Blue light in the desert night

The HESS array in Namibia waits for a split-second flash of blue light — Cherenkov radiation — that signals an atmospheric shower of charged particles caused by cosmic rays, explains Director Mathieu de Naurois.

The High Energy Stereoscopic System (HESS) is an array of five imaging atmospheric Cherenkov telescopes (IACTs) located in the Khomas Highland of Namibia, 1,800 m above sea level, and dedicated to very-high-energy gamma-ray astronomy between tens of gigaelectronvolts (GeV) and tens of teraelectronvolts (TeV) (Fig. 1). The name of the array pays homage to Victor Hess, who received the Nobel Prize in Physics in 1936 for his discovery of cosmic radiation.

The observatory is operated by a collaboration of more than 260 scientists from about 40 scientific institutions and 13 different countries: Namibia and South Africa, Germany, France, the United Kingdom, Ireland, Austria, the Netherlands, Poland, Sweden, Armenia, Japan and Australia. So far, the HESS Collaboration has published over 100 articles in high-impact scientific journals, including *Nature* and *Science*.

Cosmic particles — such as protons, nuclei, electrons and gamma-rays — interact with atoms in the Earth's upper atmosphere and develop a cascade of energetic particles extending more than several kilometres in length. The charged particles in these 'atmospheric showers' travel faster than light in the air and emit a faint flash of blue light, called Cherenkov radiation, which illuminates about 50,000 m² on the ground and lasts only a few nanoseconds. This flash is reflected by the mirrors of the telescopes onto a fast and very sensitive camera placed at the focal plane of each telescope. Although a single telescope is able to see the atmospheric showers by itself, stereoscopic vision of the same event allows one to reconstruct much more accurately the properties (energy, direction and type) of the cosmic particle that entered the atmosphere. The HESS telescope system therefore uses a dual-level trigger: each camera first triggers individually on the shower and then sends the information to a central trigger that searches for coincidences between different telescopes, in order to validate or discard the event.

Once recorded, the images of the showers are analysed and compared to Monte Carlo simulations to derive the properties of the incident particle. The shape of the image, in particular, is used to reduce the level of background induced by hadronic particles such as protons and nuclei. Composite images of the sky in very-high-energy gamma-rays are then built, event after event. Detailed spectral and morphological analyses of the emitting sources allow the properties of cosmic particle accelerators to be understood.

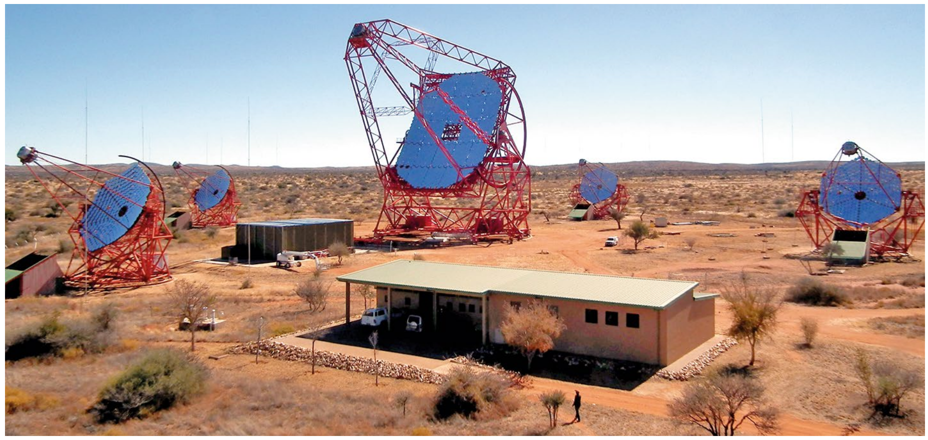

Fig. 1 | The five telescopes of the HESS array on the Khomas Highland of Namibia.

The site location in the Khomas Highland was chosen because of the quality of the sky (low back-scattered background luminosity due to the remote location, dry atmosphere and low cloud coverage) but also because of its position. The proximity of the Tropic of Capricorn allows optimal observation of the inner regions of the Galactic plane, where most of the gamma-ray sources detected by HESS are located: supernova remnants, pulsars and pulsar-wind nebulae, and black hole or neutron star binary systems.

In its first phase, inaugurated in 2003, HESS comprised four identical telescopes, each consisting of a 107-m² optical reflector (12 m diameter) composed of segmented spherical mirrors, and arranged in a square of 120 m per side. The cameras were built from 960 photomultiplier tubes with integrated trigger and digitization electronics. The HESS I legacy survey of the Galactic plane has recently been published[1] as the capstone paper in a special issue of the journal *Astronomy and Astrophysics*, dedicated to results from the first ten years of HESS I operations. Additional science highlights obtained by HESS include the first discovery of extremely rapid gamma-ray variability (on timescales of five minutes) of the blazar-type active galaxy PKS 2155−304 (ref. [2]); the identification of the Galactic Centre region as the most likely source of petaelectronvolt (PeV) cosmic rays[3]; and the discovery of TeV gamma-ray sources in the Large Magellanic Cloud, including the most powerful known pulsar-wind nebula (N157B) and the largest known non-thermally emitting shell (the superbubble 30 Dor C), indicating active star formation followed by multiple supernova explosions[4].

In 2012, a fifth, much larger telescope was added to the array: with a reflecting surface of 600 m², it is currently the largest IACT in the world and lowers the energy threshold (by recording fainter images) to a few tens of GeV, thus helping to bridge the gap with satellite instruments such as the Large Area Telescope on board the Fermi spacecraft (Fermi-LAT), operating at lower energies. In 2015–2016, the cameras of the four HESS I telescopes were fully refurbished using state-of-the-art electronics and in particular the NECTAr readout chip, designed for the next big experiment in the field, the Cherenkov Telescope Array (CTA). With a lower dead-time and better data treatment capabilities, the new cameras improve the performance of the array, especially at the low and high-energy ends of the spectrum. ❐

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