



# Searching for Unassociated Fermi Objects with the highest energy gamma rays in the Galaxy

By Maleah Rhem

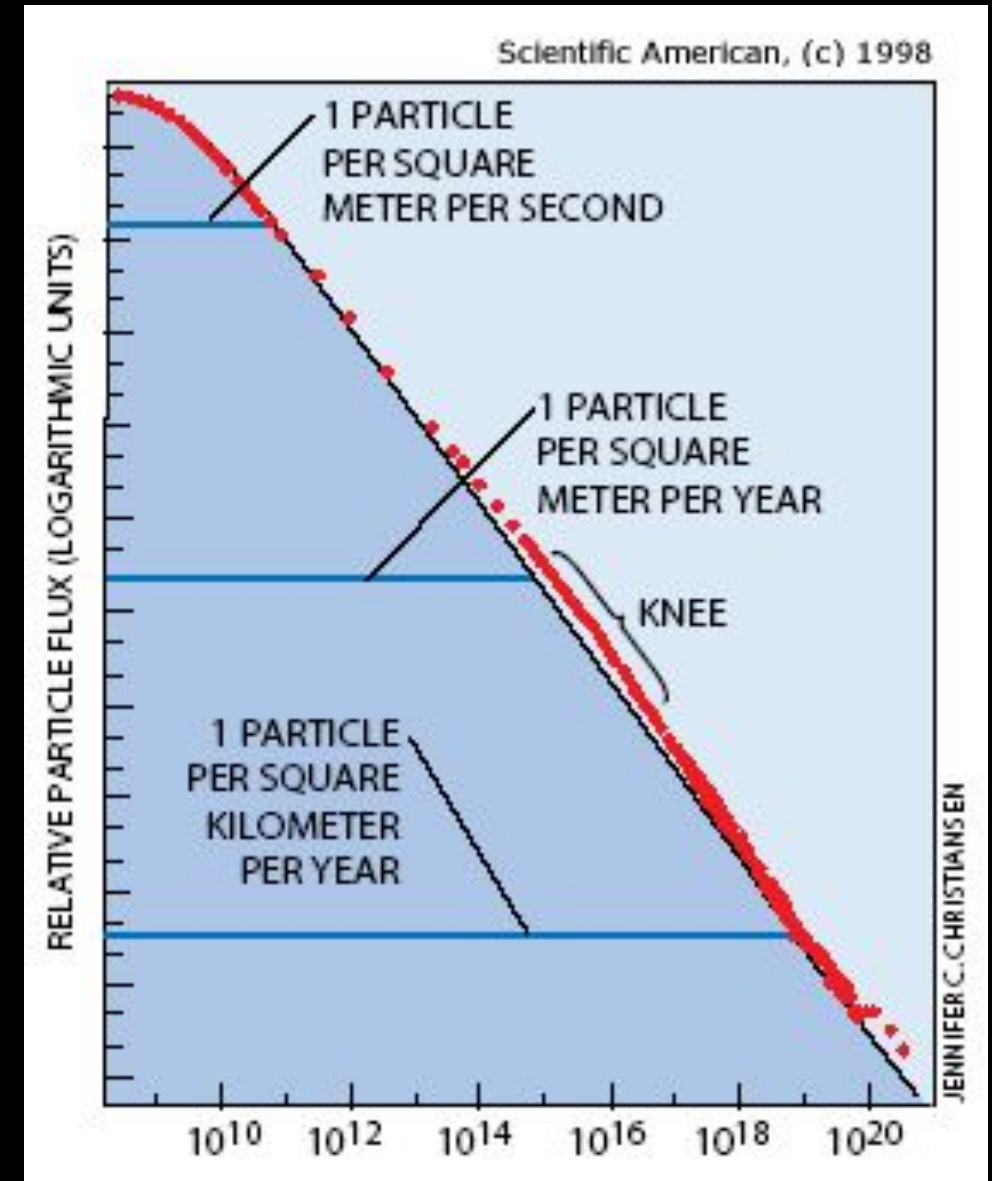
SROP Program at Pennsylvania State University

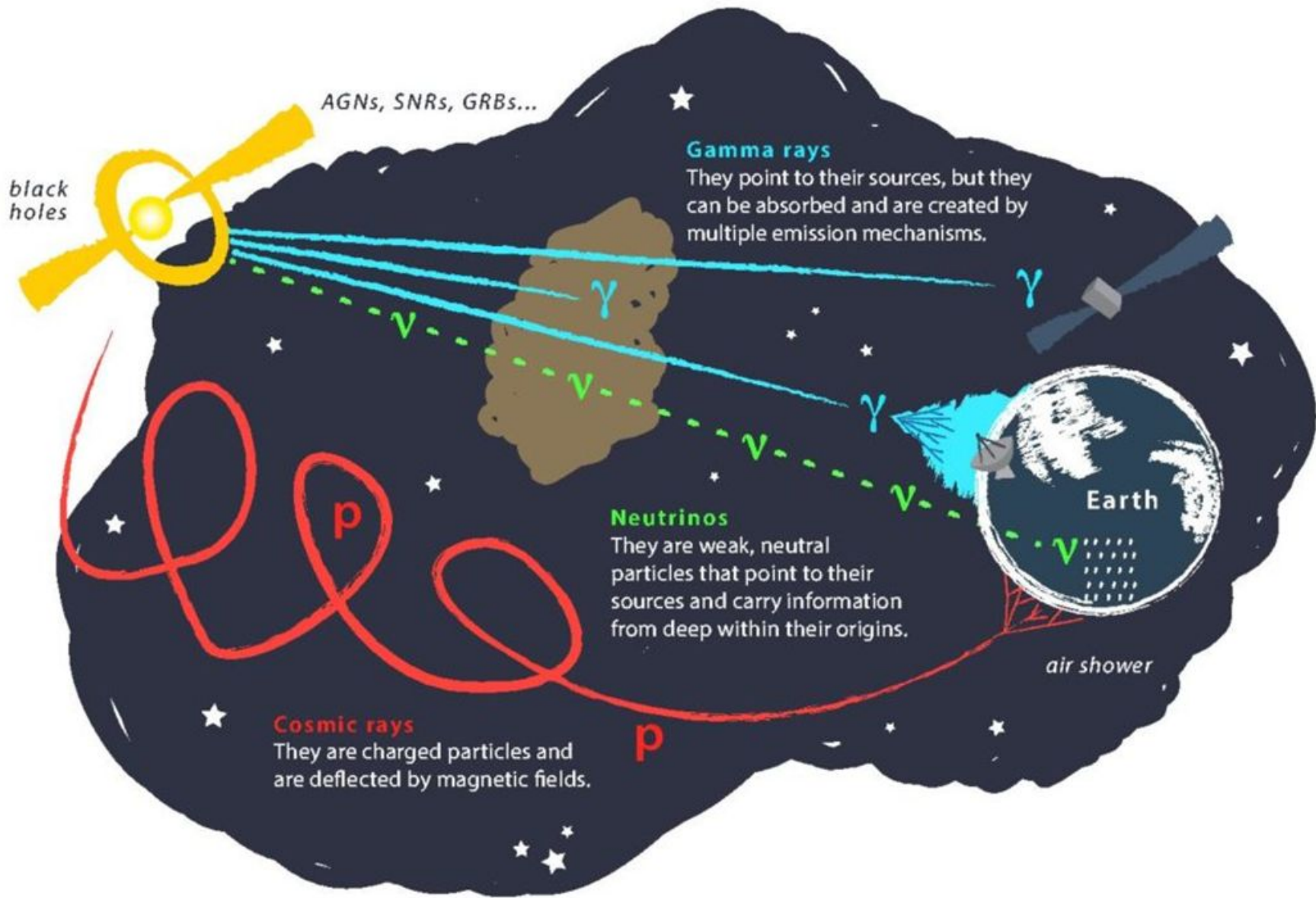
# Outline

- Introduction
  - Cosmic and Gamma-Ray Astronomy
  - HAWC and Fermi-LAT Observatories
  - The 3HWC and 4FGL Catalogs
- Method
- Results
- Conclusion and Outlook

