29th International Cosmic Ray Conference Pune (2005) **00**, 101–106

H.E.S.S. observations of the shell-type SNR RX J1713.7−3946.

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The shell-type supernova remnant (SNR) RX J1713.7−3946 (G$347.3-0.5$) was first discovered with ROSAT [1] in X-rays and later **also observed to emit TeV γ-rays [2, 3].** This object, together with several other southern hemisphere SNRs, is a prime target for observations with the High Energy Stereoscopic System (H.E.S.S.), a new system of imaging atmospheric Cherenkov telescopes which was completed at the end of 2003 in Namibia and is now in full operation [4, 5]. We present first results from deep observations of the SNR RX J1713.7−3946 conducted with the complete H.E.S.S. array in 2004. Almost all parts of the SNR emit gamma rays; the emission is found to resemble a shell structure with increased fluxes from the west and northwest part. The differential gamma-ray spectrum of the whole SNR extends over more than two orders of magnitude and appears rather hard with a power-law photon index of $\Gamma = 2.27 \pm 0.02$ (stat.) $\pm$ 0.20 (sys.). The characteristics of the energy spectrum imply efficient acceleration of charged particles to energies well beyond 100 TeV, consistent with current ideas of particle acceleration in young SNR shocks.

1. Introduction

It is commonly believed that the only sources capable of supplying enough energy output to power the flux of Galactic cosmic rays are supernova explosions [6]. **Standard estimates of the power required to sustain the observed Galactic cosmic ray population show that a few percent of the mechanical energy released in supernovae would suffice, which, allowing for adiabatic and other losses, suggests that supernova remnants could be the sources of the Galactic cosmic rays if the acceleration efficiency in the remnants is of order 10%.** Furthermore, a well developed theoretical framework for the acceleration mechanism, **diffusive shock acceleration (for reviews see eg, [7, 8, 9]) exists and with the recent inclusion of magnetic field amplification satisfactorily accounts for the acceleration of particles up to the knee (at about 10^{15} eV) and beyond [10, 11].**

One way of proving the existence of highest-energy particles in the shells of SNRs is the detection of very-high-energy (about 100 GeV up to a few tens of TeV) gamma rays that are produced in interactions of nucleonic cosmic rays with ambient matter. Recently, **H.E.S.S. has confirmed TeV gamma-ray emission from the SNR RX J1713.7−3946, in an observation campaign during the construction and commissioning phase with a partially complete array (two out of four telescopes were operational).** This was the first case of two independent detections of an SNR in TeV gamma rays. Furthermore, the H.E.S.S. measurement presented the first ever image of such an object in gamma rays. It actually resolved the complex morphology of RX J1713.7−3946. ***Dropped sentence 'Here we report on deep follow-up observations of RX J1713.7−3946 with the complete H.E.S.S. telescope array conducted in 2004.'***

2. Observations of RX J1713.7−3946 in 2004

The observations were mostly performed in *wobble mode* around the SNR centre. In this mode the telescopes were positioned such that centre of the SNR was offset $\pm 0.7^{\circ}$ in declination or right ascension away from the optical axis of the telescopes, changing to the next position every 28 minutes. Towards the end of the observation campaign, pure on-source **observations were additionally performed. In each of the five observation positions, the 1°-diameter SNR RX J1713.7−3946 was fully contained in the $\sim 5^{\circ}$ field of view of the system.**

The data sample comprises a total exposure time of 40 hours. Disregarding data taken under bad weather conditions, 36 hours of observation time corresponding to 33 hours of live time remain for the analysis. The zenith angle of observations ranged from 16° to 56° with a mean of 26°; it should be noted though that about 68% of the data were taken at small zenith angles between 16° to 26°. The energy threshold (defined by the peak gamma-ray detection rate for a given source spectrum after all gamma-ray selection cuts) of the system increases with zenith angle. For the observations presented here, assuming a spectrum appropriate for RX J1713.7−3946, the threshold was ~ 180 GeV at 16°, ~ 340 GeV at 40°, and ~ 840 GeV at 56°.

