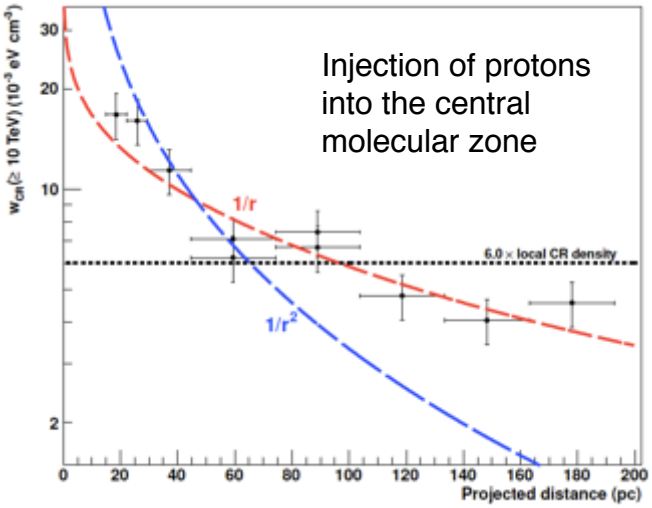


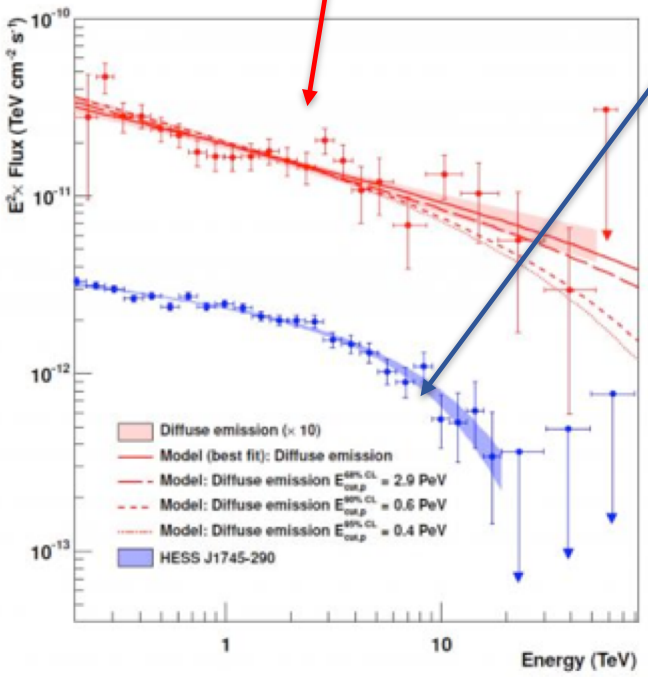
- Very hard spectrum and coincident with dense gas region
- Good PeVatron candidate

Combined study of Cherekov telescopes and particle telescopes is crucial

A Cosmic PeVatron at the center of the Milky Way ?





