Astrophys Space Sci (2007) 309: 379–384
DOI 10.1007/s10509-007-9446-3

ORIGINAL ARTICLE

Morphological and spectral studies of the shell-type supernova remnants RX J1713.7–3946 and RX J0852.0–4622 with H.E.S.S.

M. Lemoine-Goumard · F. Aharonian · D. Berge · B. Degrange · D. Hauser · N. Komin · O. Reimer · U. Schwanke

Received: 5 September 2006 / Accepted: 4 October 2006 / Published online: 18 April 2007

Abstract In 2004 and 2005, the shell-type supernova remnants RX J1713.7–3946 and RX J0852.0–4622 were observed and detected with the complete H.E.S.S. array, a system of four Imaging Cherenkov Telescopes located in Namibia and dedicated to the observations of γ-rays above 100 GeV. The energy spectra of these two sources have been measured over a wide energy range and revealed an integral flux above 1 TeV similar to that of the Crab Nebula. Their morphologies were resolved with high accuracy with H.E.S.S. and exhibit a striking correlation with the X-ray images, thereby pioneering a technique of unambiguously identifying spatially extended γ-ray sources. The results of the observations will be presented. Similarities and differences between these two sources will be pointed out as well as possible implications.

Keywords RX J1713.7–3946 · RX J0852.0–4622 · Supernova remnants · H.E.S.S.

PACS 98.38.Mz · 07.85.-m · 95.55.Ka

M. Lemoine-Goumard, F. Aharonian, D. Berge, B. Degrange, D. Hauser, N. Komin, O. Reimer, U. Schwanke for the H.E.S.S. Collaboration

M. Lemoine-Goumard (✉) · B. Degrange
Laboratoire Leprince-Ringuet, Ecole Polytechnique, 91128 Palaiseau Cedex, France
e-mail: lemoine@poly.in2p3.fr

F. Aharonian · D. Hauser
Max-Planck-Institut fur Kernphysik, 69117 Heidelberg, Germany

D. Berge
PH Department, CERN, CH-1211 Geneva 23, Switzerland

N. Komin
LPTA, Université Montpellier II, 34095 Montpellier, France

O. Reimer
W.W. Hansen Experimental Physics Laboratory, Stanford University, Stanford, CA 94305-4085, USA

U. Schwanke
Institut fur Physik, Humboldt Universitat zu Berlin, 10099 Berlin, Germany

1 Introduction

Shell-type supernova remnants (SNR) are widely believed to be the prime candidates for accelerating cosmic rays up to 10^{15} eV, but until recently, this statement was only supported by indirect evidence, namely non-thermal X-ray emission interpreted as synchrotron radiation from very high energy electrons from a few objects. A more direct proof is provided by the detection of very high energy γ-rays, produced in nucleonic interactions with ambient matter or by inverse Compton scattering of accelerated electrons off ambient photons.

Here, we present recent data on RX J1713.7–3946 and RX J0852.0–4622 obtained with H.E.S.S. in 2004 and 2005. With a diameter of 1° and 2° respectively, these two sources are the first SNRs ever resolved in TeV γ-rays.

