RESULTS FROM THE HIGH ALTITUDE WATER CHERENKOV OBSERVATORY

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Image courtesy of Philip Suárez Mauro

OUTLINE

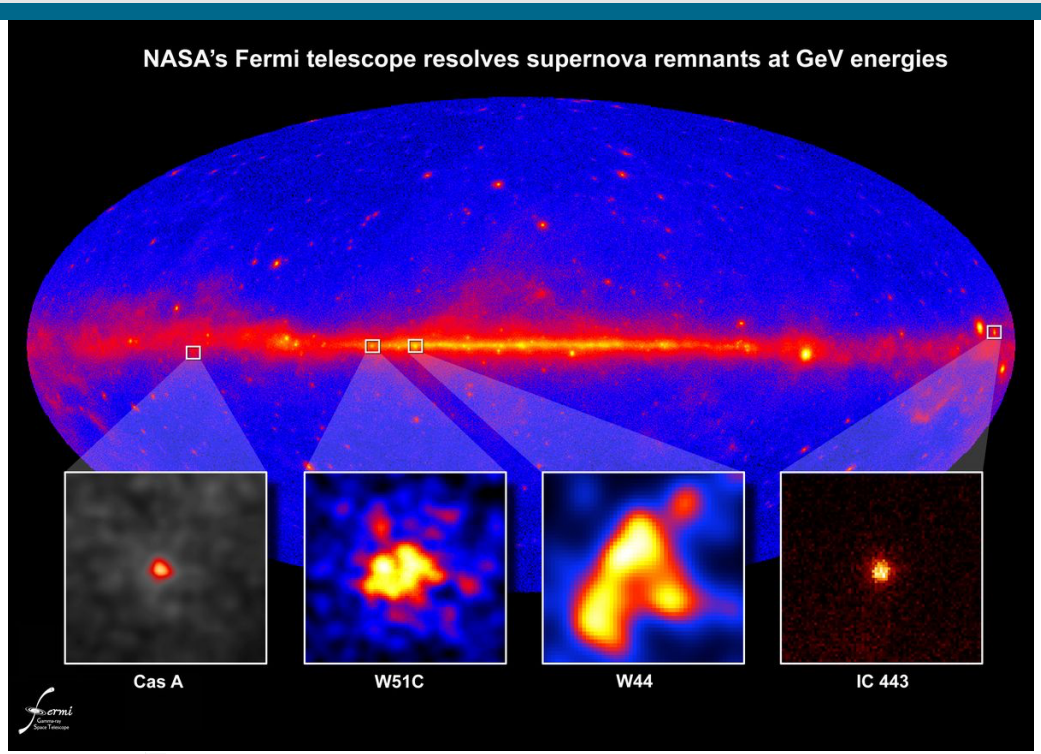
(BRIEF) INTRODUCTION & MOTIVATION

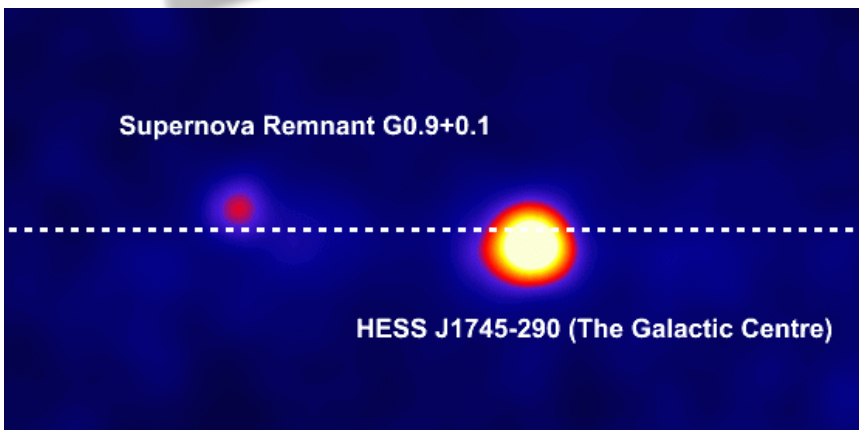
DESCRIPTION OF THE HAWC OBSERVATORY

CR-RELATED RESULTS

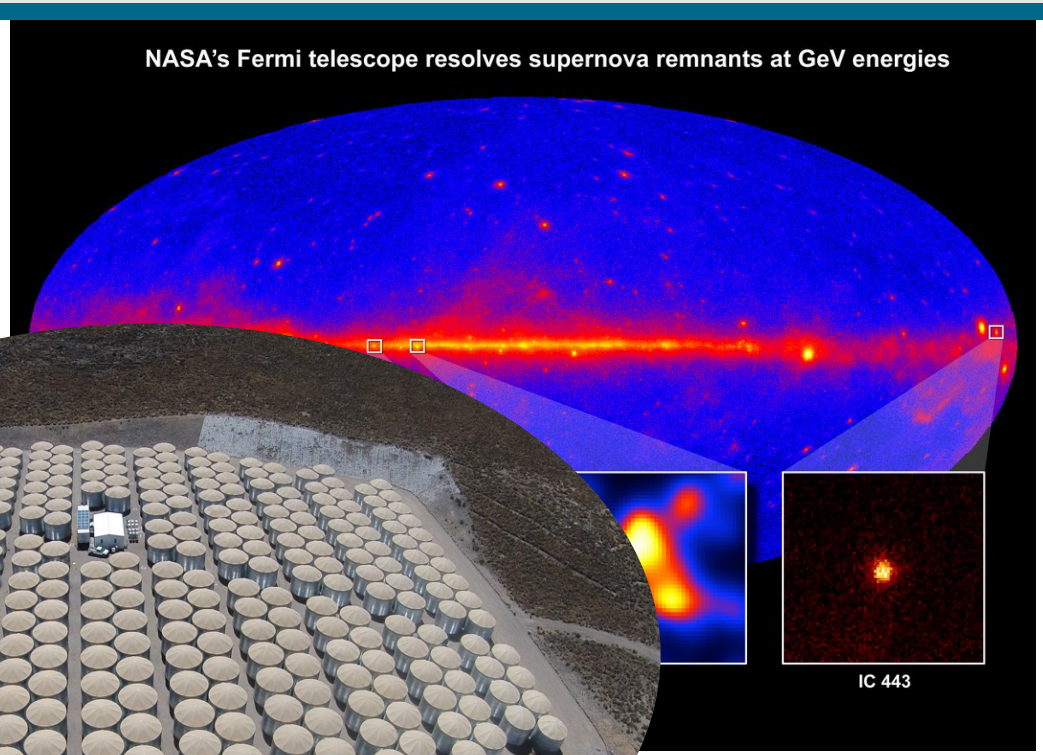
CONCLUSIONS & OUTLOOK

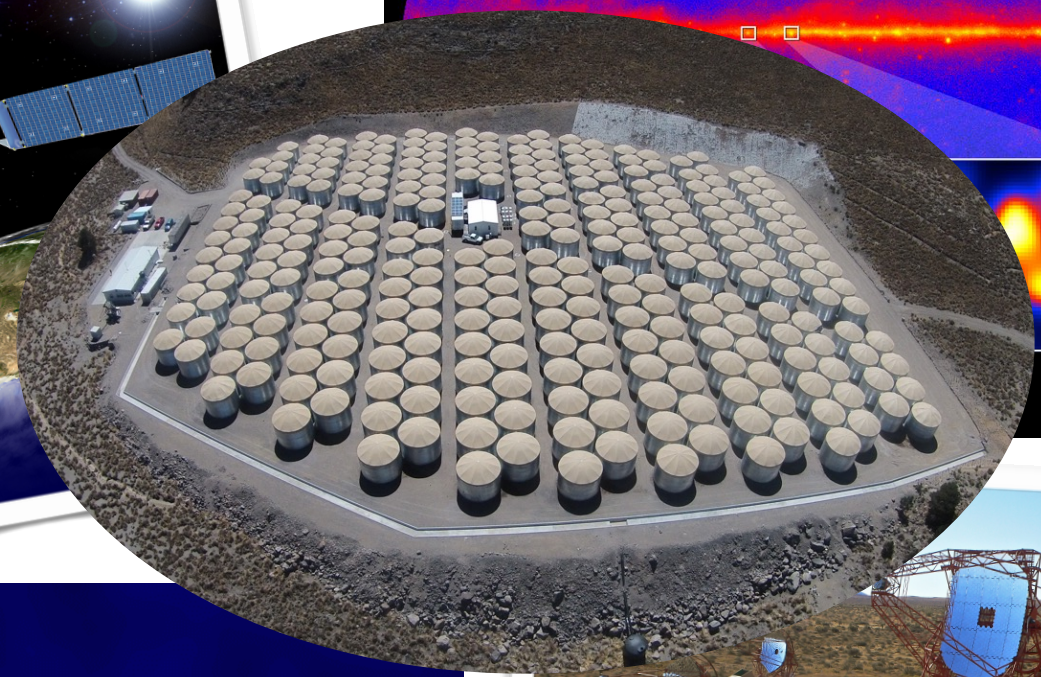
VHE γ-RAYS

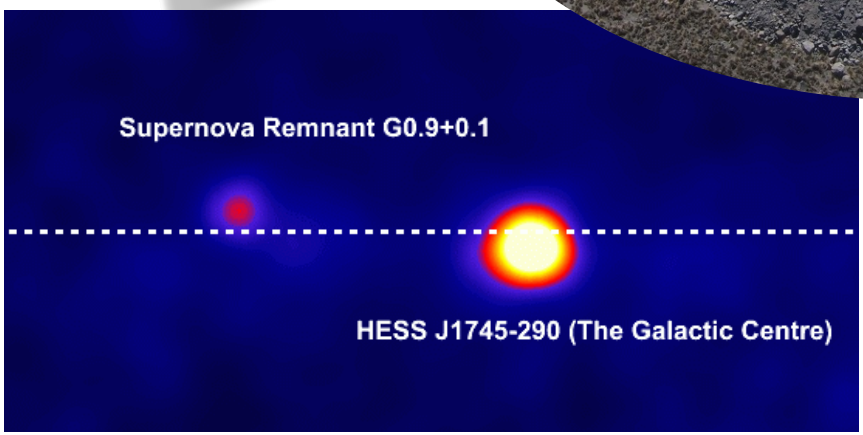




GROUND ARRAYS







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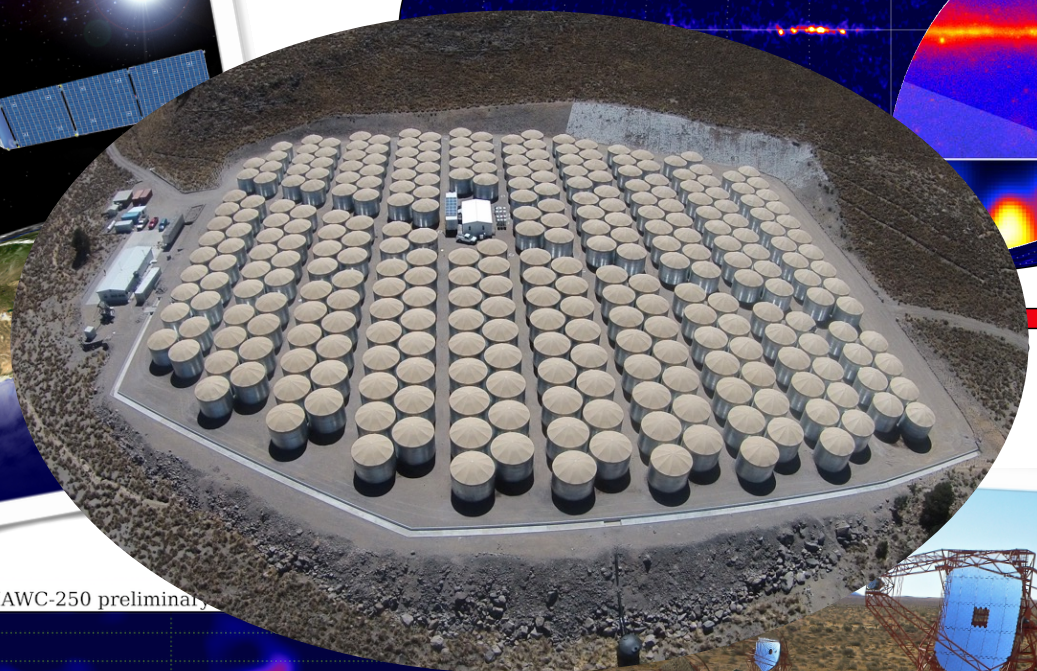
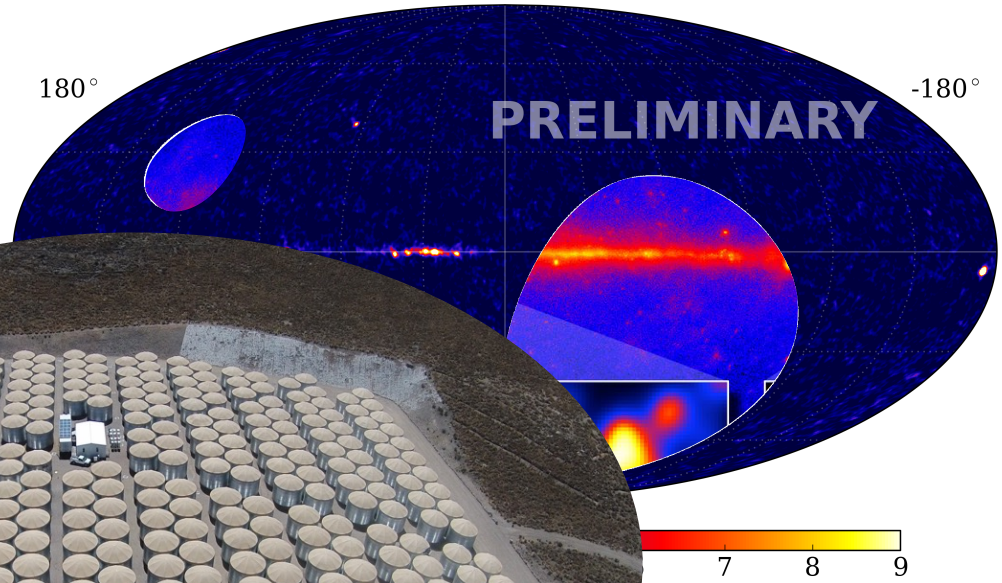
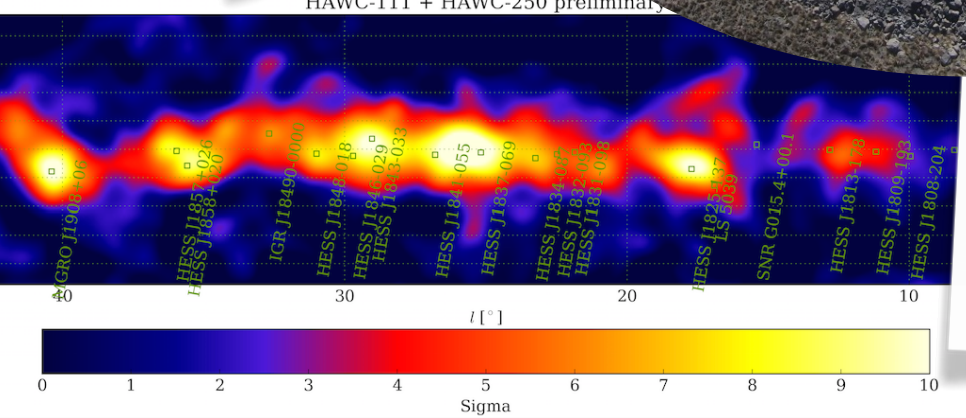


HAWC-111 (283 d) + HAWC-250 (105 d)



HAWC-111 + HAWC-250 preliminary



HAWC

HAWC Observatory

HAWC operates day and night, providing a large field of view for the observation of the highest energy gamma rays.

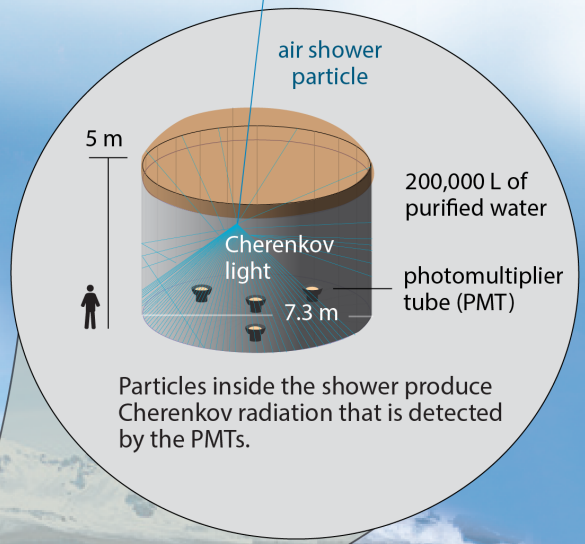
Pico de Orizaba
(5,626 m)

HAWC is located at 4,100 m above sea level, covering an area of 20,000 m^2.