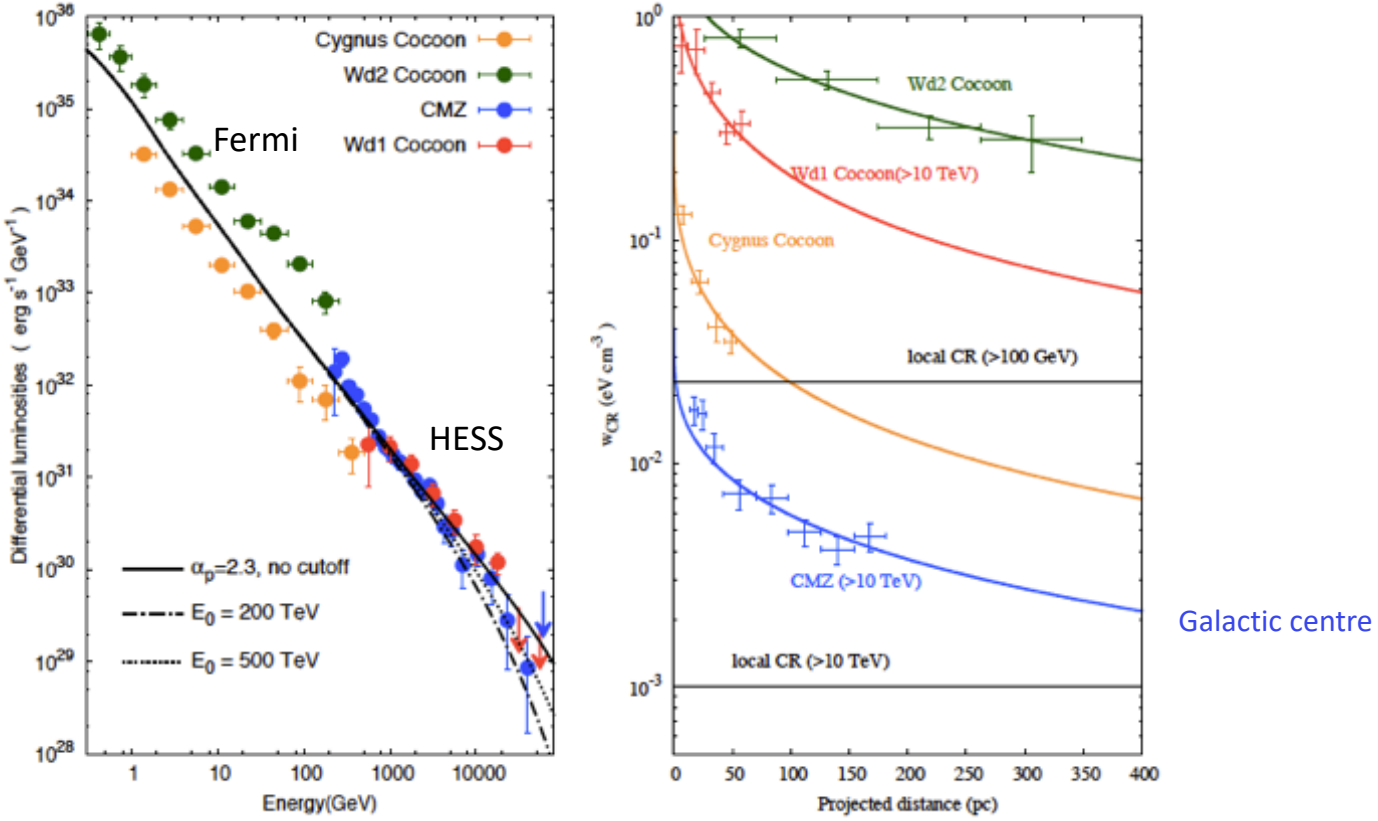


- Power law sprectrum without break or cut-off up to several tens of TeV from diffuse emission in the central 70 pc of the Milky Way
- A signature of a hadronic PeVatron (Sgr A*?) emitting up to 10^{15} eV

(HESS consortium, Abramowski et al, Nature, 2016)

Massive Stars clusters as Factories of Galactic CRs?

The 1/r decrement of the CR density with the distance from the star cluster is a signature of continuous injection of CRs and their diffusion through ISM.