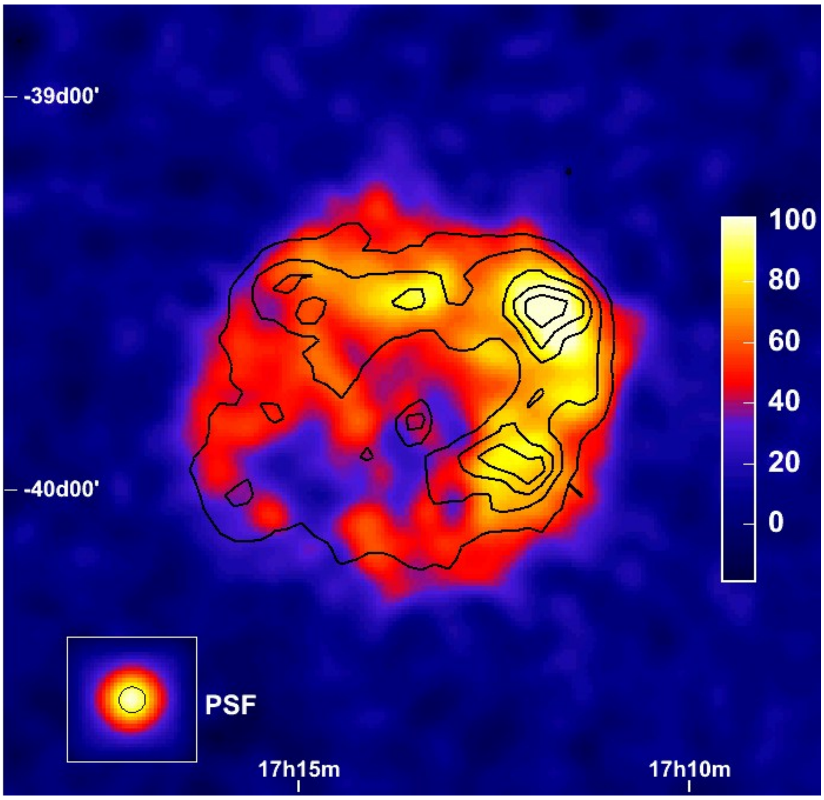

Figure 1. Gamma-ray excess image of RX J1713.7−3946. The superimposed, linearly spaced black contour lines show the X-ray surface brightness of RX J1713.7−3946 as measured by ASCA in the $1-3$ keV energy band [16]. In the lower left hand corner a simulated point source is shown as it would appear in this particular data set (taking the point spread function into account) along with a black circle of $2'$ radius denoting the σ of the Gaussian the image is smoothed with. The linear colour scale is in units of excess counts.

