李政道研究所
TSUNG-DAO LEE INSTITUTE

HAWC γ-ray Observatory

29th International Workshop on Weak Interactions and Neutrinos

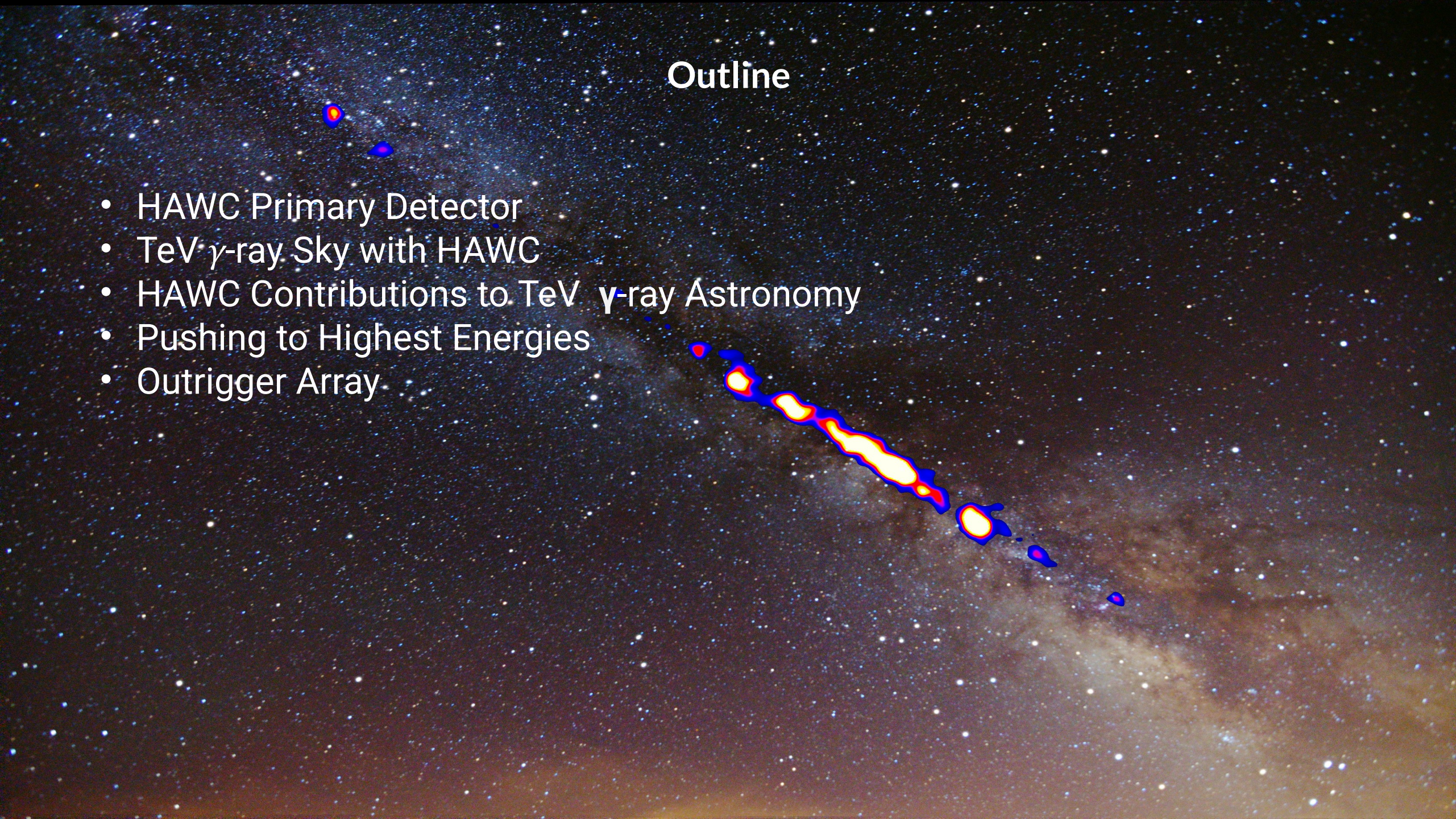
Ramiro Torres-Escobedo

(on behalf of the HAWC collaboration)

July 4, 2023

Outline

- HAWC Primary Detector
- TeV γ-ray Sky with HAWC
- HAWC Contributions to TeV γ-ray Astronomy
- Pushing to Highest Energies
- Outrigger Array



HAWC Collaboration

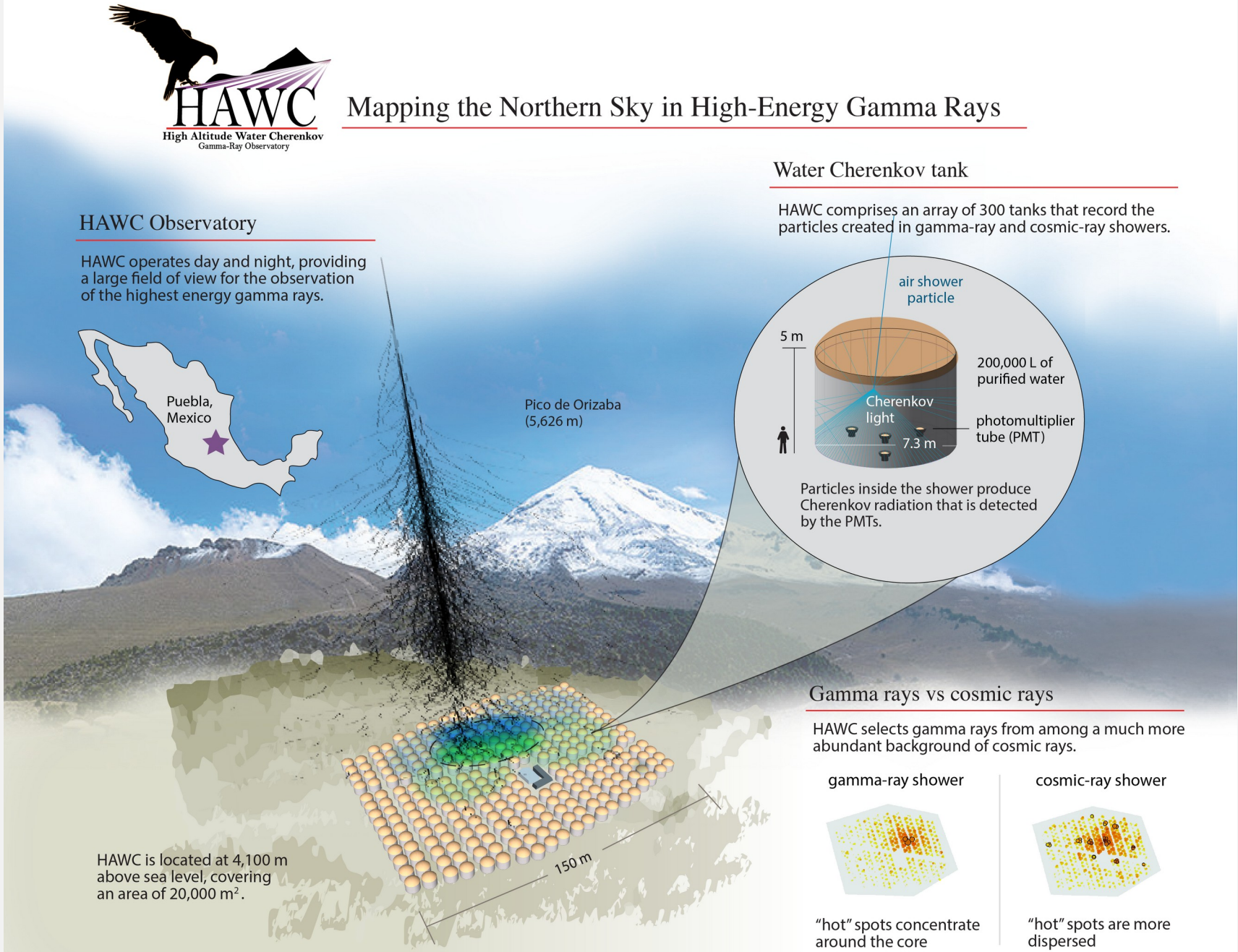
United States
University of Maryland
Los Alamos National Laboratory
University of Wisconsin
University of Utah
University of New Hampshire
Pennsylvania State University
University of New Mexico
Michigan Technological University
NASA/Goddard Space Flight Center
Georgia Institute of Technology
Michigan State University
University of Rochester

Universidad de Guadalajara
Óptica y Electrónica (INAOE)
Universidad Michoacana de San Nicolás de Hidalgo
Universidad Nacional Autónoma
Centro de Investigación y de Estudios Avanzados de México (UNAM)
Instituto Politécnico Nacional
Instituto de Física
Centro de Investigación en Computación - IPN
Instituto de Astronomía
Universidad Politécnica de Pachuca
Benemérita Universidad Autónoma de Puebla
Universidad Autónoma de Chiapa