Galactic centre

F. Aharonian,, R. Yang, E. de Ona Wilhelmi; arXiv:1804.02331v1 Apr. 2018

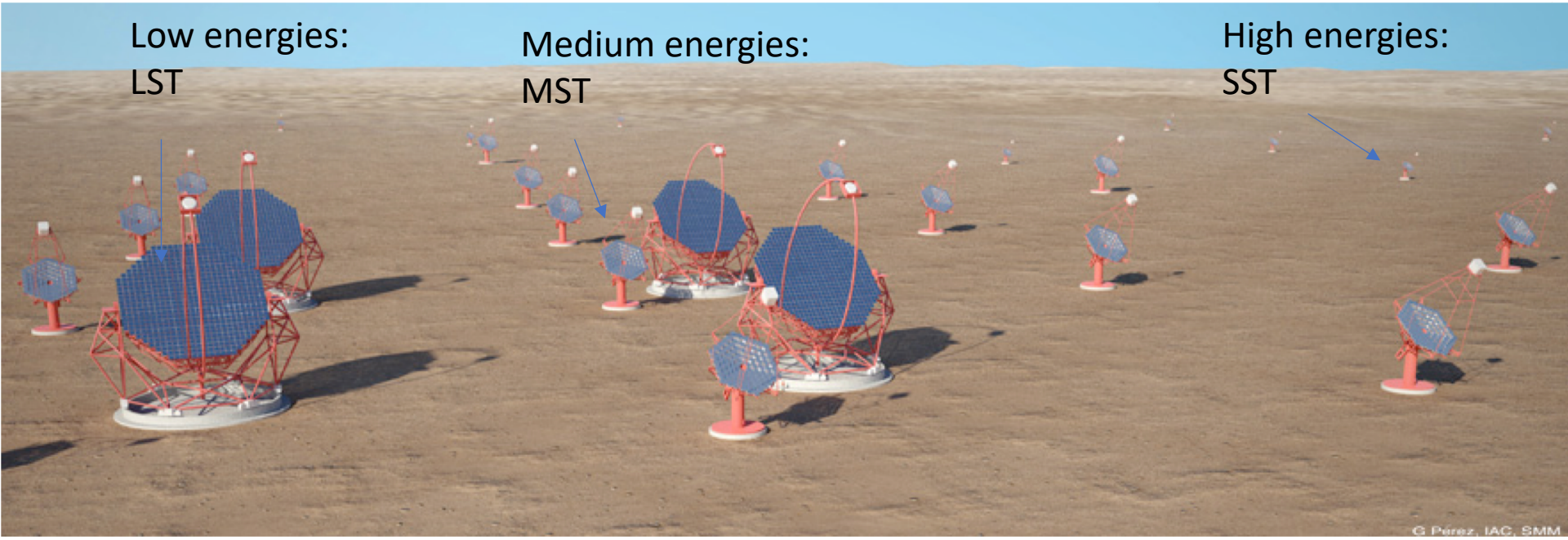
Future instruments:

- **Better sensitivity** (more sources allow population studies => insight in acceleration processes)
- **Larger energy range** (overlap between instruments, exploration at E >100 TeV)
- **Both Cherenkov and EAS telescopes needed**