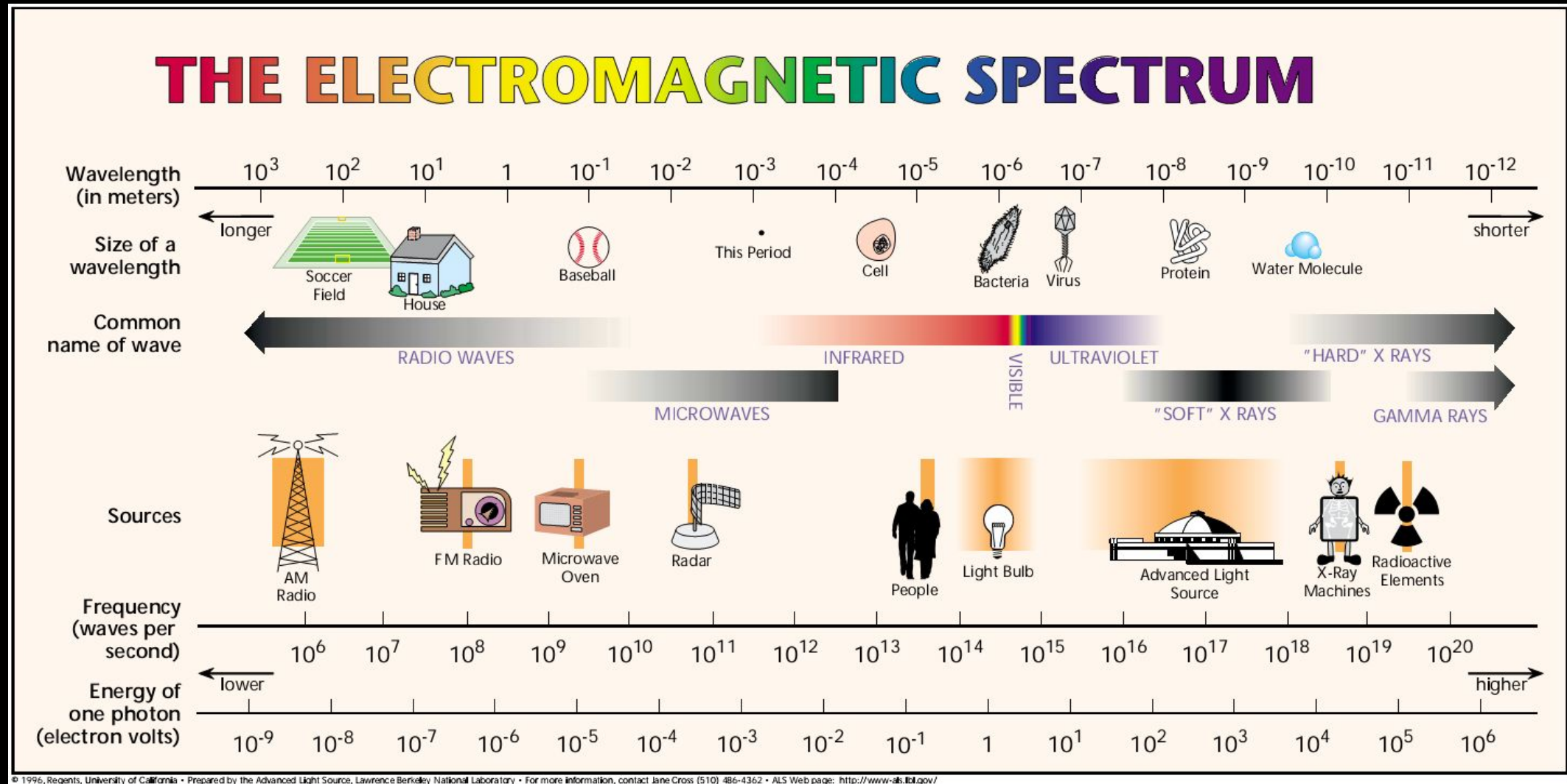
# Cosmic Rays

- Cosmic rays are atomic nuclei constantly bombarding us from space
- Sources include supernova explosions and super-massive black holes
- **Observations of cosmic rays above  $10^{20}$  eV**

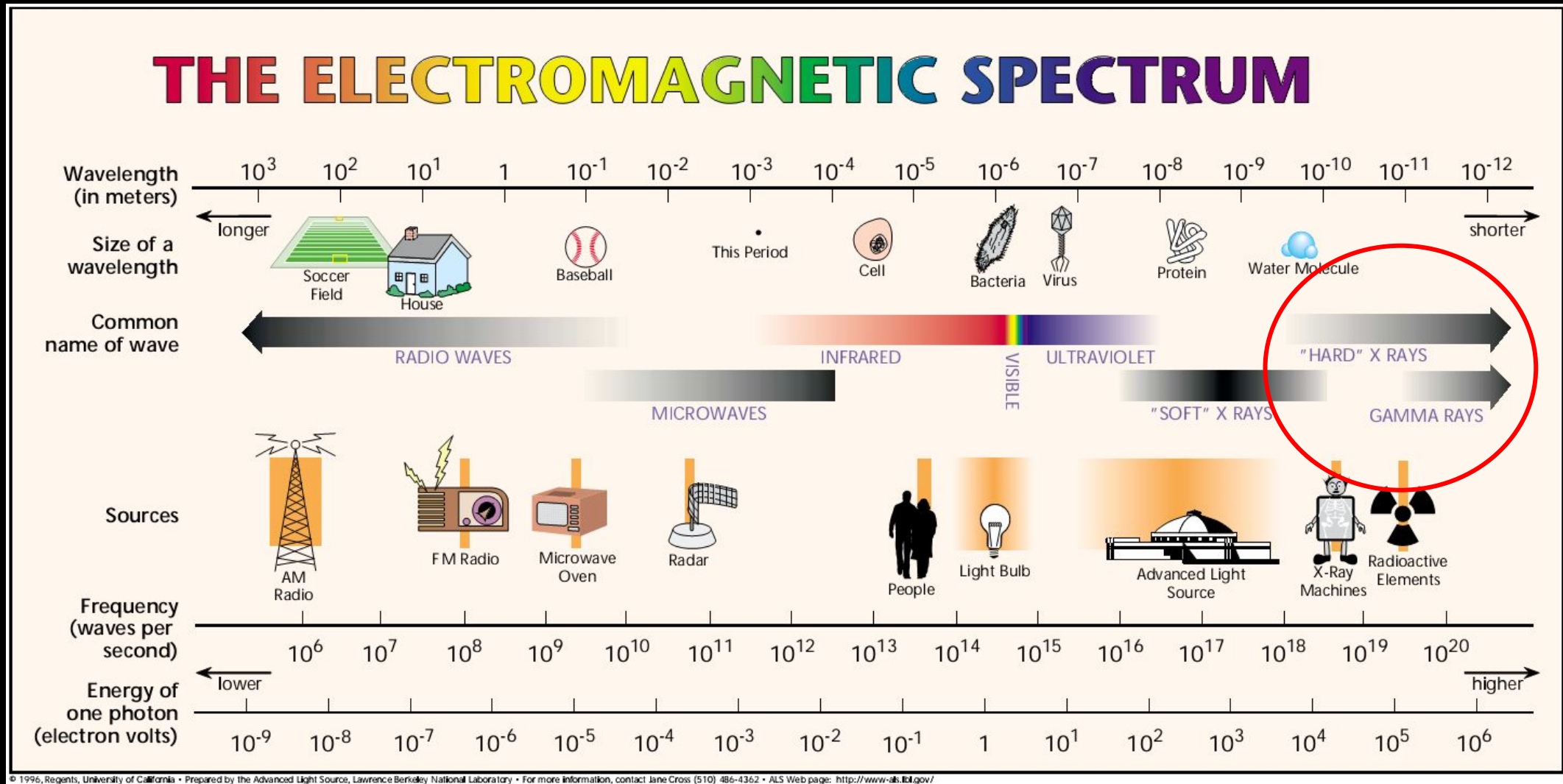




# Energy ranges for photons



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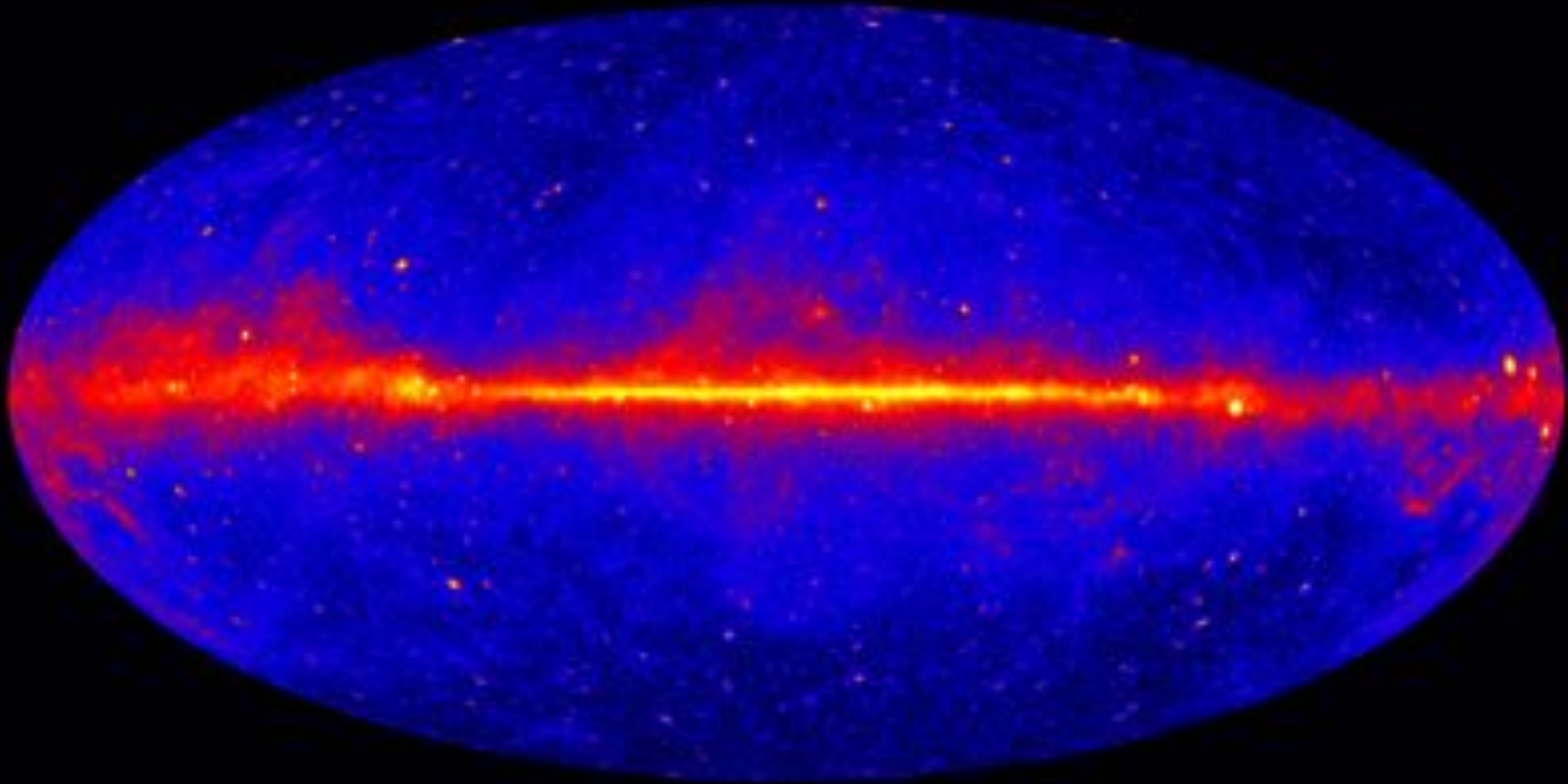