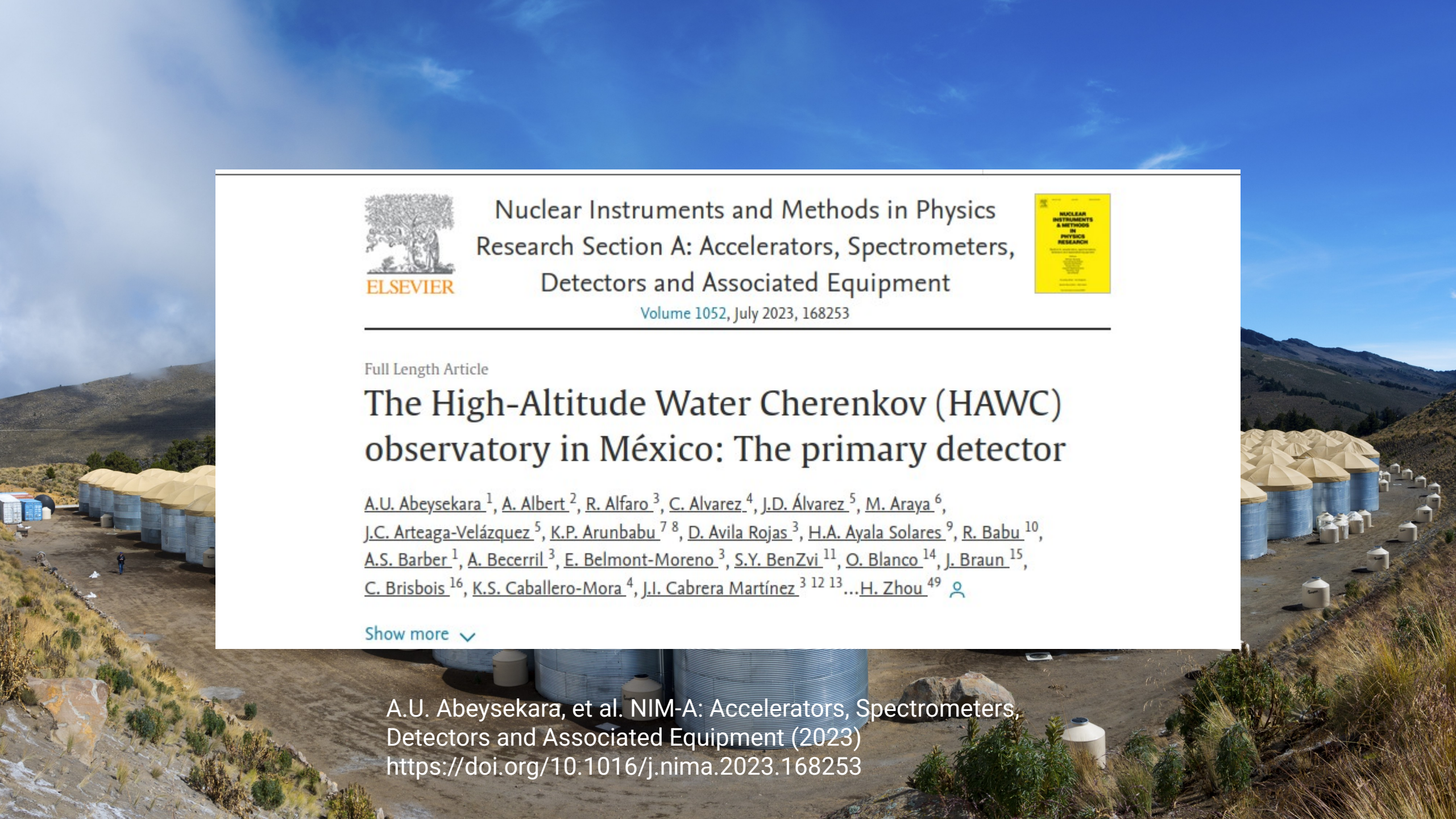
Asia
University of Seoul, South Korea
Shanghai Jiao Tong University, China

HAWC γ-ray Observatory

- 300 closely spaced isolated water Cherenkov detectors (WCDs)
- Launched into full operations since March 2015
- >95% duty cycle
- Instantaneous FOV ~ 2sr and can observe 2/3 of sky everyday
- ~ 5 billion triggers to date (~ 7 Pb of data)
- Optimized for energies 100 GeV - 100 TeV




HAWC
V2
V1



Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 1052, July 2023, 168253

Full Length Article

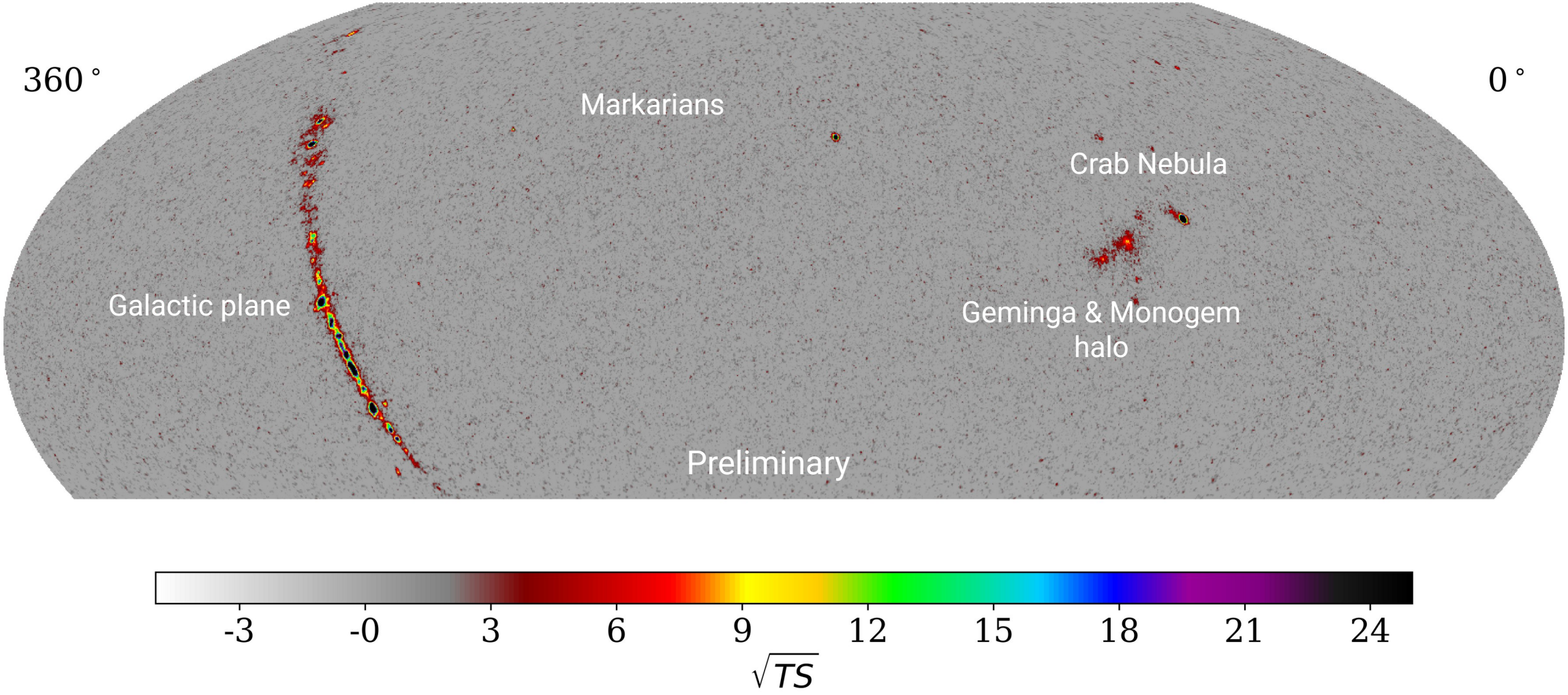
The High-Altitude Water Cherenkov (HAWC) observatory in México: The primary detector

A.U. Abeysekara [1], A. Albert [2], R. Alfaro [3], C. Alvarez [4], J.D. Álvarez [5], M. Araya [6], J.C. Arteaga-Velázquez [5], K.P. Arunbabu [7 8], D. Avila Rojas [3], H.A. Ayala Solares [9], R. Babu [10], A.S. Barber [1], A. Becerril [3], E. Belmont-Moreno [3], S.Y. BenZvi [11], O. Blanco [14], J. Braun [15], C. Brisbois [16], K.S. Caballero-Mora [4], J.I. Cabrera Martínez [3 12 13]...H. Zhou [49]