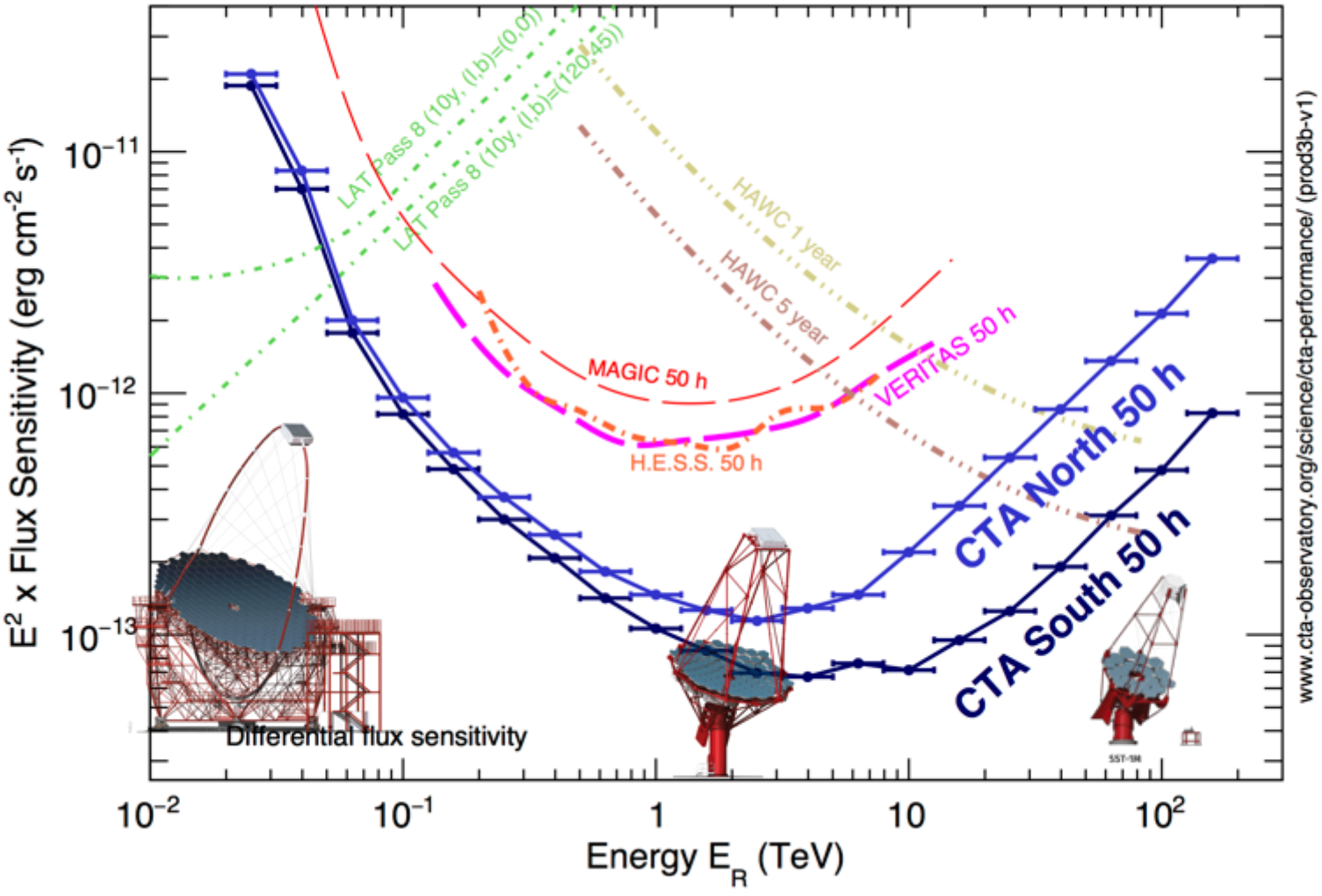
The Cherenkov Telescope Array

- More than 100 telescopes on 2 sites: Northern and Southern Hemisphere
- Between a factor 5 and 10 better sensitivity than existing instruments
- Angular resolution < 0.1° in most energy range
- Large field of view (8°)
- Energy coverage: 20 GeV-300 TeV
- Rapid slew (20s) to catch flaring sources

