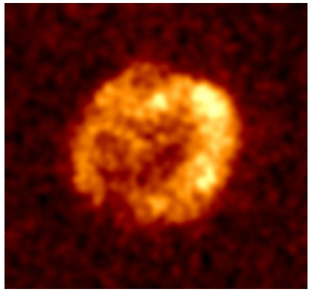
Beyond the Milky Way, galaxies with active nuclei, starburst and radio galaxies are found as faint objects in the very-high-energy gamma-ray light. In our neighbouring companion galaxy, the Large Magellanic Cloud, H.E.S.S. was able to identify several extremely luminous sources. Recent highlights from H.E.S.S. include the detection of gamma-ray bursts and – for the first time resolved – the emission from the jets of active galaxies in the gamma-ray band.

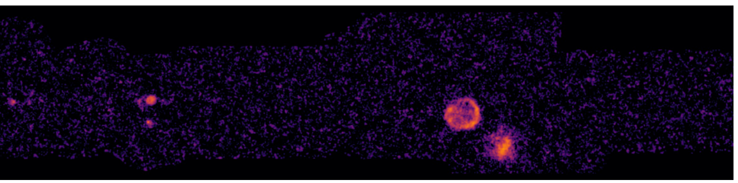


*The supernova remnant RX J1713.7-3946 seen in high-energy gamma light.*

## H.E.S.S. and the MPIK

The H.E.S.S. project was initiated by MPIK. The institute has played a central role in the design and construction of H.E.S.S.: Together with the institute's workshops, MPIK scientists and technicians were responsible – among others – for the steel structure and the drive systems of the telescopes, the mirror facets and the main trigger system. The high-performance camera of the large telescope installed in 2019 was developed under the leadership of MPIK. Additionally, the MPIK is one of two centres responsible for the quality control and calibration of the data, and plays an important role in the data analysis and interpretation. The Max Planck Society has been by far the largest financier for the construction of the H.E.S.S. telescopes.

The H.E.S.S. observatory is being operated by a collaboration consisting of more than 200 scientists from 13 countries. H.E.S.S. has been awarded in 2006 the Descartes Prize of the European Commission – the highest recognition for collaborative research – and in 2010 the prestigious Rossi Prize of the American Astronomical Society. In 2009, H.E.S.S. was ranked among the 10 world-leading astronomical observatories, based on the scientific impact derived from a citation analysis.

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The Max-Planck-Institut für Kernphysik (MPIK) is one of 86 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.

H.E.S.S.

MAX-PLANCK-GESELLSCHAFT

# H.E.S.S.

## Cosmic Accelerators in Gamma-Ray Light

## Astronomy at the Highest Energies

## H.E.S.S.

### Cosmic Accelerators in Gamma-Ray Light – Astronomy at the Highest Energies

*An array of four 12-metre-mirror telescopes and a huge fifth telescope with a 28-metre-sized mirror is observing the sky above the highlands of Namibia. Undisturbed by light from large cities, the location provides an optimal view of the central part of the Milky Way. The H.E.S.S. observatory is studying sources of high-energy gamma rays and uncovers a Universe which looks completely different to that seen by the naked eye.*

### Gamma Radiation from Space

The light that is detected by H.E.S.S. from our Milky Way and distant galaxies is a trillion times more energetic than ordinary starlight. The amount of energy is so high that it cannot be produced by normal stars. Instead, it must originate in the most extreme places in the Universe, such as in the vicinity of black holes and in shock waves of supernovae – exploding stars. H.E.S.S. was the first experiment to observe spatially and temporarily resolved images of these objects.

Closely related to the observation of high-energy gamma radiation is the question of the origin of cosmic rays. Highly energetic electrically charged particles are meandering through space under the influence of cosmic magnetic fields, and a large number of these particles hit the Earth's atmosphere. More than 100 years after their discovery by Victor Hess in the year 1912, it is not yet fully understood how these particles are accelerated to highest energies and in which astronomical objects this is accomplished. Gamma radiation is produced when these highly energetic elementary particles and atomic nuclei slam into gas clouds or interact with magnetic or radiation fields in the vicinity of the cosmic particle accelerators. This gamma-ray light thus provides an image of the cosmic accelerators.

### Gamma Astronomy with H.E.S.S.

Although very-high-energy gamma radiation is absorbed in the atmosphere of the Earth, it can nevertheless be detected by instruments like H.E.S.S. on the ground. The atmosphere plays the role of a detector medium: On its absorption, each gamma quantum produces a cascade of secondary particles, known as a particle shower. The shower particles emit a faint bluish light – called Cherenkov light. The light flash is too short – only about a billionth of a second – and too weak to be observable by the naked eye. Using large mirrors and rapid photo detectors, however, Cherenkov telescopes are able to record these weak and extremely short flashes. For this purpose, H.E.S.S. uses five telescopes that simultaneously observe each particle shower from different points of view. Similar to the depth perception we obtain with our two eyes, a stereoscopic observation enables the exact directional as well as energetic reconstruction of the incident gamma radiation. Each of the telescopes can be precisely rotated in every direction so that they can follow celestial objects as they move through the sky.

The four identical smaller telescopes (CT1-CT4) started operation between 2002 and 2004. Each of these telescopes has a mass of 60 tonnes and is 16 m high. Per telescope, 380 facets of 60 cm diameter form a focusing mirror of 107 $m^2$ area. Every single facet can by adjusted with respect to the camera with an accuracy of a few thousandths of a millimetre by motors. The large telescope (CT5) saw its 'first light' in July 2012. It has an overall mass of 580 tonnes and the height of a 20-story building when pointing up. The mirror with an area of 614 $m^2$ is composed of 875 adjustable hexagonal facets and has a focal length of 36 m. The elevation axis is 24 m above the ground. This telescope strongly enhances the sensitivity of the entire system and extends the observable energy range to lower energies.

Highly sensitive cameras form the central part of the telescopes. Their function is to record the particle showers that are produced in the atmosphere by gamma radiation. Each camera incorporates 960 (CT1-CT4) or 1758 (CT5) rapid photo sensors which convert the incident light with an exposure time of a few parts in a billion of a second into electrical signals. The cameras with a mass of about 1000 kg (CT1-CT4) or 2050 kg (CT5) have

*The High-Energy Stereoscopic System H.E.S.S.. The four smaller telescopes span a square of length 120 metres, in the centre of which the fifth, huge telescope is placed.*

a field-of-view of 5.0 (CT1-CT4) or 3.4 (CT5) degrees in the sky, corresponding to several times the extent of the full moon. The new camera of CT5, installed in 2019, with its fully digital read-out electronics and data aquisition system provides increased sensitivity for transient phenomena.

### The Sky as Seen in Gamma Rays

H.E.S.S. has examined the central part of our Galaxy for several thousand hours searching for sources of highly energetic gamma radiation. For the first time, it has produced a detailed map of the Milky Way in gamma-ray light (see below). Like pearls on a string, the map shows a large number of gamma sources – each being a cosmic particle accelerator – arranged along the Galactic equator. Many of these gamma-ray sources are connected with the remnants of exploded stars (supernovae and pulsar-wind nebulae). Shortly after start of data taking, H.E.S.S. for the first time succeeded to image the shock wave of a supernova remnant in rich details in gamma-ray light. The supermassive black hole in the Galactic Centre turned out to be a cosmic "pevatron" that accelerates particles to extreme energies. Some mysterious "dark" gamma sources, however, cannot yet be assigned to a known object in the sky. In 2018 a whole issue of the journal Astronomy & Astrophysics was dedicated to H.E.S.S. observations within our own galaxy.