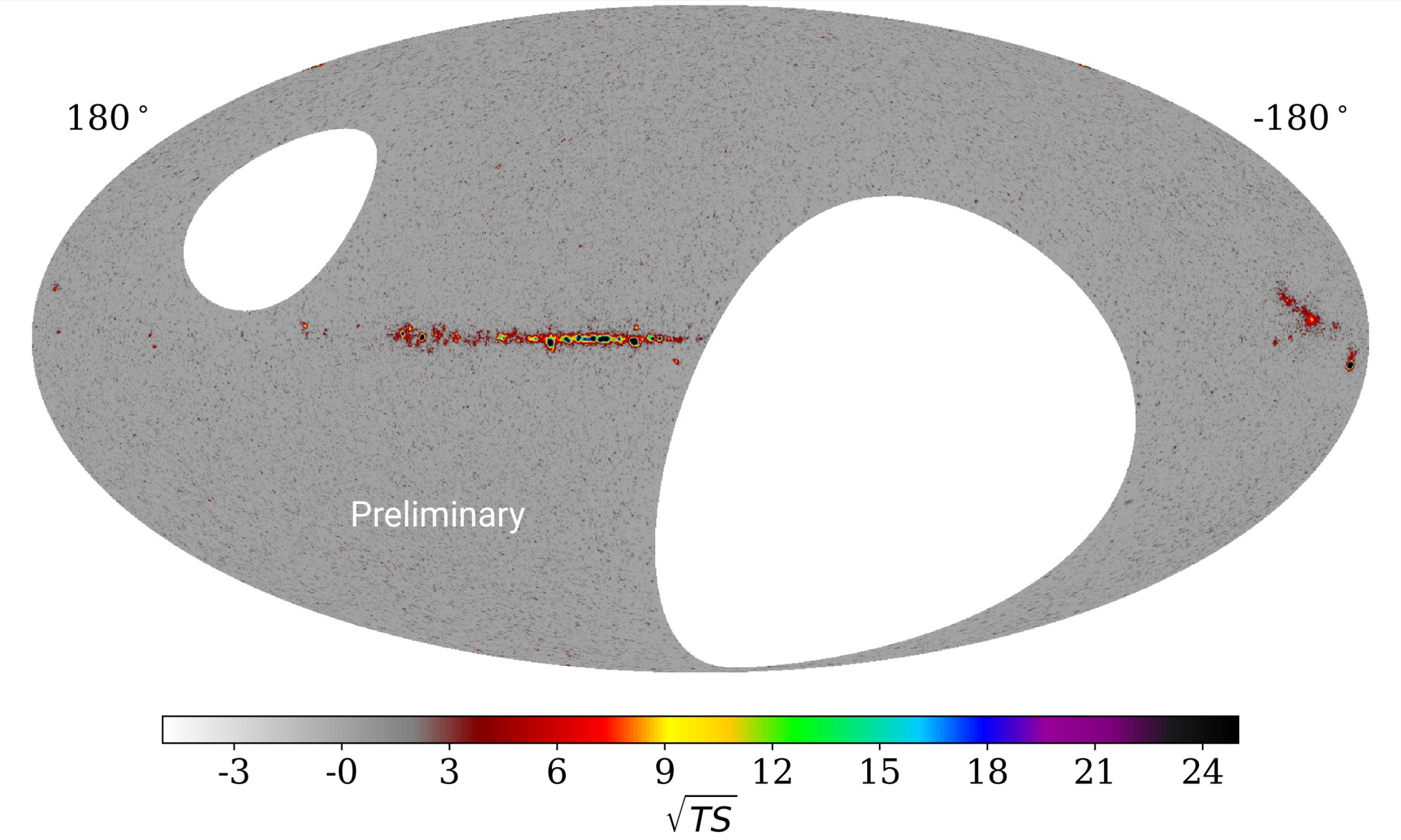
Show more

A.U. Abeysekara, et al. NIM-A: Accelerators, Spectrometers, Detectors and Associated Equipment (2023) https://doi.org/10.1016/j.nima.2023.168253

HAWC γ-ray TeV Sky (2090 Days)

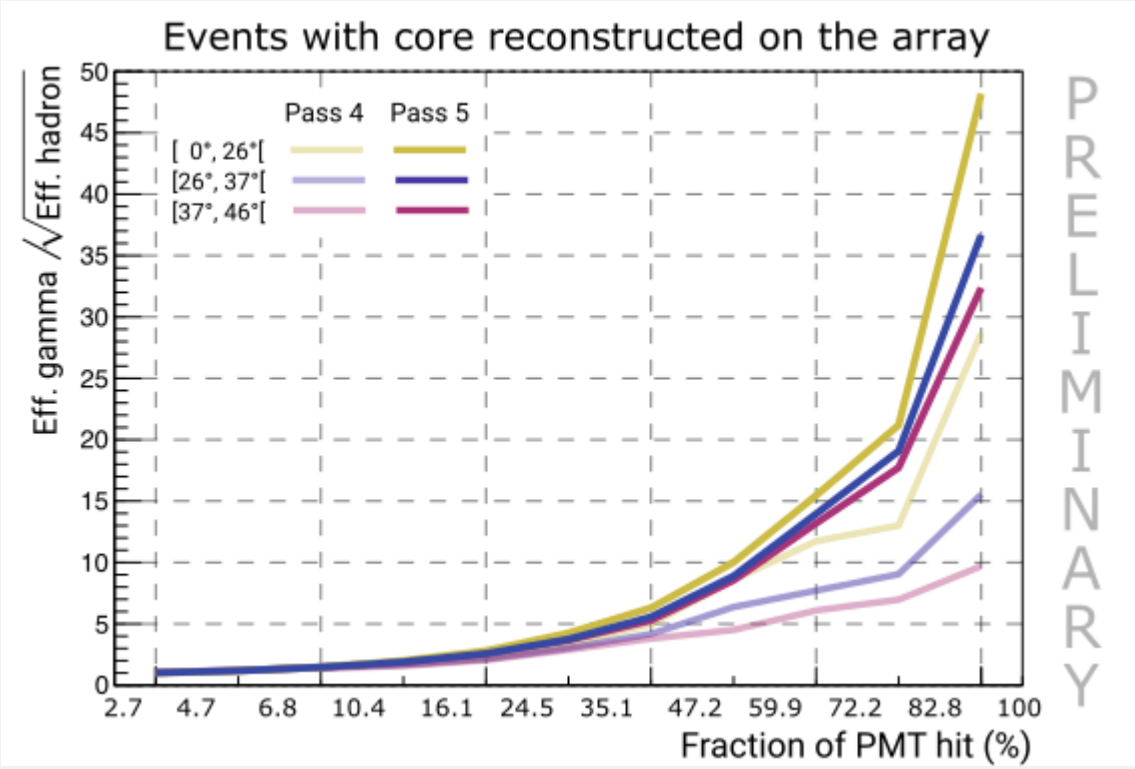


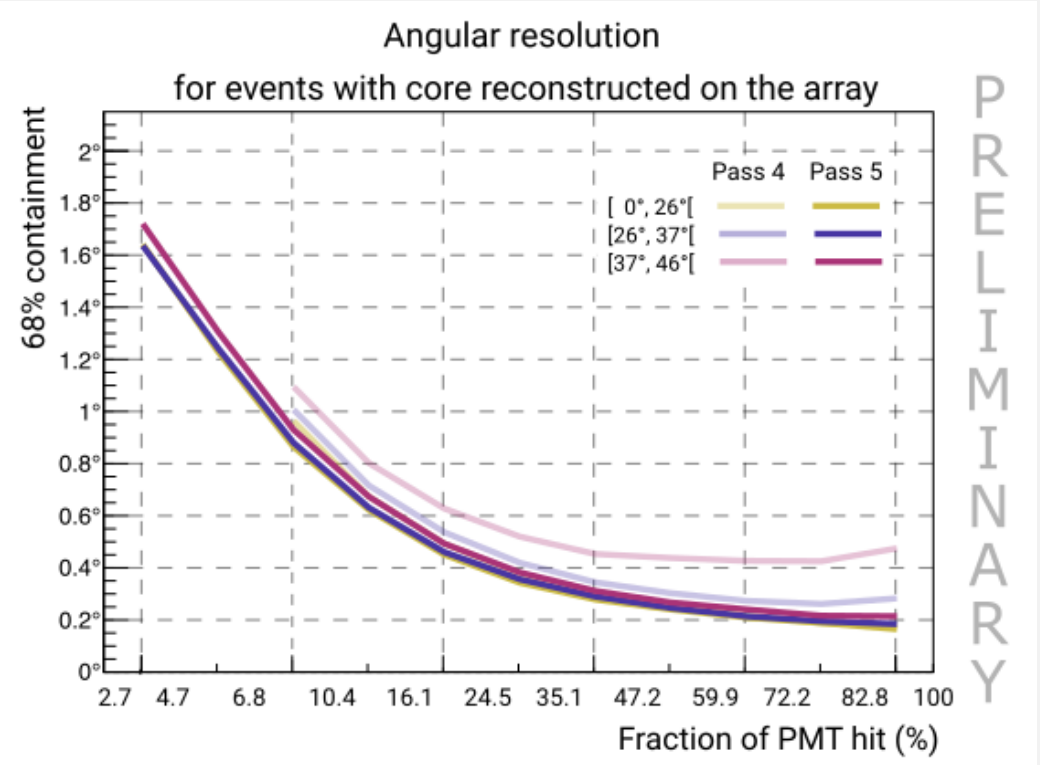
HAWC γ-ray TeV Sky Survey (2090 Days)



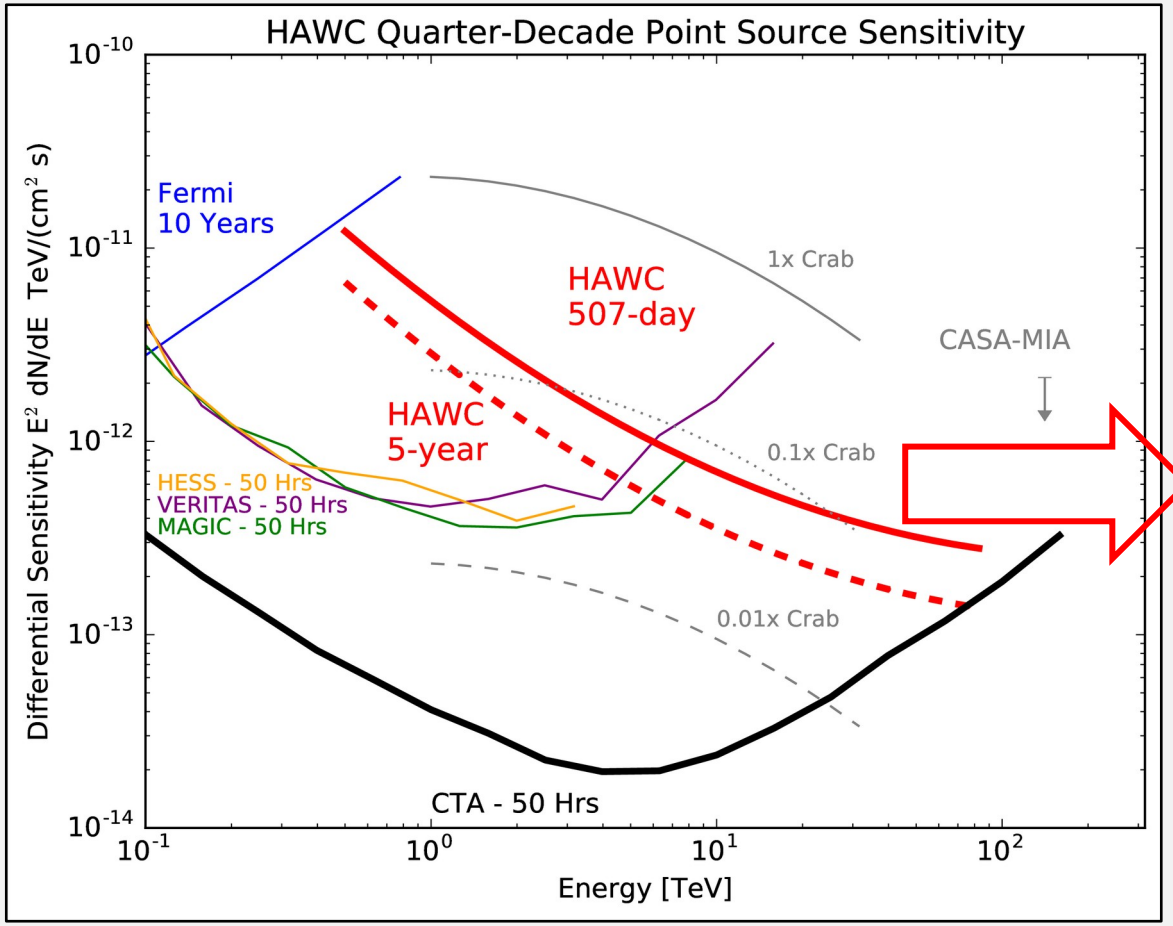
Pass 5 – Improved Reconstruction:

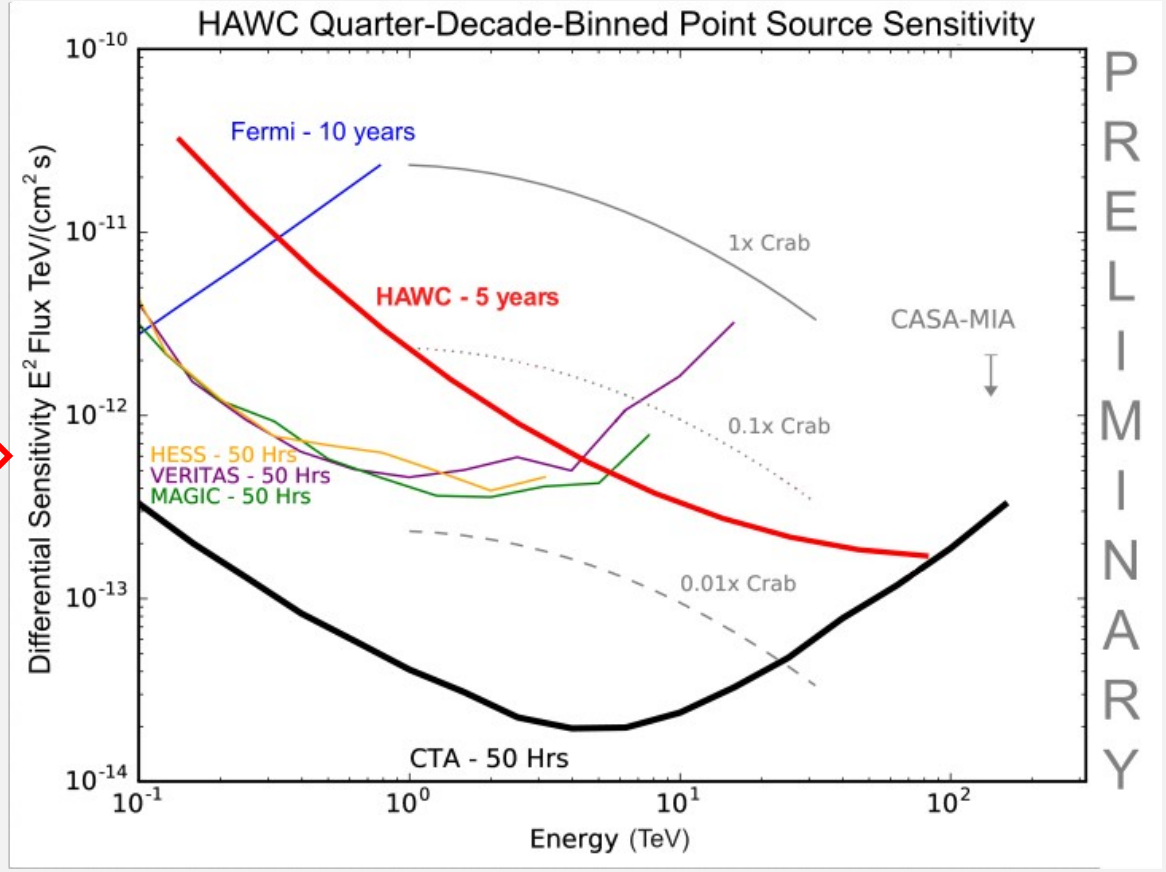
- Improved background rejection for large events
- Improved angular resolution - does not degrade for high zenith angles
- Wider FOV increases from 45˚ to 60˚



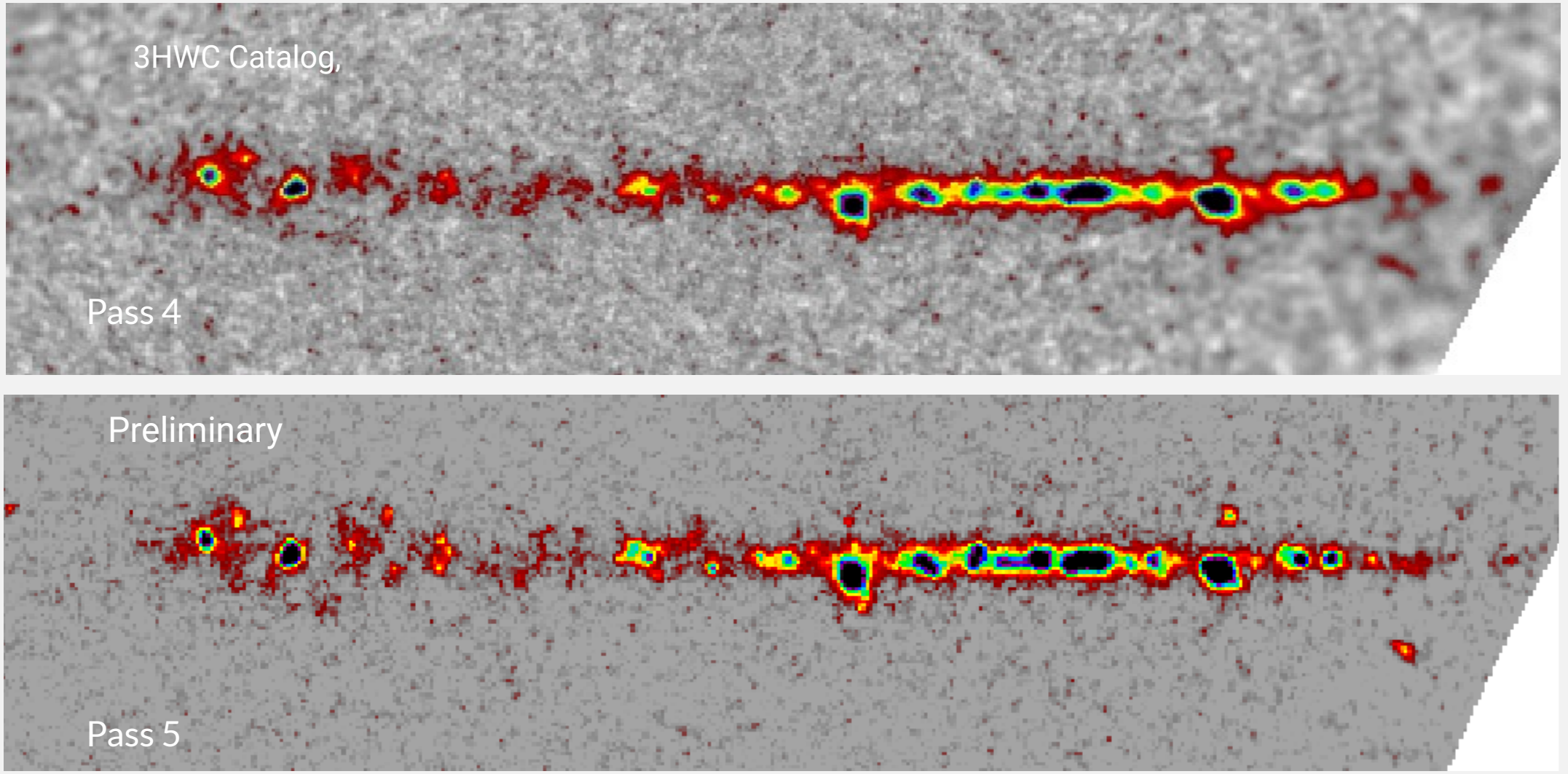


Pass 5 – Improved Reconstruction:



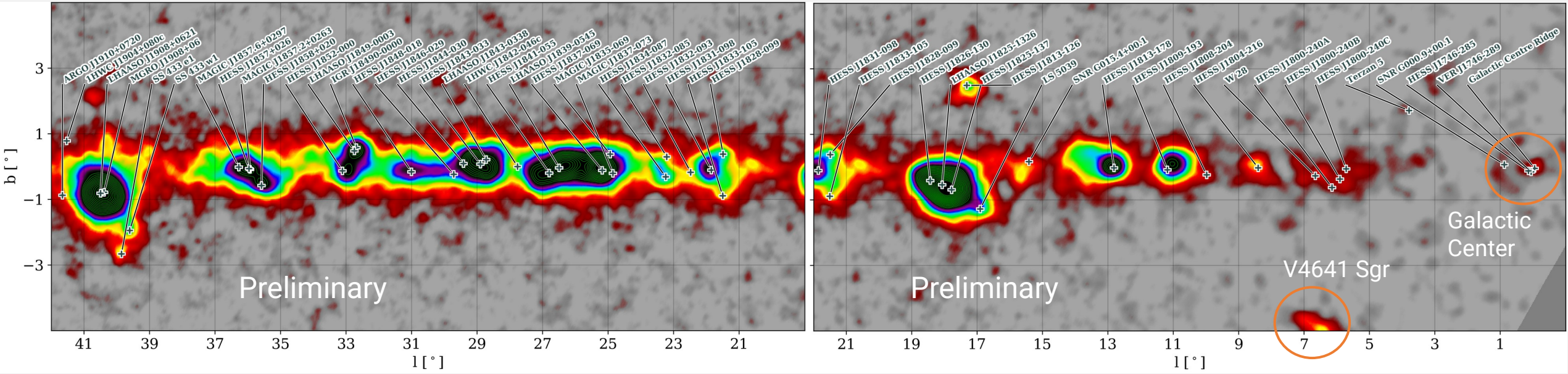


Comparison Pass 4 (1523 days) to Pass 5 (2090 days)