150 m

Water Cherenkov tank

HAWC comprises an array of 300 tanks that record the particles created in gamma-ray and cosmic-ray showers.

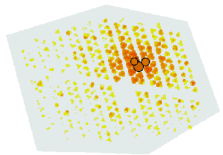


Particles inside the shower produce Cherenkov radiation that is detected by the PMTs.

Gamma rays vs cosmic rays

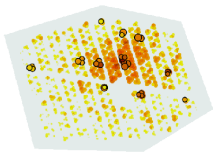
HAWC selects gamma rays from among a much more abundant background of cosmic rays.

gamma-ray shower



"hot" spots concentrate around the core

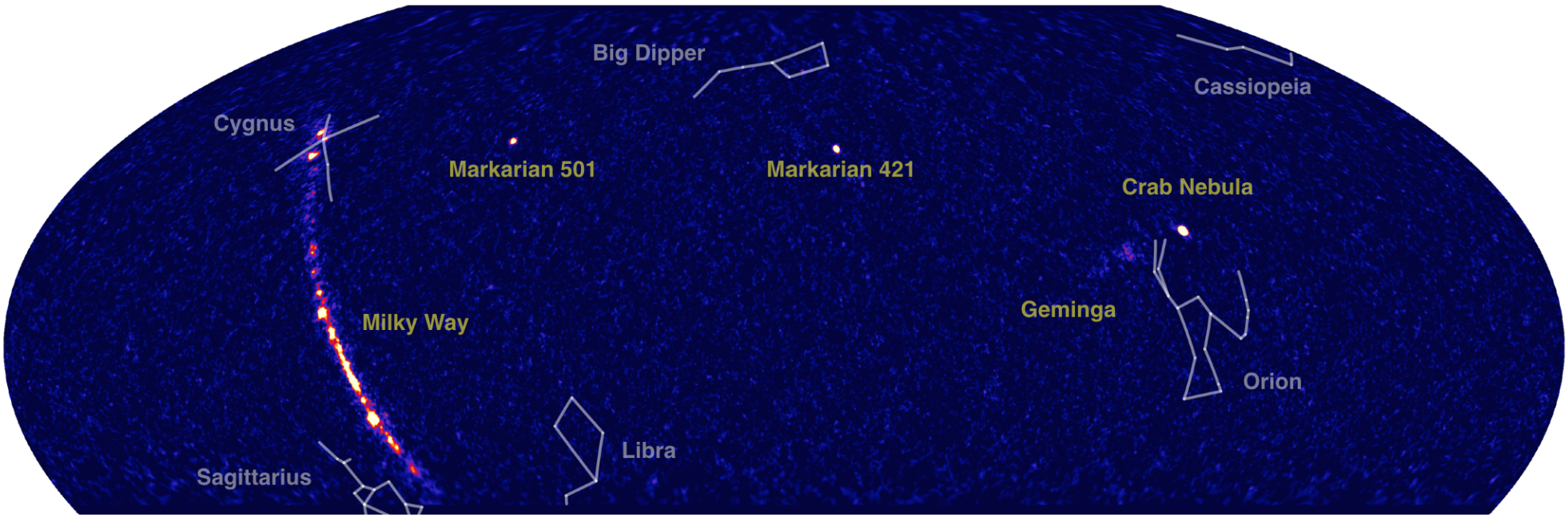
cosmic-ray shower



"hot" spots are more dispersed

HAWC

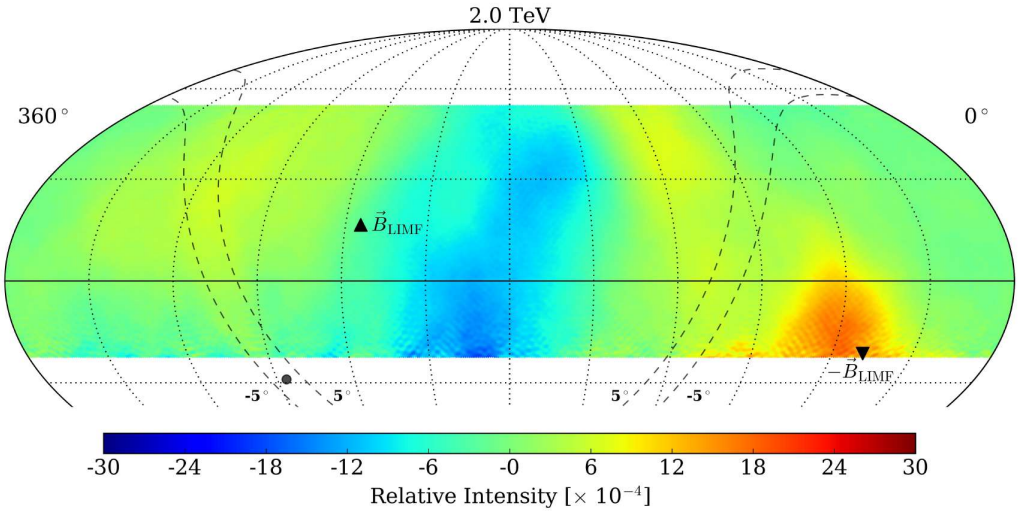
- large instantaneous sky coverage
- long, uninterrupted observation periods

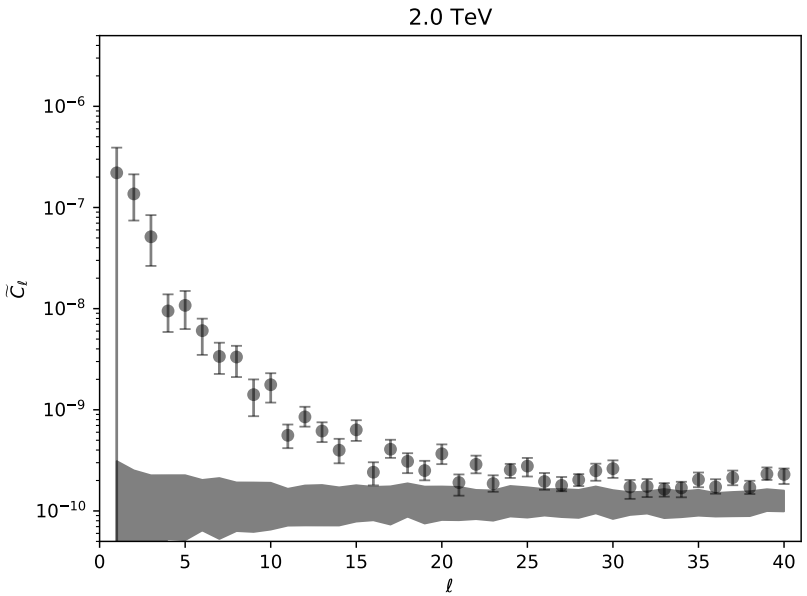


The HAWC Observatory: NIM **A1052** (2023) 168253

COSMIC RAY ANISOTROPY (HAWC)

- Anisotropy in energy bins (from 2.0 to 72.8 TeV)





differential relative intensity

angular power spectrum

CR anisotropy (2 yrs), HAWC Collaboration: *ApJ* **865** (2018) 57

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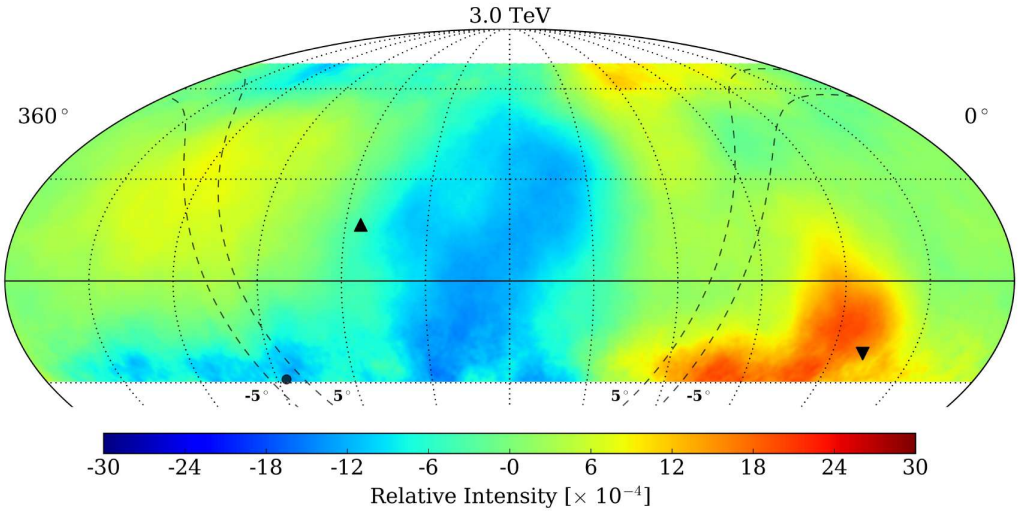

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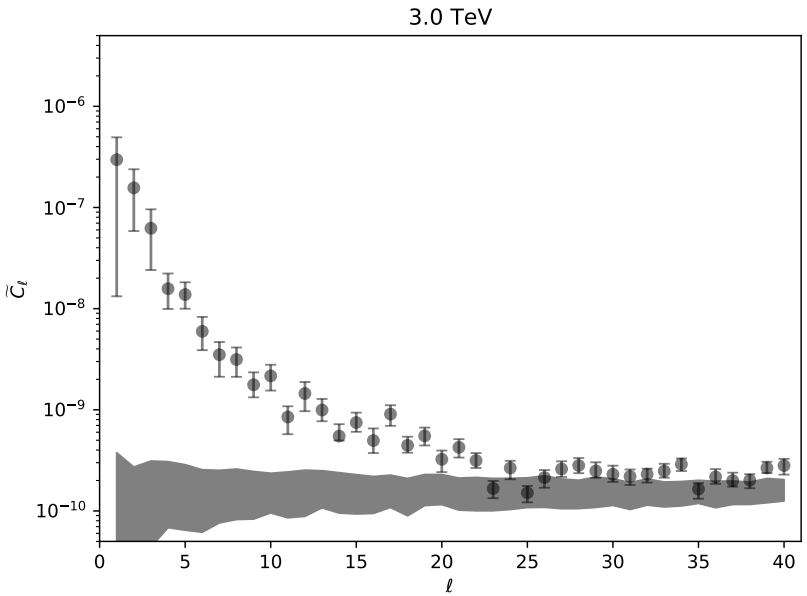

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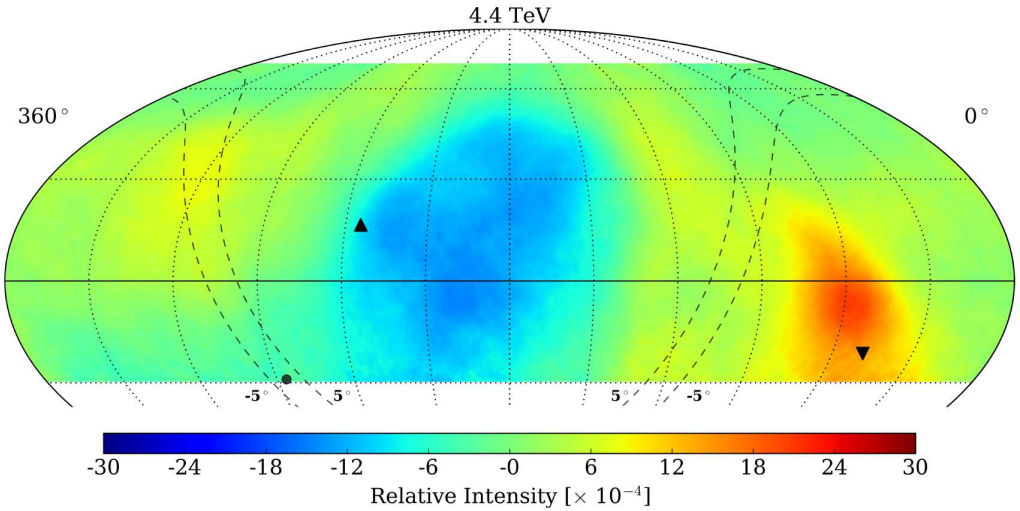

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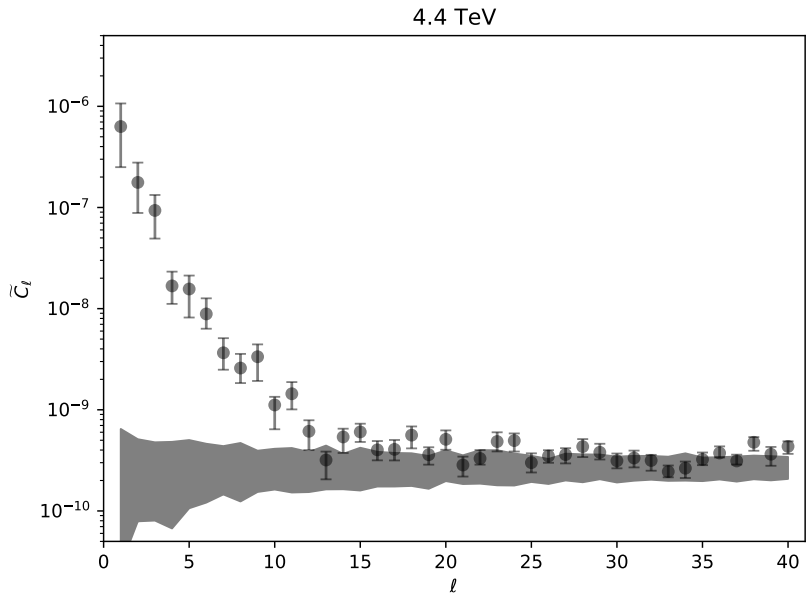

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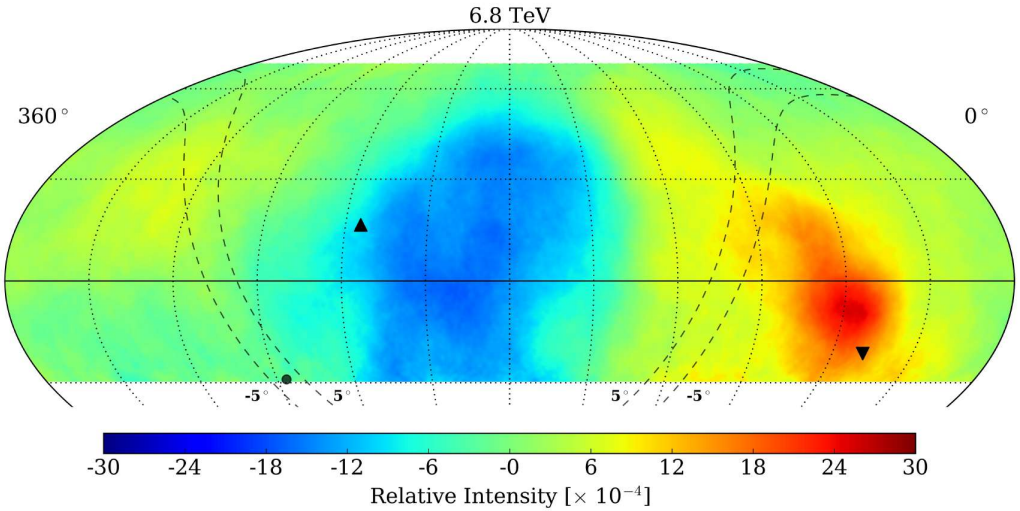