# Fermi-LAT Satellite

- The Large Area Telescope (LAT) detects gamma rays in the lower-energy range of **20 MeV to 300 GeV** ( $\sim 10^6$  eV to  $\sim 10^{11}$  eV)
- Instantaneous field of view is  $\sim 2$  steradians
- Has 36 layers of silicone strip detectors and 16 layers of tungsten foil



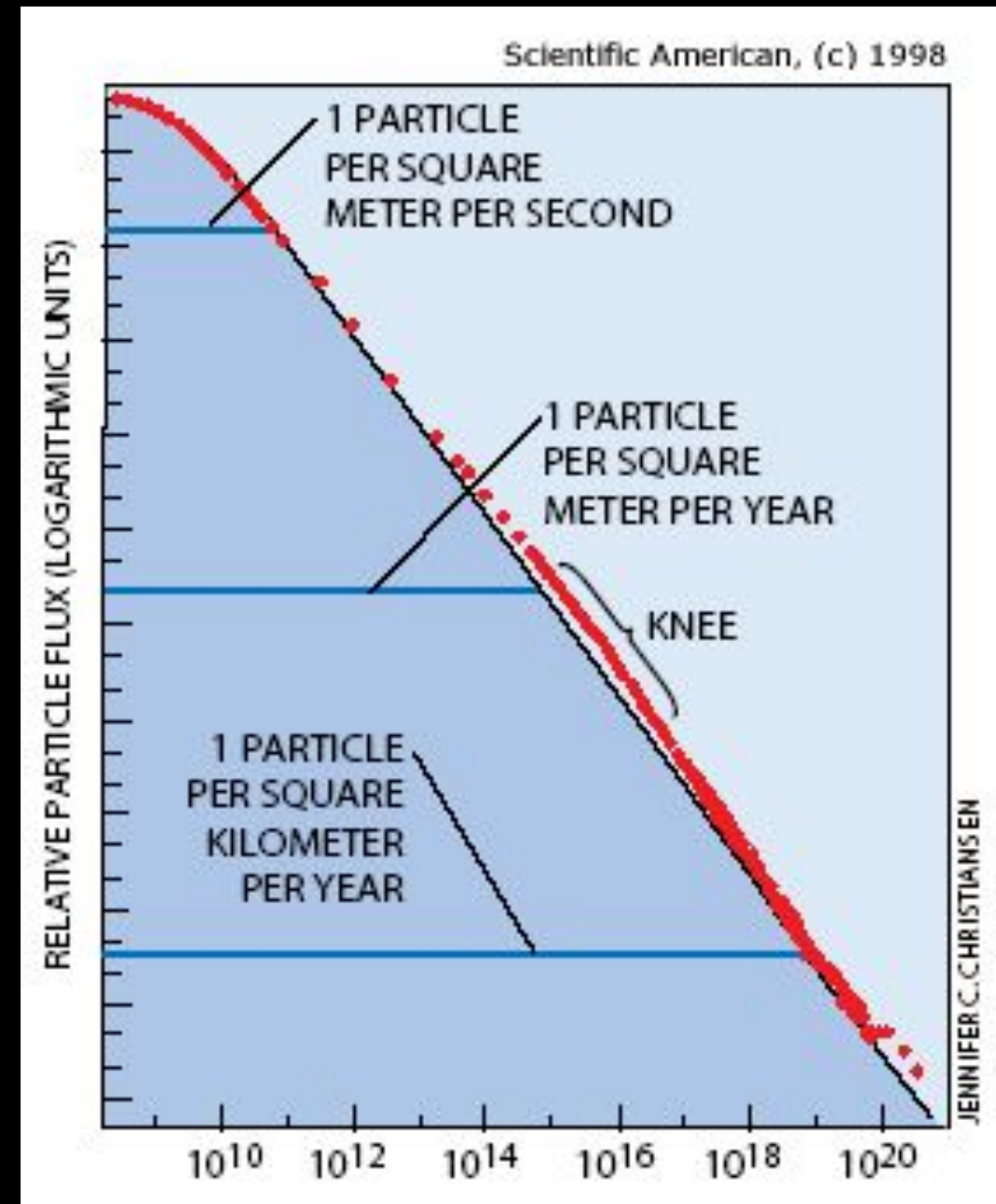
# Fermi-LAT's Field-of-view



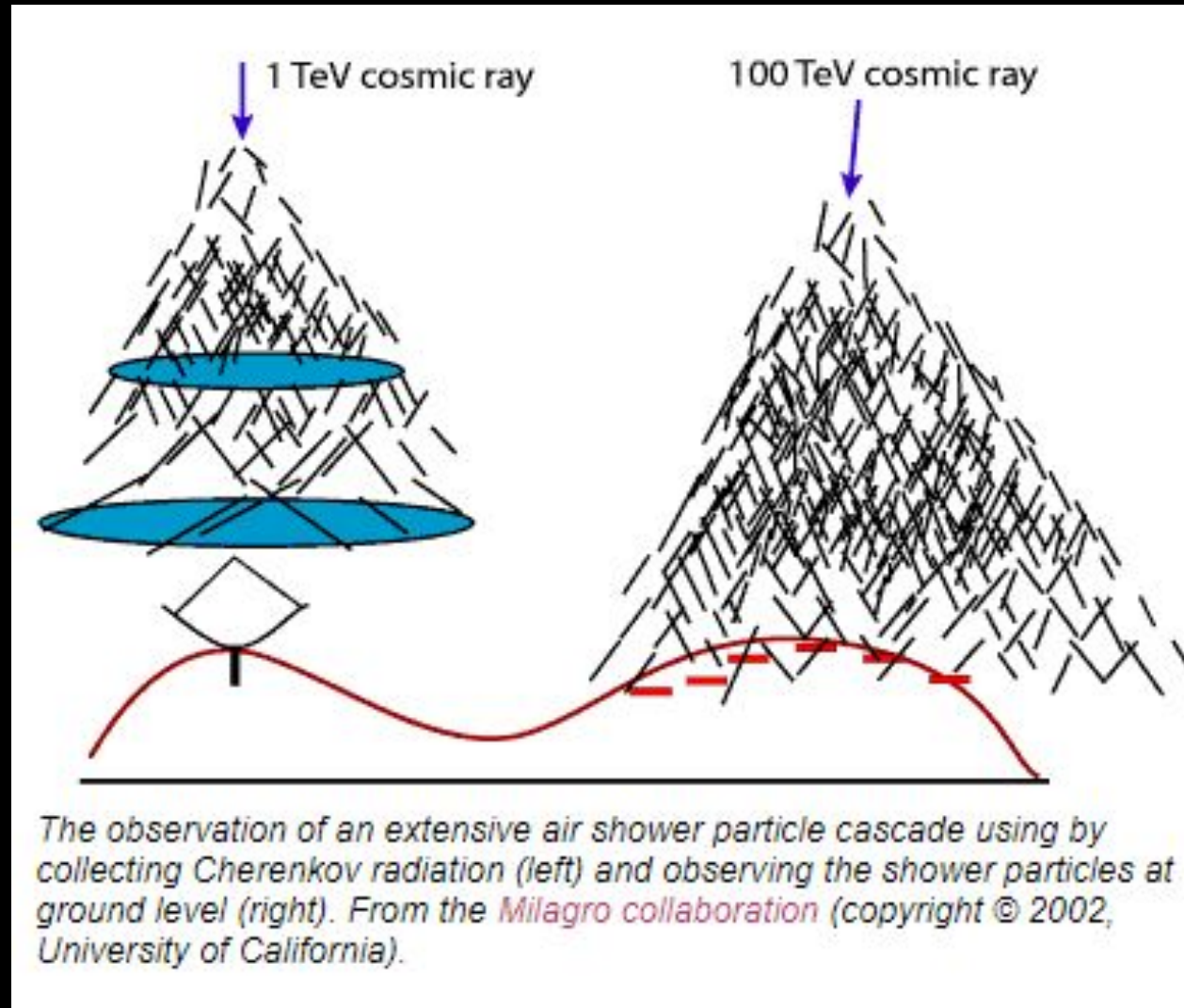


# Detection techniques

- Fermi-LAT has no sensitivity to rays with higher energies due to limited detection size
- Use **indirect detection with ground based detectors** to observe high-energy gamma rays