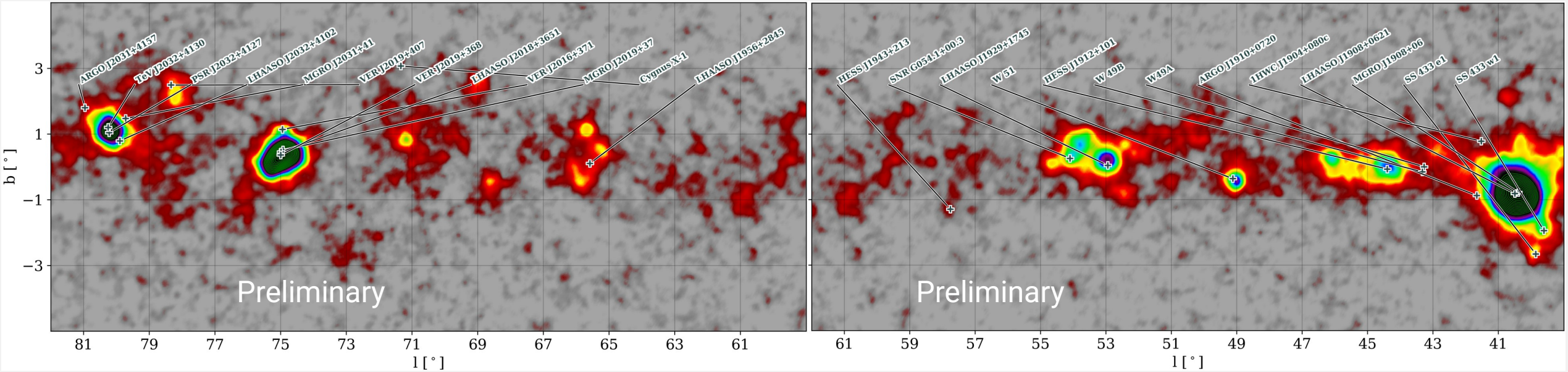


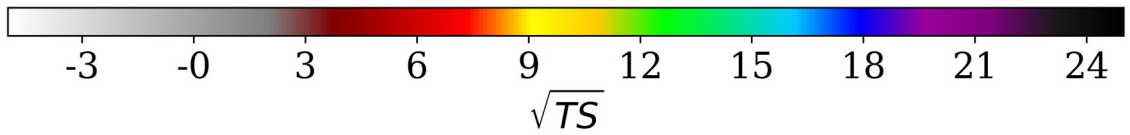
A. Albert *et al* 2020 *ApJ* **905** 76

HAWC's TeV Sky—Galactic Plane (2090 days)

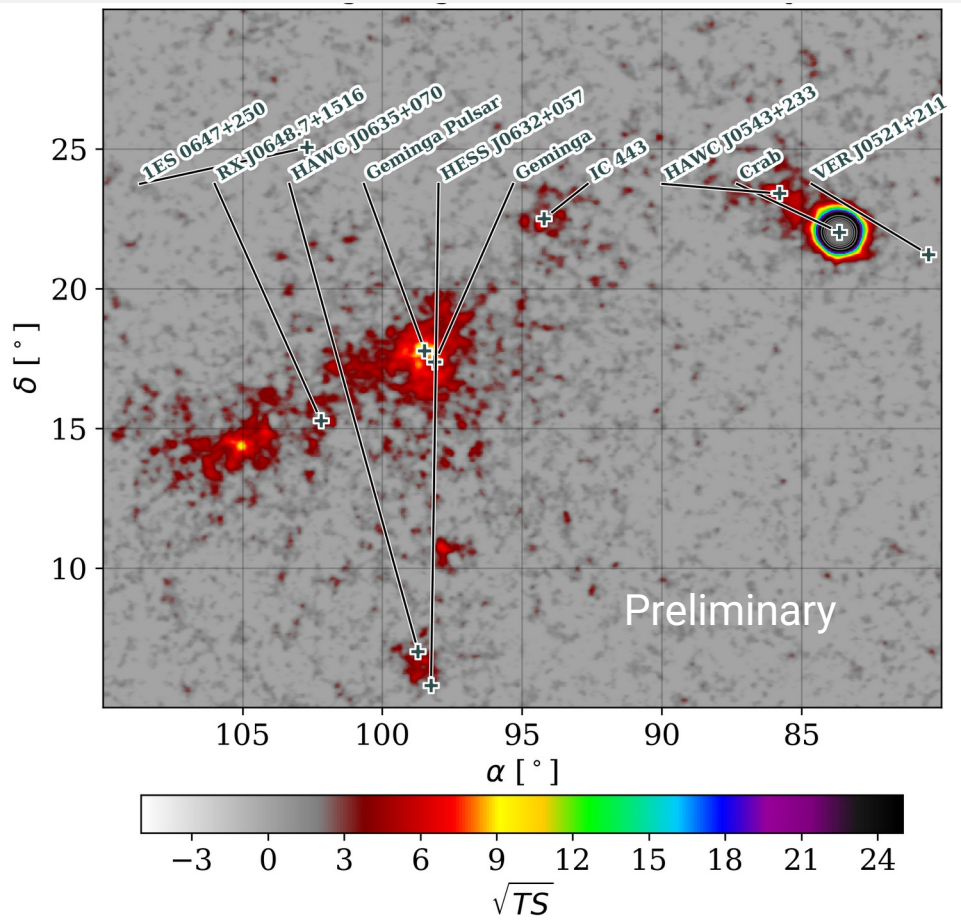


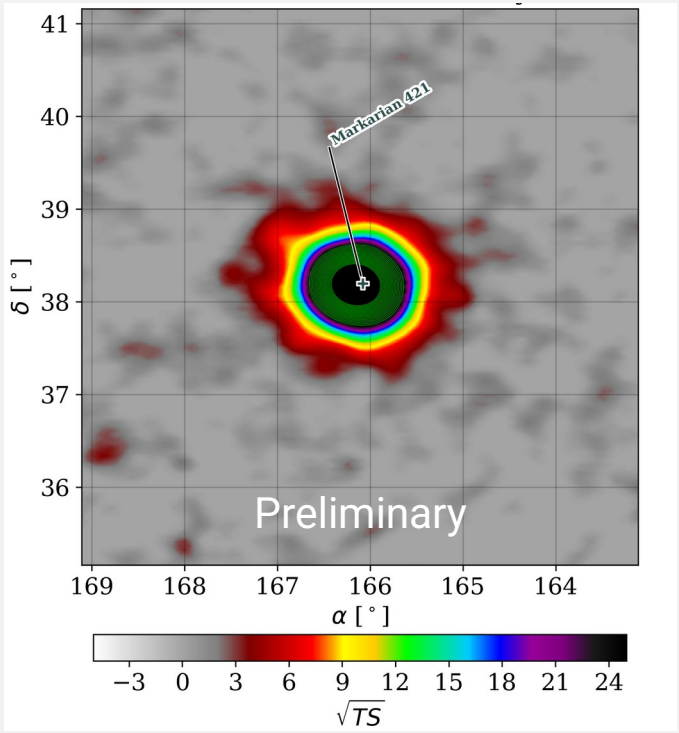
HAWC's TeV Sky—Galactic Plane (2090 days)