2 The H.E.S.S. detector and the analysis technique

H.E.S.S. is an array of four 13 m diameter imaging Cherenkov telescopes located in the Khomas Highlands in Namibia, 1800 m above sea level (Hinton 2004). Each telescope has a tesselated mirror with an area of 107 m^2 (Bernlöhr et al. 2003) and is equipped with a camera comprising 960 photomultipliers (Vincent et al. 2003) covering a field of view of 5° diameter. Due to the powerful rejection of hadronic showers provided by stereoscopy, the complete system (operational since December 2003) can detect point sources at flux levels of about 1% of the Crab nebula flux near zenith with a significance of 5 σ in 25 hours of observation. This high sensitivity, the angular resolution of a few arc minutes and the large field of view make H.E.S.S. ideally suited for the study of the γ-ray morphology of extended sources. During the observations, an array level hardware trigger required each shower to be observed by at least two telescopes within a coincidence window of 60 ns (Funk 2004). The data were recorded in runs of typical 28 minute duration in the so-called "wobble mode", where the source is offset from the center of the field of view, and were calibrated as described in detail in Aharonian et al. (2004a). In a first stage, a standard image cleaning was applied to shower images to remove the pollution due to the night sky background. Several independent analysis methods are used in the H.E.S.S. Collaboration (de Naurois 2005) to cross-check all results. The results presented in this paper were obtained both using a 3D-modeling of the light-emitting region of an electromagnetic air shower, a method referred to as "the 3D-model analysis" (Lemoine-Goumard et al. 2006), and the standard H.E.S.S. stereoscopic analysis based on the Hillas parameters of showers images. For the generation of the excess skymaps, two different methods of background subtraction have been applied. The first one is classic and was applied with the standard analysis method: the background level is estimated from OFF-source runs, observing sky regions without any γ-ray sources in the field of view (Aharonian et al. 2006). All events passing the γ-ray cuts of the different analysis methods, i.e γ-ray like background events, are used to estimate the background. The second method of background subtraction, called the "Weighting Method" (Lemoine-Goumard and Degrange 2005), is more recent and was applied with the 3D-Model. In this method, the signal and the background are estimated simultaneously in the same portion of the sky. In each sky bin (treated independently), the signal and the background are estimated from those events originating from this bin exclusively; this is done by means of a likelihood fit in which each event is characterized by a discriminating parameter whose distribution is fairly different for γ-rays and hadrons. In the case of the 3D-Model, this discriminating parameter is the 3D-width of the electromagnetic shower.

3 RX J1713.7–3946

3.1 H.E.S.S. results

RX J1713.7–3946, a shell-type SNR located in the Galactic Plane, was discovered in the ROSAT all-sky survey in

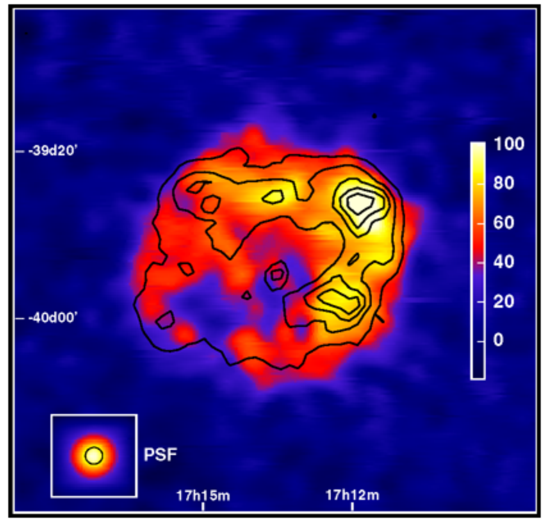

Fig. 1 Gamma-ray excess map of RX J1713.7–3946 using the whole 2004 data set, obtained with the standard analysis method. The image is smoothed with a Gaussian of 2 arcmin standard deviation, the linear colour scale is in units of excess counts. The *black lines* are the contours of the X-ray data from ASCA in the 1–3 keV energy band. In the lower left hand corner a simulated point source is shown as it would appear in this data set

1996 (Pfeffermann and Aschenbach 1996). In X-rays, the shell has a slightly elliptical shape with a maximum extent of 70′, but remarkably the X-ray spectrum is completely dominated by a non-thermal continuum with no detectable line emission. Recent CO measurements (Moriguchi et al. 2005) suggest that the supernova blast wave is expanding on the Western side into dense molecular clouds which makes this source an ideal site for the production of very high energy γ-rays by inelastic interactions of high energy protons with matter. In 2003, with a partial H.E.S.S. setup, observations of the SNR RX J1713.7–3946 were performed yielding the first ever resolved TeV γ-ray image of an astronomical object (Aharonian et al. 2004b). The image shown in Fig. 1, obtained with the standard analysis method from the 2004 data set (corresponding to 33 hours live time), confirms the previous measurement. The shell of the remnant is resolved and the correlation between X-rays and TeV is higher than 70%. The energy spectrum (Fig. 2) extends over more than two orders of magnitude, from 190 GeV up to 40 TeV, with a photon index of $2.26 \pm 0.02_{stat} \pm 0.15_{syst}$ obtained from a fit of a power law hypothesis to the data. Above 10 TeV, an indication of deviation can be noticed, but more data would be needed to draw some strong conclusions about the shape of the spectrum at high energy. The extension of the γ-ray spectrum to energies beyond 40 TeV implies an efficient acceleration of charged particles to energies of 100 TeV. The large data set has also allowed for a spatially resolved spectral study. No significant variation in the γ-ray spectral shape over the SNR region is found which is a remarkable difference with the results obtained by