# Detecting Extensive Air Showers

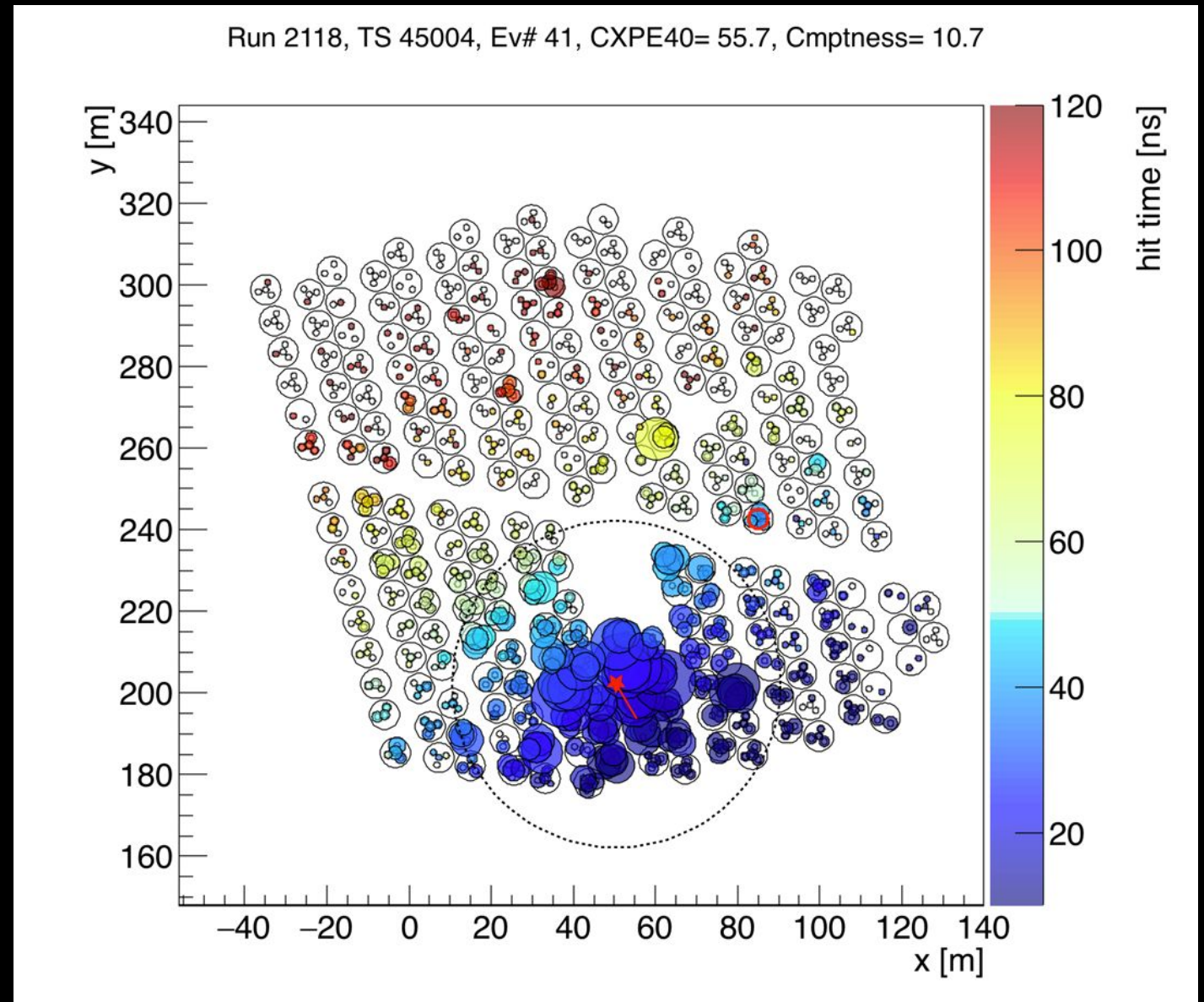
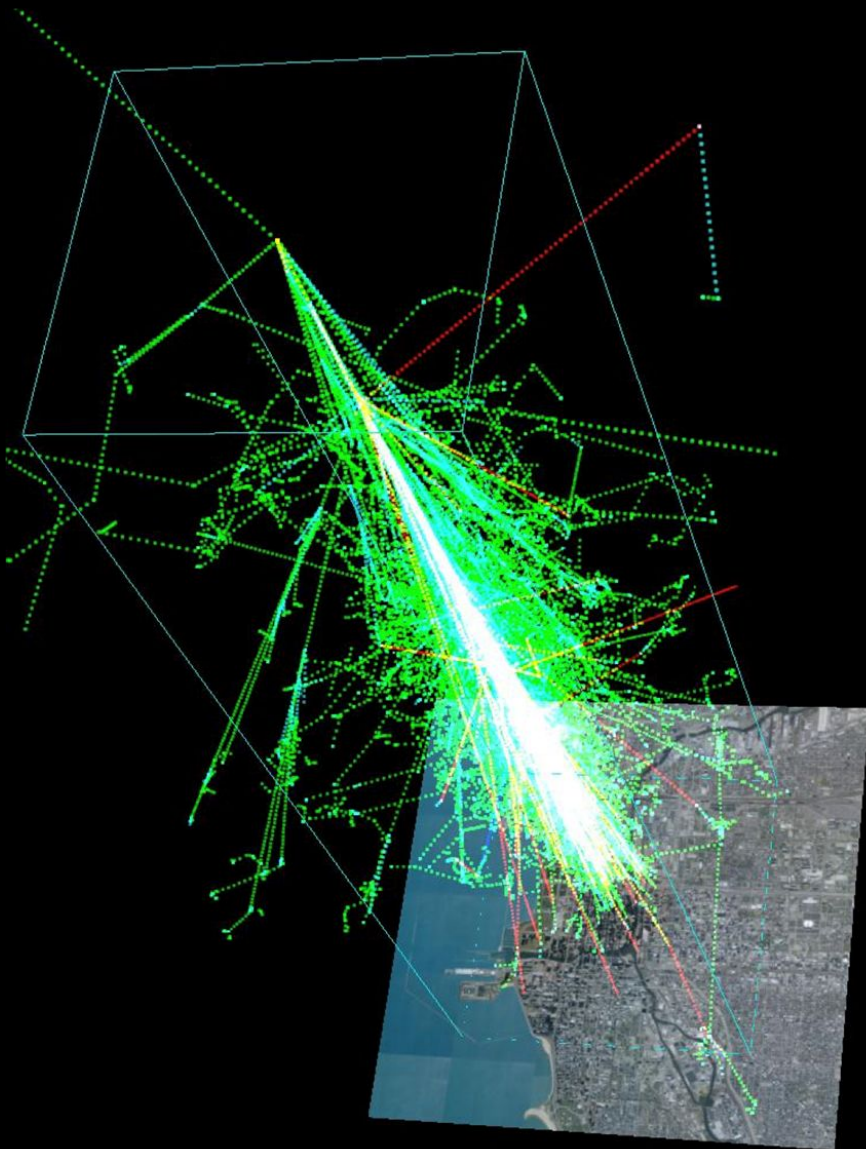


# The High Altitude Water Cherenkov (HAWC) Observatory

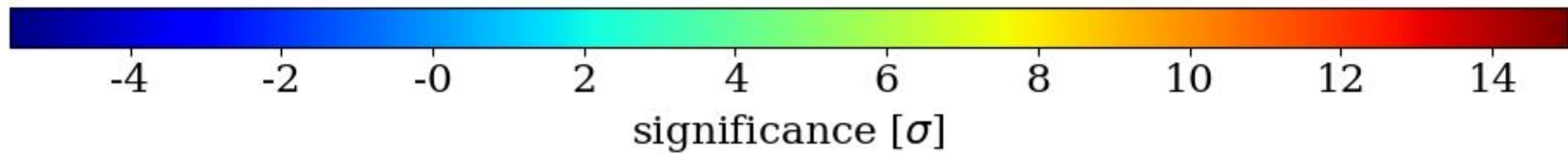
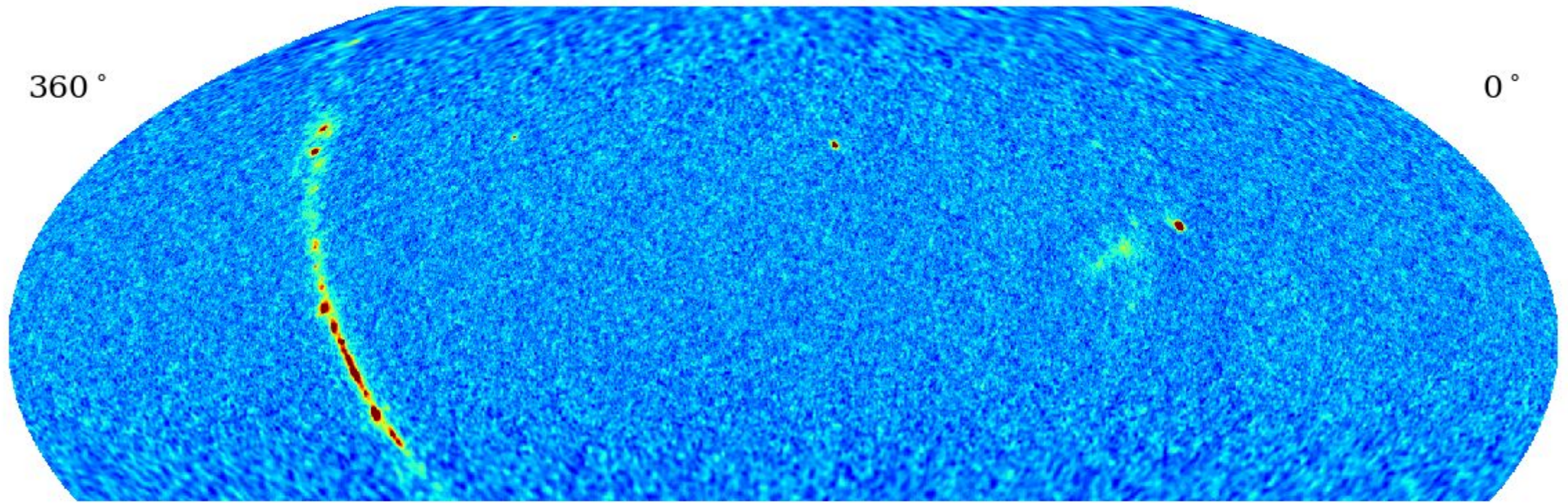
- 300 water tanks, each with  $\sim 200,000$  liters of water
- Observes up to two-thirds of our sky
- Detects gamma-ray showers through the Water Cherenkov method
- Energy range of  $\sim 10^{11}$  eV to  $\sim 10^{14}$  eV
- Gamma ray signal is along direction of initial particle; cosmic ray signal breaks apart



