

Study of Galactic Sources with H.E.S.S.

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Abstract. The H.E.S.S. imaging air Cherenkov telescope array has performed a blind survey at energies above 100 GeV of parts of the Galactic plane as well as dedicated (deeper) observations of gamma-ray source candidates. New sources including shell type super-nova remnants, pulsar-wind nebulae, binary systems, cosmic ray illuminated molecular clouds, as well as unidentified sources have been found. In this contribution, a selected overview of the recent results focussing on shell type supernova remnants and pulsar wind nebulae is given.

1. Introduction

The High Energy Stereoscopic System (H.E.S.S.) is an array of four imaging air Cherenkov telescopes located in the Khomas Highlands in Namibia. For more details on the system design and performance, see e.g. Horns et al. (these Proceedings). In the following sections, a brief summary of recent H.E.S.S. results obtained on shell type supernova remnants and pulsar wind nebulae is given. For a review of the recent results of H.E.S.S. observations of extra-galactic sources see e.g. Giebels et al. (these proceedings).

2. Shell type Supernova remnants

The H.E.S.S. telescopes have been used to observe SNRs showing non-thermal X-ray emission which indicates the presence of synchrotron emitting electrons. In case of accelerated protons, gamma-ray (and neutrino) emission can be expected from inelastic scattering processes and subsequent decay of mesons.

If roughly 10 % of the kinetic energy of the expanding SNR shell is converted into charged cosmic rays, the resulting gamma-ray emission of nearby SNRs should be detectable for the H.E.S.S. experiment [1].

2.1. SN 1006

The historical SN 1006 has not been detected during the initial observations with H.E.S.S. and therefore an upper limit of the flux was derived [2]. The limit on gamma-ray luminosity of $L_{0.26-10 \text{ TeV}} < 1.7 \times 10^{33} \text{ erg/s}$ for a distance of 2 kpc corresponds to an upper limit on the total energy in protons present in the remnant of $W_p(1.5-60 \text{ TeV}) < 1.6 \times 10^{50} (n/(0.05 \text{ cm}^{-3}))^{-1} \text{ erg}$. Deeper observations are currently carried out in order to search for gamma-ray emission from this well-studied system (see e.g. [3]).

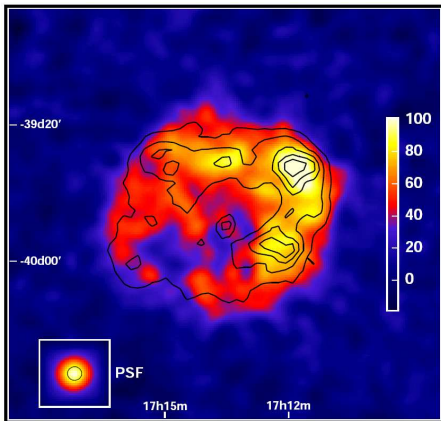


Figure 1. The smoothed (2 arcmin) gamma-ray excess map of RXJ 1713.7-3946 in color scale, the contours indicate the ASCA X-ray map.

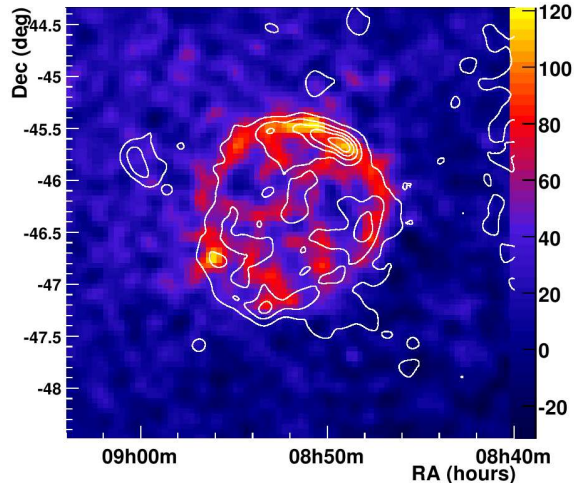


Figure 2. The smoothed (3.6 arcmin) gamma-ray excess map of RXJ 1713.7-3946 in color scale, the white contours indicate the ROSAT X-ray map in the high energy band smoothed to the same angular scale as the H.E.S.S. data.

2.2. RXJ 1713.7-3946

This SNR was initially discovered in X-rays [4] while it is a very faint radio source [5]. In gamma-rays, it is one of the brightest objects found in the Galactic plane. Evidence for gamma-ray emission from this object was first claimed by the CANGAROO collaboration [6]. H.E.S.S. observations of the extended (1° diameter) SNR RX J1713.7-3946 allowed for the first time to spatially resolve an object at very high energy gamma-rays [7]. With deeper H.E.S.S. observations (33 hrs of on-source data), spatially resolved spectroscopy of the remnant has become possible [8] showing that the emitted spectrum does not vary across the extension of the remnant. A spatially averaged energy spectrum is determined up to 40 TeV which exhibits a curvature consistent with an exponential cut-off at 12 ± 2 TeV.

The morphology observed in gamma-rays is very similar to the one observed at X-ray energies. The gamma-ray image (see Fig. 1) shows a clear rim-like feature with a pronounced brightening in the north-west. The shell-type emission appears to be quite wide: A simplified model of a geometry of the gamma-ray emitting shell indicates that the relative thickness of the emitting rim should be $\Delta R/R \approx 0.55$ in order to match the observed morphology.