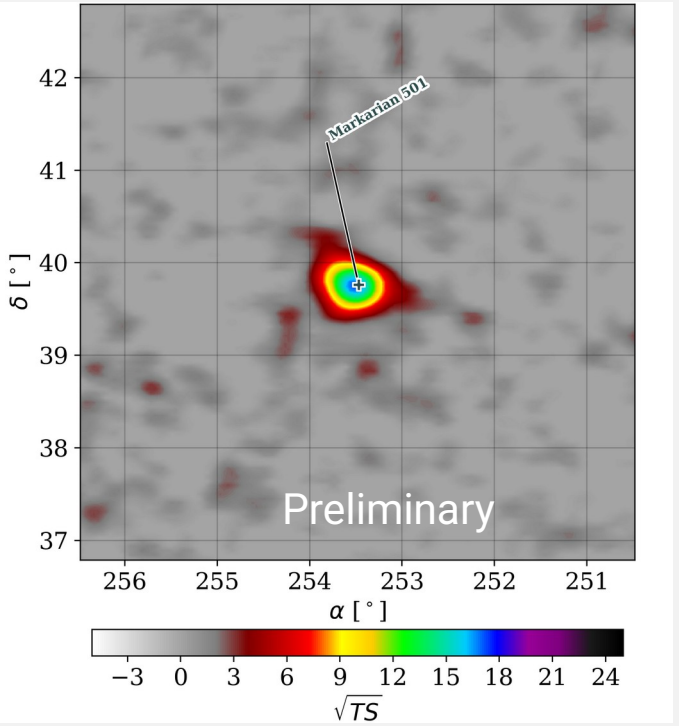




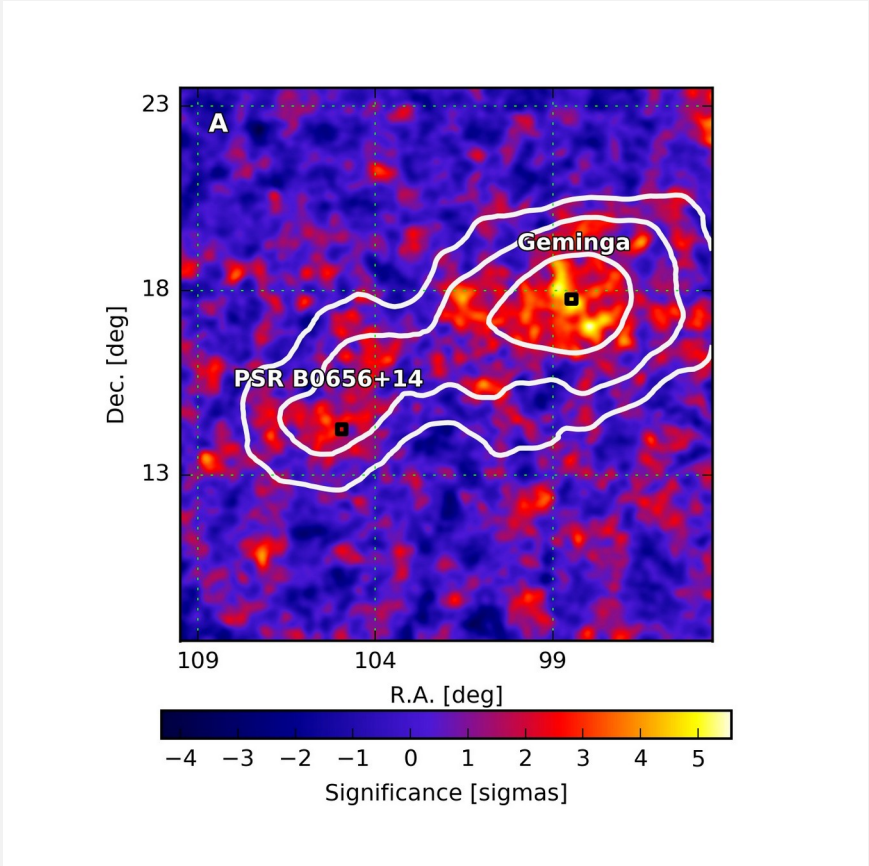
HAWC's TeV Sky— Off Galacitc Plane (2090 days)

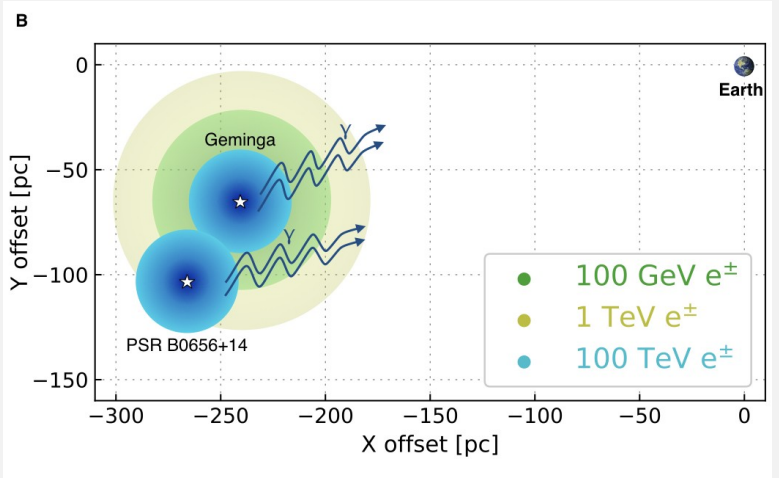


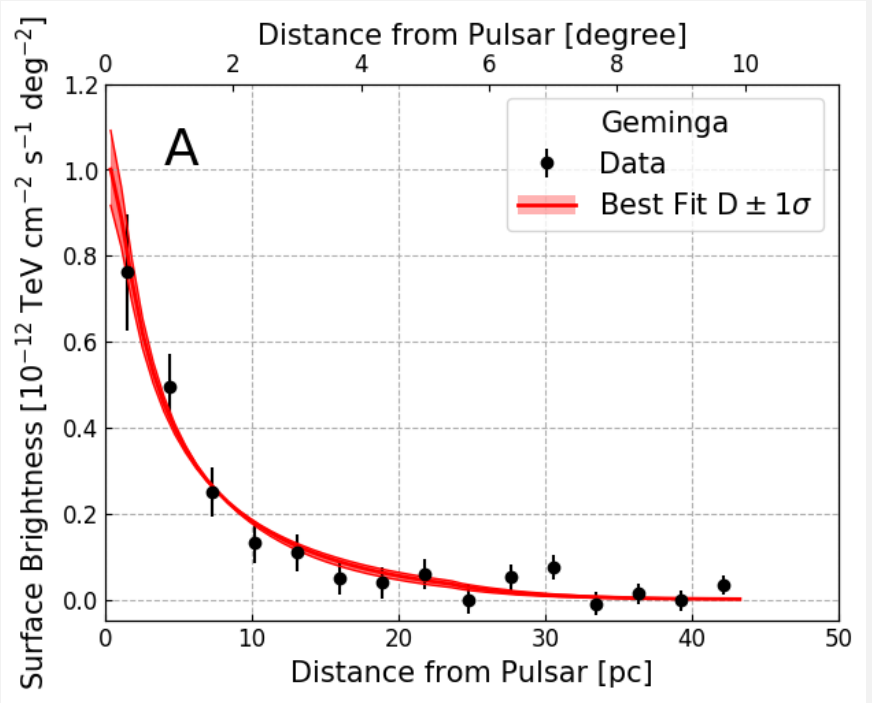




TeV Halos



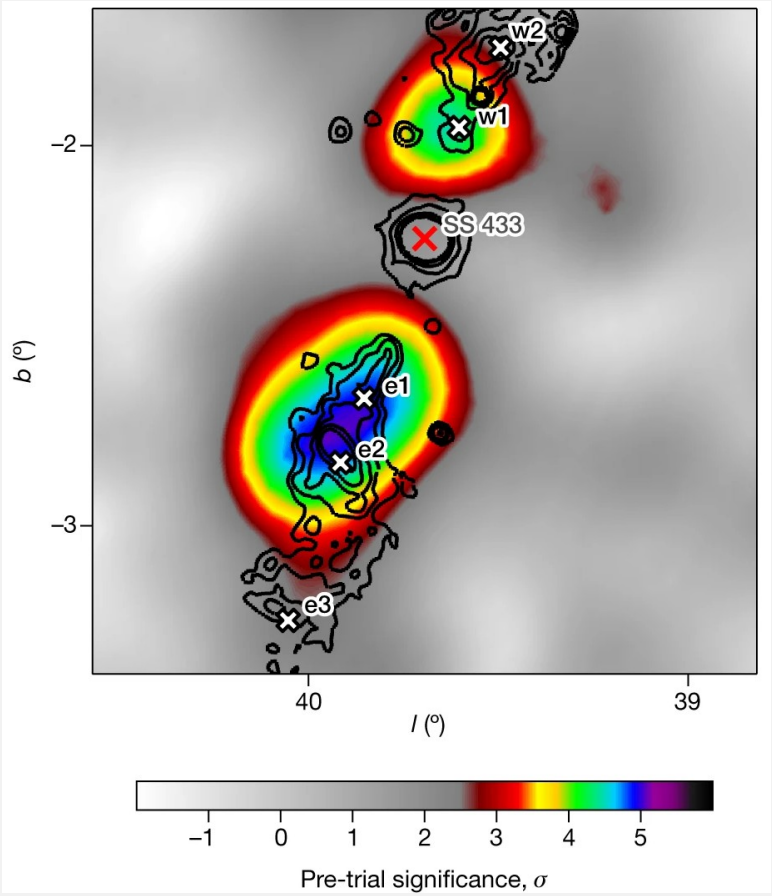




Science 2017 Vol 358, Issue 6365 pp. 911-914
DOI: 10.1126/science.aan4880

SS433 Microquasar

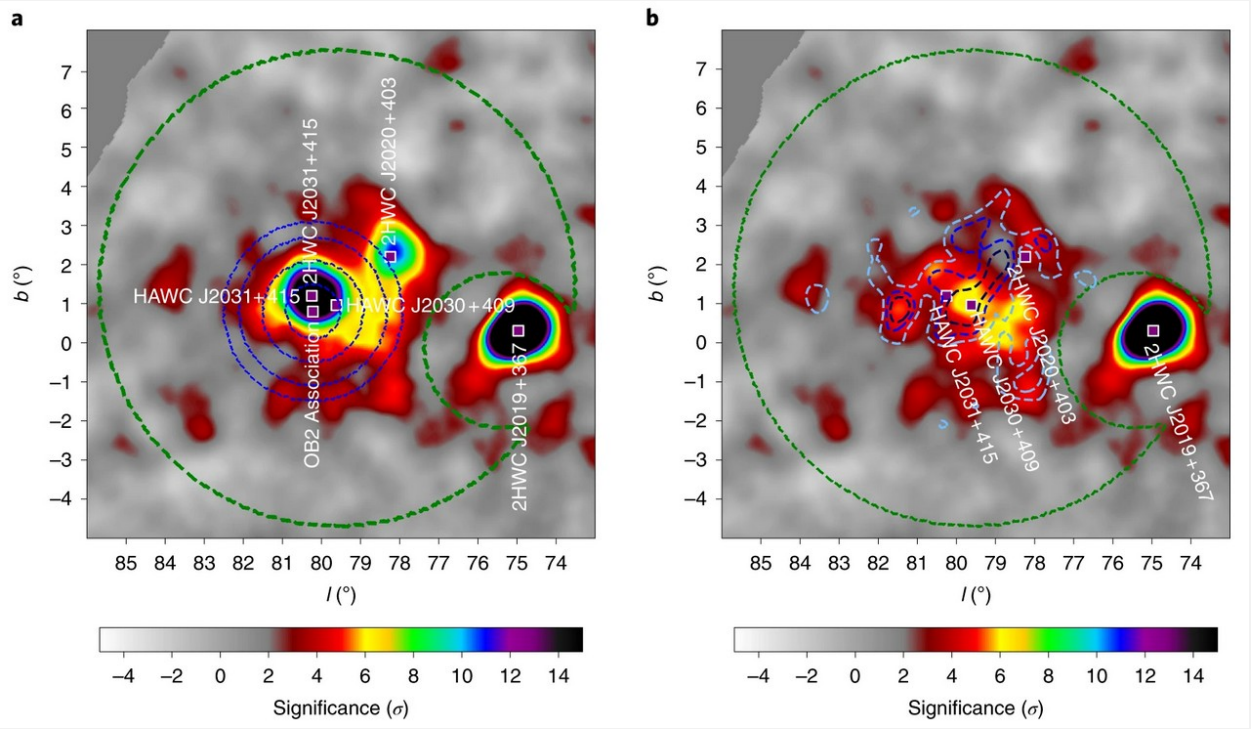
- HAWC detects TeV emission from microquasar SS433
- Binary system (Supergiant star) and compact object (black hole or neutron star)
- First evidence of TeV γ-ray emission coming from the lobes
- TeV emission can provide information about the nature of SS433



