Aerial view of HAWC with the main array surrounded by its high-energy upgrade, the outrigger array.

smaller water-Cherenkov tanks on a sparser grid. This is the concept behind the high-energy upgrade of HAWC: the "outrigger" array of 350 smaller tanks (see the title picture) with a single photomultiplier tube each surround the array of large water-Cherenkov detectors, increasing the area covered by the observatory by a factor of four.

The readout electronics for the outriggers is an adapted version of the readout electronics developed at MPIK for the FlashCam camera for the medium-size telescopes of the Cherenkov Telescope Array. CTA will also observe the high-energy gamma-ray sky, but by detecting the Cherenkov light emitted by the particle cascades in the atmosphere itself. These electronics digitize, with a 250 MHz sampling rate, the signals recorded by each photomultiplier tube in the outrigger array. When two, or more, neighbouring tanks register light within a short period, these data are stored for further processing.

HAWC and the MPIK

The group at MPIK is involved in analysing the accumulated data from the observatory, and played a major role in building the extension to the observatory to further enrich its performance at the highest energies. In addition to providing the readout electronics, the group also developed dedicated software to analyse the combined data. The outrigger array has been partially funded by MPIK.

The HAWC observatory is operated by a collaboration of 34 institutes from Mexico, the USA and Europe. Its main detector array with an area of about 20 000 m² was completed in spring 2015. The outrigger array became fully operational in summer 2018.

Contact:

Prof. Dr. Jim Hinton
Phone: +49 6221 516140
E-Mail: jim.hinton@mpi-hd.mpg.de

Dr. Harm Schoorlemmer
Phone: +49 6221 516145
E-Mail: harm.schoorlemmer@mpi-hd.mpg.de

Dr. Felix Werner
Phone.: +49 6221 516 143
E-Mail: felix.werner@mpi-hd.mpg.de

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK HEIDELBERG

Saupfercheckweg 1
69117 Heidelberg

www.mpi-hd.mpg.de

The Max-Planck-Institut für Kernphysik (MPIK) is one of 84 institutes and research establishments of the Max-Planck-Gesellschaft. The MPIK does basic experimental and theoretical research in the fields of Astroparticle Physics and Quantum Dynamics.

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

MAX-PLANCK-GESELLSCHAFT

HAWC

A wide-angle view of the non-thermal Universe

HAWC
A wide-angle view of the non-thermal Universe

On the saddle point between the volcanos Sierra Negra and Pico de Orizaba in central Mexico, numerous water tanks are watching the sky: the High Altitude Water Cherenkov gamma-ray observatory HAWC. The high altitude of 4100 metres above sea level offers a unique view of the most energetic gamma rays coming from the Universe. HAWC provides a survey of the northern skies at these highest energies with unprecedented sensitivity.

The non-thermal Universe

The gamma-ray light HAWC detects has energies above 10^{12} eV – a trillion times more energetic than visible light. This light cannot be produced by normal stars as thermal radiation. Instead, it must originate in the most extreme places in the Universe such as in the vicinity of black holes or in the shock waves of exploding stars – cosmic accelerators. The extremely accelerated – relativistic – electrically charged particles meander through space under the influence of cosmic magnetic fields. Very-high-energy gamma rays emerge from the interaction of these particles with interstellar gas or radiation fields. In contrast to charged particles, gamma rays travel in a straight line and can thus be traced back to the sources.

The HAWC observatory and Pico de Orizaba (Citlaltépetl).

Direct detection of particle cascades

HAWC measures the cascade of particles produced by the interaction of a high-energy gamma ray in the atmosphere. As the particles travel into one of the 300 tanks (7.3 m in diameter and 4.5 m high, filled with high-purity water) of the observatory, they produce a short flash of so-called Cherenkov light.