Unfortunately, neither the distance nor the age of the remnant are known accurately. The most recent estimates based upon the column density determined from X-ray spectroscopy assume a distance of 1 kpc. Assuming this distance, the observed gamma-ray luminosity in the energy range from 0.2 to 40 TeV translates into total energy of protons of $W_p(2 - 400 \text{ TeV}) = 6 \times 10^{49} \text{ erg } (n/1 \text{ cm}^{-3})^{-1}$. A hadronic origin of the observed gamma-ray emission appears to be a natural explanation and well within the energy budget of the kinetic energy released in the expanding shell. However, alternative explanations in a leptonic scenario are currently not excluded (see also [8, 13] for a discussion of the possible model scenarios).

2.3. RXJ 0852.0-4622 (“Vela Jr”)

Quite similar to RX J1713.7-3946, “Vela Jr” was discovered as a bright and extended (diameter of 2°) X-ray source [9]. The distance is constrained to be in the range of 200–400 pc (see

discussions e.g. in [10]). Indications for gamma-ray emission from the northwestern rim of the remnant were first reported by the CANGAROO collaboration [11]. Gamma-ray emission from the entire rim was found already after a short observation (3.2 hrs) with the H.E.S.S. telescopes [12]. Deeper observations of 20 hrs have been carried out with H.E.S.S. in 2005 and have been reported recently [13].

When considering images accumulated in distinct energy intervals, the source morphology does not change. A spatially averaged energy spectrum appears very similar in shape and normalization to the energy spectrum obtained from RXJ 1713.7-3946. The morphology (see Fig. 2) is again very similar to the one observed in the X-ray band. The gamma-ray image indicates the presence of a shell type emission structure which is remarkably narrow in comparison to the one observed from RXJ 1713.7-3946. A simple model for the geometry of the emission region leads to the conclusion that the relative width of the emitting shell is less than 20 % of the radius of the source (corresponds to $\Delta R < 0.7$ pc at 250 pc distance).

Again, the observations can be naturally accounted for by cosmic ray interactions with a similar value of the total energy of protons (W_p) as in the case of RXJ 1713.7-3946 (see above). However, a leptonic origin can not be ruled out. The detection of neutrinos from these sources would be decisive for the understanding of the origin of gamma-rays.

3. Pulsar wind nebulae and composite systems

The ongoing survey of the inner part of the Galactic plane with the H.E.S.S. telescopes [14, 15] has revealed a number of sources which are not directly associated with obvious counterpart candidates. Even though possible candidates appear to be close to the gamma-ray source, quite often they neither match the source position nor the spatial extension. While the identification of these sources is still ongoing (see e.g. [16]), pulsar wind nebulae (PWN) appear to be good candidates for the association of some of the gamma-ray sources even for cases where there is an offset between the pulsar and the gamma-ray source position. The first example of such an “offset nebula” was found to be HESS J1825-137. This object was discovered in the blind survey of the Galactic plane [14] and later associated with the asymmetric X-ray pulsar-wind system G18.0-0.7 [17]. The asymmetry of the PWN is assumed to be the result of the interaction of the PWN with an asymmetric reverse shock [18].

Based upon the argument that the X-ray emission is produced by short lived energetic electrons while the gamma-rays are emitted by lower energy and longer lived electrons it is possible to explain the fact that the gamma-ray source is a factor of six larger than the X-ray emitting region [19]. Deeper observations with H.E.S.S. have revealed a significant softening of the gamma-ray spectrum with increasing distance to the pulsar position [20]: This observation strengthens the case for HESS J1825-137 to be an “offset” pulsar wind nebula.

The gamma-ray source associated with Vela X [21] seems at first glance quite similar, but both the energy spectrum and the multi-wavelength morphology are quite different from HESS J1825-137. More observations are required to probe possible spectral changes in the extended emission region.

Further examples of gamma-ray sources associated with pulsar wind nebulae include MSH 15-52 [22] which is again spatially extended with a featureless power-law type energy spectrum extending up to 40 TeV as well as the recently discovered gamma-ray emission from the northern wing of the “Kookaburra” [23].

In addition to the well-established associations of gamma-ray sources with pulsar wind nebula systems, a number of candidates have been found in a systematic search in the Galactic plane survey data [24].

Finally, composite objects which show both, a pulsar wind nebula and a shell type SNR have been discovered by H.E.S.S. The first example of a gamma-ray emitting composite source is G0.9+0.1 [25]. The spatial resolution of the H.E.S.S. telescopes is sufficient to discern that the

bulk of the gamma-ray emission is produced from the plerionic part of the system while there is no evidence for gamma-ray emission from the shell of the SNR. Further examples for gamma-ray sources which may be associated with composite systems are HESS J1634-472 (G337.2+0.1 [26]) and HESS J1834-087 (G23.3-0.3).

4. Summary

Only a small selection of focussed results on supernova remnants (shell type SNRs, pulsar wind nebulae, and composite systems) has been presented. More H.E.S.S. discoveries (not discussed here) including variable gamma-ray emission from high mass X-ray binary systems (PSR B1259-63, LS 5039) [27, 28], gamma-rays from the Galactic center [29] and neighboring molecular clouds [30], as well as the discovery of unidentified gamma-ray sources have dramatically changed our view of the very high energy gamma-ray sky.

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