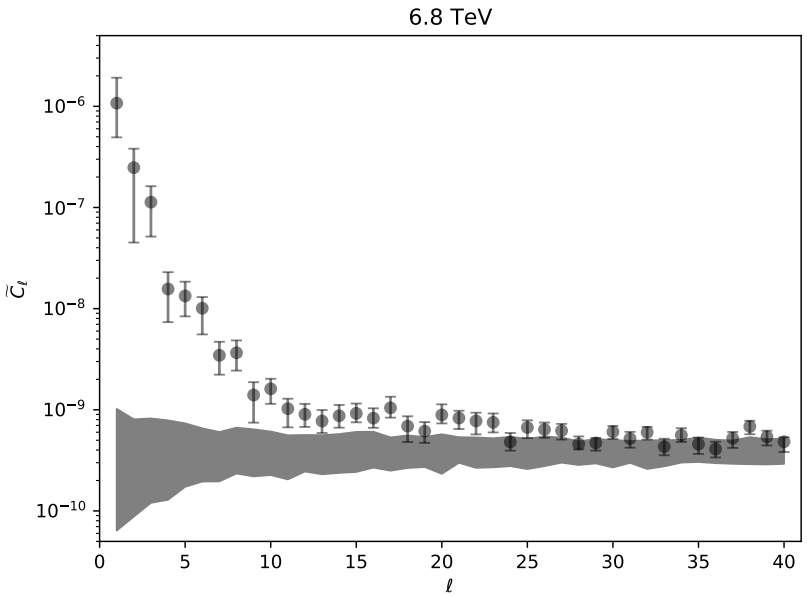

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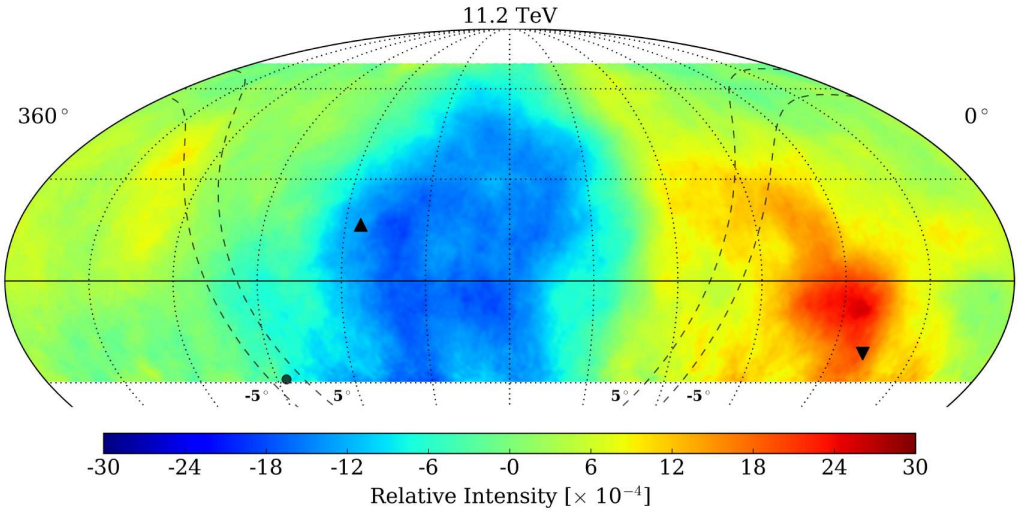

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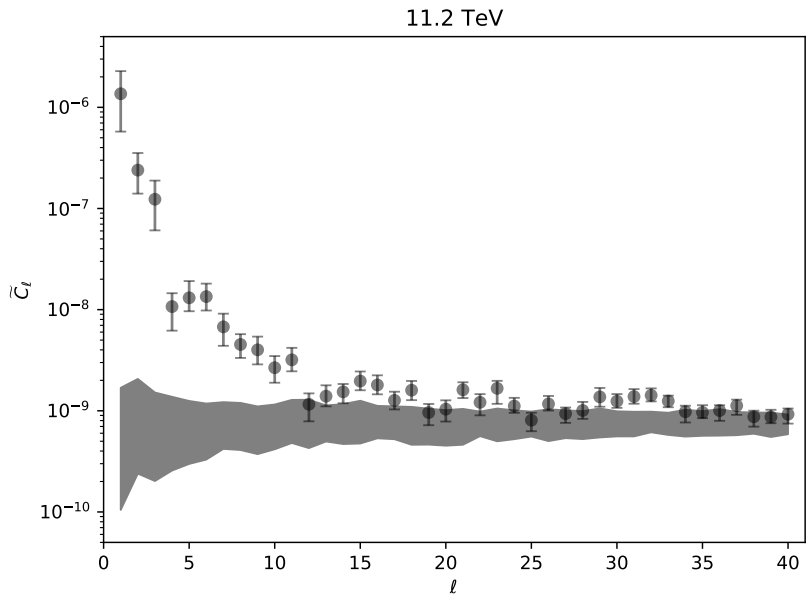

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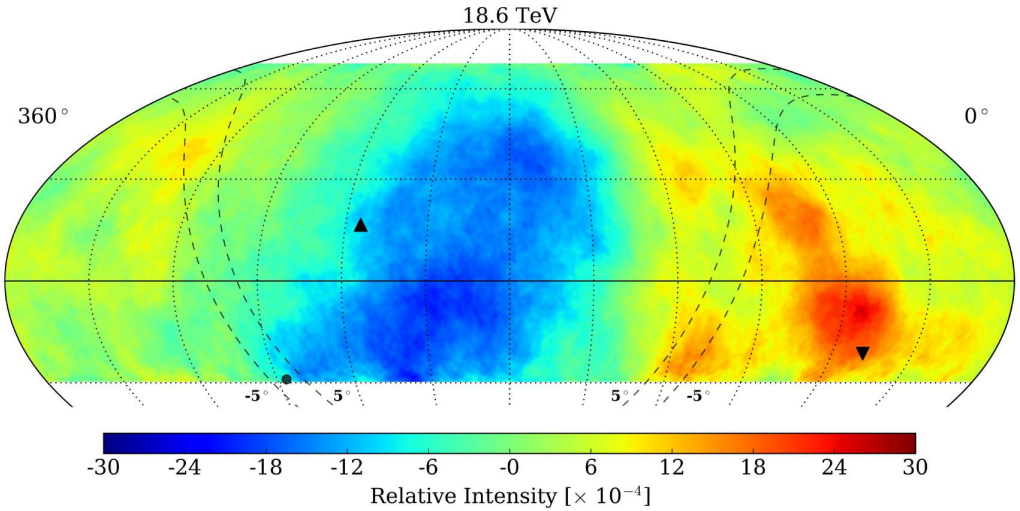

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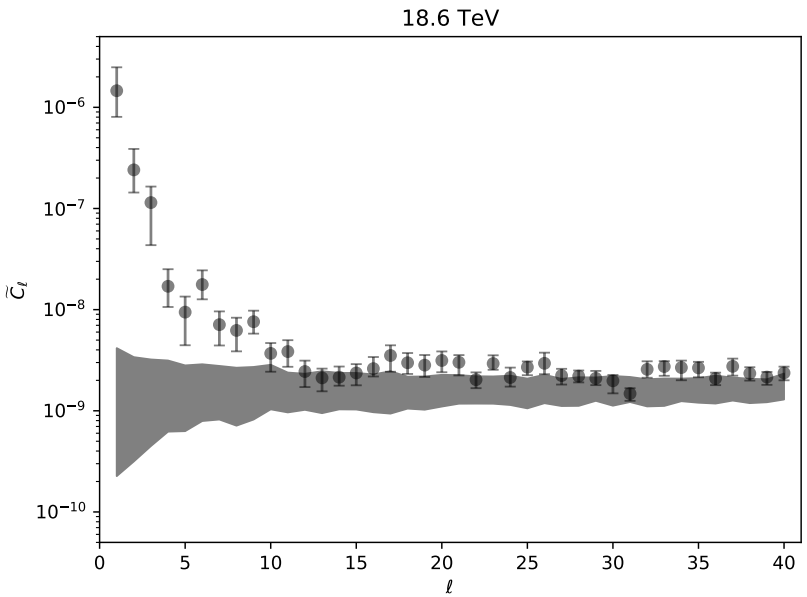

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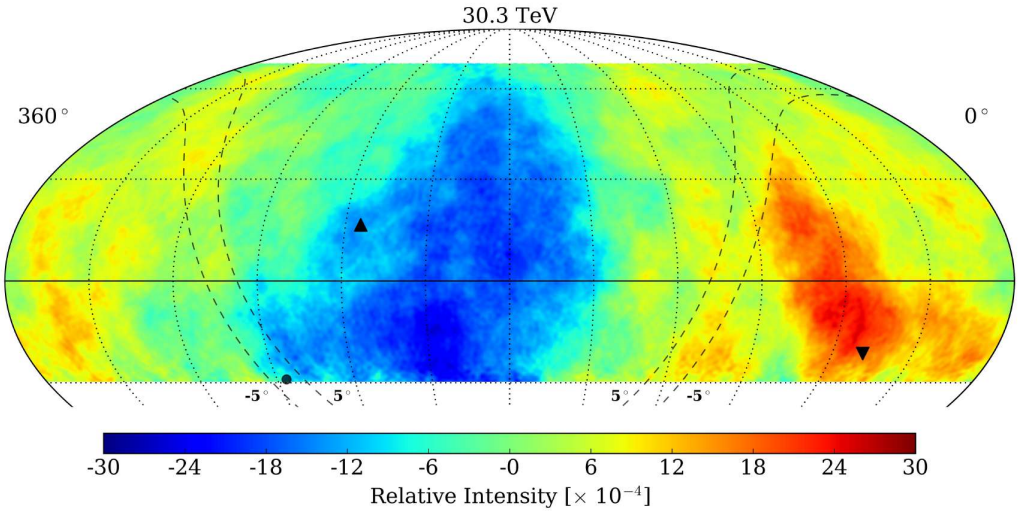

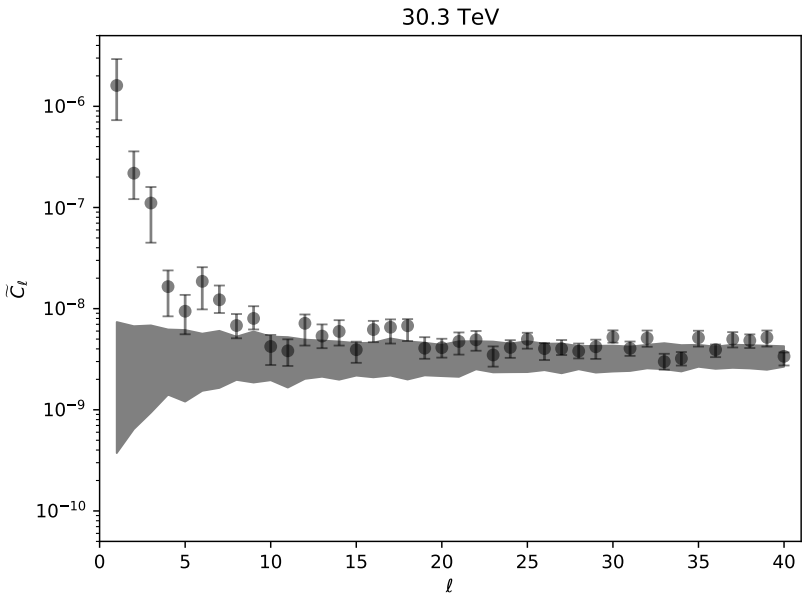

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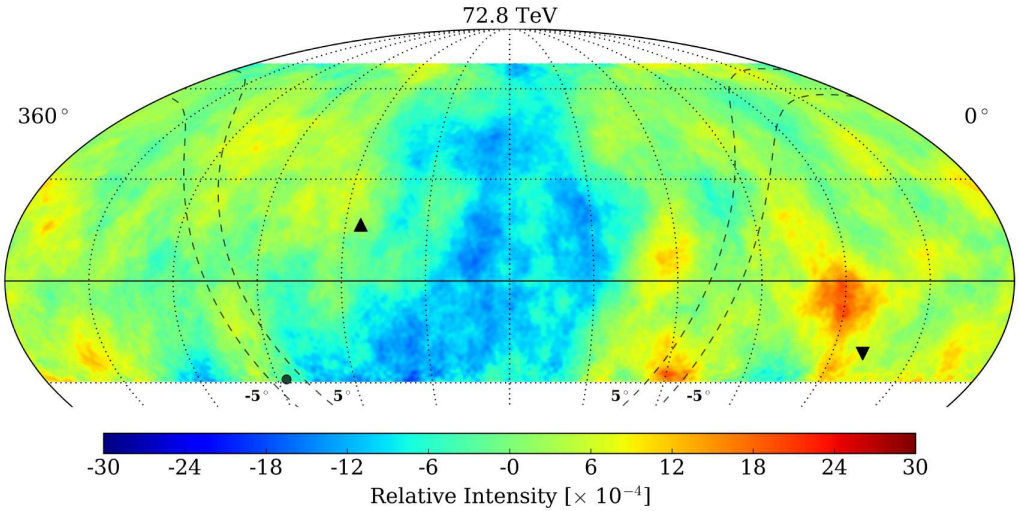

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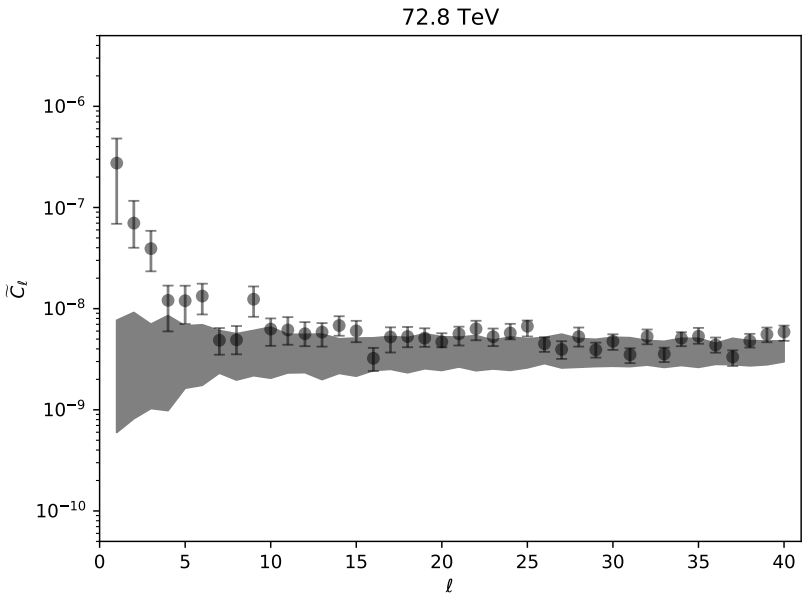
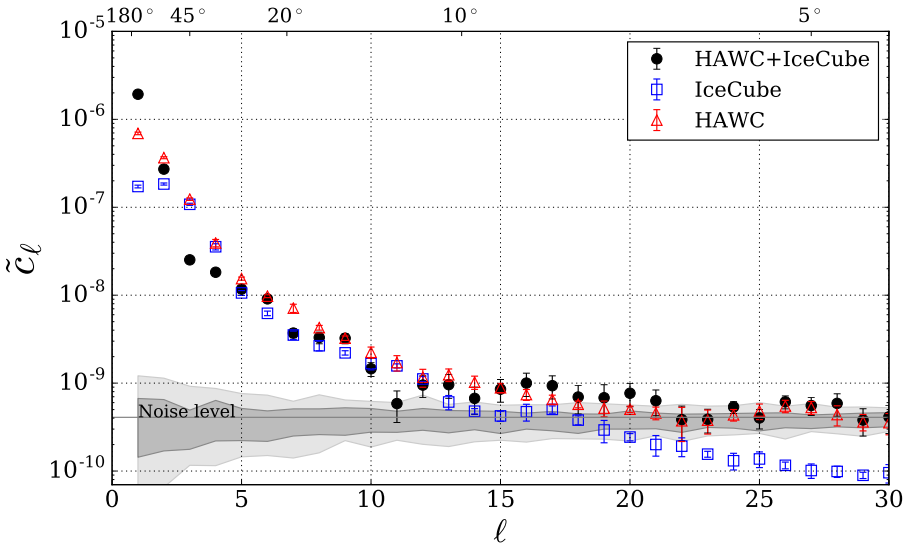


angular power spectrum

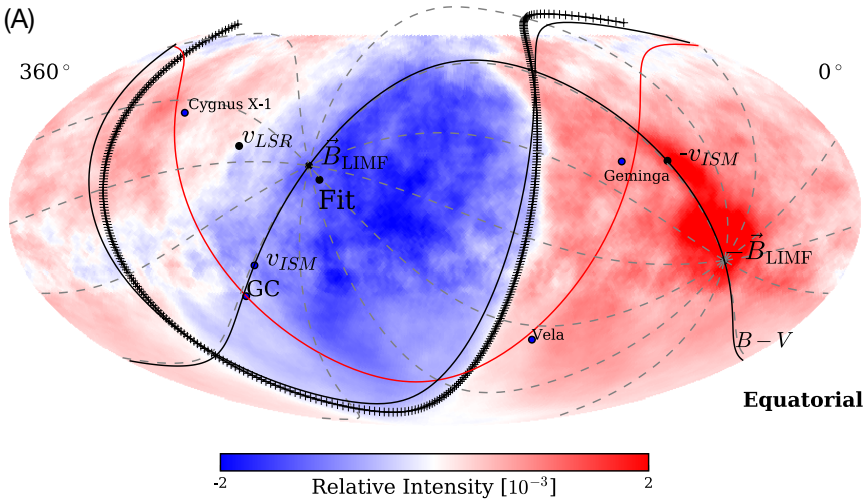
CR anisotropy (2 yrs), HAWC Collaboration: *ApJ* **865** (2018) 57