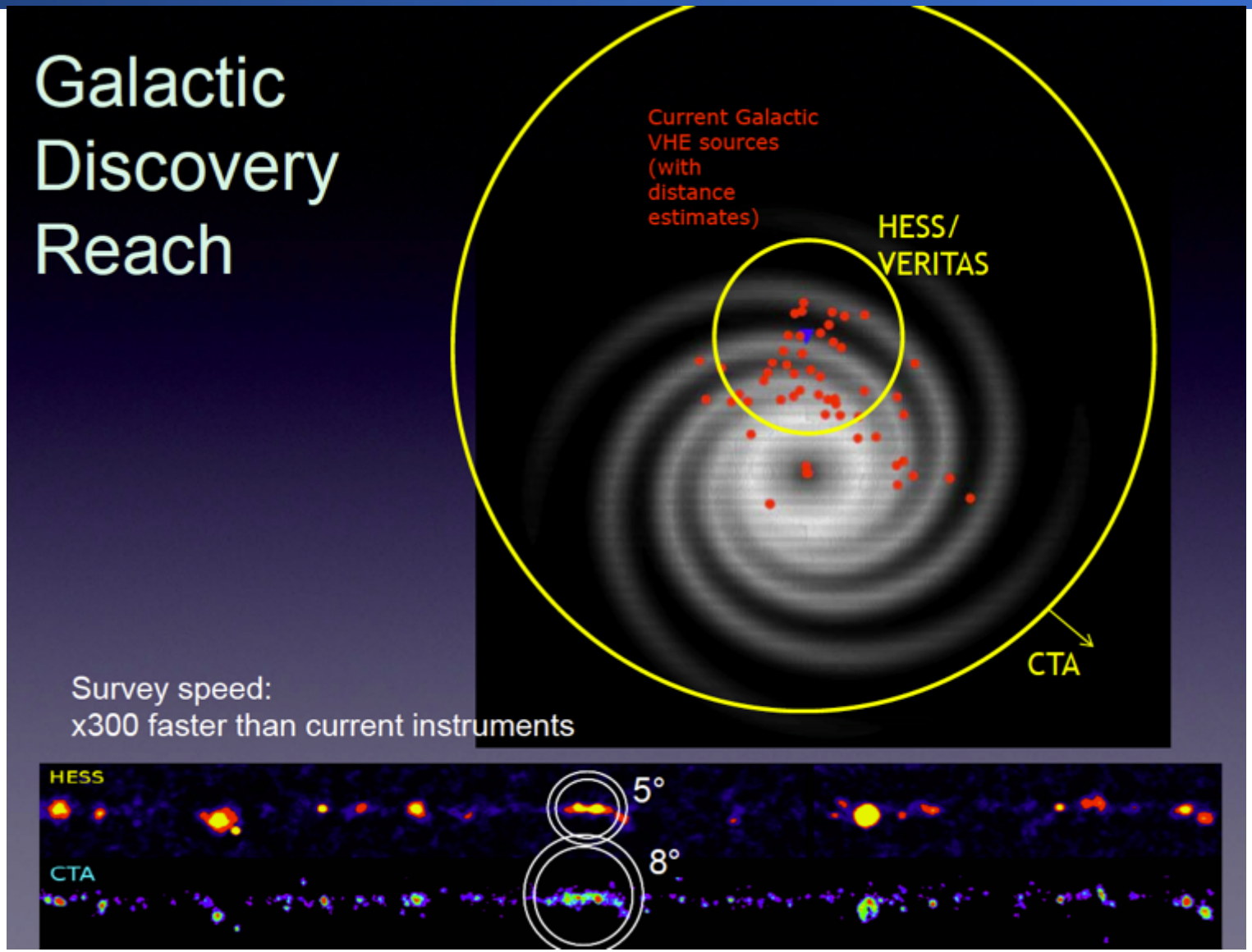
cta
cherenkov telescope array



The Cherenkov Telescope Array

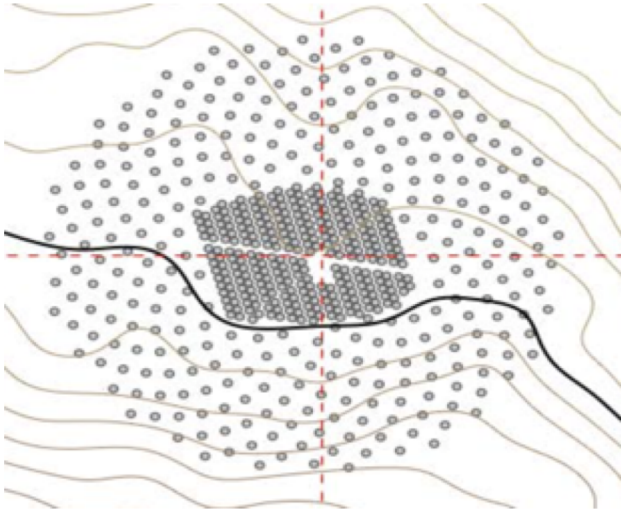


CTA Performance



Slide from R. Ong

Future of HAWC



UPGRADE

- Sparse array of small outrigger tanks
- A gain of 3–4 in sensitivity for gammas above 10 TeV

