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Morphological Studies of the PWN Candidate HESS J1809-193

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Abstract: The source HESS J1809−193 was discovered in 2006 in data of the Galactic Plane survey, followed by several re-observations. It shows a hard gamma-ray spectrum and the emission is clearly extended. Its vicinity to PSR J1809-1917, a high spin-down luminosity pulsar powerful enough to drive the observed gamma-ray emission, makes it a plausible candidate for a TeV Pulsar Wind Nebula (PWN). On the other hand, in this region of the sky a number of faint, radio-emitting supernova remnants can be found, making a firm conclusion on the source type difficult.

Here we present a detailed morphological study of recent H.E.S.S. data and compare the result with X-ray measurements taken with *Chandra* and radio data. The association with a PWN is likely, but contributions from supernova remnants cannot be ruled out.

Introduction

Since the beginning of observations with H.E.S.S. (High Energy Stereoscopic System) in 2003 the number of known TeV gamma-ray emitting sources has increased drastically. The ongoing scan of the Galactic plane revealed several bright and extended sources for which no clear association with objects in other wavelength could be found [1, 2].

Pulsars, rapidly rotating neutron stars, are widely believed to be able to accelerate particles up to PeV energies. Those objects loose their rotational energy in winds of relativistic particles. The confinement of the wind in the interaction with the ambient interstellar material forms shocks; the particles accelerated there are visible as a Pulsar Wind Nebula (PWN) (see [3] for a review). Synchrotron radiation seen in radio and X-rays prove the existence of relativistic electrons in the PWN. These electrons undergo inverse Compton (IC) scattering off ambient radiation fields, like the Cosmic Microwave Background, Galactic infrared background and optical star light, leading to the production of TeV gamma-rays.

Here we present the observation of one TeV source, HESS J1809−193, which is located close to a powerful pulsar and thus a good PWN candidate. X-ray emission from the direction of the pulsar support the theory of being a PWN. However, confusion with other sources cannot be ruled out.

TeV observations of HESS J1809−193

H.E.S.S. is a system of four Imaging Atmospheric Cherenkov telescopes (IACTs) dedicated to the observation of TeV gamma-rays. Its high sensitivity allows the detection of point sources with a flux of 1% of that of the Crab nebula within 25 h [4]. Its large field of view and an angular resolution of better than $0.1°$ makes it an ideal tool for observations of extended objects and for the conduction of sky surveys.

In the original Galactic plane survey conducted with H.E.S.S., TeV emission from

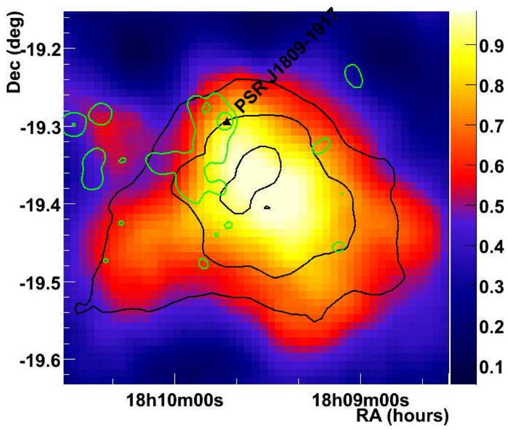

Figure 1: TeV gamma-ray excess counts from the direction of HESS J1809−193 (colour scale). The image is smoothed with the point-spread function. Overlaid are 5, 7 and 9 σ significance contours, oversampled with a circle with radius $0.1°$. The position of the pulsar is marked with a black triangle. The green contours denote the diffuse X-ray emission from Fig. 2.

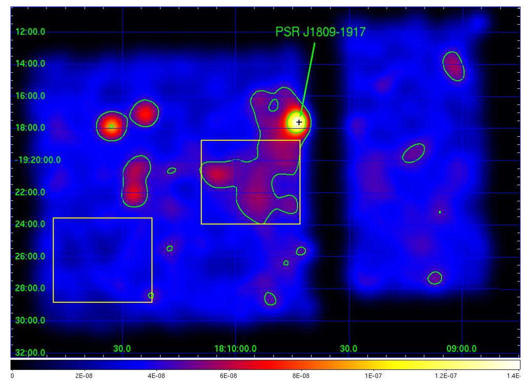

Figure 2: Chandra X-ray excess of the field of view of HESS J1809−193. The map is exposure-corrected and smoothed with a Gaussian with $32''$.

HESS J1809−193 was only marginally detected. Further re-observations confirmed the existence of gamma-ray emission [5]. Further observations were performed in autumn 2006; in total data with a live time of 32 h is available.

The gamma-ray excess map of the source HESS J1809−193 is shown in Fig. 1. The emission is clearly extended lying south-west of the pulsar. In addition faint emission can be seen to the south-east. In total, an excess of 3600 events with a significance of $19\,\sigma$ was detected. The source shows an energy spectrum consistent with a power law with an index of $2.2 \pm 0.1_{\rm stat} \pm 0.2_{\rm syst}$ and an energy flux between 1 and 10 TeV of roughly $1.3 \times 10^{-11}\,{\rm erg\,cm^{-2}\,s^{-1}}$ [5]. If this energy flux is projected to the distance of the pulsar, only 1.2% of the pulsar's spin down luminosity of $1.8 \times 10^{36}\,{\rm erg\,s^{-1}}$ is needed to power the H.E.S.S. source. Therefore it seems to be plausible that HESS J1809−193 is indeed a Pulsar Wind Nebula.