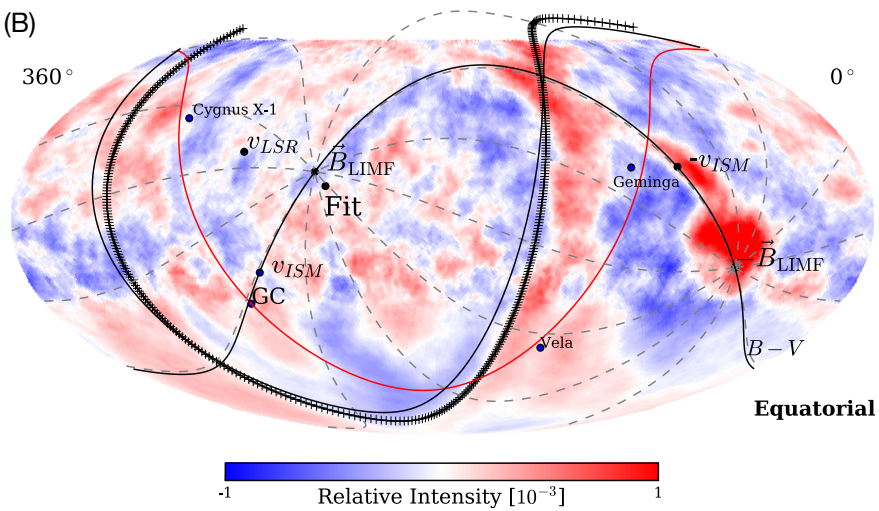
COSMIC RAY ANISOTROPY (HAWC+ICECUBE)

- Anisotropy at 10 TeV



angular power spectrum



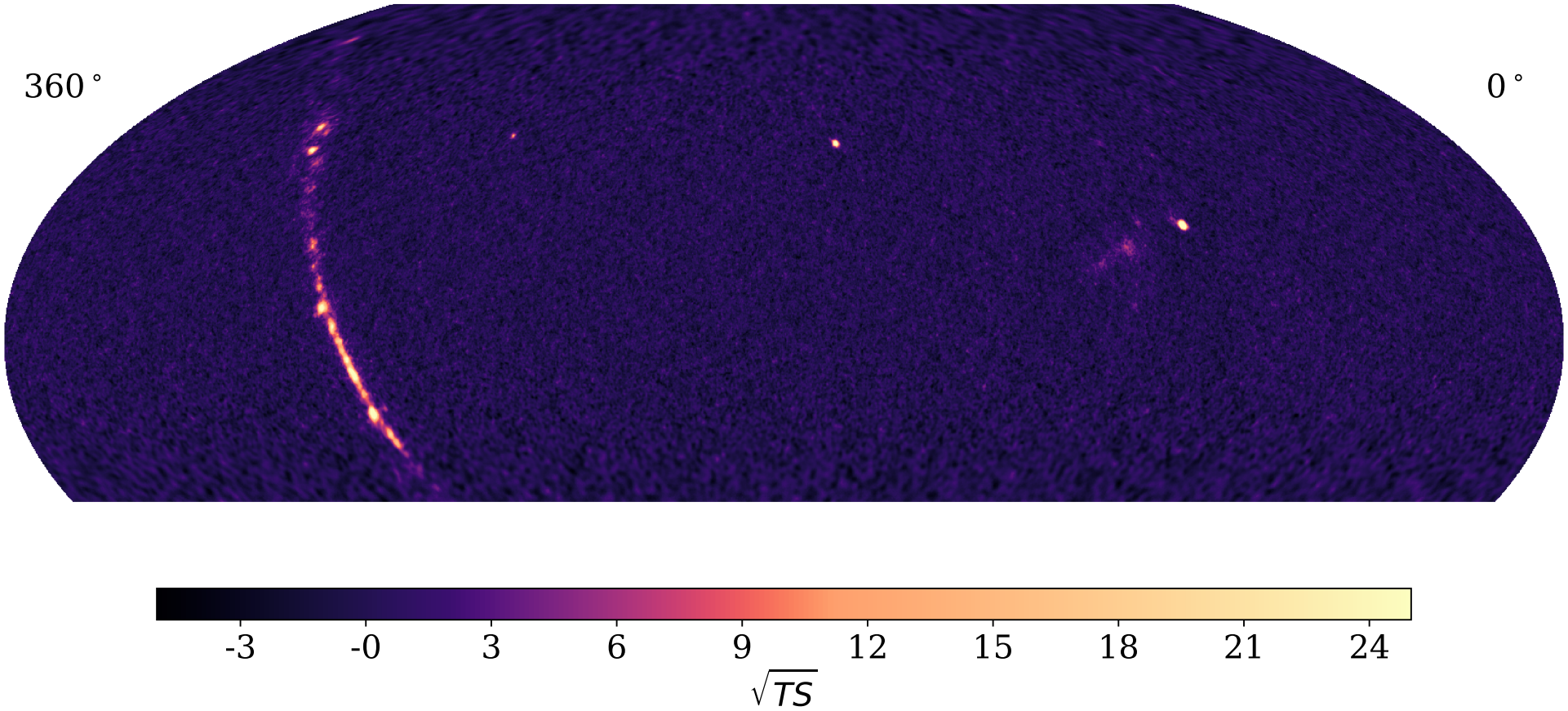


CR anisotropy at 10 TeV, HAWC+IceCube: *ApJ* **871** (2019) 76

THE 3rd HAWC CATALOG OF VHE γ-RAY SOURCES

- Significance map (point-source hypothesis)

All-sky view; 0.0 ° ; 1523 days



The 3HWC Catalog, HAWC Collaboration: *ApJ* **905** (2020) 76

THE 3rd HAWC CATALOG OF VHE γ-RAY SOURCES

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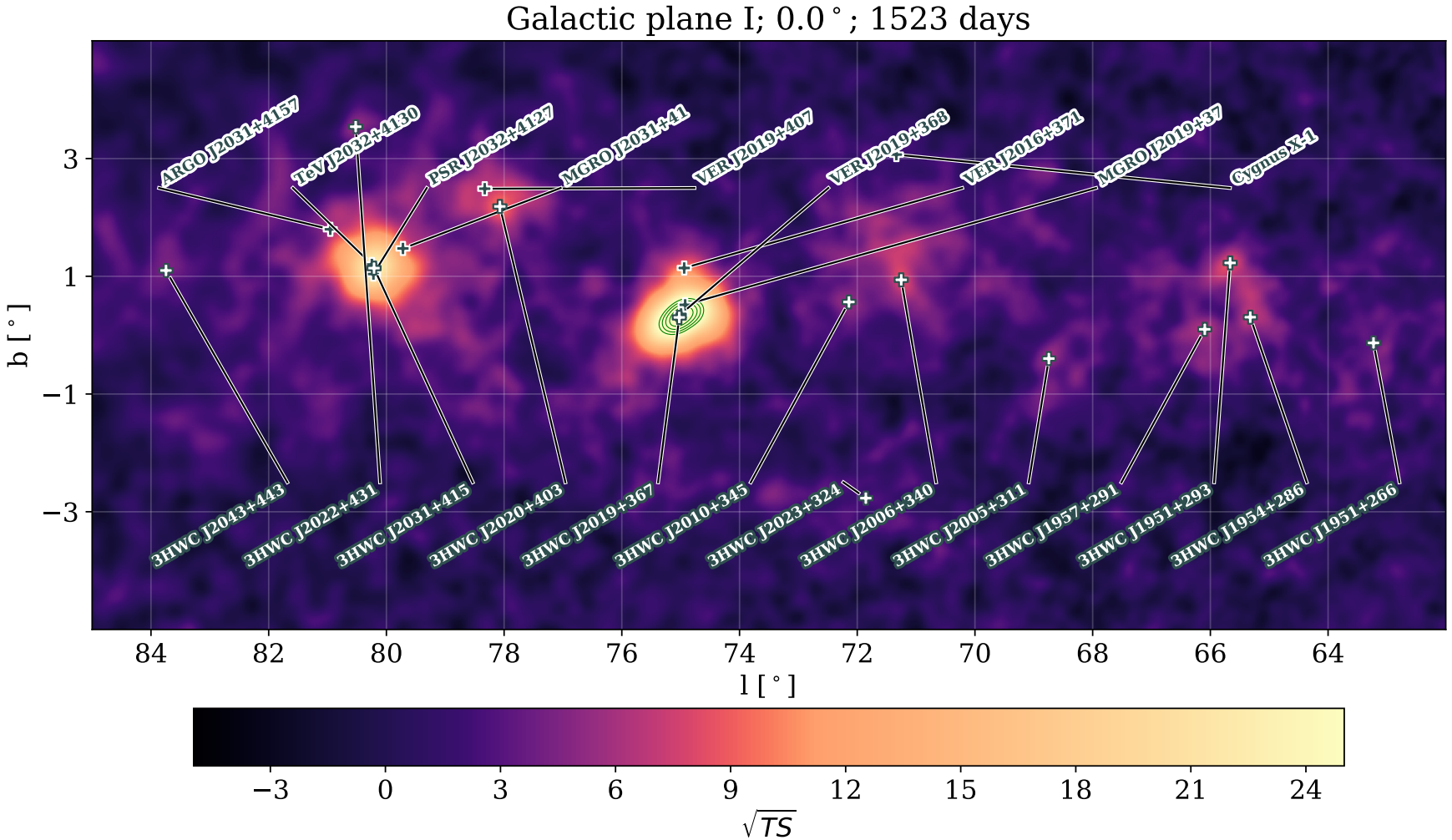
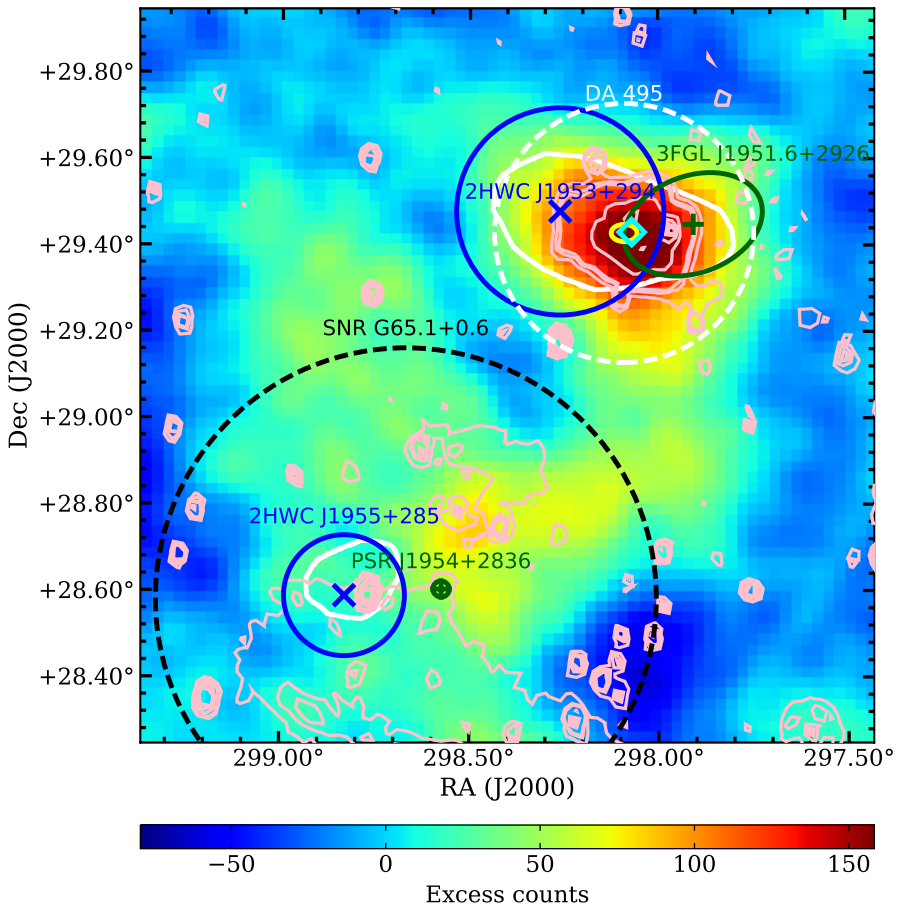


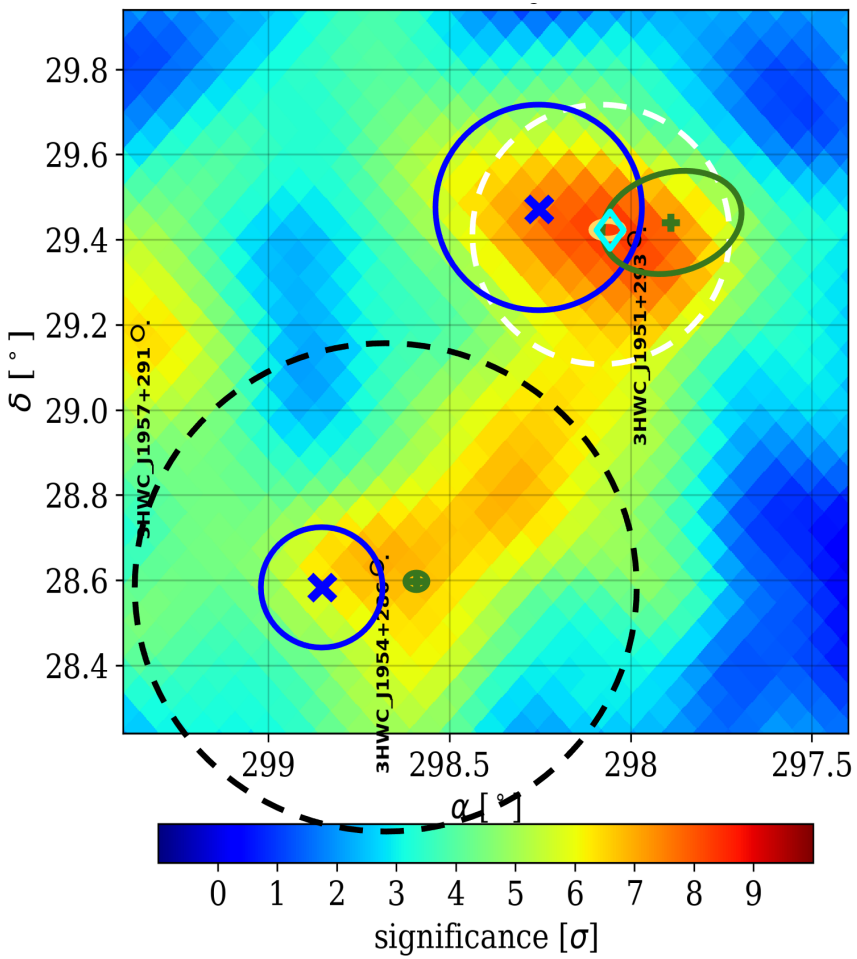
The 3HWC Catalog, HAWC Collaboration: *ApJ* **905** (2020) 76

NEW TEV γ-RAY SOURCES

- PWN DA 495 (2HWC J1953+294)