# Simulation of a gamma-ray induced shower



# HAWC's Field-of-view



# The 3HWC and 4FGL Catalogs

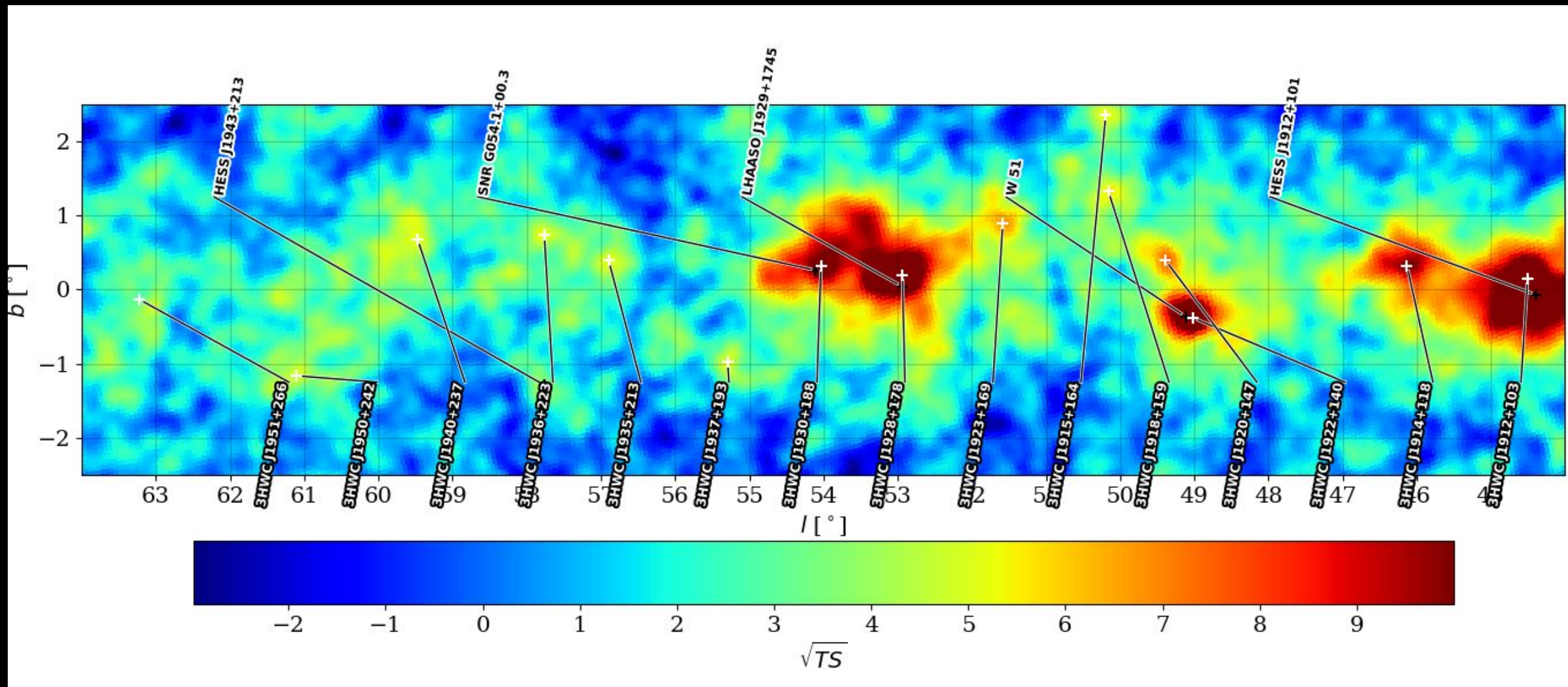
- 3HWC Catalog

- 1,523 days of HAWC data
- Data from 65 TeV candidate sources
- **20 unassociated sources**

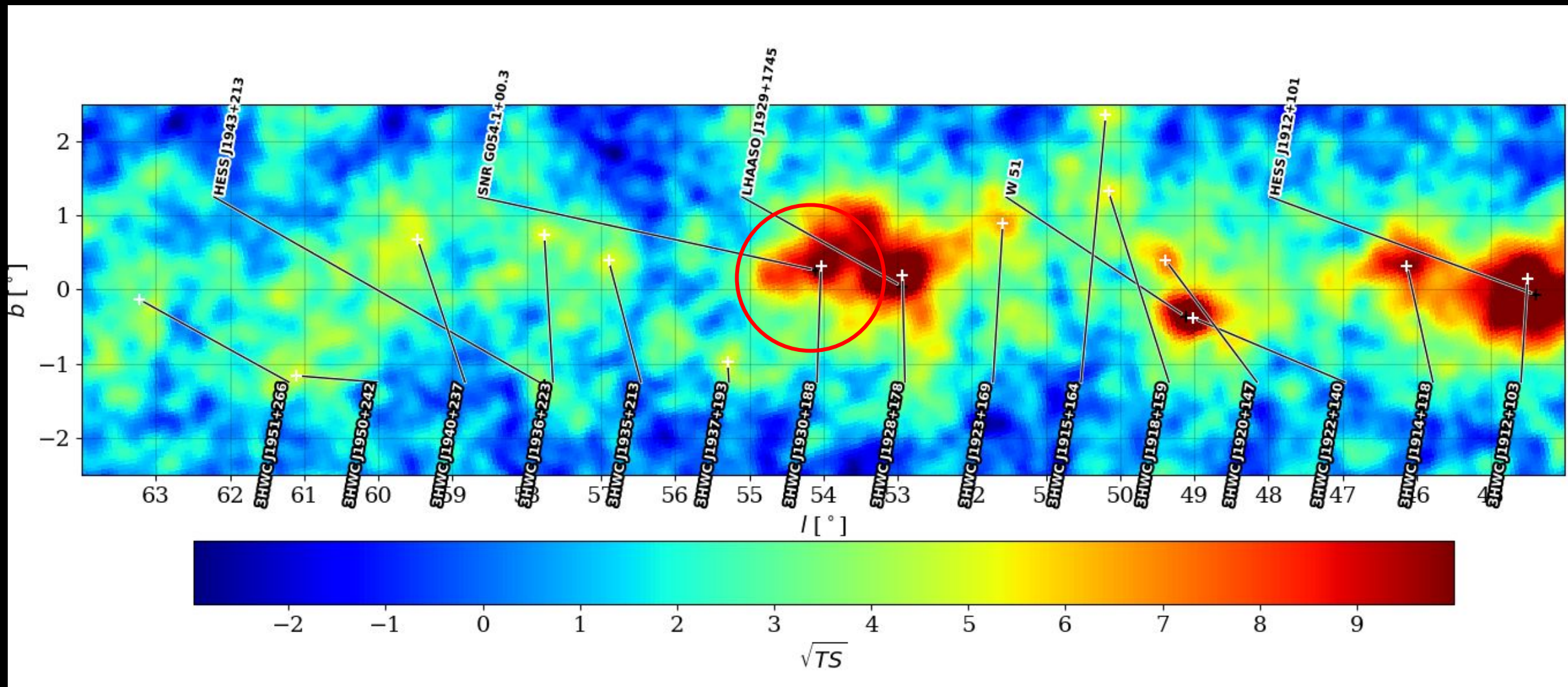
- 4FGL Catalog

- 10 years of Fermi-LAT data
- Data from 5,064 GeV sources
- **1,410 unassociated sources**