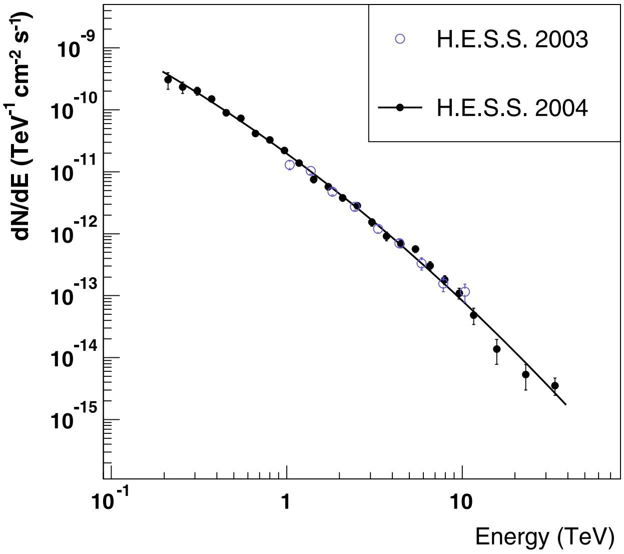

Fig. 2 Differential γ-ray energy spectrum of RX J1713.7–3946, for the whole SNR, obtained with the standard analysis method. The best fit of a power law with energy dependent photon index is plotted as *black line*. For comparison the H.E.S.S. 2003 data points are also shown (*blue open circles*). The spectrum ranges from 190 GeV to 40 TeV. *Error bars* are the 1 sigma statistical errors

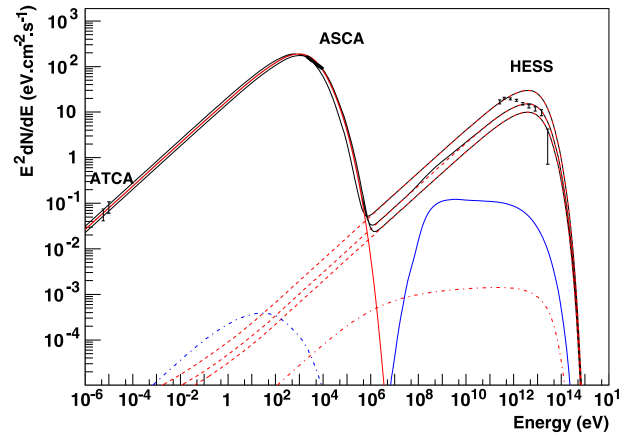

Fig. 3 Broadband SED of RX J1713.7–3946 in the case of a leptonic process. The ATCA radio data and ASCA X-ray data for the whole SNR are indicated along with the H.E.S.S. measurement obtained with the 3D-Model. Note that the radio flux was determined by Lazendic et al. (2004) for the North-Western part of the remnant and was scaled up by a factor 2 here to account for the whole SNR. The energy distribution of the primary particles follows a power law with a spectral index of 2.0 with an exponential cut-off at 80 TeV. Three different values of magnetic field are used: 6 μG, 8 μG and 10 μG. The *red lines* correspond to electrons, and *blue lines* to protons. The following processes were taken into account: synchrotron radiation of primary electrons (*red straight line*) and of secondary electrons (*blue dotted line*), IC scattering (*red dotted line*), bremsstrahlung (*red dotted-dashed line*) and proton–proton interaction (*blue straight line*)

using the X-ray data of the XMM-Newton satellite (Cassam-Chenaï et al. 2004). Indeed, Cassam-Chenaï et al. observed that the X-ray spectrum is steeper in the presumed shock front in the West, where the blast wave probably impacts the molecular clouds, than in the South-East where the front propagates into a low density medium.

