The highest-energy gamma rays and multi-messenger astrophysics

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for the HAWC Collaboration

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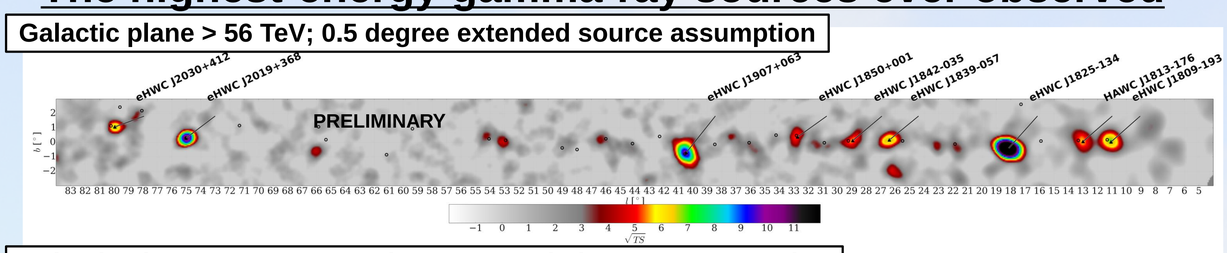
Abstract

The High Altitude Water Cherenkov (HAWC) Observatory, located in Puebla, Mexico, has observed many sources emitting gamma rays above 100 TeV. These objects appear to come from a wide variety of source classes: pulsar wind nebulae such as the Crab Nebula; unidentified objects such as MGRO J1908+06; and at least one superbubble containing freshly accelerated cosmic rays likely originating from a star-forming region (the TeV counterpart to the Cygnus Cocoon). In this poster we will show multi-messenger and multi-wavelength observations for selected high-energy gamma-ray sources. The detection of neutrinos from any of them would be a smoking gun that they are PeVatrons and contribute to the knee of the cosmic-ray spectrum.

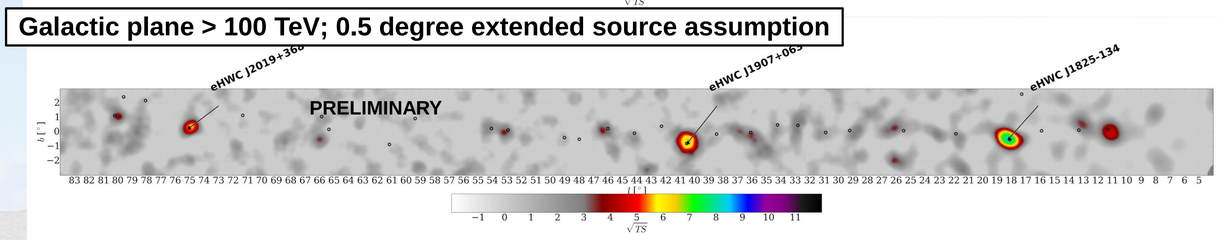
HAWC observes many > 100 TeV sources from many different source classes. Multi-messenger and multi-wavelength spectra of these sources could identify some of them as PeVatrons

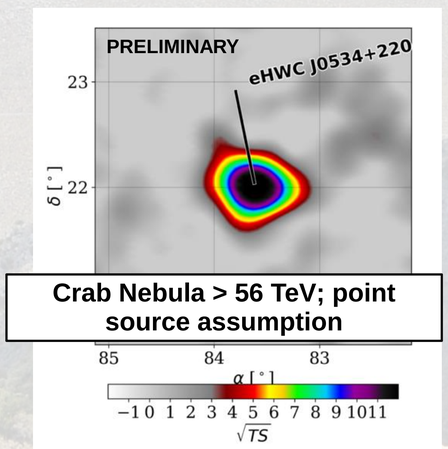
The highest-energy gamma-ray sources ever observed