VERITAS counts map

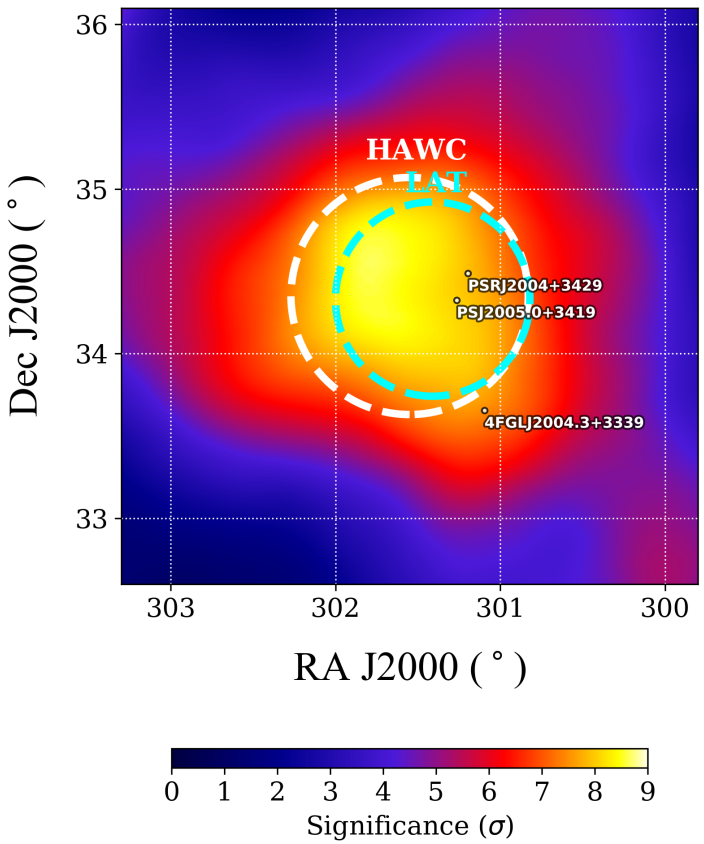


3HWC significance map

VERITAS+Fermi-LAT+HAWC: *ApJ* **866** (2018) 24

NEW TEV γ-RAY SOURCES

- 2HWC J2006+341



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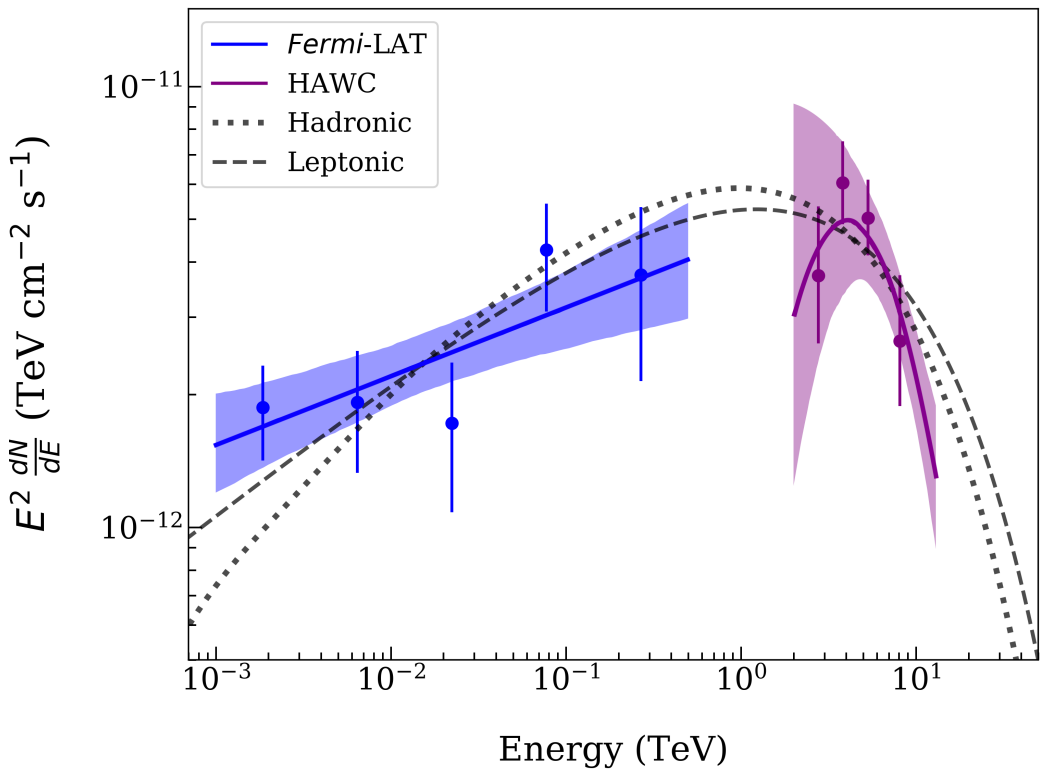
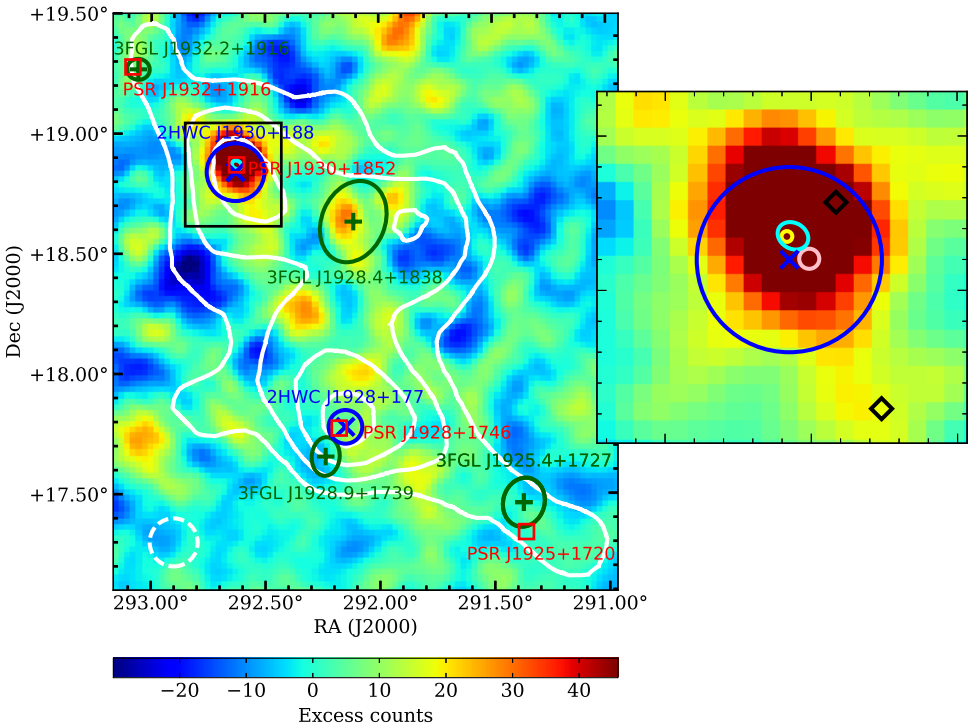


SED from HAWC and LAT data

HAWC+Fermi-LAT detection of J2006: *ApJL* **903** (2020) L14

NEW TEV γ-RAY SOURCES

- SNR G54.1+0.3 (2HWC J1930+188)



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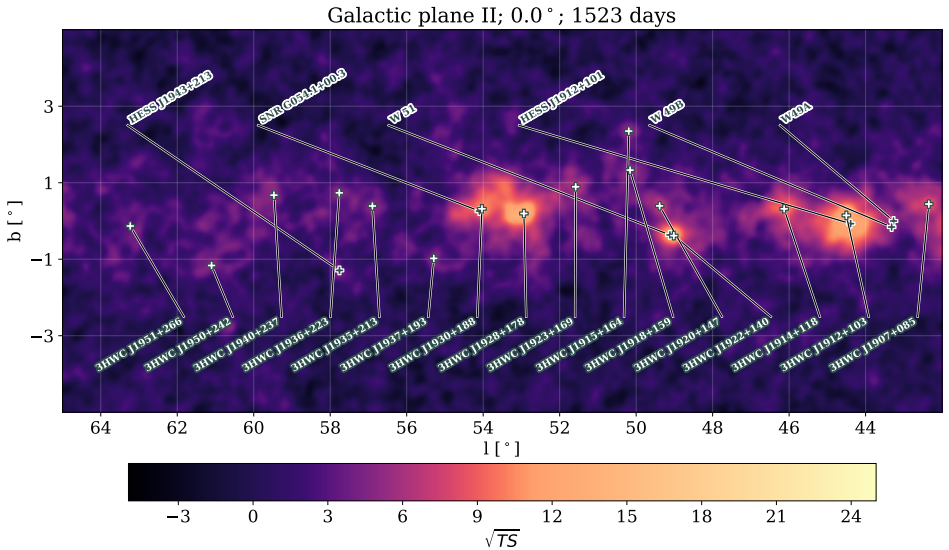
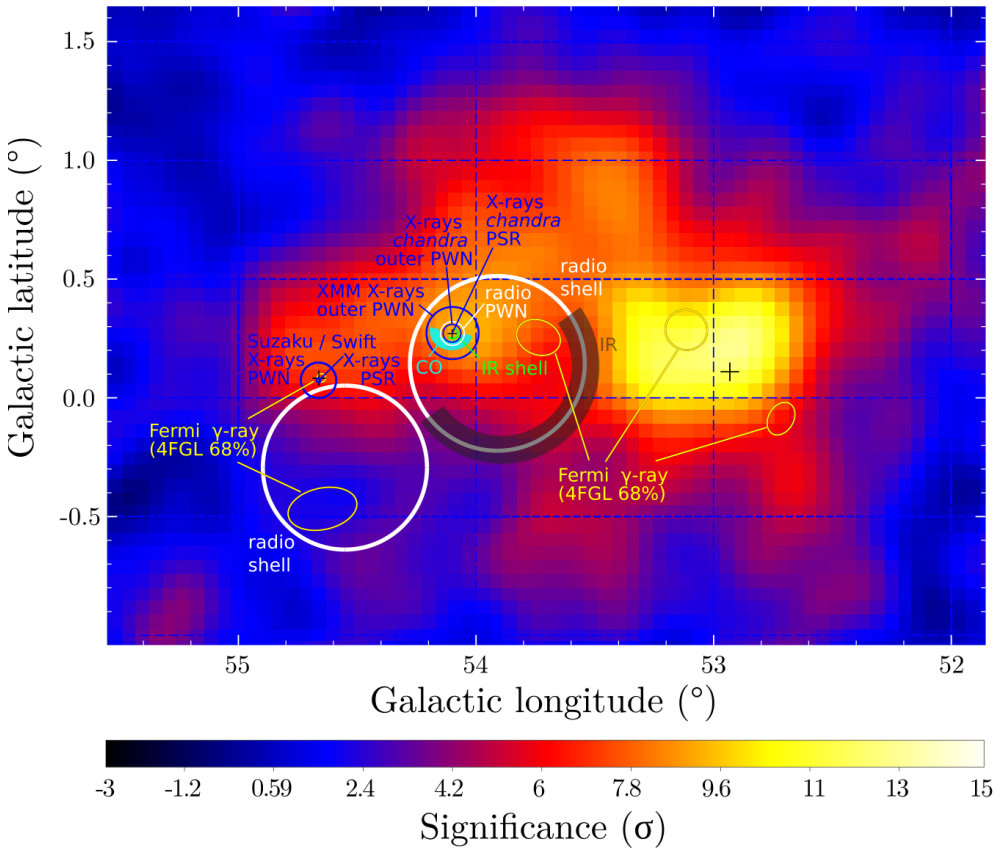


3HWC significance map

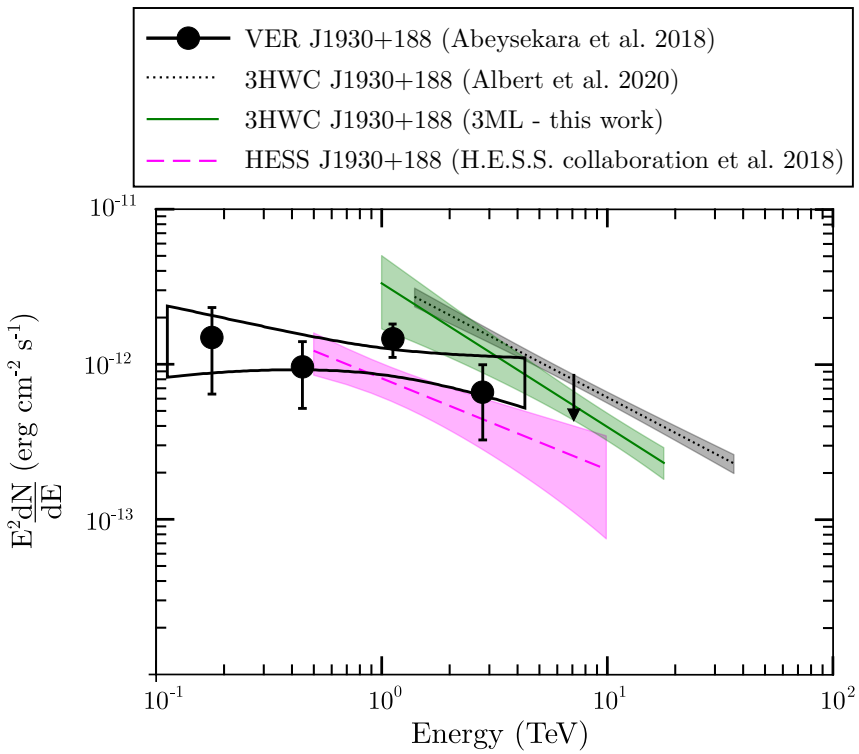
VERITAS+Fermi-LAT+HAWC: *ApJ* **866** (2018) 24

NEW TEV γ-RAY SOURCES

- 3HWC J1928+178 and HAWC J1932+192



3HWC significance map

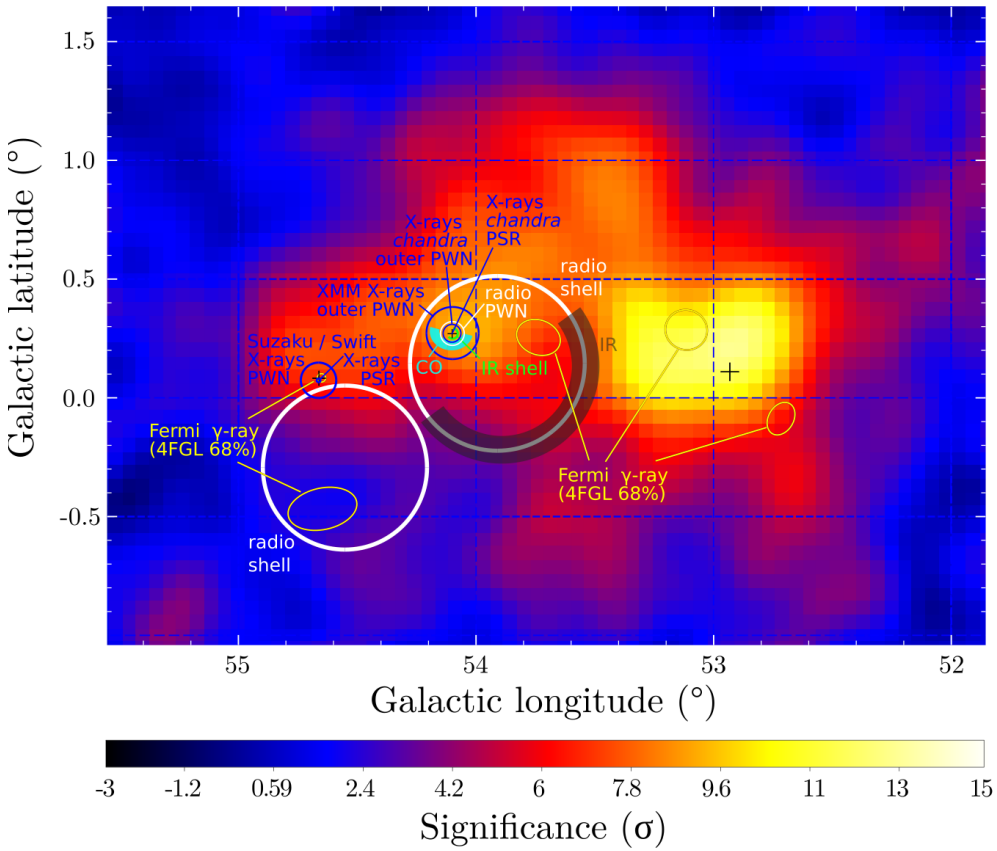


SED of 3HWC J1930+188

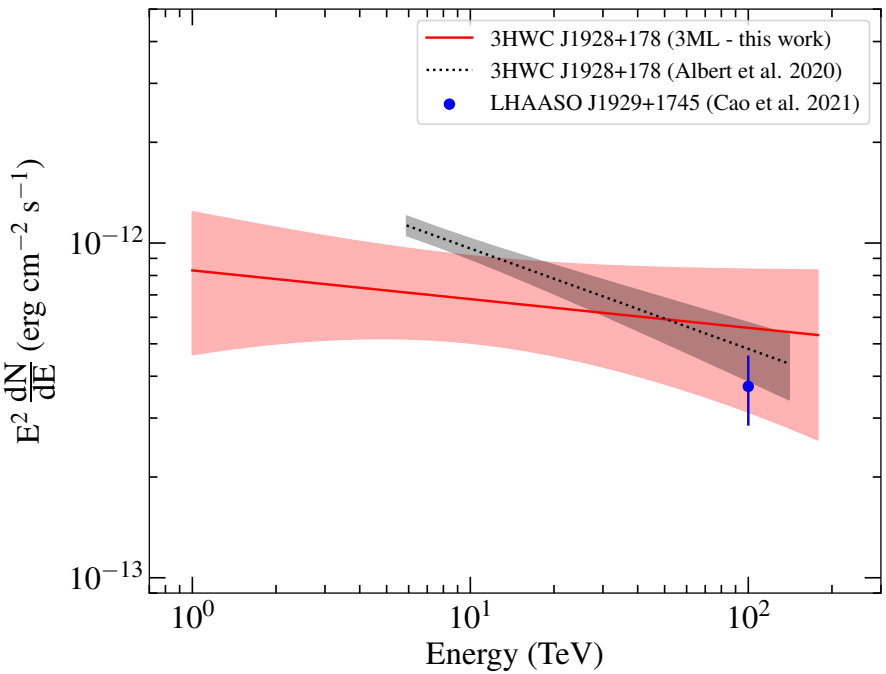
HAWC Collaboration: *ApJ* **942** (2023) 96