3.2 Possible emission processes

One of the key issues in the interpretation of the signal observed with H.E.S.S. is the identification of the primary particle population responsible for the production of the γ-rays. As seen above, there is a striking correlation between the ASCA X-ray and the H.E.S.S. γ-ray data. At first sight this supports the idea that X-rays and γ-rays are produced by the same particle population, namely electrons. But, on the other hand, it is really difficult to explain why the spectral shape in X-rays changes significantly in distinct regions of the remnant but not in γ-rays, if they stem from the same particle population. In order to show that an electronic scenario is able to reproduce the multi-wavelength data (from radio to γ-rays) with plausible input parameters, a simple one-zone model is used. It is assumed that the primary particles spectrum follows a power law with an exponential cut-off. The energy distribution of the electrons is then calculated taking into account energy losses due to Inverse Compton and synchrotron emission, Bremsstrahlung as well as losses due to Bohm diffusion. However, this scenario presented in Fig. 3 hardly reproduces the radio, X-ray and γ-ray data simultaneously. First, the magnetic field required to explain both the X-ray and the γ-ray flux is extremely low (∼8 μG) and is difficult to reconcile with the paradigm of the diffusive shock acceleration of cosmic rays at supernova shock waves which predicts strong field amplifications in the region of the shock. Then, one notes that such a model does not provide a reasonable description of the H.E.S.S. data, as the Inverse Compton peak appears too narrow to reproduce the flat TeV emission.[1] Assuming alternatively that nuclear cosmic-ray particles, accelerated at the SNR shock, dominantly produce VHE γ-rays, a reasonable match to the data is readily achieved as can be seen in Fig. 4. The best fit is obtained by using a magnetic field of 35 μG, an energy injected into protons of 10^{50} erg and a density of 1.5 cm^{-3}. This high density is disfavoured by the limit implied by the absence of thermal X-rays, unless the explosion occurred inside a bubble created by the stellar wind of the massive star. Furthermore, one should note that if the shock is strongly modified by the accelerated particles, the shock heating is substantially reduced and the XMM-Newton data would be compatible with higher densities.

[1] It should be noted however that a recent work by Porter et al. (2006) shows that an additional contribution of optical and infra-red photons to inverse-Compton emission can broaden the γ-ray spectrum and could reproduce the multi-wavelength data on RX J1713.7–3946 by still using a low magnetic field.

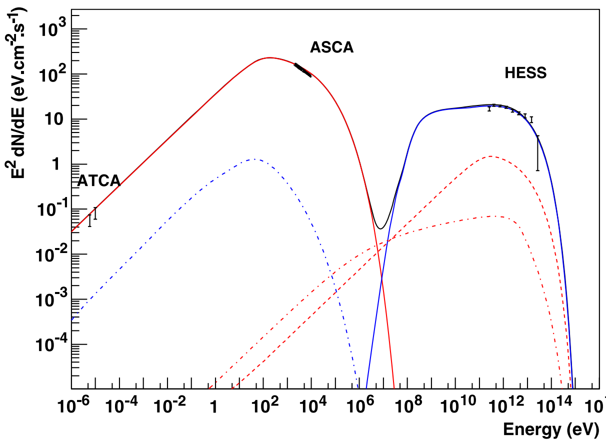

Fig. 4 Broadband SED of RX J1713.7–3946 in the case of a hadronic process. The ATCA radio data and ASCA X-ray data for the whole SNR are indicated along with the H.E.S.S. measurement obtained with the 3D-Model. Note that the radio flux was determined by Lazendic et al. (2004) for the North-Western part of the remnant and was scaled up by a factor 2 here to account for the whole SNR. The energy distribution of the primary particles follows a power law of index 2.0 with an exponential cut-off at 120 TeV. The magnetic field is 35 μG while the density of the medium is 1.5 cm^{-3}. The *red lines* correspond to the electrons, and *blue lines* to the protons. The following processes were taken into account: synchrotron radiation of primary electrons (*red straight line*) and of secondary electrons (*blue dotted line*), IC scattering (*red dotted line*), bremsstrahlung (*red dotted-dashed line*) and proton–proton interaction (*blue straight line*)