# Associated and Unassociated Sources in the 3HWC catalog

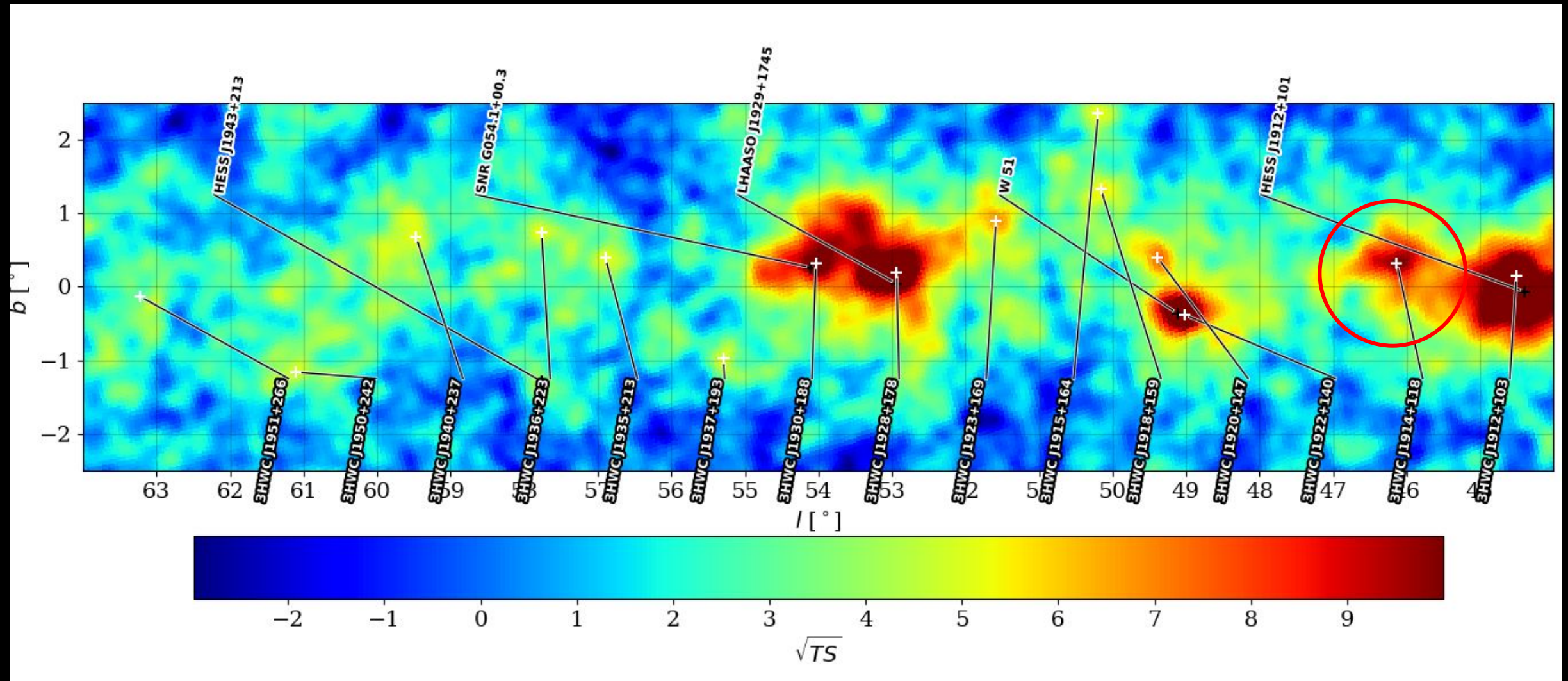


# Associated and Unassociated Sources in the 3HWC catalog





# Associated and Unassociated Sources in the 3HWC catalog



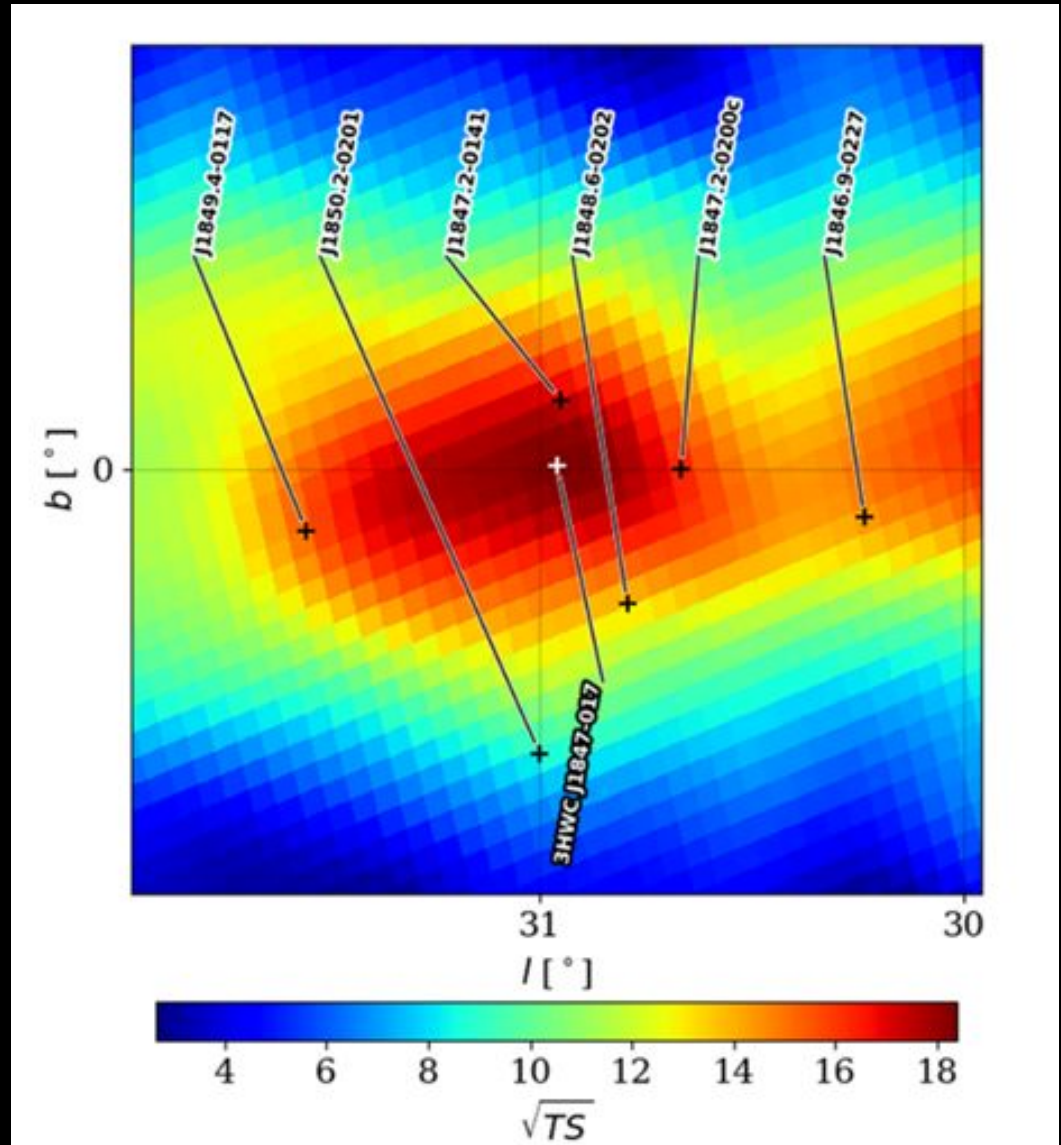
The goal: to find spatial associations  
between the unassociated sources from  
HAWC and Fermi

# Method

## Criteria for Investigating 3HWC Sources

- Must have unassociated Fermi sources within a distance of  $1^\circ$  nearby
- Fermi sources are plotted with their 3HWC counterparts on significance maps

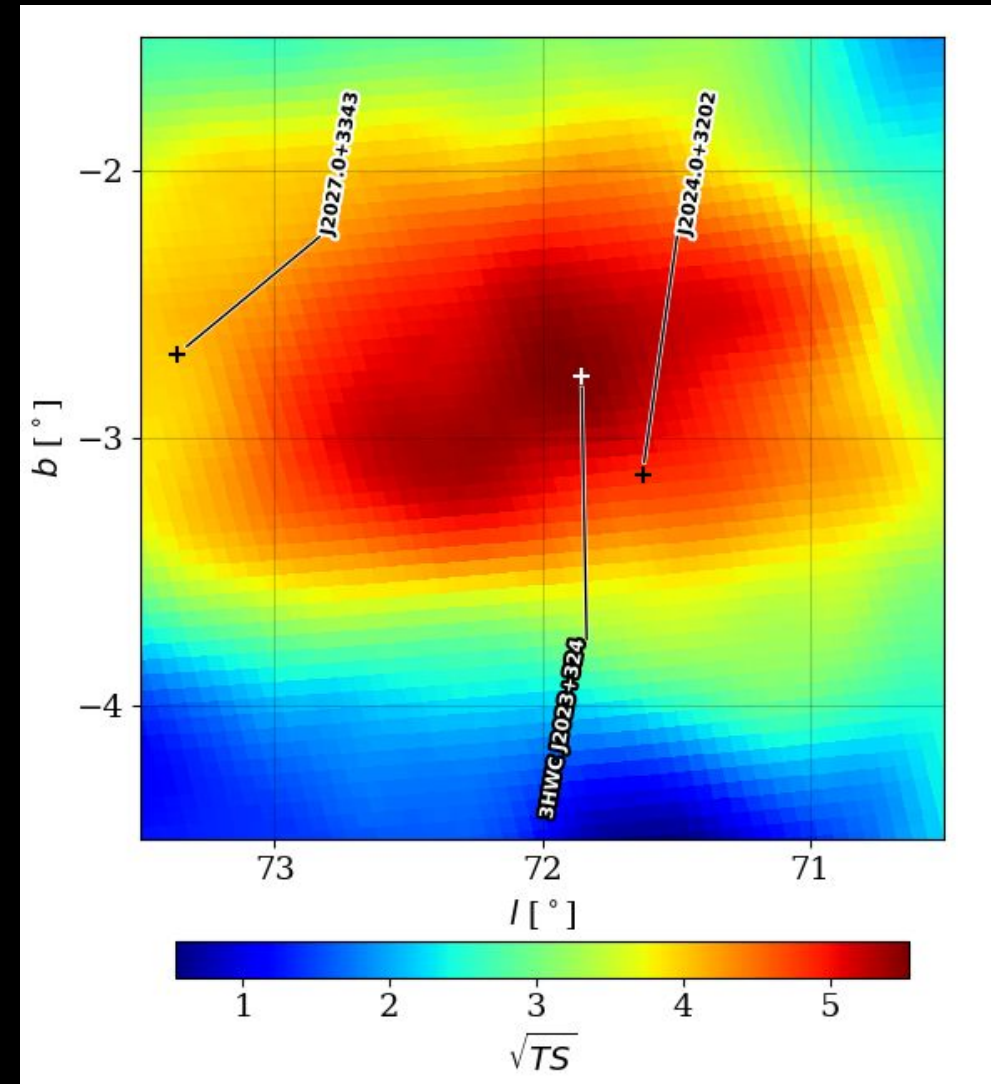
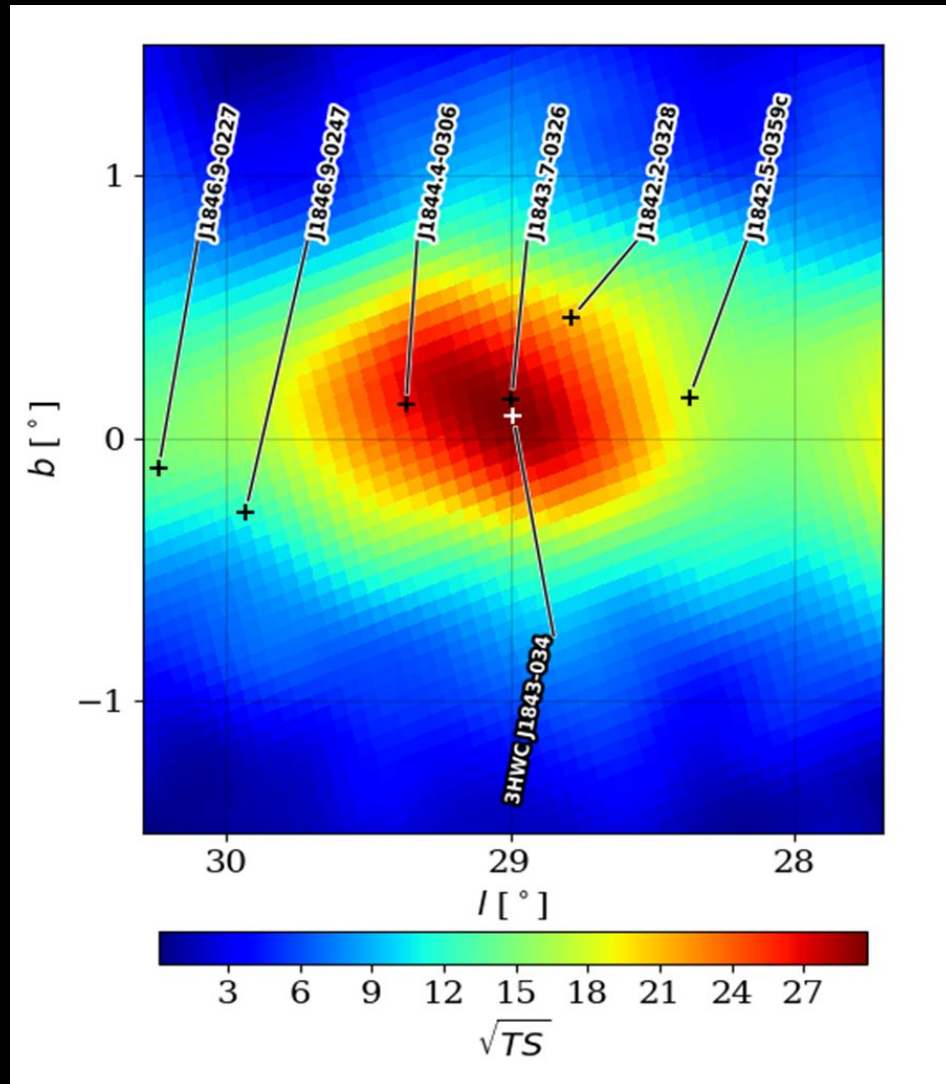
## 3HWC J1847-017



