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High energy stereoscopic system: Latest results

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Abstract

Gamma-rays are produced in the interactions of energetic particles and hence provide a probe of the non-thermal universe. The High Energy Stereoscopic System (HESS) is currently the most sensitive instrument for gamma-ray observations at energies around 1 TeV. After two years of full operation, HESS has produced significant results in several areas of galactic and extragalactic astronomy. New results on supernova remnants, pulsar wind nebulae, molecular clouds and active galaxies are briefly described.

Keywords: Gamma-rays; Active galaxies; Supernova remnants; Microquasars; Pulsar wind nebulae

1. Introduction

The High Energy Stereoscopic System (HESS) is an array of four 13 m diameter imaging Cherenkov telescopes, designed for high sensitivity measurements of astrophysical gamma-ray sources in the 100 GeV to 10 TeV regime. Its southern hemisphere location (in the Khomas highlands of Namibia) makes it an ideal instrument for the study of the inner parts of our galaxy. Observations with the full array began in early 2004, with roughly 60% of observation time spent on galactic sources and surveys. Discoveries with HESS have now quadrupled the size of the catalogue of very-high-energy (VHE; $E > 100$ GeV) γ-ray sources. Below we review some of the recent results from the HESS collaboration. Note that a more detailed summary of recent results on the VHE emission of supernova remnants can be found in an article by S. Funk in these proceedings.

2. Active galaxies

A highlight of the first two years of operation of HESS is the discovery of four new very-high-energy (VHE) blazars. One of these VHE blazars, 1ES 1101–232, is the most distant known, with a redshift of 0.186. The VHE spectra of blazars show the imprint of absorption on the extragalactic background light (EBL), with increasing absorption for more distant objects. As the amount of absorption increases with energy, measured spectra are *softened* with respect to intrinsic spectra. The observed relatively hard spectrum of 1ES 1101–232 suggests that either the level of the EBL is lower then previously assumed, or that the intrinsic spectrum of this object is harder ($\Gamma < 1.5$) than is compatible with standard blazar models. This fact has been used by the HESS collaboration to derive an upper limit on the EBL which is close to the *lower* limits derived from galaxy counts (Aharonian et al., 2006a). The EBL between 1 and 4 μm has now therefore been effectively resolved. The EBL is of profound astrophysical interest as it represents the integral of all light produced over the history of the universe. It can therefore be used to test models of cosmological star formation, in particular the formation of the first stars, as well as more exotic phenomena that may have been at work in the early universe.

The active galaxy M 87 represents a rather different object to this distant blazar. It is the only known extragalactic very-high-energy source that does not appear to have a jet aligned close to the line-of-sight. This powerful nearby source represents the first of a new class of high energy

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objects. First discovered by the HEGRA collaboration, observations with HESS are improving our knowledge on the position, spectrum and light-curve of the VHE emission (Aharonian et al., 2005a). These measurements should enable us to identify the acceleration site of the particles responsible for the TeV emission in M 87 and their hadronic or leptonic nature.

3. Supernova remnants

One of the most promising sites for the acceleration of cosmic rays in our galaxy is in the shock waves of expanding supernova remnants (SNRs). The shell-type SNRs RX J1713.7–3946 (Aharonian et al., 2006b) (see Fig. 1) and RX J0852.0–4622 (Aharonian et al., 2005b) have been the targets of deep observations with HESS. These detailed spectral and morphological studies, together with observations at X-ray wavelengths, are placing strong constraints on models of acceleration in these objects. In the case of RX J1713.7–3946, the simplest models of TeV emission in terms of inverse Compton scattering of electrons can not reproduce the shape of the measured VHE gamma-ray energy spectrum. Models involving the interactions of accelerated protons with ambient material can more easily explain the spectrum but in this scenario the close match between gamma-ray and X-ray morphology is perhaps harder to explain. In either case, HESS measurements have unambiguously demonstrated the presence of accelerated particles in the shells of these two objects.