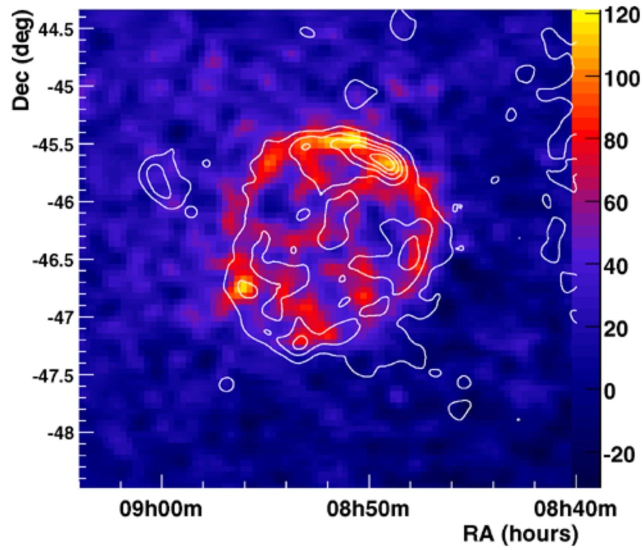

Fig. 5 Excess skymap of RX J0852.0–4622 smoothed with a Gaussian of 0.06° standard deviation, obtained with the 3D-Model. The white lines are the contours of the X-ray data from the ROSAT All Sky Survey for energies higher than 1.3 keV (smoothed with a Gaussian of 0.06° standard deviation to enable direct comparison of the two images)

4 RX J0852.0–4622 (Vela Junior)

4.1 H.E.S.S. results

RX J0852.0–4622 is a second shell-type SNR discovered in the ROSAT all-sky survey whose X-ray emission is mostly non-thermal (Aschenbach 1998). Indeed, up to now no thermal X-rays were detected from this source, which could imply a limit on the density of the material in the remnant $n_0 < 2.9 \times 10^{-2} (D/1\ \text{kpc})^{-1/2} f^{-1/2}\,\text{cm}^{-3}$, where f is the filling factor of a sphere taken as the emitting volume in the region chosen (Slane et al. 2001). The X-ray non-thermal spectrum of the whole remnant in the 2–10 keV energy band is well described by a power law with a spectral index of 2.7 ± 0.2 and a flux $F_X = 13.8 \times 10^{-11}\,\text{erg}\,\text{cm}^{-2}\,\text{s}^{-1}$ (Hiraga et al. 2006). In the TeV range, the announcement of a signal from the North-Western part of the remnant by CANGAROO was rapidly followed by the publication of a complete γ-ray map by H.E.S.S. obtained from a short period of observation (3.2 hours) (Aharonian et al. 2005). The study of this source is really complex due to several points: its extension (2° diameter), its location at the South-Eastern corner of the Vela remnant and the uncertainty on its distance and age. Indeed, RX J0852.0–4622 could be as close as Vela (∼250 pc) and possibly in interaction with Vela, or as far as the Vela Molecular Ridge (∼1 kpc).

