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Observations of Supernova Remnants with H.E.S.S.

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The High Energy Stereoscopic System (H.E.S.S.) consists of four telescopes each equipped with a 960 photomultiplier tube camera covering a field of view of 5°. The complete system has an angular resolution of a few arc minutes, an effective energy range from 100 GeV to 20 TeV with energy resolution of 15 to 20 percent and a flux sensitivity approaching 10^{-13}erg cm^{-2}s^{-1}. These characteristics, together with its southern hemisphere location, make H.E.S.S. ideally suited for spectral and morphological studies of Galactic Plane sources such as the supernova remnants RX J1713-3946 and SN 1006. Here we present data taken on these sources in 2003, during the construction and commissioning phase of H.E.S.S..

Keywords: Gamma rays; SNRs; TeV

1. Introduction

The H.E.S.S. array is situated in the Khomas highland of Namibia, at an elevation of 1800 metres above sea level. The four telescopes are placed in a square formation with a side length of 120 metres. The telescopes, of steel construction, have an effective mirror area of 107 m^2. The H.E.S.S. cameras each consist of a hexagonal array of 960 photo-multiplier tubes (PMTs). Each PMT covers an area of 0.16° in diameter projected onto the sky[1]. The total field of view on the sky is 5° in diameter.

The experiment commenced operations in June, 2002, with the first of four Cherenkov telescopes, two more telescopes were installed in January and September of 2003, and the array was completed with the fourth telescope in January 2004. Details of the data analysis procedures for H.E.S.S. data may be found in Ref. 2 and Ref. 3.

2. Observations

Table 1 summarises observations of Galactic sources made with H.E.S.S. in 2003 and the first half of 2004. In selecting sources to observe, priority in the first stages of operation of the array was given to those objects already claimed to emit γ-rays in the very high energy (VHE) range. A number of other objects were also observed, including notably the binary system containing PSR B1259-63.

Table 1. Summary of observations of Galactic sources with H.E.S.S. in 2003 and the first half of 2004

Source	**Previous detection**	**Flux** % Crab	**H.E.S.S. Obs.** hours	significance	**Flux** % Crab
Crab	Whipple, etc.	100	2.8	$> 50\sigma$	100
SN 1006	CANGAROO	70	18	-	< 10
Vela	CAN.	60	5.6	-	< 7
PSR B1706-44	CAN.	50	14	-	< 3
RX J1713-3946	CAN.	~ 100	18	20σ	20
Gal. centre	CAN., Whipple	~ 100	17	11σ	6
PSR B1259-63	-	-	39	10σ	5
HESS J1303-63	-	-	39	13σ	10

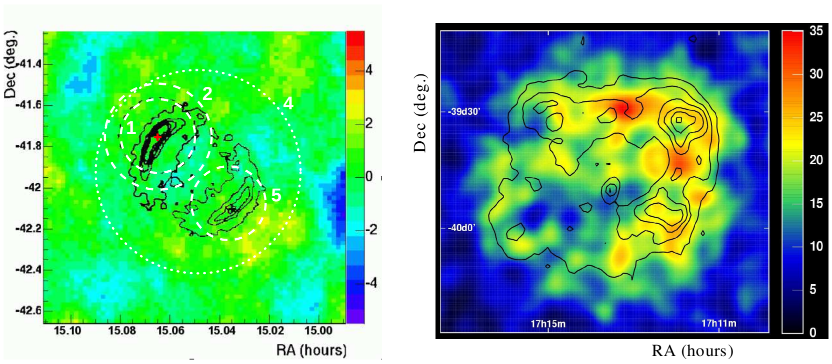

Fig. 1. Left: a sky map of significance (σ) for H.E.S.S. observations of SN 1006, the circles represent integration regions for upper limits on the flux. Right: Excess count map of H.E.S.S. observations of RX J1713-3946. The overlaid contours in both plots indicate ASCA X-ray observations of the same source.

The Crab nebula was discovered at TeV energies in 1989[4] and is conventionally used as a standard reference source of TeV γ-rays, due to its relative stability and high flux. Observations were made of this source in October of 2003, during the construction phase of the experiment, with the three available H.E.S.S. telescopes. A strong signal was seen in under three hours of observations at a confidence level of more than 50σ [5]. The flux of $2.05 \pm 0.09 \times 10^{-11}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ above 1 TeV and the photon index of 2.57 ± 0.04 are consistent with those seen by other experiments[6,7,8]. The errors quoted are statistical, there is an estimated systematic error of 0.1 on the photon index and 20% on the flux.