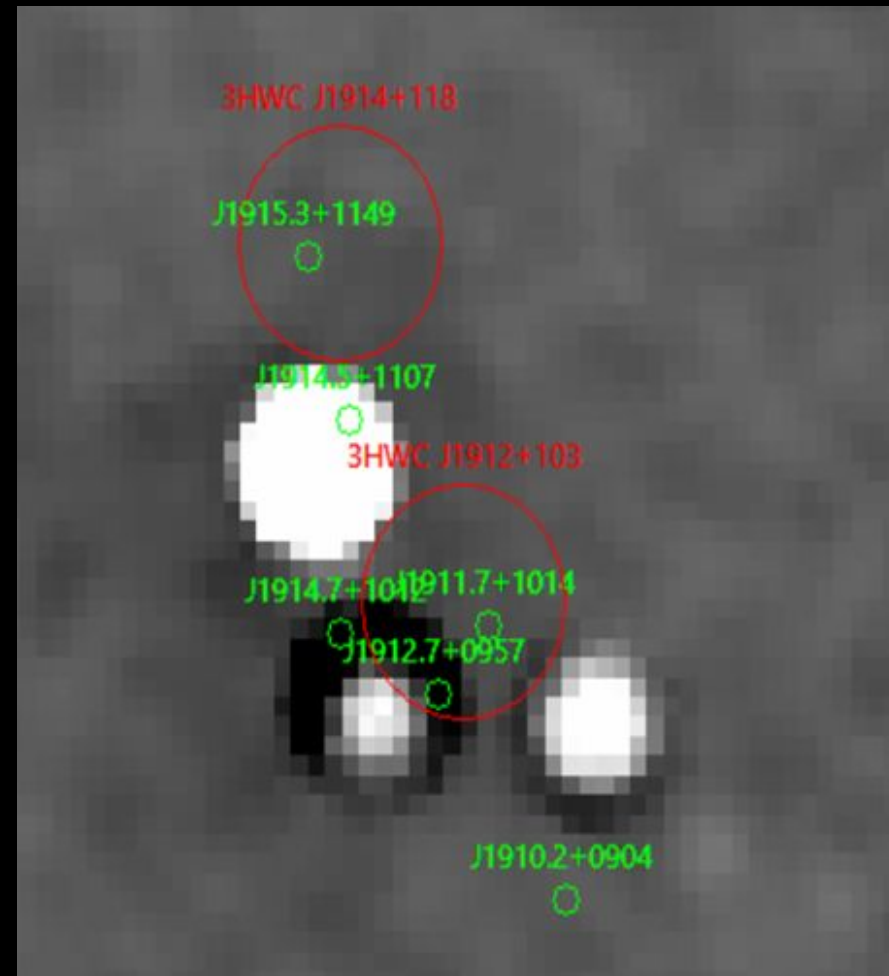
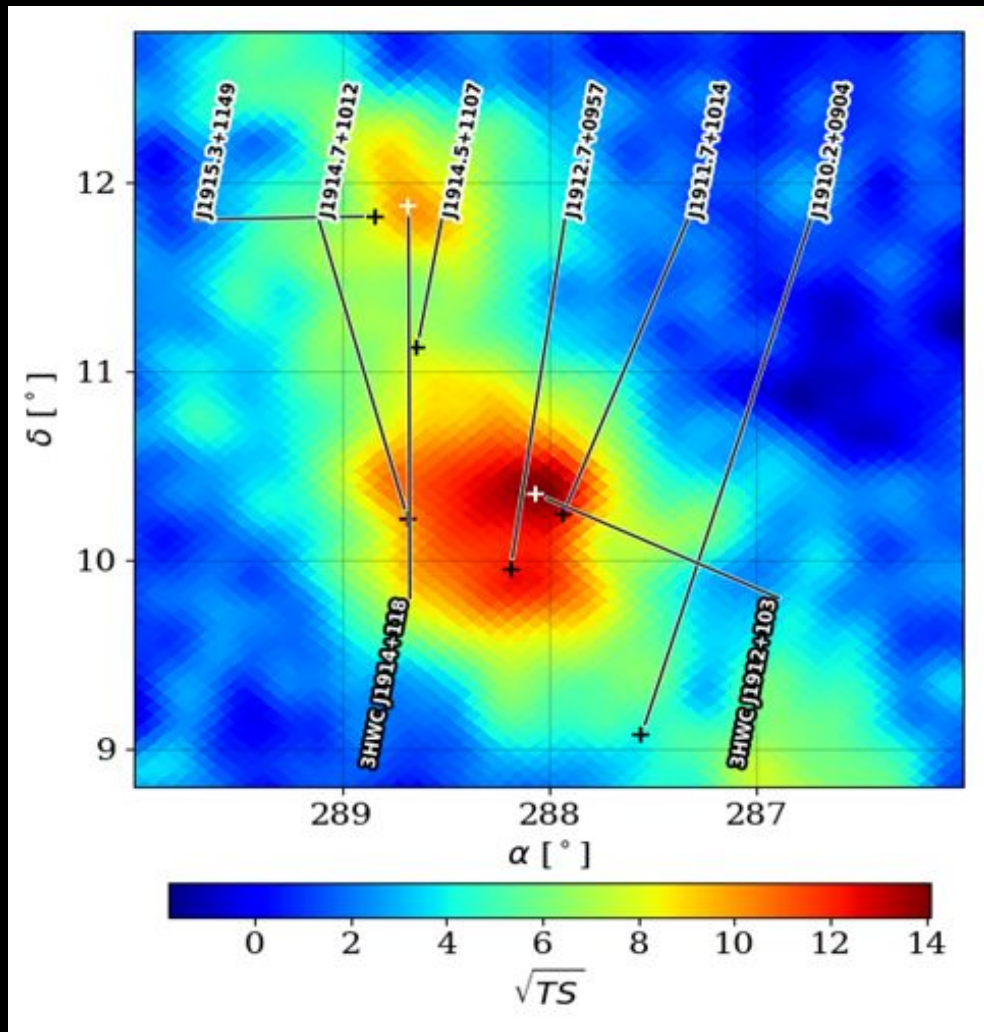
# Results – 14 3HWC Sources