Figure 5 presents the γ-ray image of RX J0852.0–4622 obtained with the 3D-Model from a long observation in 2005 (corresponding to 20 hours live time). The morphology appearing from this skymap reveals a very thin shell of 1° radius and thickness smaller than 0.22°. Another interesting feature is the remarkably circular shape of this shell, even if the Southern part shows a more diffuse emission. Keeping all events inside a radius of 1° radius around the center of the remnant, the cumulative significance is about 19σ and the cumulative excess is ∼5200 events. The overall γ-ray morphology seems to be similar to the one seen in the X-ray band, especially in the Northern part of the remnant where a brightening is seen in both wavebands. The correlation coefficient between the γ-ray counts and the X-ray counts in bins of 0.2° × 0.2° is found to be equal to 0.60 and comprised between 0.54 and 0.67 at 95% confidence level. The differential energy spectrum (Fig. 6) extends from 300 GeV up to 20 TeV. The spectral parameters were obtained from a maximum likelihood fit of a power law hypothesis $dN/dE = N_0 (E/1\ \text{TeV})^{-\Gamma}$ to the data, resulting in an integral flux above 1 TeV of $(15.2 \pm 0.7_{\text{stat}} \pm 3.20_{\text{syst}}) \times 10^{-12}\ \text{cm}^{-2}\,\text{s}^{-1}$ and a spectral index of $2.24 \pm 0.04_{\text{stat}} \pm 0.15_{\text{syst}}$. As in the case of RX J1713.7–3946, an indication of curvature at high energy can be noticed. No spatially resolved spectral analysis could be done for this source due to the limited statistics in each region, but the overall radial profiles were compared in two distinct energy bands showing that the morphology does not change significantly with energy. Therefore, one does not expect a significant variation of the spectral shape across the remnant.

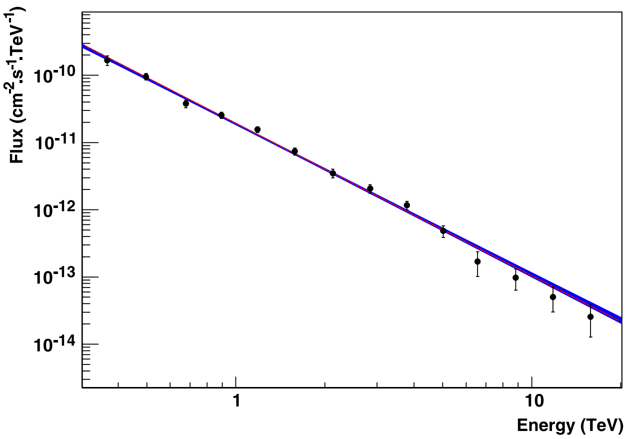

Fig. 6 Differential energy spectrum of RX J0852.0–4622, for the whole region of the SNR. The shaded area gives the 1σ confidence region for the spectral shape under the assumption of a power law. The spectrum ranges from 300 GeV to 20 TeV

4.2 Emission processes

As in the case of RX J1713.7–3946, one of the key issues is the interpretation of the γ-ray signal in terms of an electronic or a hadronic scenario. Despite the large uncertainty on the distance and age of the remnant, the multi-wavelength data already give some strong constraints. In a leptonic scenario, where γ-rays are produced by Inverse Compton scattering of high energy electrons off ambient photons, the ratio of the X-ray flux and the γ-ray flux determines the magnetic field to be close to 7 µG. This value is completely independent of the distance and only assumes a filling factor (fraction of the Inverse Compton emitting electrons containing the magnetic field responsible for the synchrotron emission) of 1; this low magnetic field seems hardly compatible with the amplification suggested by the thin filaments resolved by Chandra (Bamba et al. 2005). In the nearby case ($\sim$200 pc), the limit on the width of the shell ΔR obtained by the morphological analysis of the H.E.S.S. data is $\Delta R < 0.7$ pc, which leads to an escape time by diffusion and by convection lower than both the age of the remnant and the synchrotron cooling time for energies higher than $\sim$10 TeV. Therefore, one would expect to see a variation of the width of the shell with the energy, which is not observed by H.E.S.S. and disfavours the electronic scenario at this distance. In a hadronic scenario, in which we assume that the measured differential γ-ray spectrum $\phi(E)$ is entirely due to proton–proton interactions, one can estimate the total energy in accelerated protons in the range 10–100 TeV required to produce the γ-ray luminosity observed by H.E.S.S.:

$$L_\gamma(1-10\text{ TeV}) = 4\pi D^2 \int_{1\,\text{TeV}}^{10\,\text{TeV}} E\phi(E)dE$$
$$= 2.6\times 10^{32}\left(\frac{D}{200\,\text{pc}}\right)^2 \text{erg}\,\text{s}^{-1}$$