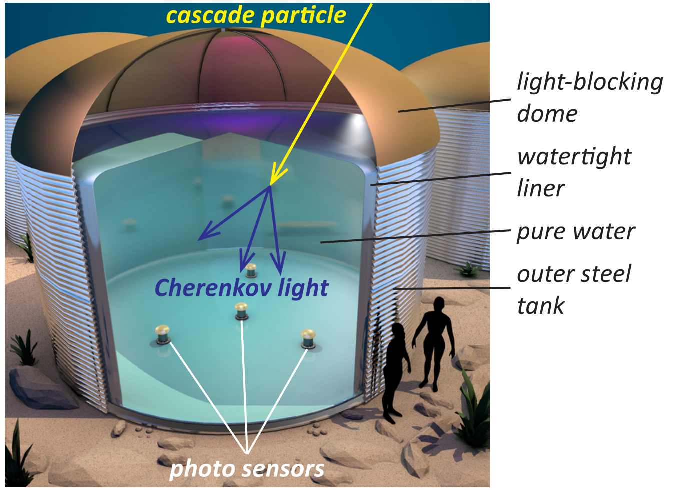
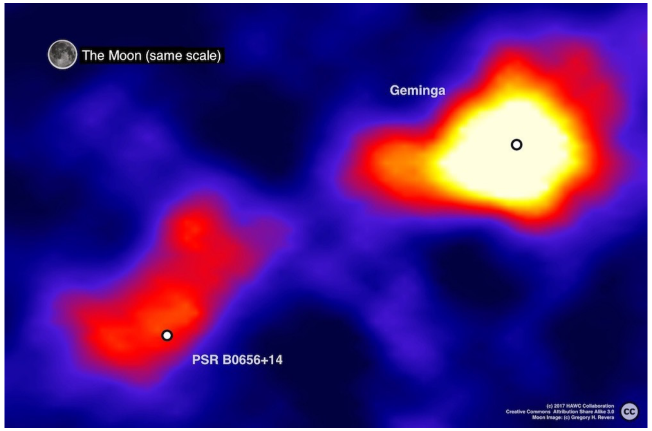


Illustration of one of the water-Cherenkov detectors of HAWC.

Four large photomultiplier tubes installed at the bottom of the water tank record the flashes of light. Combining the brightness and timing information of all the photo sensors in the observatory, yields the properties of the particle cascade. These measurements are used to identify which type of primary particle – gamma ray or cosmic ray (i. e. charged particle) – caused the particle cascade and what was the energy and direction of this primary particle.

As the direction can be determined for all particle cascades arriving at the ground, HAWC has a large aperture and continuously scans about 15% of the whole sky resulting in roughly two-thirds of the northern sky every day. This wide-angle view makes HAWC particularly suitable for investigating extended objects and for the search for yet unknown gamma-ray sources.



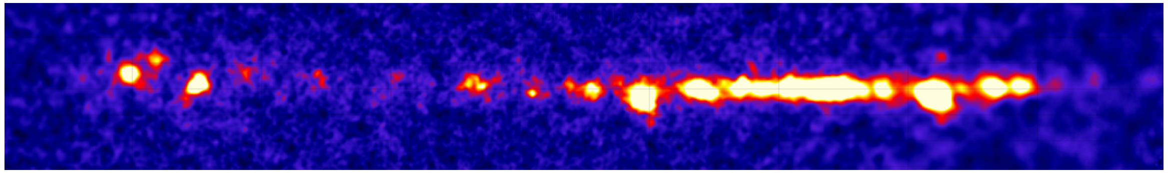
HAWC's wide-angle view of the region around the two nearby pulsars Geminga and PSR B0656+14.

By accumulating all observations over the lifetime of the observatory, a deep image of the very-high-energy sky is generated.

From the first years of observations important insights about the very-high-energy sky were obtained. In total, HAWC has detected 40 sources of very-high-energy gamma-ray emission, of which 14 were previously unknown. Among these, there are two very extended regions of emission, roughly ten times the size of the full moon on the sky. This emission is believed to be caused by very-high-energy electrons which are accelerated by pulsars and released into interstellar space. The data analysis showed that the electrons escaping from their accelerators are considerably slower than previously assumed.

An extension of the array

Since the number of gamma rays decreases rapidly while their energy increases, large collection areas are needed to make highest-energy observations. On the other hand, with increasing gamma-ray energy the number of particles produced by the interaction in the atmosphere increases. Therefore, more energetic gamma rays can be observed using



The Galactic plane as seen by HAWC with clearly resolved emission from many sources.