NEW TEV γ-RAY SOURCES

- 3HWC J1928+178 and HAWC J1932+192



3HWC significance map

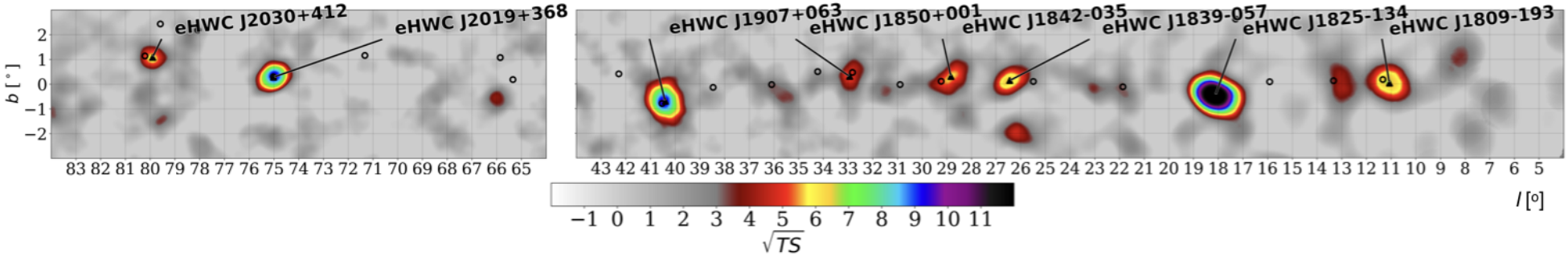


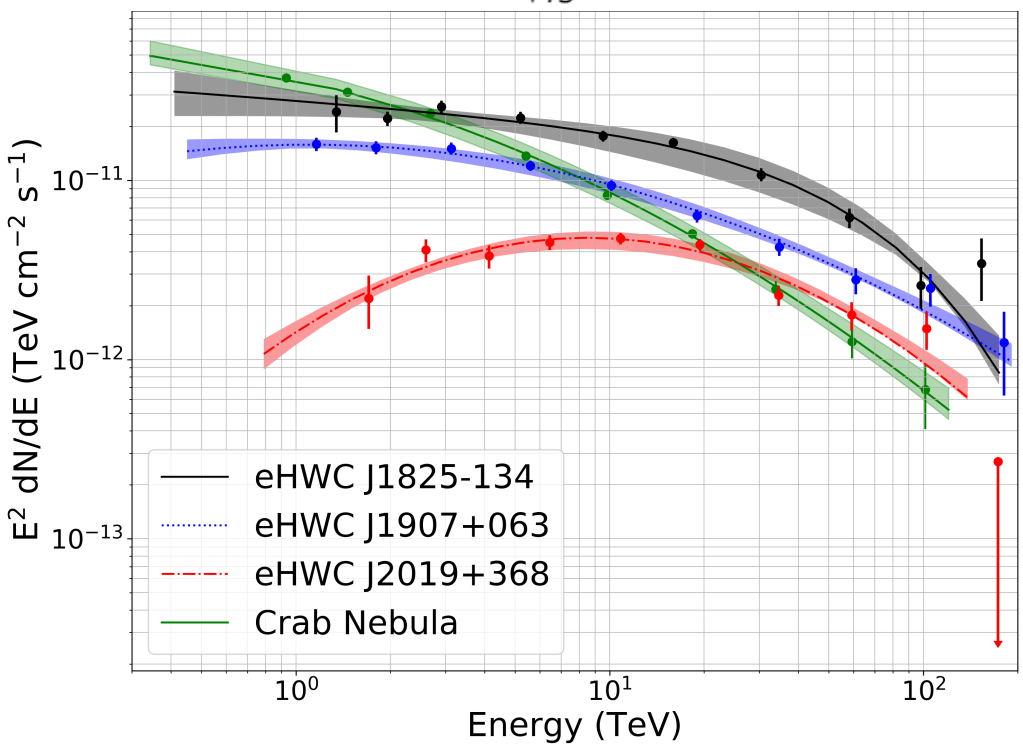
SED of 3HWC J1928+178

HAWC Collaboration: *ApJ* **942** (2023) 96

CATALOG OF γ-RAY SOURCES ABOVE 56 TEV

- Significance map ($E > 56$ TeV, 0.5° hypothesis)

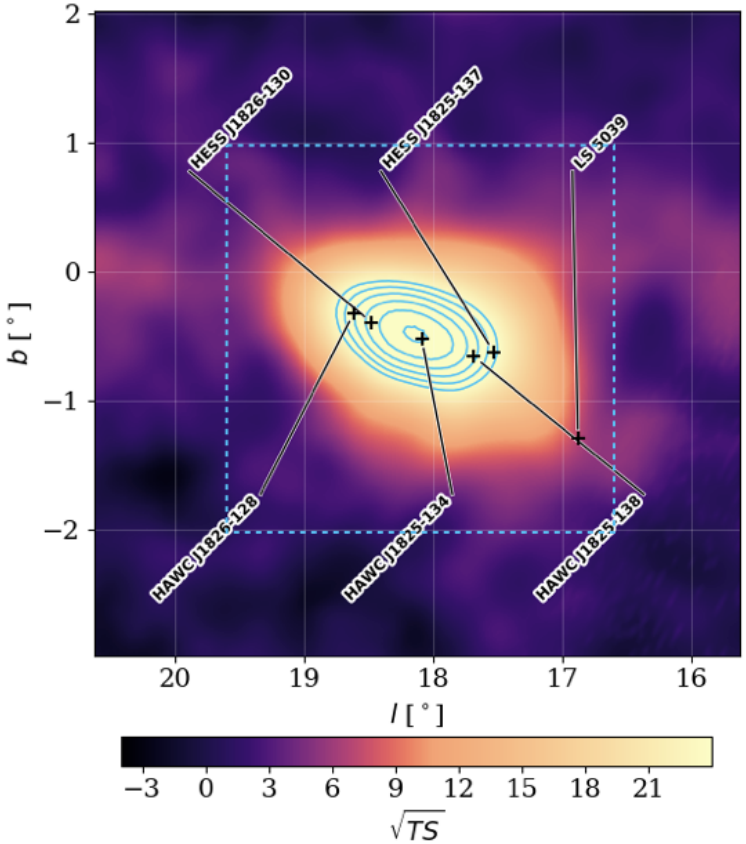




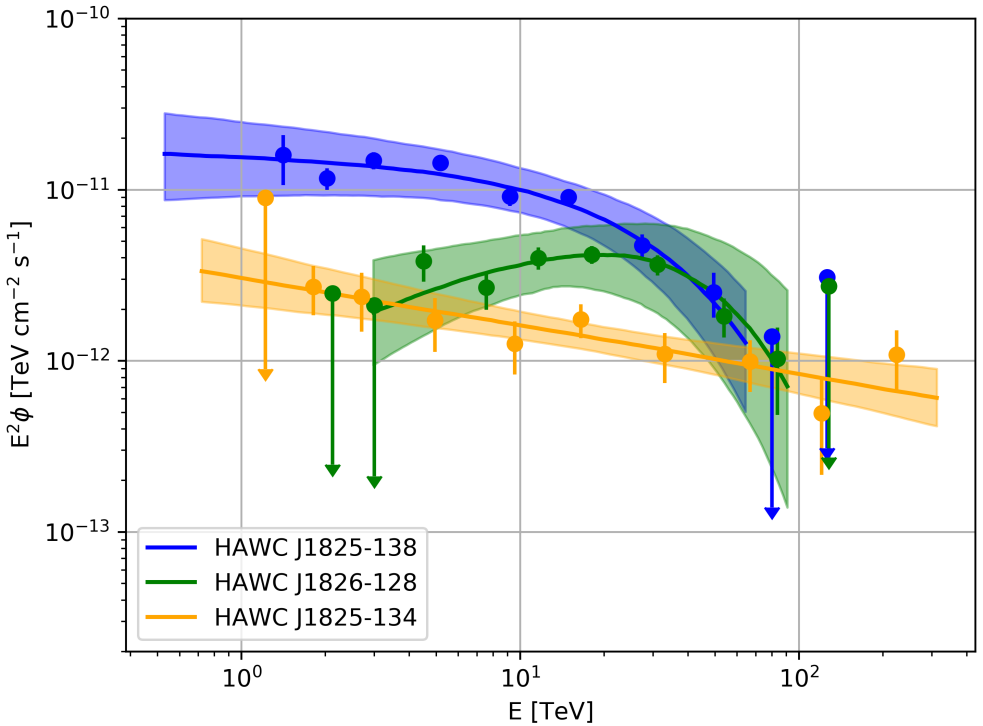
HE Catalog, HAWC Collaboration: *PRL* **124** (2020) 021102

EVIDENCE OF 200 TEV γ RAYS

- eHWC J1825-134



Significance map

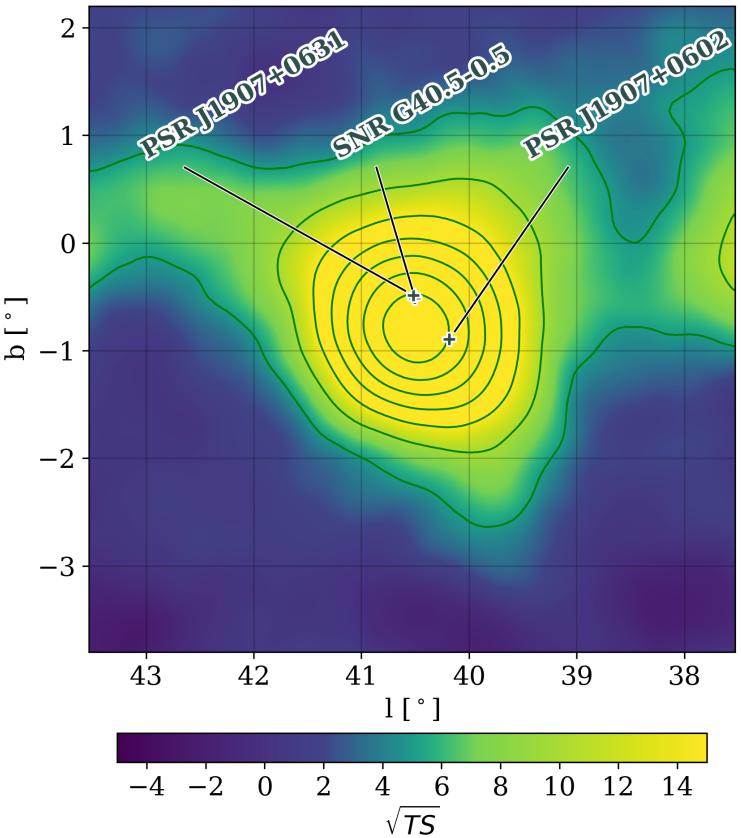


SED from HAWC data

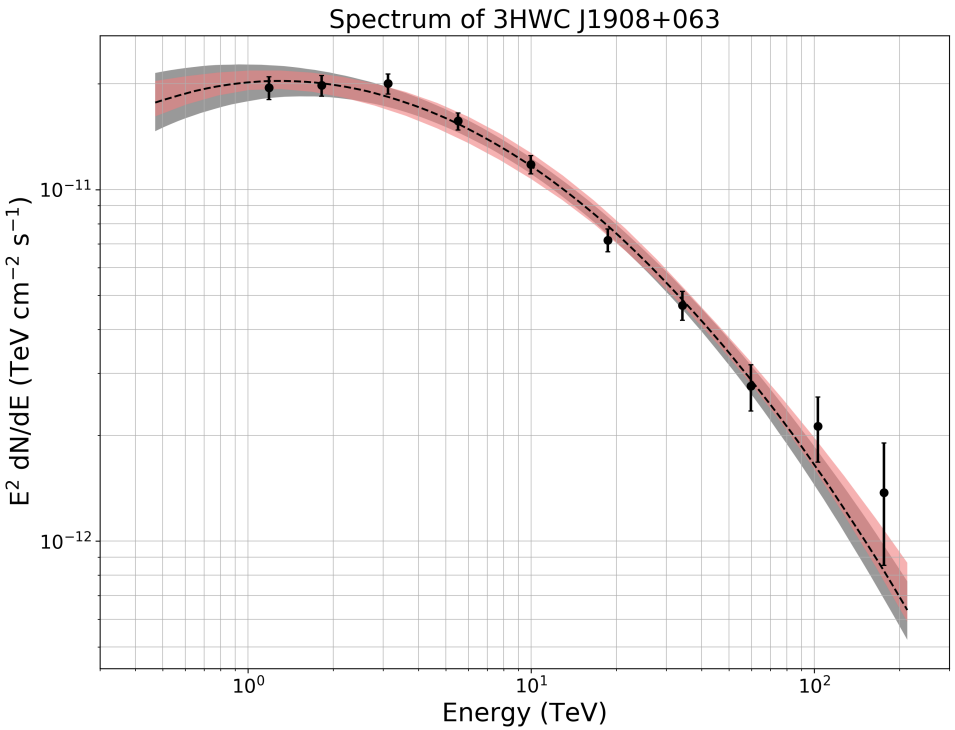
HAWC J1825-134, HAWC Collaboration: *ApJL* **907** (2021) L30