In this energy range, the characteristic cooling time of protons through the π^0 production channel is approximately independent of the energy and can be estimated to be: $\tau_\gamma = 4.4\times 10^{15}(\frac{n}{1\text{ cm}^{-3}})^{-1}$. Thus:

$$W_p(10-100\text{ TeV}) \approx L_\gamma \times \tau_\gamma \approx 1.1\times 10^{48}\left(\frac{D}{200\,\text{pc}}\right)^2\left(\frac{n}{1\,\text{cm}^{-3}}\right)^{-1}\text{erg}$$

Assuming that the proton spectrum continues down to $E \approx$ 1 GeV with the same spectral slope as that of the photon spectrum, the total energy injected into protons is estimated to be:

$$W_p^{\text{tot}} \approx 10^{49}\left(\frac{D}{200\,\text{pc}}\right)^2\left(\frac{n}{1\,\text{cm}^{-3}}\right)^{-1}\text{erg}$$

Therefore, for densities compatible with the absence of thermal X-rays, the only way to explain the entire γ-ray flux by proton-proton interactions in a homogeneous medium is to assume that RX J0852.0–4622 is a nearby supernova remnant ($D < 600$ pc). Indeed, for larger distances and a typical energy of the supernova explosion of 10^{51} erg, the acceleration efficiency would be excessive. Nevertheless, a distance of 1 kpc should also be considered if one assume that RX J0852.0–4622 is the result of a core collapse supernova which exploded inside a bubble created by the wind of a massive progenitor star (Berezhko and Völk 2006). According to stellar wind theory, the size of the bubble evolves according to the formula: $R = 45(\frac{n_0}{1\,\text{cm}^{-3}})^{-0.2}$ pc. For a density of 1 cm^{-3}, the radius of this bubble would be equal to 45 pc. In the case of a close supernova remnant, its size would be significantly lower than the size of the bubble and the hypothesis of a homogeneous medium would be satisfactory. In the opposite, for larger distances ($D \sim 1$ kpc), the presence of the Vela Molecular Ridge can produce a sudden increase of the density leading to a smaller bubble (15.6 pc for a density of $200\,\text{cm}^{-3}$), which would make the proton-proton interactions efficient at the outer shock.

5 Summary

We have firmly established that the shell-type supernova remnants RX J1713.7–3946 and RX J0852.0–4622 are TeV emitters and for the first time we have resolved their morphologies in the γ-ray range. For both sources, the shell observed with H.E.S.S. is highly correlated with the emission observed in X-rays. Their overall γ-ray energy spectrum extends over two orders of magnitude, providing the direct proof that particles of $\sim$100 TeV are accelerated at the shock. It is remarkable to note that these spectra are extremely similar although the morphology of the two supernova remnants are very different with a much thicker shell in the case of RX J1713.7–3946.

The question of the nature of the particles producing the γ-ray signal observed by H.E.S.S. was also addressed. In the case of RX J1713.7–3946, the proton scenario seems favoured because of the shape of the γ-ray spectrum, and the absence of significant variation of the γ-ray spectral index across the remnant. Nevertheless, this scenario would require either a density of $\sim 1.5\ \mathrm{cm}^{-3}$ (disfavoured by the absence of thermal X-rays) or a "bubble scenario" in which the explosion of the supernova occurred inside a bubble created by the massive progenitor. In the case of RX J0852.0–4622, whose distance and age are still rather uncertain, the H.E.S.S. data already give some constraints. In the case of a close remnant, the results of the morphological study combined with our spectral modeling highly disfavour the leptonic scenario which is unable to reproduce the thin shell observed by H.E.S.S. and the thin filaments resolved by Chandra. In the case of a medium distance, the explosion energy needed to explain the γ-ray flux observed by H.E.S.S., taking into account the limit on the density implied by the absence of thermal X-rays, would highly disfavour the hadronic process. At larger distances, both the leptonic and the hadronic scenario are possible, at the expense, for the leptonic process, of a low magnetic field of $\approx 7\ \mu\mathrm{G}$. Such a small magnetic field exceeds typical interstellar values only slightly and is difficult to reconcile with the theory of magnetic field amplification at the region of the shock.