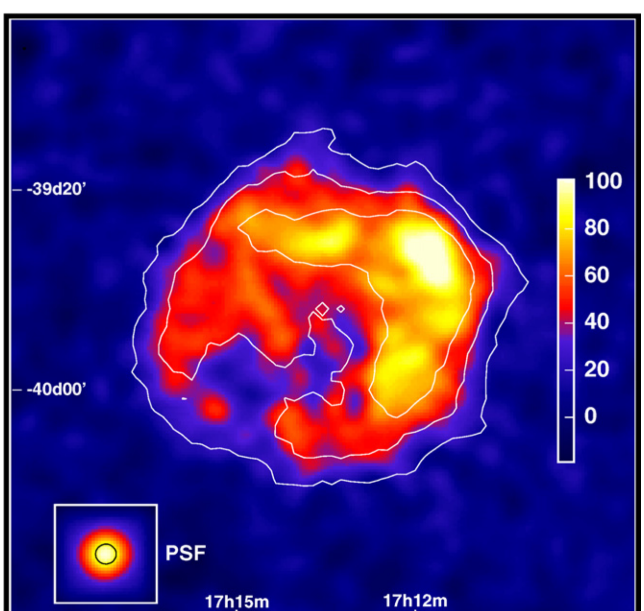

Fig. 1. The supernova remnant RX J1713.7–3946 in VHE gamma-rays. A smoothed excess map from HESS is shown with a colour scale. Contours show levels of statistical significance. See Aharonian et al. (2006b) for details.

4. The galactic centre

The centre of our own galaxy has been one of the principal targets of HESS. Our data have allowed us to study the central VHE source, HESS J1745–290, with unprecedented precision (Aharonian et al., 2004) and have revealed the existence of diffuse gamma-ray emission extending along the galactic plane (Aharonian et al., 2006c). HESS J1745–290 has a position compatible with that of Sgr A* and marginally consistent with the centre of the SNR Sgr A East. The source exhibits a rather hard ($\Gamma = 2.25 \pm 0.04 \pm 0.10$) power-law spectrum from 0.16–30 TeV, incompatible with predictions for Dark Matter annihilation (Aharonian et al., 2006d), but consistent with expectations for diffusive shock acceleration. After subtracting a point-like source at the position of HESS J1745–290, residual gamma-ray emission is seen stretching along the galactic plane. This diffuse emission is correlated with the distribution of dense molecular material in the galactic centre (GC) region (see Fig. 2), suggesting a decay of neutral pions produced in hadronic interactions as a likely source of the gamma-rays. Following this interpretation, the spatial distribution of gamma-rays can be used to infer the injection of energetic protons and nuclei at the GC around 10^4 years ago.

5. The microquasar LS 5039

The X-ray binary system LS 5039 was the first object of this class to be discovered in VHE gamma-rays (Aharonian et al., 2005c). The system has been dubbed a microquasar due to the presence of (milli-arcsecond) radio jets in the system. Very recently, analysis of the HESS data on this object has revealed a clear modulation of the gamma-ray flux with the period of the binary system (3.9 days), see Fig. 3 (Aharonian et al., 2006e). This measurement represents the first detection of a periodic signal in VHE gamma-ray astronomy. Furthermore, there is strong evidence for changes in the shape of the gamma-ray energy spectrum with phase. The peak TeV gamma-ray flux occurs when the compact object (black hole or neutron star) lies between the companion star and the Earth. Such a modulation is expected if gamma-ray absorption via pair-production on the intense radiation field of the companion star is the primary reason for periodicity. However, the changes in energy spectrum with phase that are seen are hard to explain with any simple model. Further HESS and lower wavelength studies of this object may shed light on this mystery.

6. Pulsar wind nebulae

Much of the spin-down power of young pulsars appears to go into the production of relativistic particle winds. Indeed, pulsar wind nebulae (PWN) appear to be highly efficient electron accelerators. Combined X-ray and gamma-ray observations of these objects are required to