HE γ-RAY SPECTRA

- MGRO J1908+06



Significance map

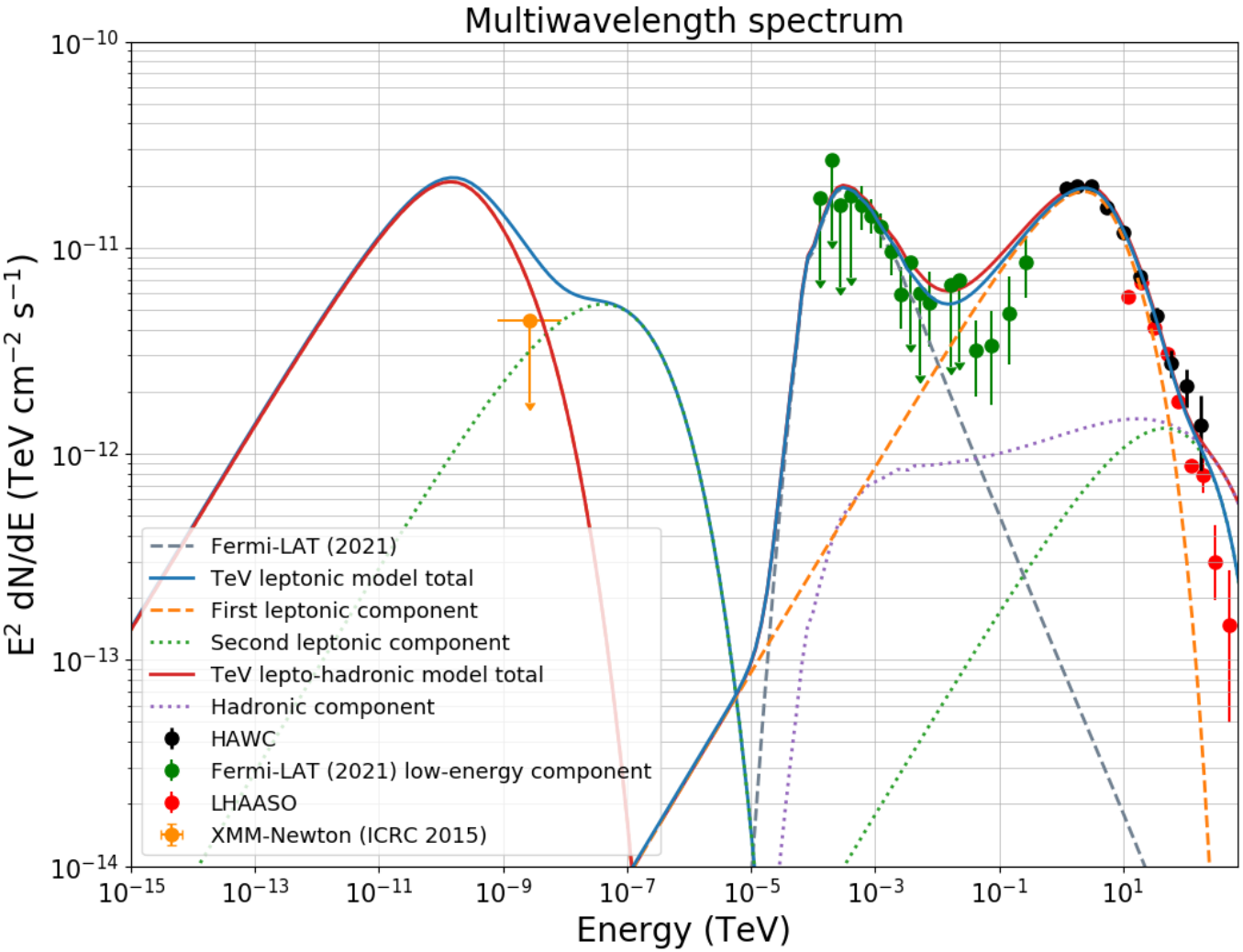


SED from HAWC data

MGRO J1908+06, HAWC Collaboration: *ApJ* **928** (2022) 116

HE γ-RAY SPECTRA

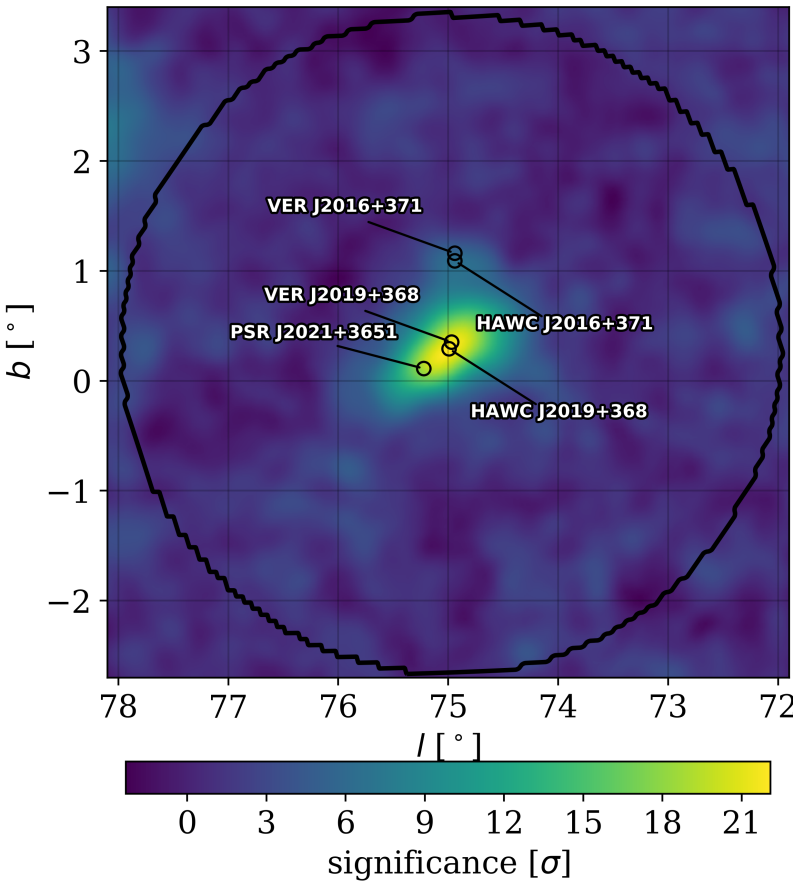
- MGRO J1908+06



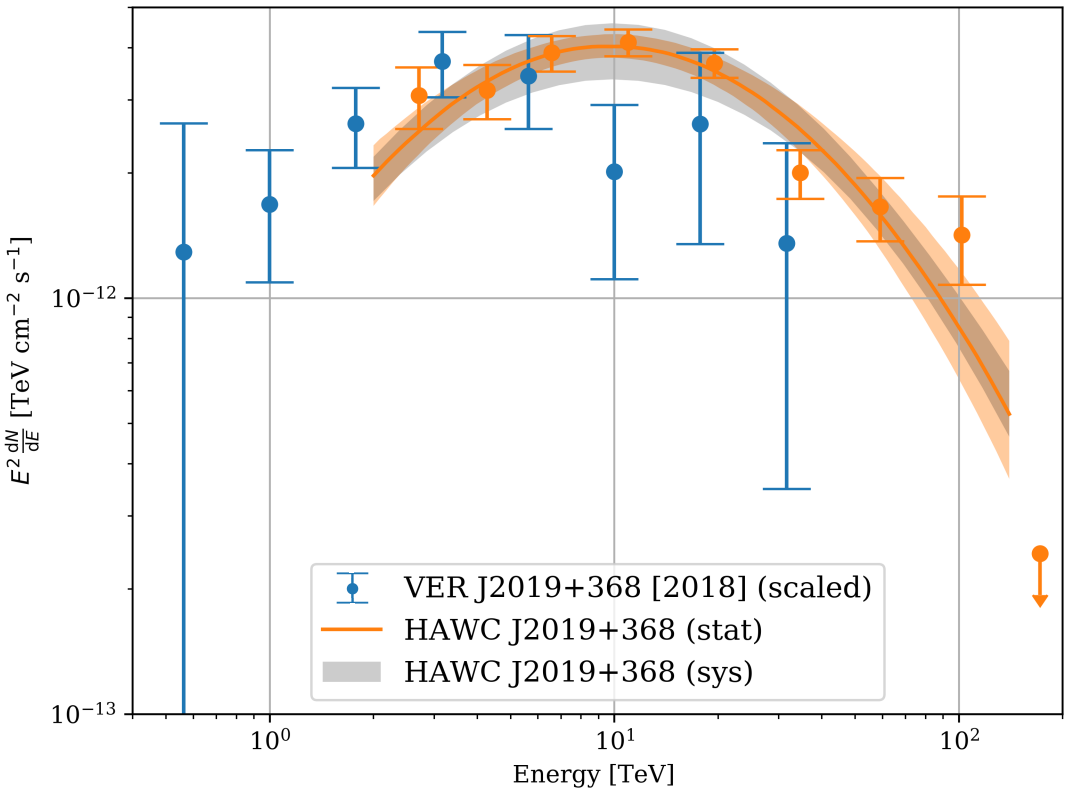
MGRO J1908+06, HAWC Collaboration: *ApJ* **928** (2022) 116

HE γ-RAY SPECTRA & MORPHOLOGY

- HWC J2019+368



Significance map

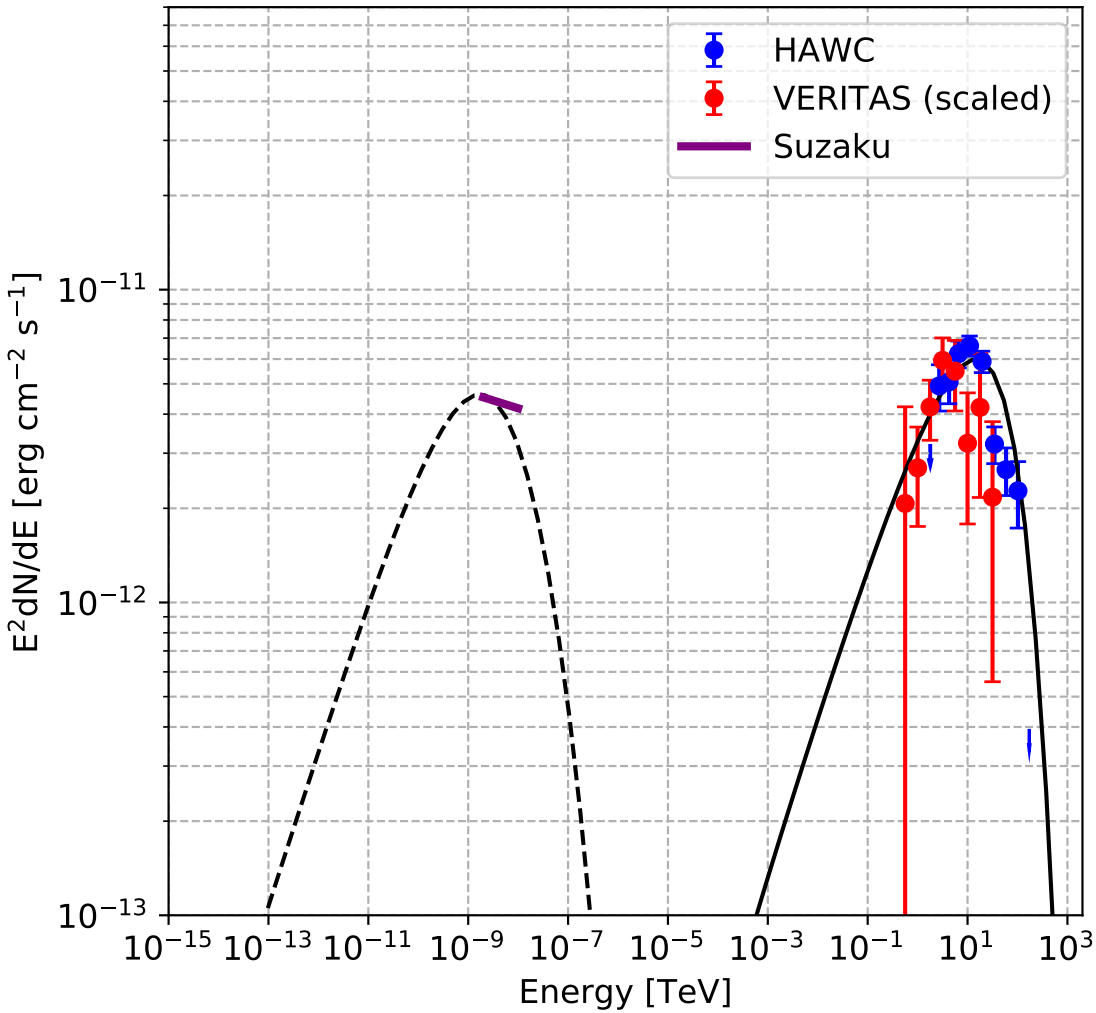


SED from HAWC data

HWC J2019+368, HAWC Collaboration: *ApJ* **911** (2021) 143

HE γ-RAY SPECTRA & MORPHOLOGY

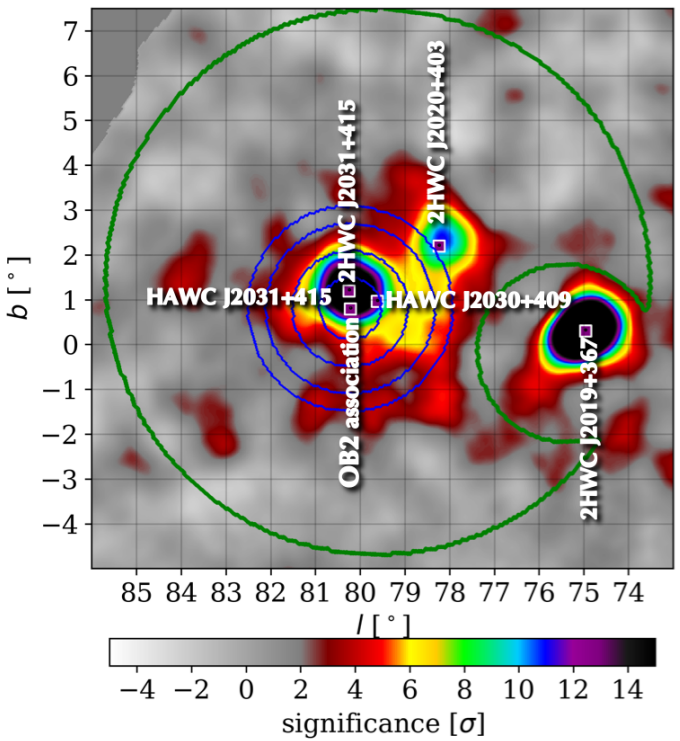
- HWC J2019+368



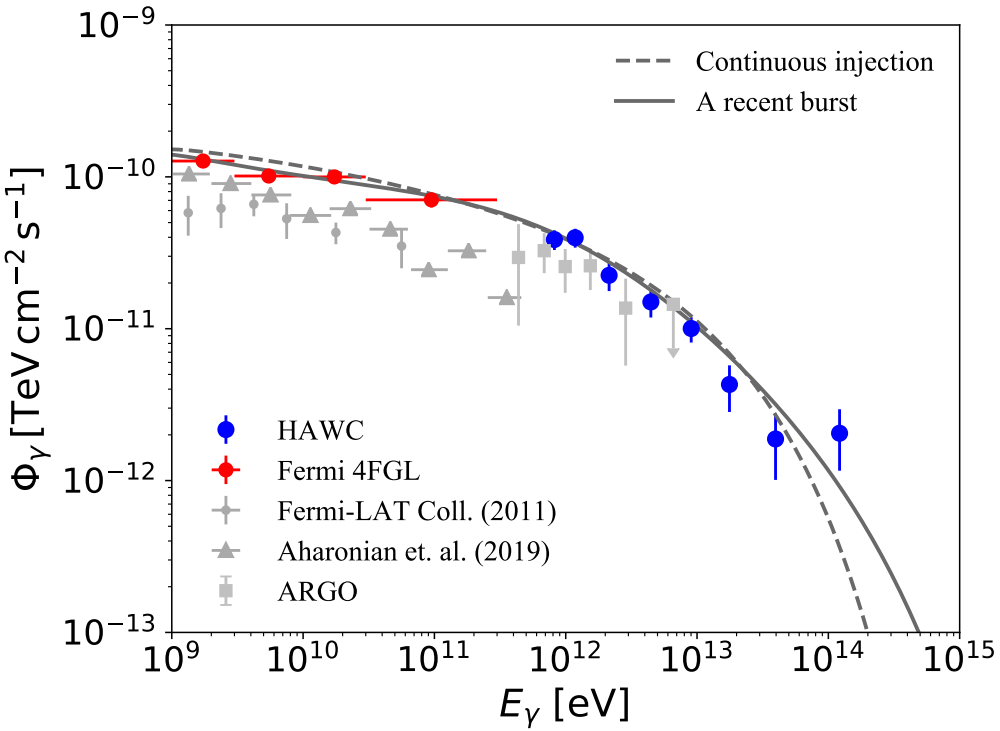
HWC J2019+368, HAWC Collaboration: *ApJ* **911** (2021) 143