SN 1006 was claimed as a source of TeV γ-rays in 1988 by the CANGAROO collaboration[9], who reported an excess coincident with the northwest rim of the Supernova Remnant (SNR) as seen in X-rays. It was observed in 2003 by H.E.S.S. with two telescopes and no excess was seen. A sky-map of the region surrounding the SNR is shown in figure 1 (left), together with intensity contours for X-ray observations of the source. The superimposed circles identify regions for which upper limits

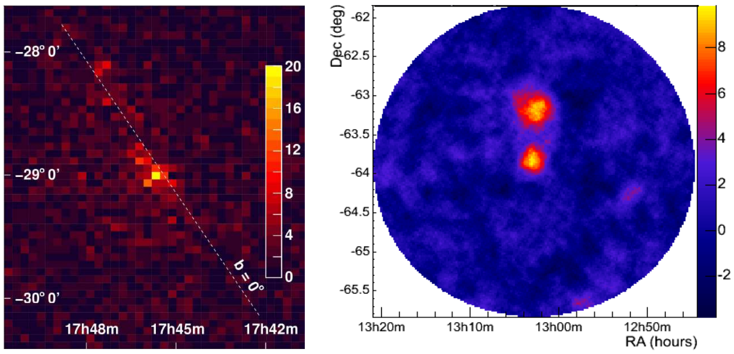

Fig. 2. Left: 2-D excess map of H.E.S.S. observations of the galactic centre. Right: 2-D significance map of H.E.S.S. observations of the area surrounding PSR B1259-63. The γ-ray emission from the binary system containing the pulsar is seen at the centre and the emission from the unidentified source HESS J1303-63 is seen just above it.

have been made by H.E.S.S. Region 2 coincides with the CANGAROO claimed angular extent; the upper limit has a magnitude roughly 14% of the equivalent CANGAROO integral flux above the CANGAROO energy threshold.

The SNR RX J1713-3946 is a large shell-type SNR, discovered in the ROSAT all-sky survey (ROSAT) and detected in γ-rays by the CANGAROO experiment[10]. It was observed by H.E.S.S. in 2003 with two telescopes and a strong signal was seen, in excess of 20σ [11]. Figure 1 (right) shows a sky map of the excess seen from this source, along with contours denoting the intensity of X-ray emission as seen by the ASCA satellite. The shell structure of the SNR can be clearly seen in both γ-rays and X-rays and there is a strong correlation in morphology between the two wavelengths. The spectrum seen by H.E.S.S. is hard, with a photon index of 2.2 ± 0.7, which is consistent with an hypothesis of γ-ray emission associated with proton acceleration in the interaction of the shell with molecular clouds in the vicinity of the remnant.

The Galactic centre is an interesting candidate at most wavelengths and was observed by H.E.S.S. in 2003 with two telescopes. γ-ray emission from a direction consistent with the black hole Sagittarius A*, within their angular resolution, had been previously claimed by CANGAROO[12] and the Whipple collaboration[13]. A strong excess was seen by H.E.S.S. at a confidence level of 11σ[14]. Figure 2 (left) shows a map of the γ-ray excess in the direction of the Galactic Centre; the centre of gravity of the emission is consistent with both the black hole Sagittarius A* and the SNR Sagittarius A East, within the source position reconstruction accuracy of 40 arcseconds. The differential energy spectrum of the emission is measured by H.E.S.S. to have a photon index of 2.2 ± 0.09.

The binary system containing PSR B1259-63 was observed by H.E.S.S. in 2004 with the four-telescope array. This period of time coincided with the periastron of the pulsar orbit around its companion star, which should correspond with variability of the flux of VHE γ-rays. The source was detected at a level of 6σ before the periastron in February and again afterwards in March, April, and May[15]. It was not observed at the exact periastron due to the presence of the moon in the night sky. The sky map of the region surrounding the pulsar is shown in figure 2 (right). The γ-ray flux from the binary system is seen to show significant variability on a monthly time-scale, making it the first variable galactic γ-ray source to be detected at TeV energies. In figure 2 (right) one can also see a second VHE source, HESS J1303-63[16]. This source was serendipitously discovered during observations of the pulsar. It is slightly extended, ($\sim 0.2^{\circ}$), and has a photon index of 2.2 ± 0.2. This source has at present no known counterpart at other wavelengths.

3. Conclusions

The H.E.S.S. experiment has been fully operational with four telescopes since January of 2004 and has achieved its designed sensitivity and operational characteristics. Useful scientific results have been produced throughout the construction phase with two three and four telescopes and exciting discoveries have been made. An extensive campaign of observations of galactic sources is underway and more exciting results are expected. Sources discussed here will be re-observed with the improved sensitivity and resolution of the full array and such deeper observations are expected to provide further interesting insights from these sources.

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