Finally, it appears clearly from Figs. 3 and 4, that the flux expected for lower energy γ-rays ($E < 200$ GeV) for the leptonic process (synchrotron + IC scattering) or for the hadronic process (proton–proton interactions) are significantly different. The results which should hopefully be obtained by GLAST or H.E.S.S. II will therefore have a great interest for the domain.

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.

References

Aharonian, F., et al. (H.E.S.S. Collaboration): Calibration of cameras of the H.E.S.S. detector. Astropart. Phys. **22**, 109 (2004a)

Aharonian, F., et al. (H.E.S.S. Collaboration): High-energy particle acceleration in the shell of a supernova remnant. Nature **432**, 75 (2004b)

Aharonian, F., et al. (H.E.S.S. Collaboration): Detection of TeV γ-ray emission from the shell-type supernova remnant RX J0852.0-4622 with H.E.S.S. Astron. Astrophys. **437**, L7 (2005)

Aharonian, F., et al. (H.E.S.S. Collaboration): A detailed spectral and morphological study of the gamma-ray supernova remnant RX J1713.7-3946 with H.E.S.S. Astron. Astrophys. **449**, 223 (2006)

Aschenbach, B.: Discovery of a young nearby supernova remnant. Nature **396**, 141 (1998)

Bamba, A., Yamazaki, R., Hiraga, J.S.: Chandra observations of galactic supernova remnant Vela Jr.: a new sample of thin filaments emitting synchrotron X-rays. Astrophys. J. **632**, 294 (2005)

Berezhko, E.G., Völk, H.J.: Theory of cosmic ray production in the supernova remnant RX J1713.7-3946. Astron. Astrophys. **451**, 981 (2006)

Bernlöhr, K., et al.: The optical system of the H.E.S.S. imaging atmospheric Cherenkov telescopes. Astropart. Phys. **20**, 111 (2003)

Cassam-Chenaï, G., Decourchelle, A., Ballet, J., et al.: XMM-Newton observations of the supernova remnant RX J1713.7-3946 and its central source. Astron. Astrophys. **427**, 199 (2004)

de Naurois, M.: In: Proceedings of the "Towards a Network of Atmospheric Cherenkov Detectors VII" (2005)

Funk, S.: The trigger system of the H.E.S.S. telescope array. Astropart. Phys. **22**, 285 (2004)

Hinton, J.A.: The status of the H.E.S.S. project. New Astron. Rev. **48**, 331 (2004)

Hiraga, J., et al.: 2006, private communication

Lazendic, J.S., Slane, P.O., Gaensler, B.M., et al.: A high-resolution study of nonthermal radio and X-ray emission from supernova remnant G347.3-0.5. Astrophys. J. **602**, 271 (2004)

Lemoine-Goumard, M., Degrange, B.: A new method of background subtraction adapted to the study of extended sources. In: Proceedings of "Towards a Network of Atmospheric Cherenkov Detectors VII" (2005)

Lemoine-Goumard, M., Degrange, B., Tluczykont, M.: Selection and 3D-reconstruction of gamma-ray-induced air showers with a stereoscopic system of atmospheric Cherenkov telescopes. Astropart. Phys. **25**, 195 (2006)

Moriguchi, Y., Tamura, K., Tawara, Y., et al.: A detailed study of molecular clouds toward the TeV gamma-ray supernova remnant G347.3-0.5. Astrophys. J. **631**, 947 (2005)

Pfeffermann, E., Aschenbach, B.: ROSAT Observation of a New Supernova Remnant in the Constellation Scorpius, Report 263, MPE, Garching (1996)

Porter, T.A., Moskalenko, I.V., Strong, A.W.: Inverse compton emission from galactic supernova remnants: effect of the interstellar radiation field. Astrophys. J. Lett. **648**, 29 (2006)

Slane, P., et al.: RX J0852.0-4622: Another nonthermal shell-type supernova remnant (G266.2-1.2). Astrophys. J. **548**, 614 (2001)

Vincent, P., et al.: Performance of the H.E.S.S. cameras. In: Kajita T., et al.(eds.) Proceedings of the 28th International Cosmic Ray Conference, p. 2887. Universal Academy Press, Tokyo (2003)