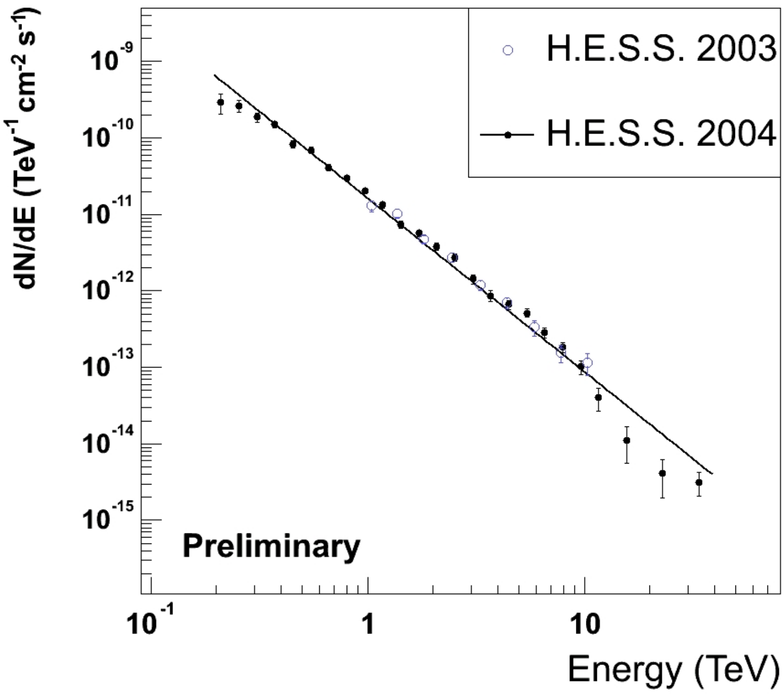

Figure 2. Preliminary differential gamma-ray energy spectrum of RX J1713.7−3946, for the whole region of the SNR. The best fit of a power law is plotted as black line. It seems that a pure power law doesn't describe the data appropriately, nevertheless, from the fit a photon index of $\Gamma = 2.27 \pm 0.02$ (statistical) is obtained in very good agreement with the 2003 data set plotted as blue open triangles [12]. Note the vast increase in energy coverage due to the increased sensitivity of the complete telescope array. The spectrum ranges now from 190 GeV to 40 TeV, spanning more than two decades in energy. Error bars are the $\pm 1\sigma$ errors.

3. Analysis Results

The pre-processing of the data, that is, the calibration, the event reconstruction and the event selection, applied here is described in detail in [13, 14]. Figure 1 shows a $2° \times 2°$ field of view around RX J1713.7−3946. A hard cut on the image size at 200 photo electrons was applied to obtain a superior resolution **for individual photons** of $0.08°$. The corresponding energy range is 300 GeV to 40 TeV. This image of RX J1713.7−3946 is within statistics in **good** agreement with the 2003 H.E.S.S. measurement shown for example in Fig. 1 of [12]. **There** is no evidence for time variability, as expected for an object of this size. **The overall gamma-ray appearance resembles a shell morphology with bright emission regions in the west and northwest part where the SNR is believed to impact molecular clouds [15]. It is worth noting that there is a possible gamma-ray void in the central-southeast region.** The cumulative significance for the whole SNR is about 40σ with these hard cuts which corresponds to an excess of 7400 events from the region of RX J1713.7−3946.

The **preliminary** spectrum of the whole SNR is shown in Figure 2. The data **are** in excellent agreement with the previous measurement in 2003, which covered the energy range from 1 TeV to 10 TeV. The latest data spans more than two orders of magnitude in energy, it ranges from 190 GeV to 40 TeV. There are indications for a deviation of the data from a pure power law at energies around 10 TeV. However, given the **cumulative** significance of about 6σ at energies above 10 TeV (**with the last four bins of the spectrum being below** 3σ **each**), no strong conclusion can be drawn from that. ***Statement, that more data is required, was dropped***.

4. Summary

First results from H.E.S.S. re-observations of the shell-type SNR RX J1713.7−3946 were presented here. The gamma-ray morphology of this source was resolved with high precision revealing a shell-like structure with increased emission from the western part. **The obtained gamma-ray image** resembles very much the picture available from X-ray measurements, however at photon energies some nine orders of magnitude higher. The spectrum of the source appears rather hard and extends over more than two orders of magnitude. It implies energies of 100 TeV and beyond for the parent particle population. ***Dropped sentence 'Further analysis of the data set is underway and will be published in the near future.'***

5. Acknowledgements

The support of the Namibian authorities and of the University of Namibia in facilitating the construction and operation of H.E.S.S. is gratefully acknowledged, as is the support by the German Ministry for Education and Research (BMBF), the Max Planck Society, the French Ministry for Research, the CNRS-IN2P3 and the Astroparticle Interdisciplinary Programme of the CNRS, the U.K. Particle Physics and Astronomy Research Council (PPARC), the IPNP of the Charles University, the South African Department of Science and Technology and National Research Foundation, and by the University of Namibia. We appreciate the excellent work of the technical support staff in Berlin, Durham, Hamburg, Heidelberg, Palaiseau, Paris, Saclay, and in Namibia in the construction and operation of the equipment.

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