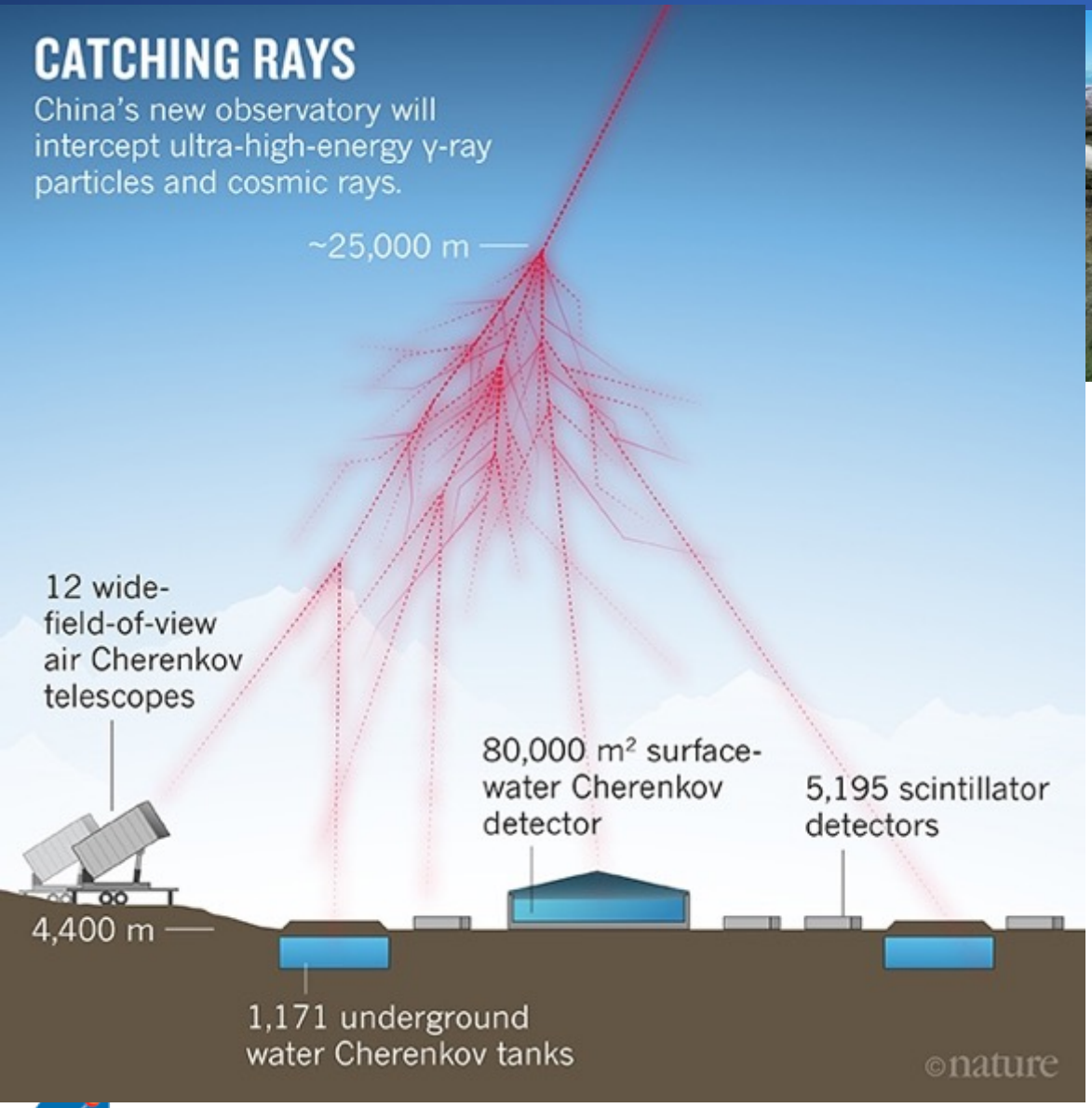
PARTICLE DETECTORS IN THE SOUTH

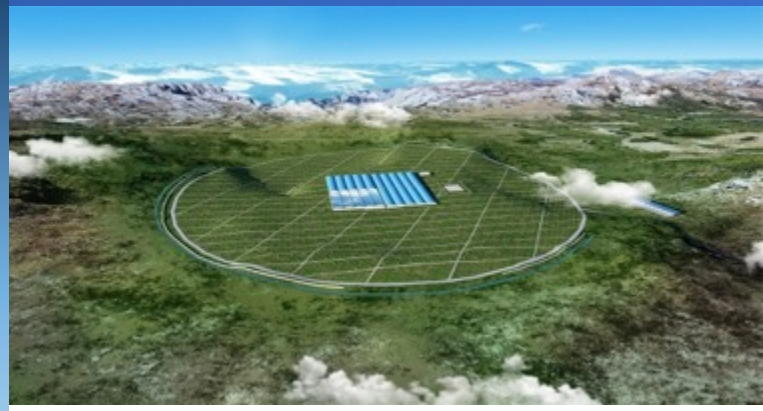
- HAWC South
- ALTO arXiv:1708.01053, arXiv:1708.01059
- LATTES (B. Tomé parallel session 06/06)

Southern sky coverage is missing!