Galactic plane > 56 TeV; 0.5 degree extended source assumption

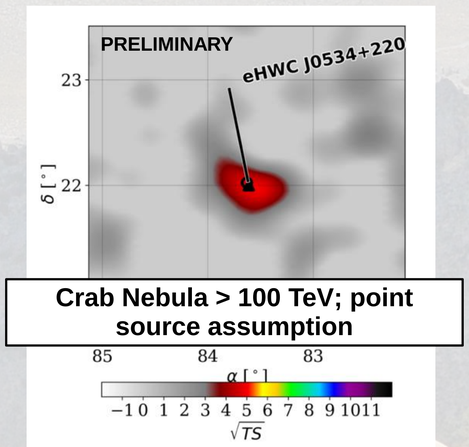


Galactic plane > 100 TeV; 0.5 degree extended source assumption





Crab Nebula > 56 TeV; point source assumption

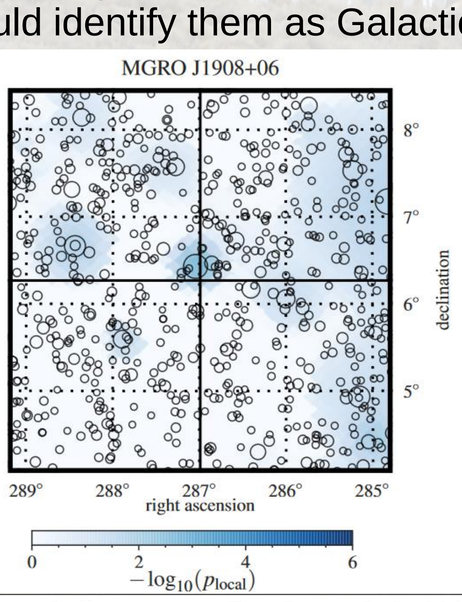


Crab Nebula > 100 TeV; point source assumption

HAWC's highest-energy gamma-ray observations. Sources that are significant (> 5σ) above the energy threshold are labeled. Maps contain 1343 days of data. All sources in the Galactic plane are spatially extended above 56 TeV.

Multi-messenger implications

The detection of neutrinos from any of these sources would indicate a hadronic component. Since the gamma-ray emission extends past 100 TeV for all these sources, coincident neutrinos could identify them as Galactic PeVatrons.

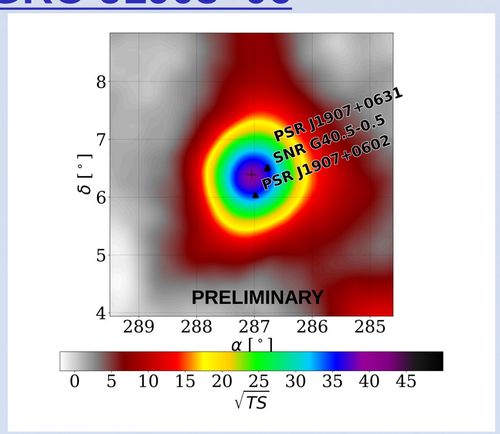


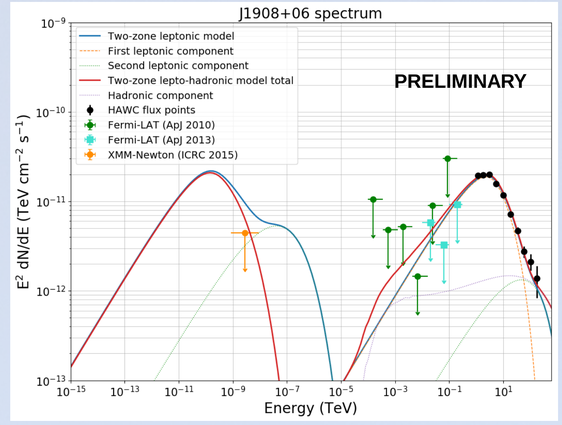
IceCube Collaboration, Eur. Phys. J. C (2019)

Many of these sources have long been neutrino targets. For example, at left is the p-value map for IceCube around MGRO J1908+06. In IceCube's search for point-like sources in the astrophysical muon neutrino flux, this source has the highest p-value for any Galactic source (although still consistent with background).

Multi-wavelength spectra of high-energy energy sources

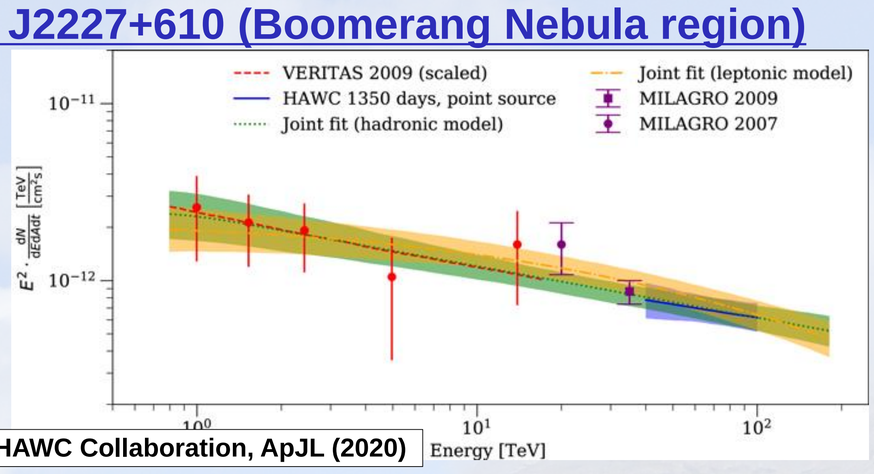
MGRO J1908+06





MGRO J1908+06 is one of the highest-energy gamma-ray sources (emitting above 100 TeV) and has long been a neutrino target. The region around it contains two pulsars and a supernova remnant. Recent HAWC observations show that it is best-fit by a two-component model. The first component provides the bulk of the emission and is predominantly leptonic, while the second component may be either leptonic or hadronic in nature.