3HWC J1843-034 → J1843.7-0328

3HWC J2023+124 ext. → J2024.0+3202



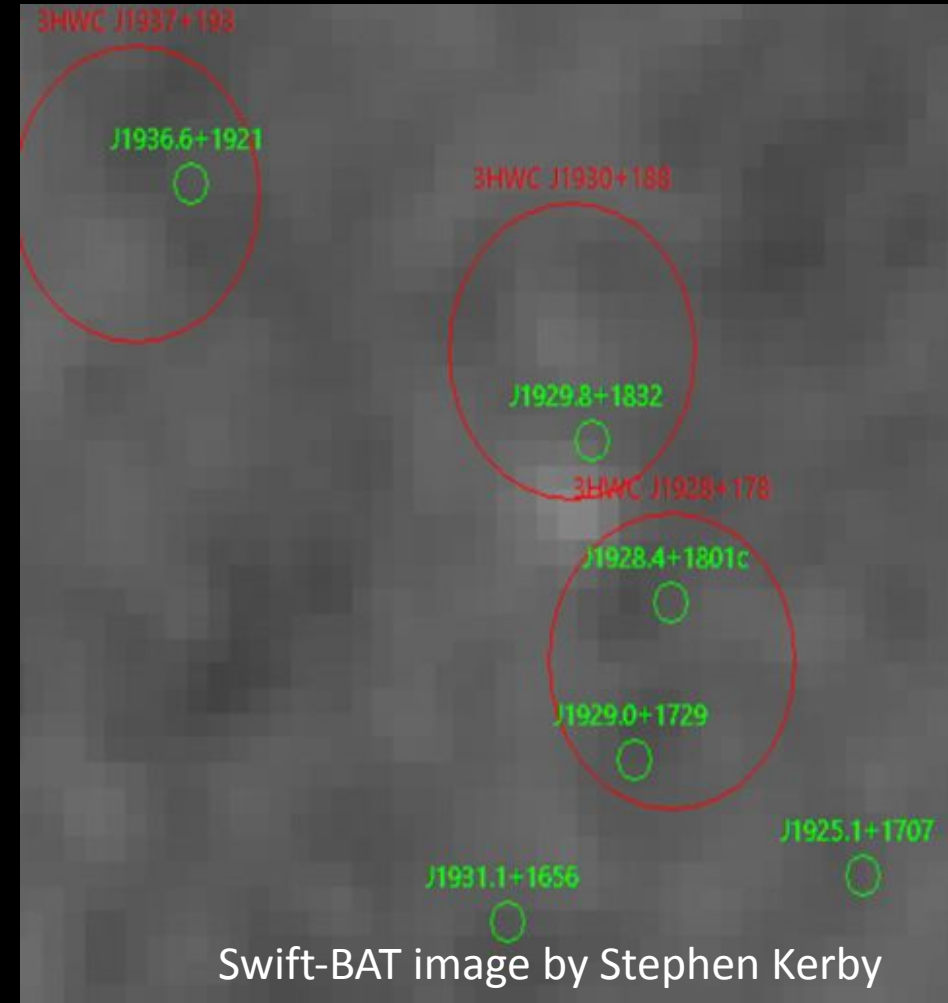
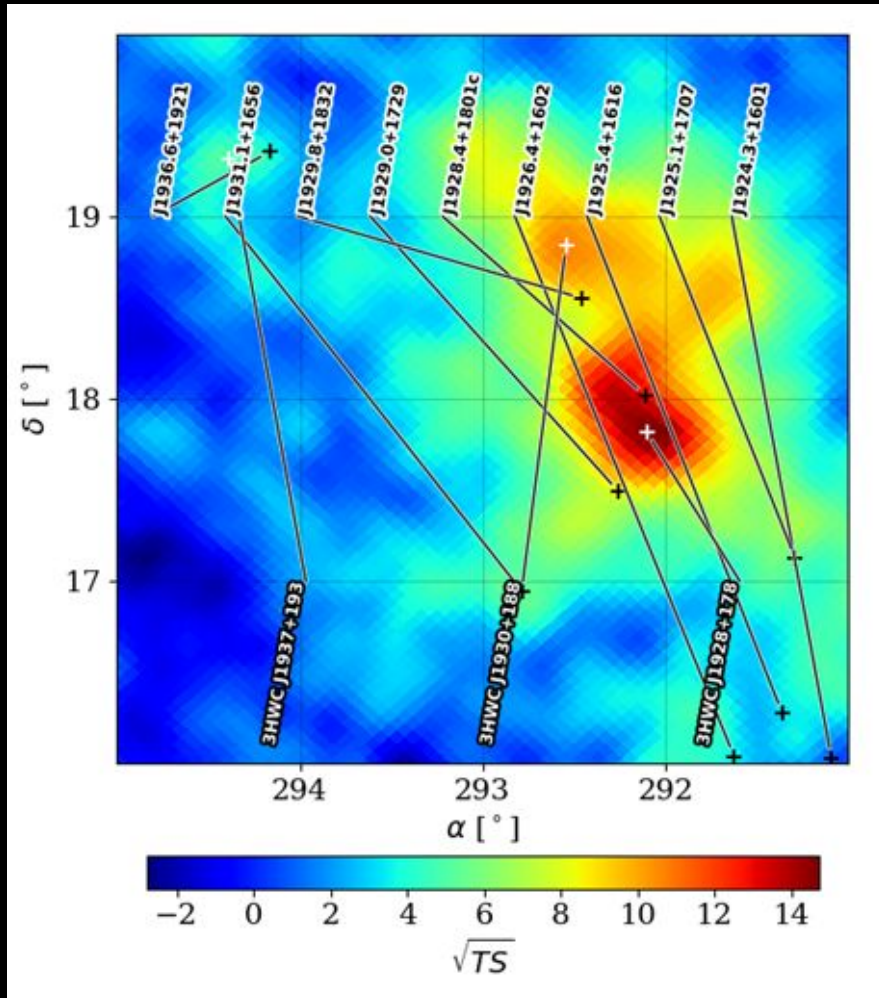
# Swift-BAT Data (15-150 KeV)



Swift-BAT image by Stephen Kerby

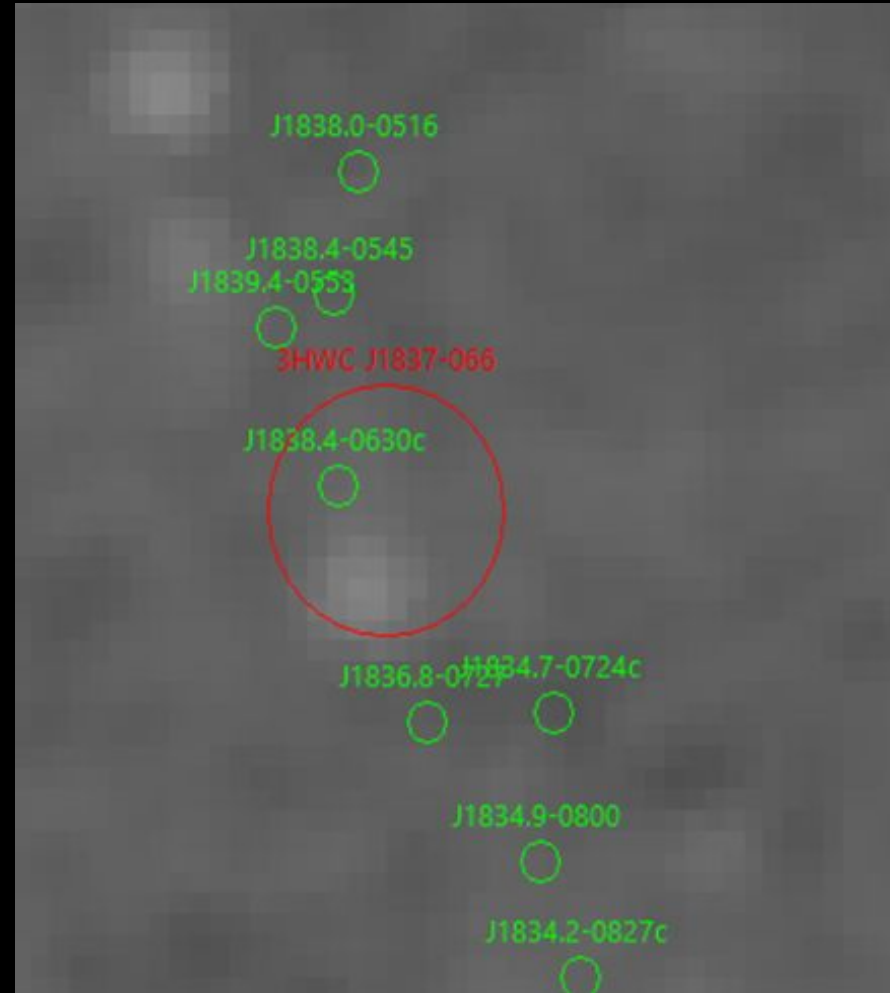
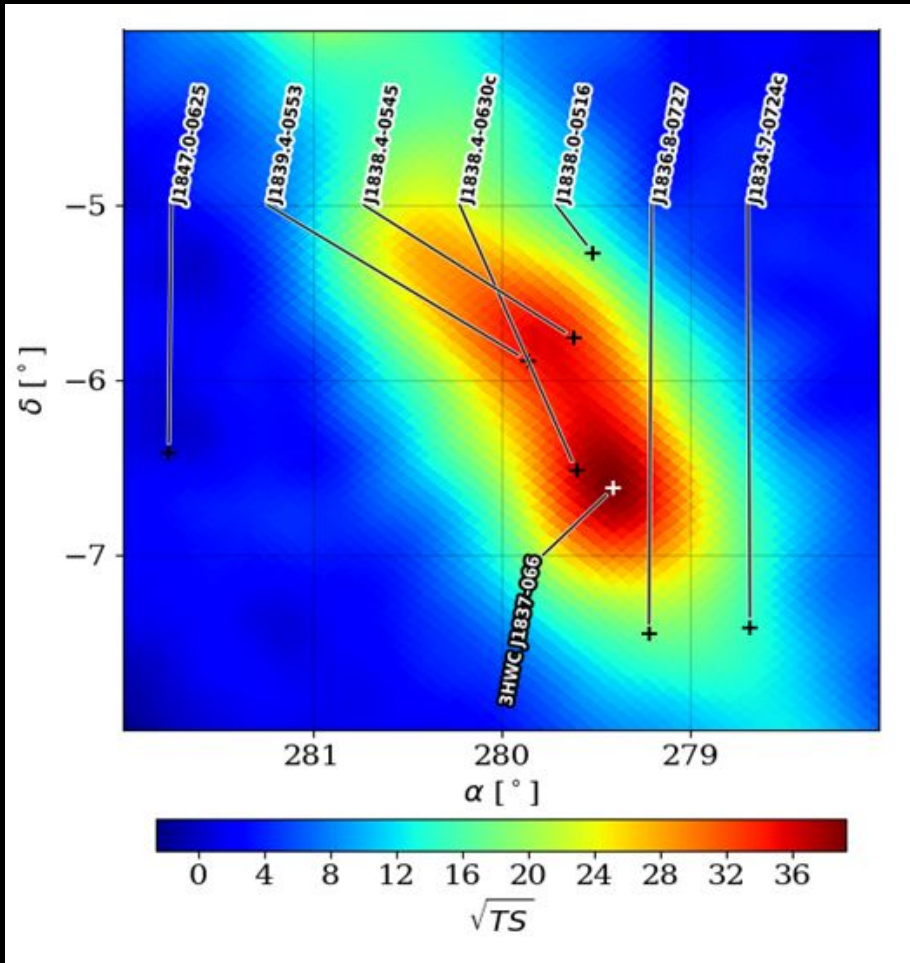
Significance map for 3HWC 1912+103 and 3HWC 1914+118 (left) and the Swift-BAT observation of these sources (right). The red circles represent HAWC's field of view, and the green spots are unassociated sources from 4FGL.

# Swift-BAT data for the J1928/J1930 region



Significance map for 3HWC J1928+178 and 3HWC J1930+188 (left) with their unassociated source detected by Fermi. SWIFT-BAT map (right) for these same sources with HAWC's field of view included.

# 3HWC J1837-066



Swift-BAT image by Stephen Kerby

Significance map for 3HWC J1837-066 (left) with a new excess found within the angular uncertainty region in SWIFT-BAT's observation (right). From our research, this was the most interesting candidate correlation that should be further looked at.

# Conclusion & Outlook

- Found at least one significant association for a previous unassociated gamma-ray source
- Coincident excesses over 10 orders of magnitude in energy! From  $10^4$  eV up to  $10^{14}$  eV
- Study the energy spectrum of the 3HWC source from X-ray energies up to VHE gamma rays
- Write a ToO proposal for SWIFT-XRT (0.2-10 KeV)