Nature volume 562, pages 82–85 (2018)
https://doi.org/10.1038/s41586-018-0565-5

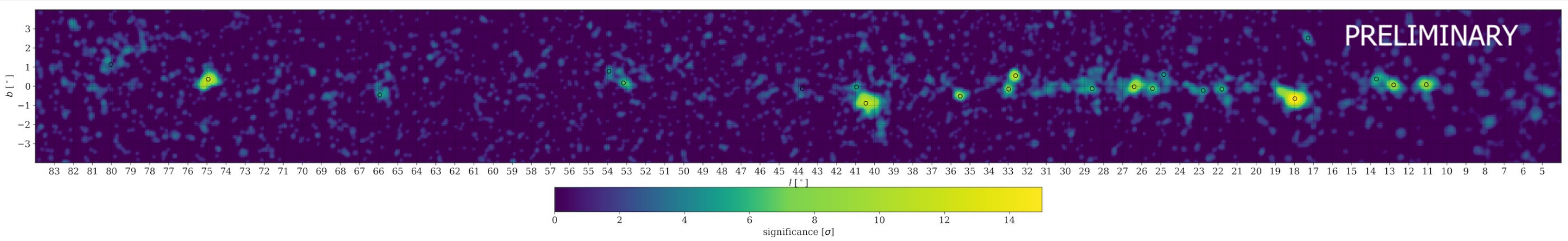
Cocoon Region

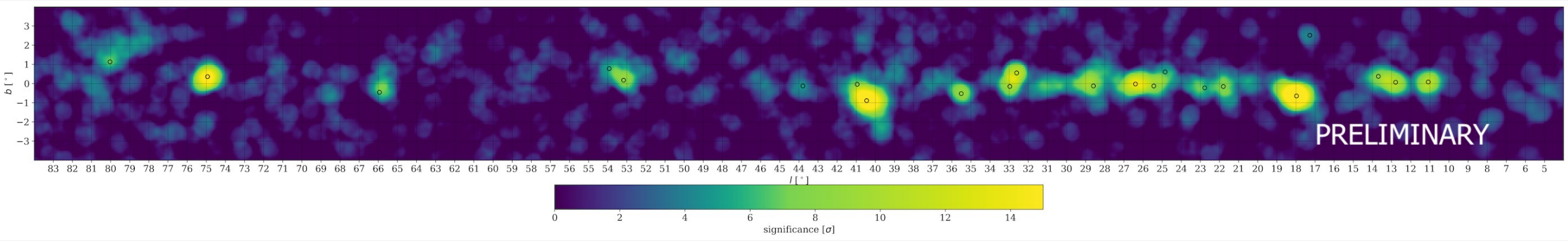
- First observations of γ-rays emission at energies 1—100 TeV
- These γ-rays are likely emitted from freshly accelerated cosmic-rays with 10 TeV—1 PeV
- Cygnus cocoon bubble coinciding with star formation region Cyg OB2



Nature, volume 5, pages 465–471 (2021)
https://doi.org/10.1038/s41550-021-01318-y

HAWC's Sky > 56 TeV (2400 days)

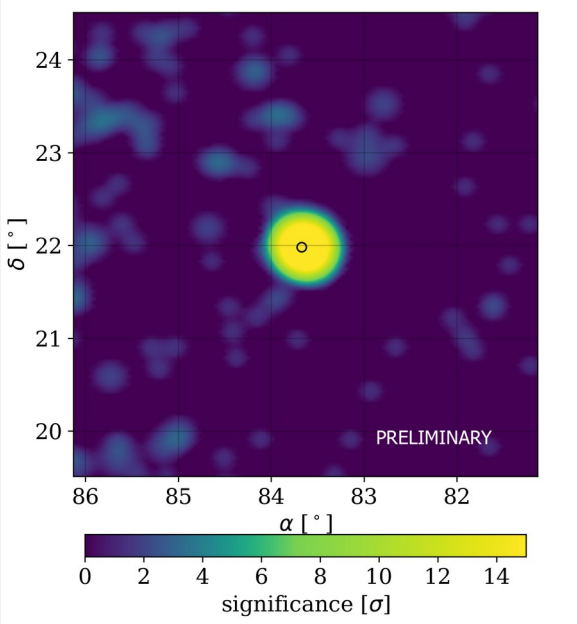




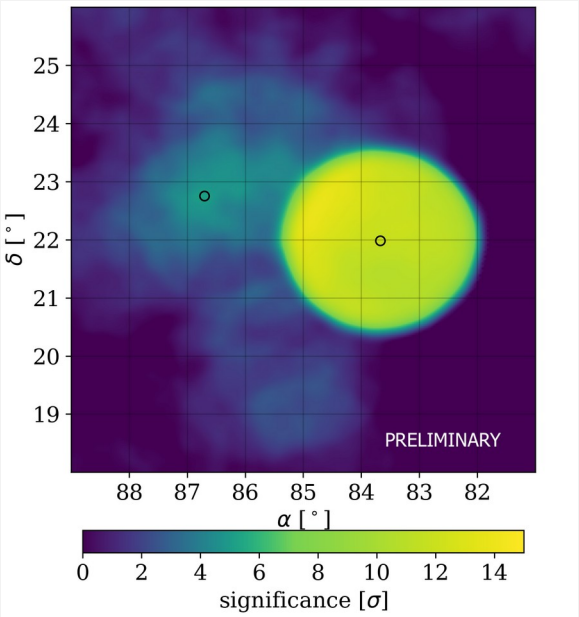
- Pass 5: 25 sources > 56 TeV
- Compared to 9 in Pass 4 (A. U. Abeysekara *et al.* Phys. Rev. Lett. 124, 021102)
- Most high energy sources appear to be extended

HAWC's Sky > 56 TeV Off Plane (2400 days)

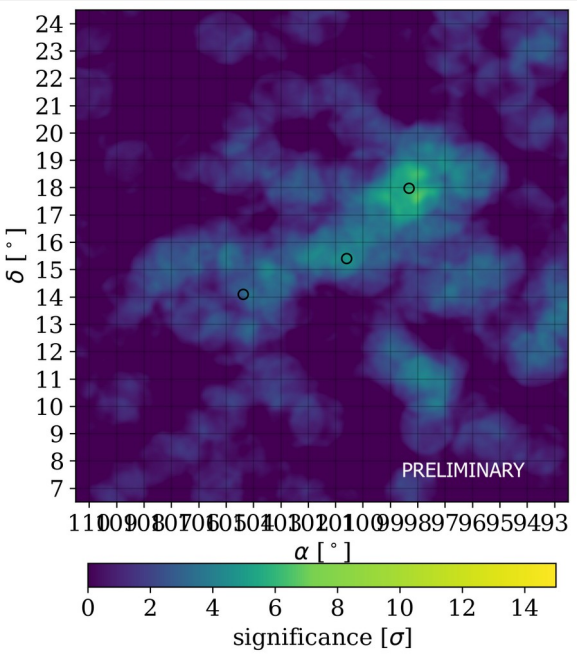
Crab



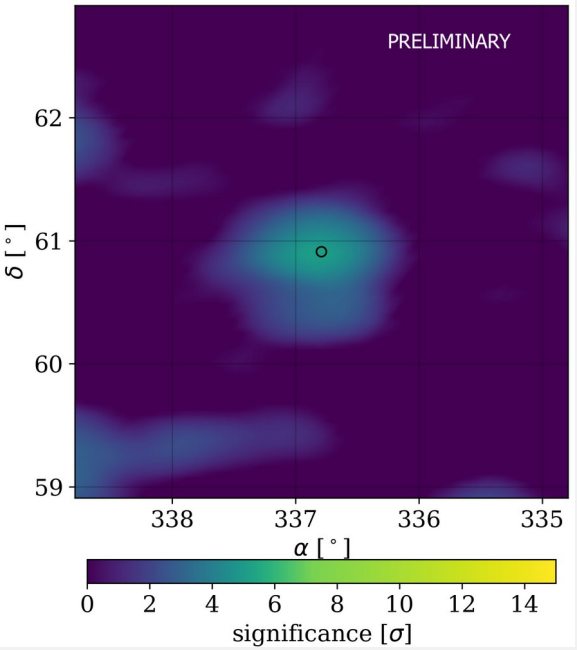
Crab "on fire" - emission from TeV J0543+234