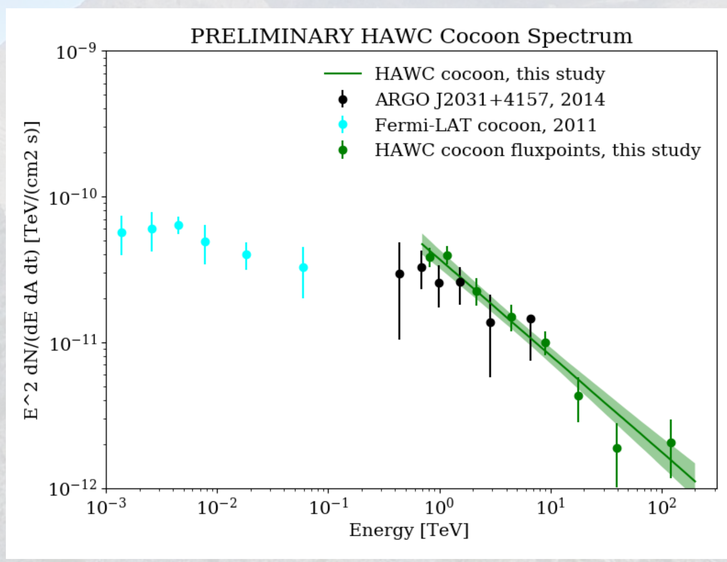
HAWC J2227+610 (Boomerang Nebula region)



HAWC Collaboration, ApJL (2020)

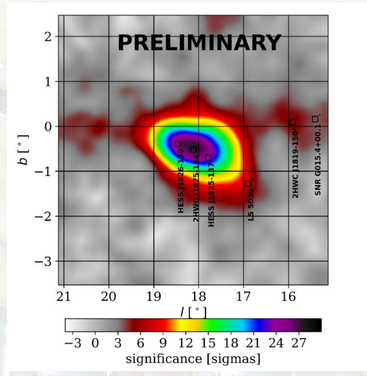
A joint fit to HAWC and VERITAS data indicates that the emission from this region is likely hadronic, with a lower limit to the cutoff energy of 800 TeV, which could indicate a Galactic PeVatron. The most likely source of the protons is the SNR G106.3+2.7. Leptonic emission cannot currently be excluded, though.

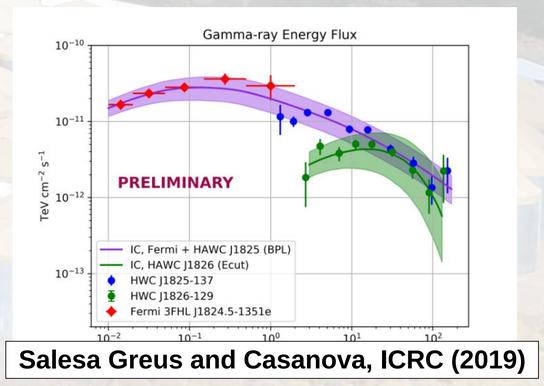
Cygnus Cocoon



Preliminary results for the TeV counterpart to the Cygnus Cocoon show a power-law spectrum extending past 100 TeV. The Cygnus Cocoon is a superbubble of freshly accelerated cosmic rays observed at GeV energies by Fermi-LAT. It is associated with a massive star-forming region. If the > 100 TeV emission is shown to be hadronic, this Cocoon could accelerate particles to the knee of the cosmic-ray spectrum

J1825 region





Salesa Greus and Casanova, ICRC (2019)

The 2HWC J1825-134 region is the brightest spot in the sky above 56 TeV. It can be disentangled into two high-energy sources: HWC J1825-137 and HWC J1826-129. Shown above is the joint fit of HWC J1825-137 and Fermi source 3FHL J1824.5-1351e, performed using Naima. This assumes leptonic emission. Also shown is the Naima fit for HWC J1826-129.

Acknowledgements

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