TeV Source finder for CTA south

LHAASO

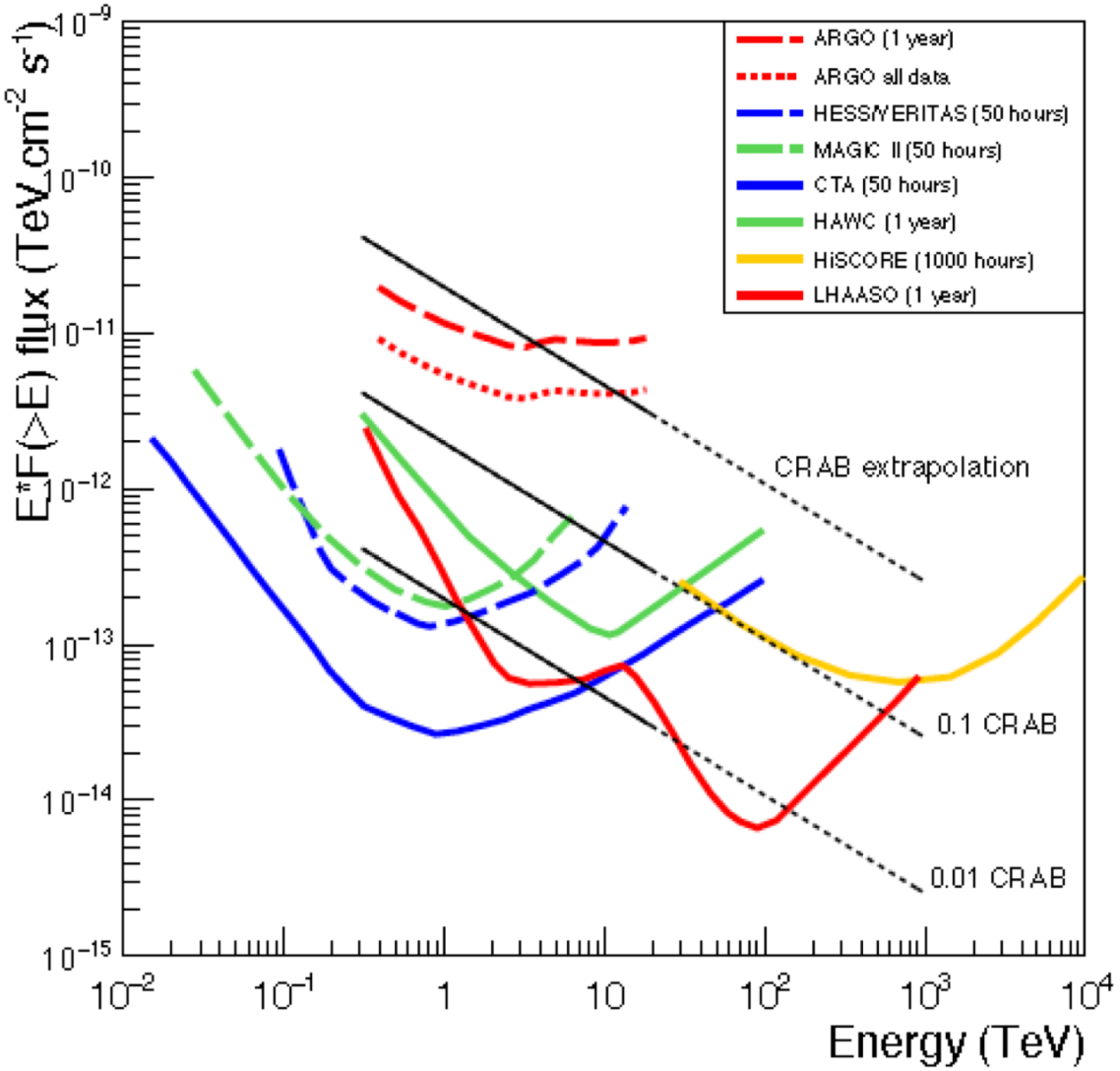




- 1.3 km^2 detector
- Water Cherenkov tanks
- Scintillator detectors
- Air Cherenkov telescopes

UNDER CONSTRUCTION

Complementarity of future instruments



Conclusions

- VHE gamma-ray astronomy has become a major exciting field of research which addresses a wide, and expanding, range of astrophysical topics
- There is an incredible diversity in the Galactic gamma-ray sky: many sources, many source classes
- Gamma rays can shed light on the origin of cosmic rays and give insight in fundamental physics and cosmology
- Present results demonstrate the importance of complementary instrumental approaches in gamma-ray astronomy
- Future observatories will improve significantly our understanding of the violent Universe with a large potential for new discoveries