VHE COSMIC-RAY ACCELERATORS

- Cygnus Cocoon



3HWC significance map

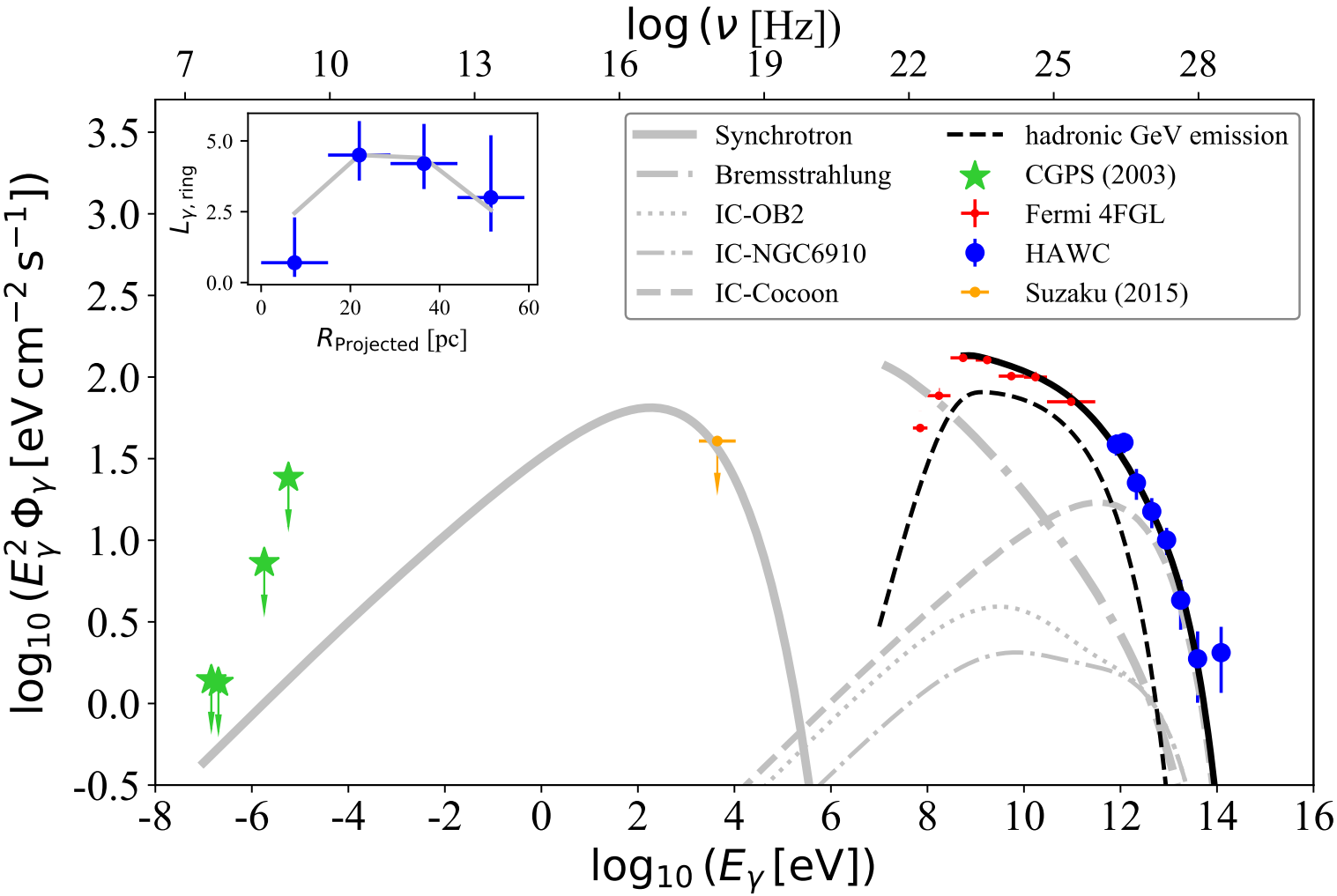


SED from HAWC and LAT data

Cygnus Cocoon, HAWC Collaboration: *Nat. Astro.* **5** (2021) 465

VHE COSMIC-RAY ACCELERATORS

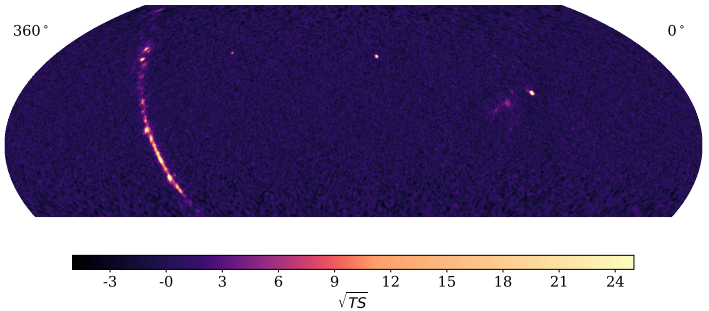
- Cygnus Cocoon

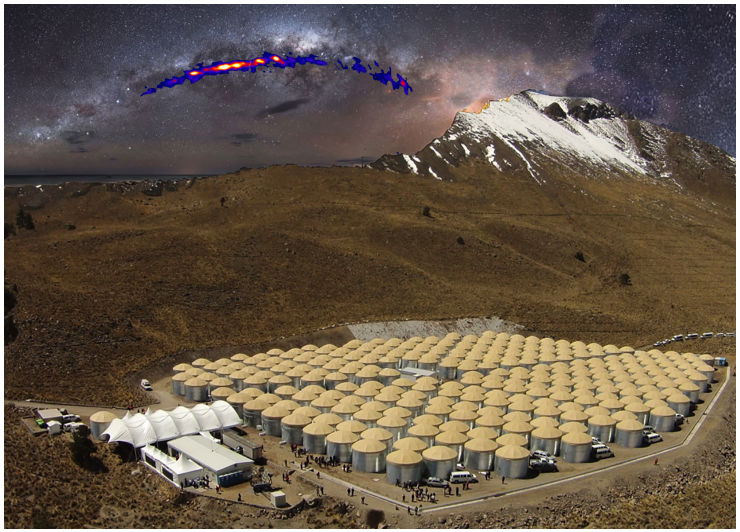


Cygnus Cocoon, HAWC Collaboration: *Nat. Astro.* **5** (2021) 465

CONCLUSION & OUTLOOK

- CR anisotropy
  HAWC catalog public!
  New TeV sources
  Pevatron candidates

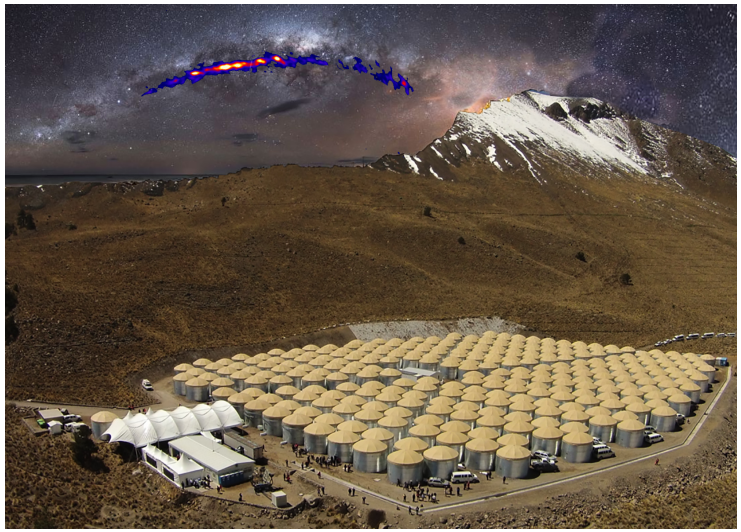


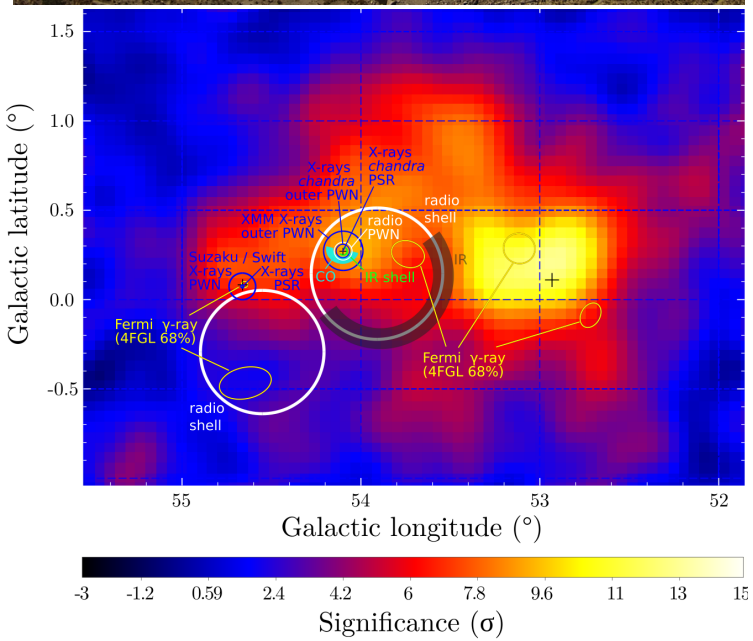


CONCLUSION & OUTLOOK

- CR anisotropy
  HAWC catalog public!
  New TeV sources
  Pevatron candidates

- Other science contributions
  Dark matter, CRs, solar physics, particle physics, multi-messenger studies, diffuse emission, extended regions, EBL, realtime alerts...



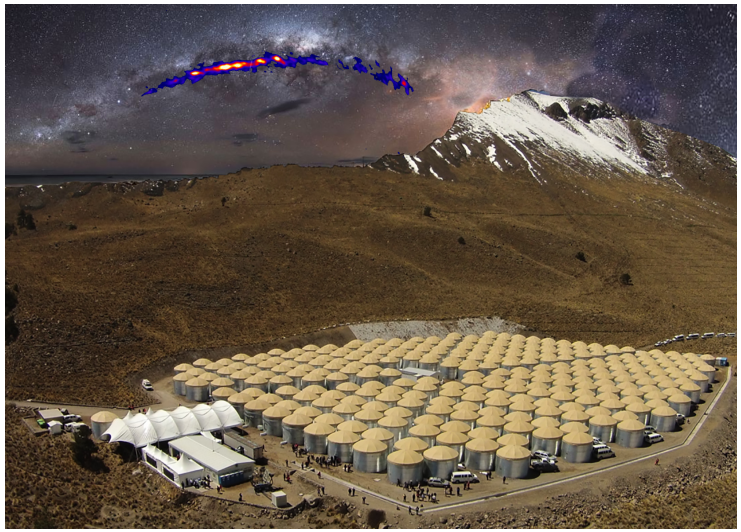


CONCLUSION & OUTLOOK

- CR anisotropy
  HAWC catalog public!
  New TeV sources
  Pevatron candidates

- Other science contributions
  Dark matter, CRs, solar physics, particle physics, multi-messenger studies, diffuse emission, extended regions, EBL, realtime alerts...

- Outrigger array completed
  Enhanced sensitivity above 10 TeV



THANK YOU VERY MUCH!

Image courtesy of Philip Suárez Mauro

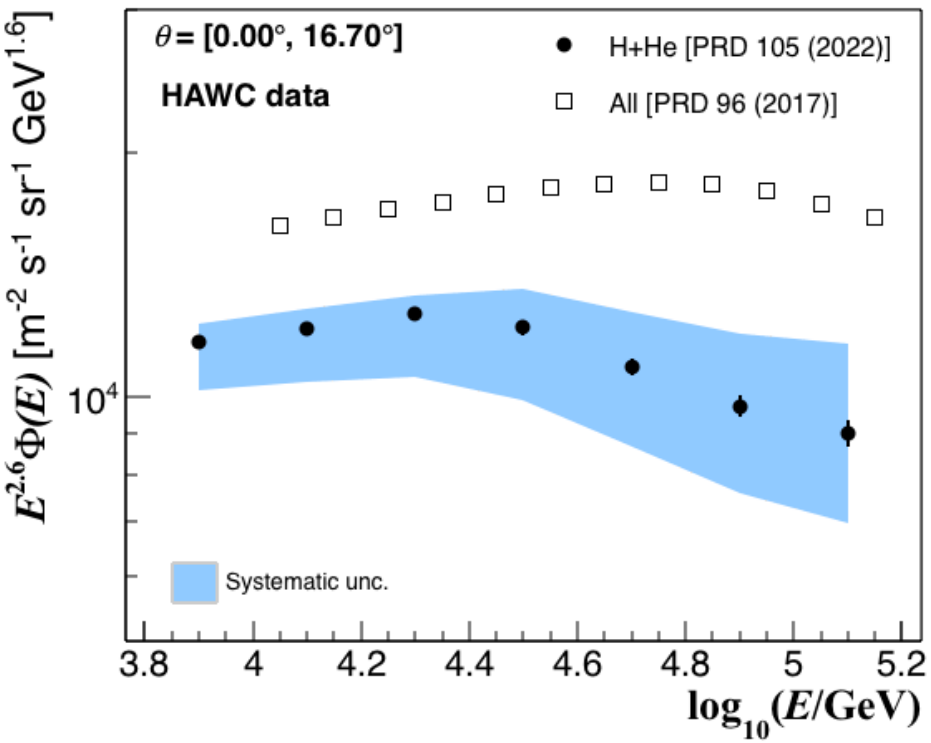
BACK-UP SLIDES

Most recent HAWC papers

- "The High-Altitude Water Cherenkov Observatory in México: The Primary Detector," NIM **A1052** (2023) 168253.
- "Searching for TeV Dark Matter in Irregular Dwarf Galaxies with HAWC Observatory," ApJ **945** (2023) 25.
- "Search for Gamma-Ray and Neutrino Coincidences Using HAWC and ANTARES Data," ApJ **944** (2023) 166.
- "Validation of standardized data formats and tools for ground-level particle-based gamma-ray observatories," A&A **667** (2022) A36.
- "Detailed Analysis of the TeV Gamma-Ray Sources 3HWC J1928+178, 3HWC J1930+188, and the New Source HAWC J1932+192," ApJ **942** (2023) 96.
- "Gamma-Ray Emission from Classical Nova V392 Per: Measurements from Fermi and HAWC," ApJ **940** (2022) 141.

Cosmic ray spectrum

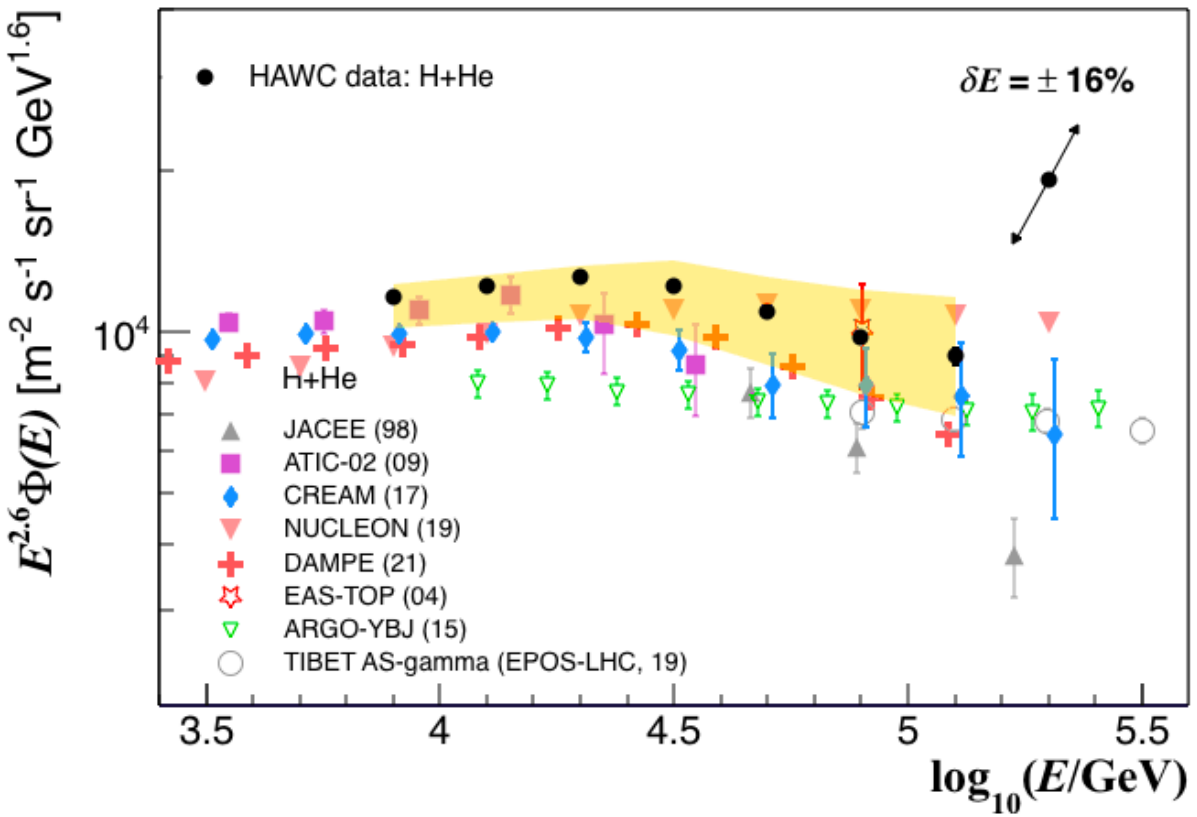
- H + He nuclei between 6 and 158 TeV



HAWC Collaboration: Phys. Rev. **D 105** (2022) 063021

COSMIC RAY SPECTRUM

- H + He nuclei compared to other data



HAWC Collaboration: Phys. Rev. **D 105** (2022) 063021

COSMIC RAY SPECTRUM

- all particle spectrum between 10 TeV and 1 PeV