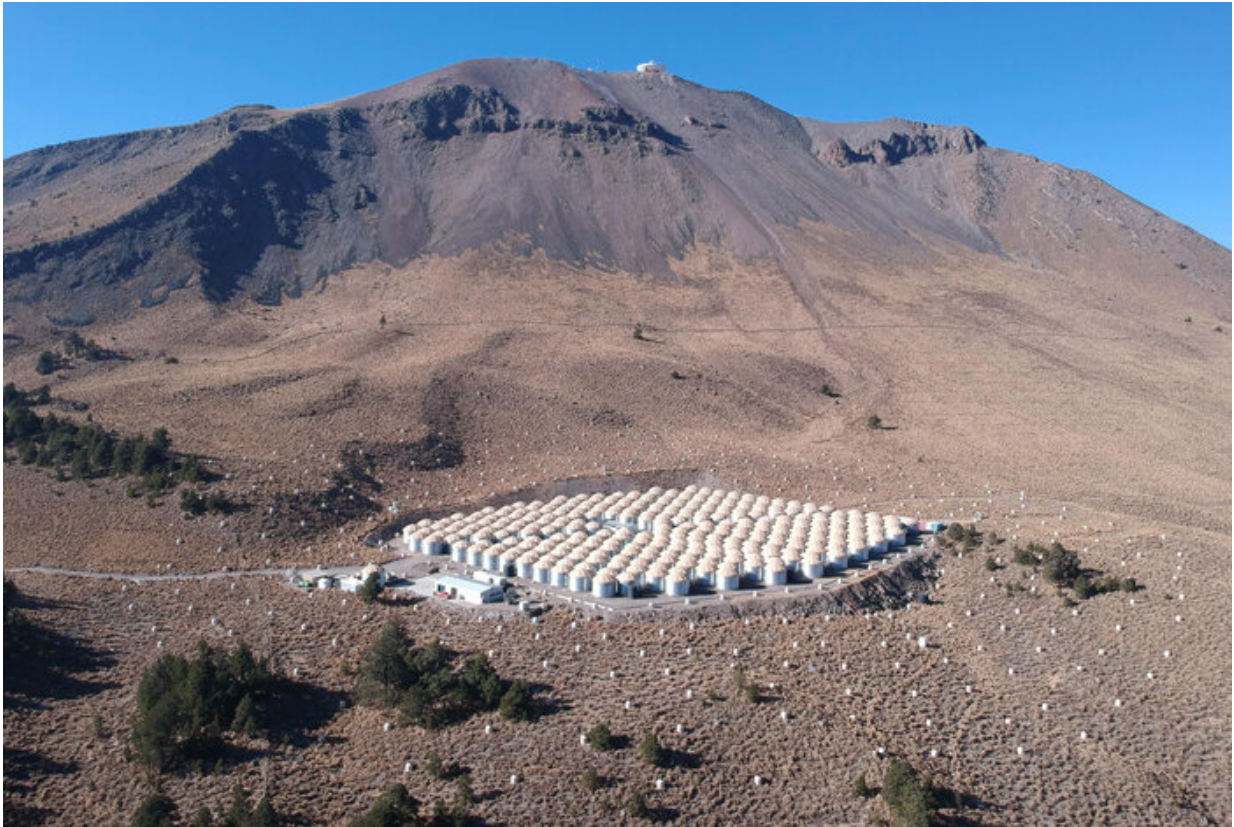


Ultra-high-energy gamma rays originate from pulsar nebulae

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After discovering nine ultra-high-energy gamma-ray sources in 2020, researchers at the High Altitude Water Cherenkov Observatory (HAWC) took advantage of the facility's wide field-of-view and survey capabilities to determine that the regions around powerful pulsars universally emit ultra-high-energy gamma rays. Credit: Instituto Nacional de Astrofísica, Óptica y Electrónica

The discovery that the nebulae surrounding the most powerful pulsars are pumping out ultra-high-energy gamma rays could rewrite the book about the rays' galactic origins. Pulsars are rapidly rotating, highly magnetized collapsed stars surrounded by nebulae powered by winds generated inside the pulsars.

"We took advantage of the wide field-of-view and survey capabilities at the High Altitude Water Cherenkov Observatory (HAWC) to search around a collection of powerful pulsars. We found significant evidence that ultra-high-energy gamma-ray emission is a universal feature found near these objects," said Kelly Malone, an astrophysicist in the Nuclear and Particle Physics and Applications group at Los Alamos National Laboratory and lead author of the HAWC Collaboration's new study of gamma radiation from pulsars.

The HAWC Collaboration comprises more than 100 international researchers. Malone developed the gamma-ray energy estimation algorithm that is used in the paper and led the entire analysis.

Conventional wisdom had attributed ultra-high-energy (more than 56 teraelectronvolts) gamma ray emissions to sources of neutrinos and gamma rays called PeVatrons, which are associated with this acceleration of charged [cosmic rays](#) to petaelectronvolt energies. The energies are about five times higher than those produced by accelerators on Earth. This came into question when, in 2020, the HAWC Collaboration released a catalog of nine gamma-ray sources emitting above 56 teraelectronvolts. That's the highest-energy catalog of astrophysical sources ever produced. The team was surprised to find that all of the detected sources were near the most powerful pulsars ever observed.

In the new paper, the team searched for ultra-high-energy gamma-ray signals near extremely powerful pulsars.

"We find that ultra-high-energy emission appears to be a generic feature for these objects. The gamma rays are likely created by interactions in the [pulsar](#) wind. This allows us to create a fuller picture of how the most energetic gamma rays ever detected are created in our galaxy," Malone said. "Now that we know that pulsar wind nebulae emit at these energies, we can focus on detecting more of them with longer searches and more sensitive experiments."

The HAWC Collaboration recently constructed an upgrade to the detector that is more sensitive to the highest energy gamma rays. Additionally, the planned Southern Wide-field Gamma-ray Observatory (SWG0) experiment will be extremely sensitive above 50 teraelectronvolts and will be able to perform detailed studies of emissions associated with pulsars.

The HAWC Observatory is composed of an array of water-filled tanks high on the flanks of the Sierra Negra volcano in Puebla, Mexico, where the thin atmosphere offers better conditions for observing [gamma](#) rays. When [gamma rays](#) strike molecules in the atmosphere they produce showers of energetic particles. When some particles in cosmic ray showers travel strike the water inside the HAWC detector tanks, they produce flashes of light called Cherenkov radiation. By studying these Cherenkov flashes, researchers reconstruct the sources of the particle showers to learn about the particles that caused them.

The paper, "Evidence that Ultra-high-energy Gamma Rays Are a Universal Feature near Powerful Pulsars," is published in *The Astrophysical Journal Letters*.

More information: Evidence that Ultra-high-energy Gamma Rays Are a Universal Feature near Powerful Pulsars *The Astrophysical Journal Letters*, doi.org/10.3847/2041-8213/abf4dc

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