X-Ray Observations

In the data of the Galactic plane scan performed with the ASCA satellite diffuse emission was detected [6], which turned out to be coincident with the TeV source. The X-ray source $\mathrm{G}11.0 + 0.0$ has been discussed to be either a young shell-type supernova remnant (SNR) or a plerionic SNR.

High-resolution observations with the *Chandra* satellite revealed a compact X-ray nebula north of the pulsar and additional faint emission south [7]. Here we present *Chandra* data which was taken in February 2007 (ObsID 6720). Figure 2 shows the exposure-corrected and smoothed X-ray excess map. It shows a strong X-ray nebula, high resolution images show its extension to the north of the pulsar [7]. Further faint emission can be seen to the south.

The significance of the diffuse emission was tested by comparing the on-source region with an off-source region in the same field of view (these regions are indicated by the yellow rectangles in Fig. 2). Taking into account the small acceptance difference of 4% (estimated from the exposure map at 2 keV), the source region shows an excess of about 900 events with a statistical significance of $10\,\sigma$.

The contour of the diffuse X-ray emission is overlaid in the TeV excess map in Fig. 1. It should be noted that due to the gap between the chips of the X-ray detector and the different nature of the

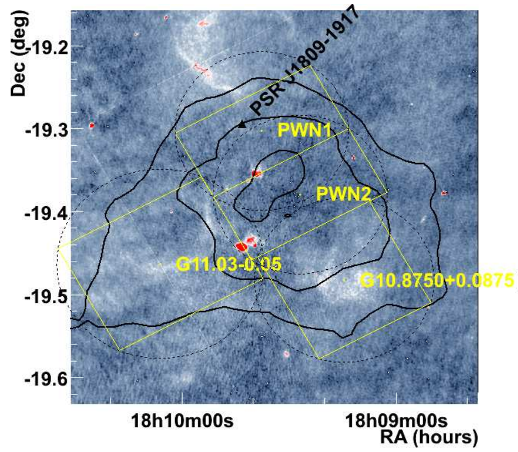

Figure 3: MAGPIS radio image. Overlaid are the 5, 7 and 9 σ H.E.S.S. significance contours. The yellow rectangles indicate the test regions for the spectral analysis of the H.E.S.S. data.

chips on the right hand side, no conclusions can be drawn on the existence of diffuse emission to the west. However, it can be seen that the X-ray nebula's extension to the south is far smaller than the extension of the TeV emission.

Radio Data of the Field of View

We compared the region of HESS J1809−193 with radio data of the Multi-Array Galactic Plane Imaging Survey [8] shown in Fig. 3. North of the pulsar is the SNR G$11.18 + 0.11$ [9, 10], not coincident with the H.E.S.S. excess. Located south-east of the pulsar and coincident with the H.E.S.S. excess is the SNR G$11.03 - 0.05$ [9, 10]. Further south-west of the pulsar is the supernova remnant candidate $10.8750 + 0.0875$ [8]. In the region between the latter two SNRs and the pulsar no diffuse radio emission can be found.

For a spectral analysis different regions according to the radio data have been chosen. Two regions for the SNRs G$11.03-0.05$ and $10.8750+0.0875$ and another two regions for the possible pulsar wind nebula (PWN1, PWN2). These regions are indicated in Fig. 3.

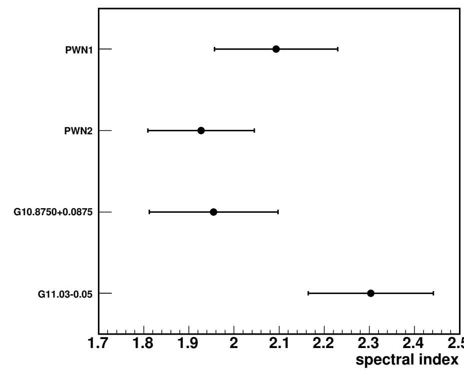

Figure 4: Spectral indices for the test regions indicated in Fig. 3.

Spectral Analysis

The TeV energy spectra of each region were fitted with a power law. The spectral indices are shown in Fig. 4. The regions PWN1, PWN2 and $10.8750 + 0.0875$ are with increasing distance to the pulsar. A steepening of the spectrum with increasing distance would be a clear indication for a PWN (see [11]). A significant different energy spectrum between the region of the SNR G$11.03 - 0.05$ and the rest of the emission region would be a hint for different source associations. However, due to the large statistic uncertainties no conclusion on spectral variations over the extension of the source can be drawn.

Discussion

The existence of the powerful pulsar PSR J1809 − 1917 which can easily power the TeV emission suggests that the TeV emission is a PWN associated with the pulsar. The association with a PWN is further supported by a compact X-ray nebula and diffuse X-ray emission coincident with the H.E.S.S. source. The X-ray emission is significantly smaller than the TeV source. This has been already seen for the PWN HESS J1825 − 137 [12].

On the other hand, two supernova remnants coincide with the TeV emission. They do not show X-ray emission, however, TeV emission can still be expected, in particular if if they are associated with dense molecular clouds [13, 14]. Further studies will include the search for dense molecular clouds in the region.

Conclusion

Detailed studies of the source HESS J$1809-193$ and comparison with objects in other wavelength show that this source is likely a PWN powered by the pulsar PSR J$1809-1917$. The number of TeV emitting PWNe is increasing, showing that TeV PWN constitute a significant fraction of the Galactic TeV gamma-ray source population.

Contribution of gamma-ray emission from faint radio supernova remnants cannot be ruled out. Radio-emitting, X-ray quiet SNRs, possibly in connection with dense molecular clouds, remain interesting targets for gamma-ray observations.

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