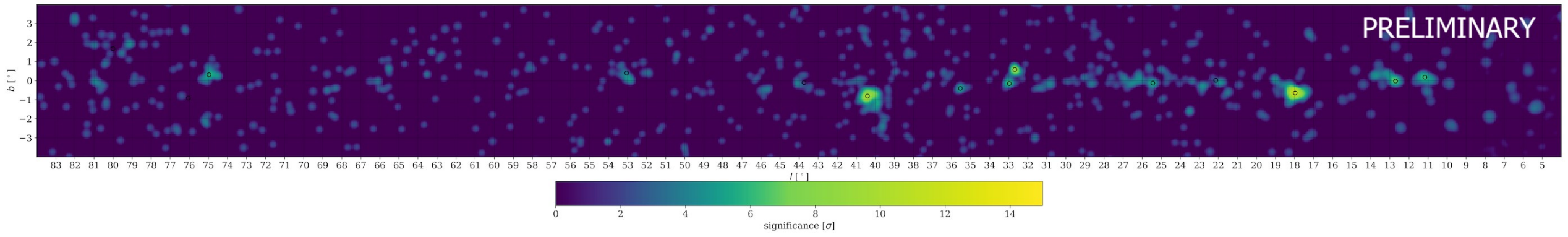
Geminga

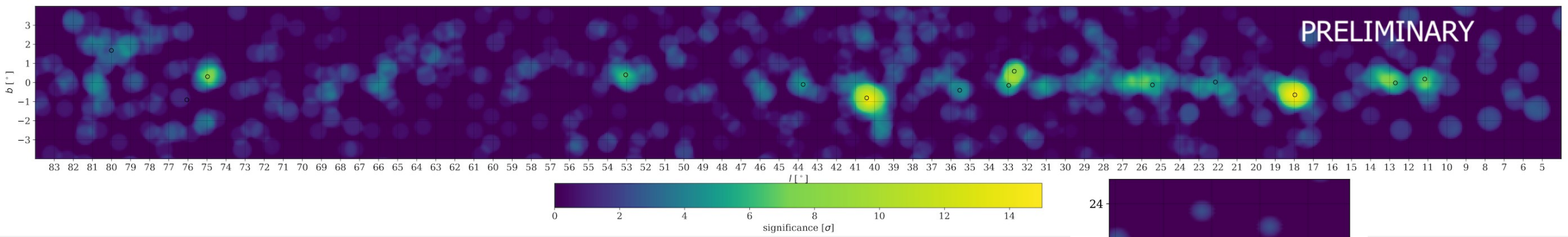


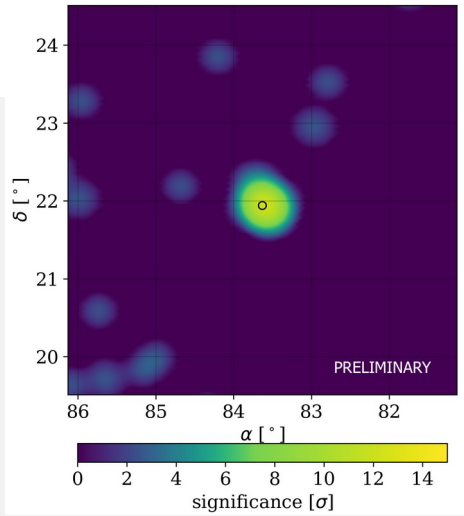
Boomerang



HAWC's Sky > 100 TeV (2400 days)



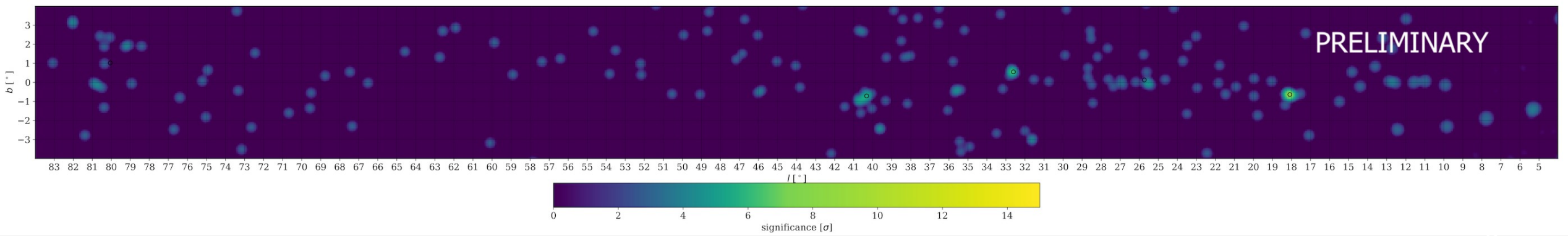


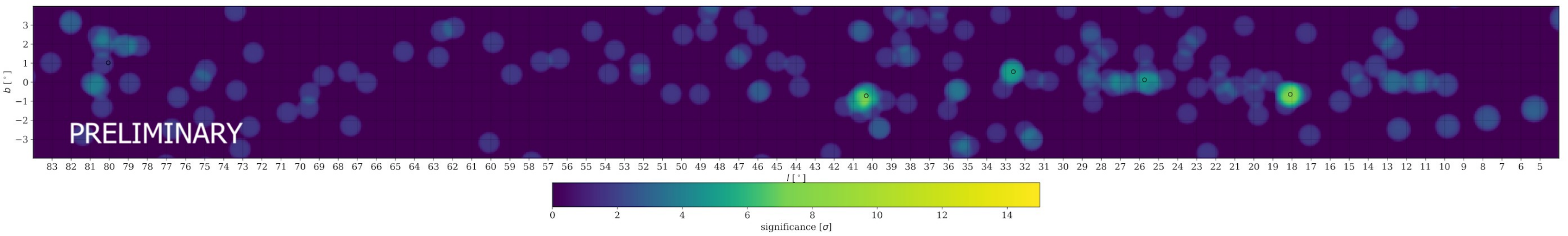


Ext 0.5 Deg

- Pass 5: 18 sources > 100 TeV (compared to 3 in Pass 4)
- Most high energy sources appear to be extended
- Crab appears point-like

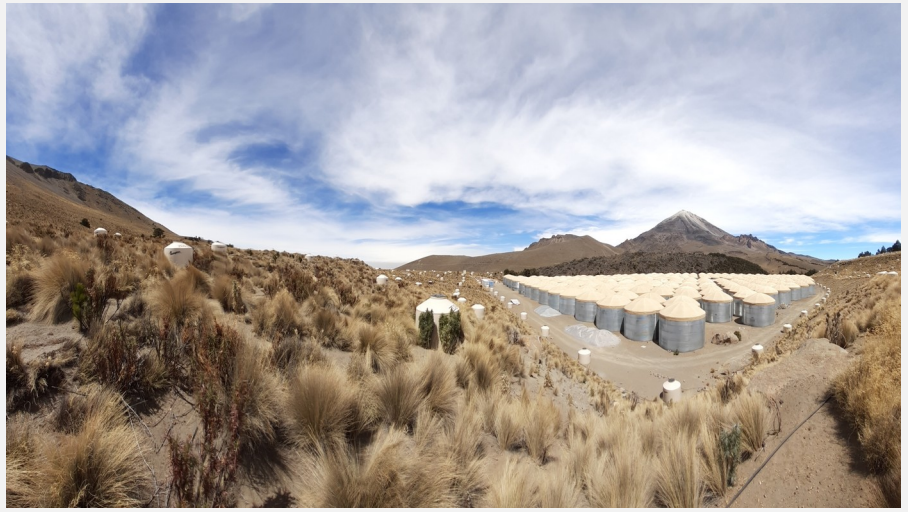
HAWC's Sky > 177 TeV (2400 days)

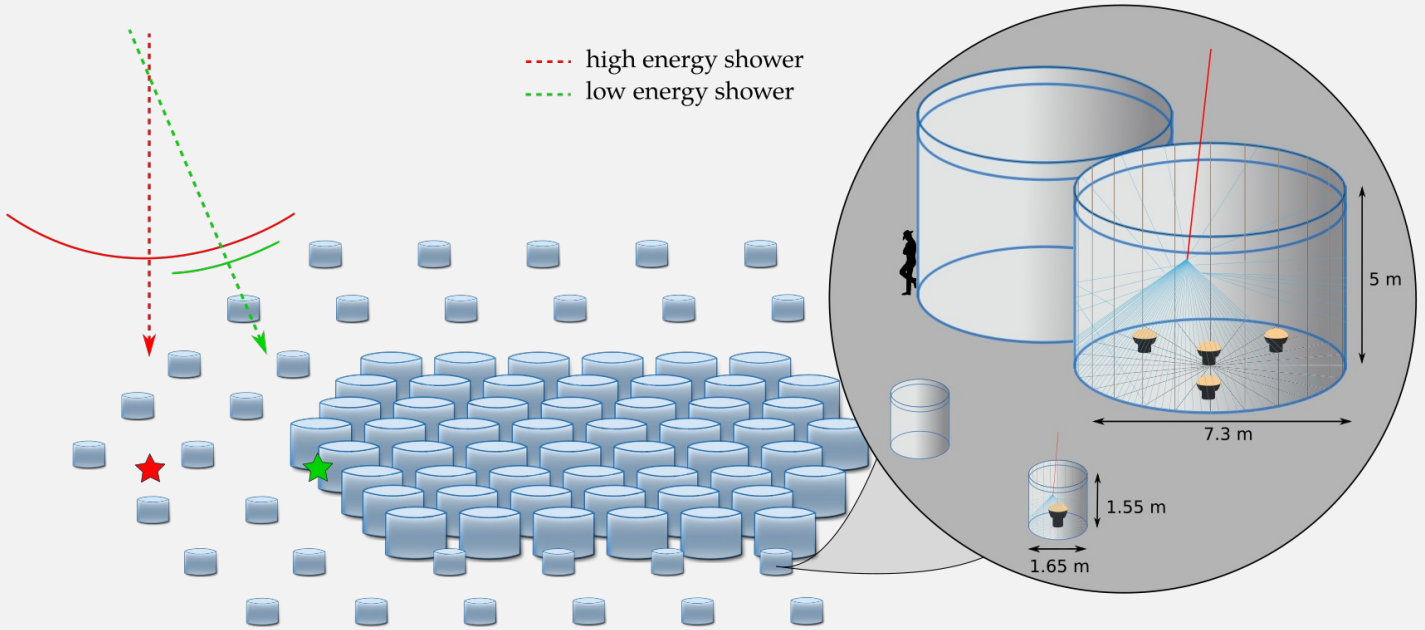




- Pass 5: 4 sources > 177 TeV (compared to 0 in Pass 4)
- Possible detection for PeVatrons
- Most high energy sources appear to be extended

HAWC Outrigger Array





- Outrigger array upgrade fully operational since 2018
- Sparsely spaced OR array of 345 smaller WCDs
- Expected to increase sensitivity by 4 times
- Increase detection area up 100, 000 m^2
- Essential for detection of TeV halos & PeVatrons

谢谢！