A GeV to TeV view of shell-type SNRs

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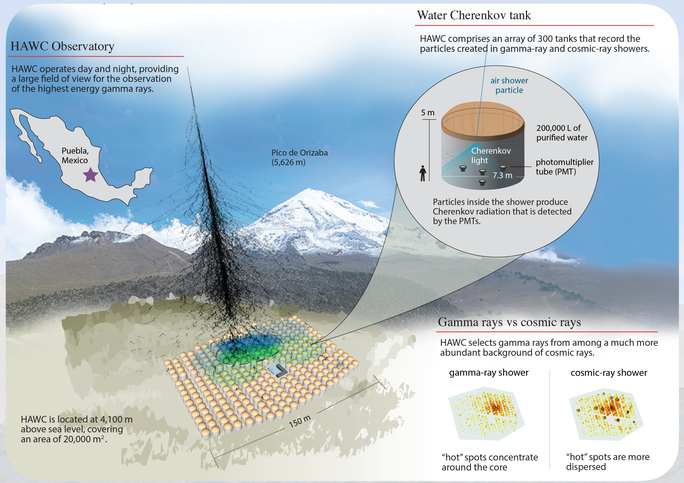
Abstract

Shock acceleration by the shells of supernova remnants (SNRs) has been hypothesized to be the mechanism that produces the bulk of Galactic Cosmic Rays, possibly up to PeV energies. Some SNRs have been shown to accelerate cosmic rays to TeV energies and above. But which SNRs are indeed efficient accelerators of protons and nuclei? And what is the maximum energy up to which they can efficiently accelerate particles? Measurements of non-thermal emission, especially in the gamma-ray regime, are essential to answer these questions.
The High-Altitude Water Cherenkov (HAWC) observatory, surveying the northern TeV gamma-ray sky, is currently the most sensitive wide field-of-view survey instrument in the VHE (very-high-energy, >100 GeV) range and has recorded more than five years of data. The Large Area Telescope (LAT) onboard the Fermi satellite has been surveying the GeV gamma-ray sky for more than ten years. Combining measurements from both instruments allows the study of gamma-ray emission from SNRs over many orders of magnitude in energy. In this presentation, I will show measurements of VHE gamma-ray emission from Fermi-LAT-detected SNRs with the HAWC Observatory.

HAWC Detector Facts

- HAWC stands for "High-Altitude Water Cherenkov" observatory.
- Location: Sierra Negra, Mexico.
- Elevation: 4100 m a.s.l.
- Duty cycle > 95%.
- Instantaneous field of view: 2 sr.
- 300 water tanks in main array plus 345 outriggers.
- One of the tanks is filled with tequila.
- Energy range: 300 GeV to 100 TeV.
- Angular resolution: >= 0.1˚.
- Declination range: -26˚ to +64˚.
- More than 5 years of data collected.
- Learn more at **https://www.hawc-observatory.org/**

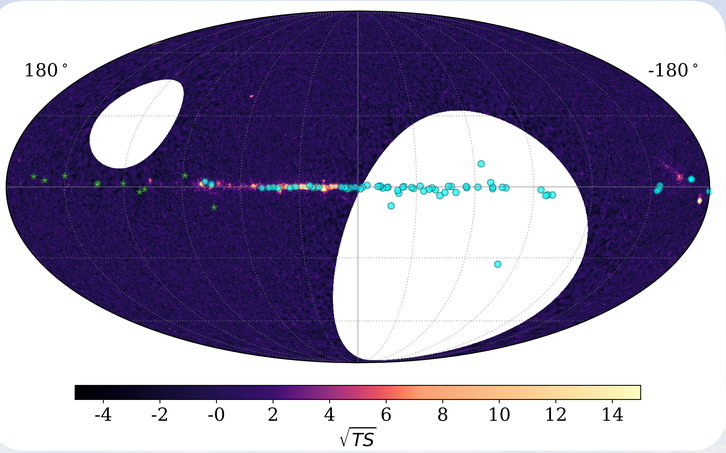


Analysis idea

1. Select sources from various GeV gamma-ray catalogs (4FGL-DR2[1,2], 3FHL[3], FGES[4], 1SNR[5]) that:
   - Are inside HAWC's field of view
   - Are not detected by HAWC
   - Are well separated from gamma-ray sources detected by HAWC
   - Are identified as or associated with shell-type supernova remnants (SNRs)
2. Source model:
   - Morphology as in GeV gamma-ray catalog (point source or extended)
   - Spectral shape as in GeV, extrapolated to TeV energies, free normalization.
3. Fit flux normalization to HAWC data[6,7], obtain detection significance and upper limit on TeV gamma-ray flux.
4. For sources with upper limit on TeV gamma-ray flux below extrapolation from GeV:
   - Model spectrum as extrapolated from GeV catalog (fixed normalization and shape) with an additional exponential cutoff.
   - Fit cutoff energy to HAWC data, obtain upper limit on cutoff energy.

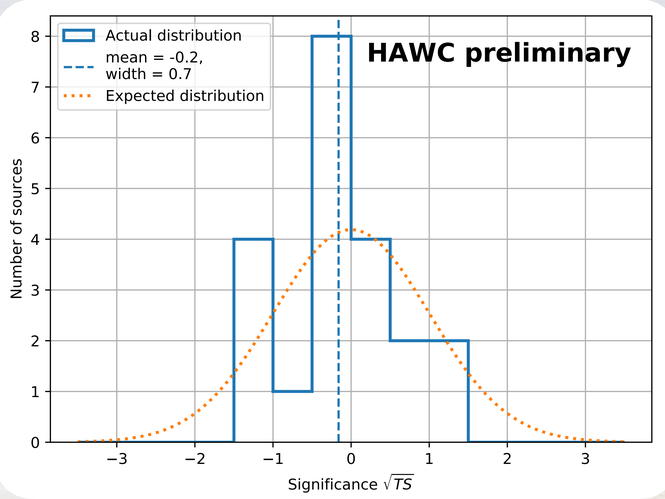
Selected Sources

The figure on the right shows HAWC's all-sky significance map for the point source search, based on 1523 days of observation, in Galactic coordinates[8]. White areas of the sky are not observed by HAWC. Teal circles and green stars mark the position of shell-type SNRs and SNR candidates from the LAT catalogs. The ten green stars correspond to sources passing the selection criteria for this study.



Results and Future Work

The figure on the right shows the distribution of detection significances for the ten selected SNRs. Six of them were found in multiple catalogs and hence have more than one entry in the histogram. Negative significance values are assigned to sources with a negative best-fit flux.
Within uncertainties, the distribution matches the expectation for the null hypothesis (background-only case), indicating that there is no evidence for sub-threshold gamma-ray emission in this sample of SNRs.
Full results including upper limits on the TeV gamma-ray flux and cutoff energy will be presented in a separate publication (under preparation).



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