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GMRT Observations of H.E.S.S. Sources

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Abstract. We have observed 4 VHE gamma-ray sources discovered by the High Energy Stereoscopic System (H.E.S.S.) with the Giant Metrewave Radio Telescope (GMRT). The sources viz., HESS J1813−178, HESS J1825−137, HESS J1834−087, and HESS J1837−069 were observed simultaneously at 0.61 and 0.235 GHz and at 1.28 GHz. Resolved source counterparts for 3 of these were detected at all the three frequencies. None was detected for HESS J1825−137. We investigate the consistent multiwavelength behaviour of these sources and plausible gamma-ray emission mechanisms.

1. Introduction

The H.E.S.S. collaboration began observations with its complete array of four 12 m imaging atmospheric Cherenkov telescopes in 2004. Aharonian et al. (2005) gave initial results of its survey of the Galactic plane including the discovery of eight new TeV sources. Further details of these and of six fainter sources were given by Aharonian et al. (2006a). To interpret these sources one needs not only directional coincidence with counterparts in other wavebands but also a gamma-ray emission model that is consistent with the multiwavelength evidence. To look for such evidence at low radio frequencies we observed the fields of the four most northerly of the new H.E.S.S. sources with the GMRT in March 2006. The sources are listed below with their flux densities and their photon spectral indices. Brief details are included of possible counterparts in other wavebands. The source locations and morphologies are shown in the Figures below.

2. Results

2.1. HESS J1813−178

This source has a flux density above 200 GeV which is 6% of that of the Crab Nebula and a spectral index of 2.09 ± 0.08. There is a directional coincidence with the hard spectrum bright ASCA X-ray source AX J1813−178. Brogan et al. (2005) reported that it coincides also with a shell-type radio source G12.82−0.2 in the new VLA 90 cm survey. These both lie 10arcmin from the centre of the bright radio and IR star-forming region W33.

The GMRT maps of this source confirm that this SNR is coincident with the TeV gamma-ray source and add points to the radio spectrum of its shell. An XMM-Newton 0.5−10 keV observation by Funk et al. (2007) shows that the ASCA source is within the SNR and has a compact X-ray core with an extended tail, resembling a pulsar wind nebula (PWN). The 2.5arcmin diameter of the SNR is smaller than the H.E.S.S. point spread function, so it is not possible to determine whether the gamma-rays originate in the the PWN or the SNR shell.

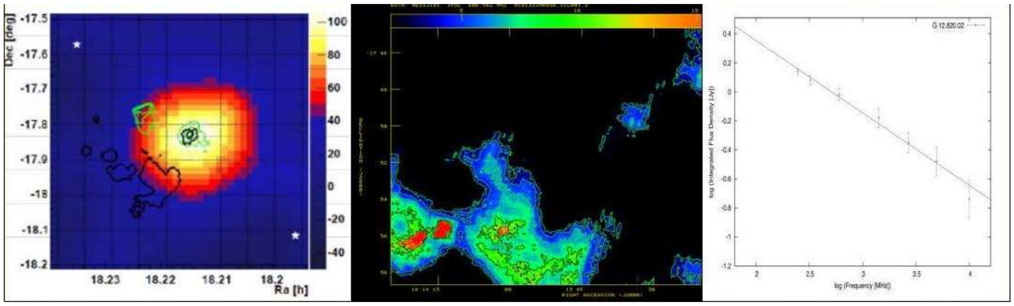

Figure 1. Left: HESS J1813−178 with VLA 90 cm radio contours (black) and ASCA contours (green); Middle: GMRT map at 610 MHz; Right: radio spectrum.

2.2. HESS J1825−137

This source, with flux density 17% of the Crab and photon spectral index 2.46 ± 0.08, has a centroid 13arcmin from the pulsar PSR J1826−1334. There is a diffuse X-ray emission region G18.0−0.7 (Gaensler et al. 2003), 5arcmin in diameter and extending asymmetrically to the south of the pulsar, which is interpreted as synchrotron emission produced by a PWN. We see no significant radio emission from this region. To check the hypothesis that the TeV source is the PWN of PSR J1826−1334 Aharonian et al. (2006b) investigated its energy dependent morphology. In this model high energy electrons generate the TeV gamma-rays via the Inverse Compton (IC) mechanism. As they convect or diffuse away from the pulsar they lose energy. Measurements confirm that the spectral index of the gamma-ray emission increases with distance from the pulsar. Quantitative consideration of the energy losses take into account the transport mechanism and the relative importance of the IC and synchrotron loss processes, which depend on the magnetic field. Our upper limit on the radio synchrotron emission may constrain the field strength.

2.3. HESS J1834−087

The source, with flux density 8% of the Crab Nebula and photon spectral index 2.45 ± 0.16, falls directionally mainly inside the shell of the SNR G23.3−0.3 (W41) which has been mapped by the VLA at 90 cm and 20cm. The radio map shows a shell structure of about 0.5° diameter. The shell structure was successfully resolved with the GMRT at 610 and 235 MHz. Two HII regions were also resolved. The detailed origin of the VHE gamma-rays,whether partly in the shell or entirely in the interior of the SNR, perhaps by a compact object, remains to be determined. No X-ray pulsar or PWN has yet been detected in this region. Alternatively the pulsar PSR J1833−0827, now well outside the remnant, might have been created in the supernova explosion, with such large speed that it has since left the shell. Gamma-ray emission from the interior of the shell might also be due to the presence of a dense molecular cloud (Albert et al. 2006).

2.4. HESS J1837−069

The source has a flux 13.4% of the Crab and spectral index 2.27 ± 0.06. There is a bright ASCA X-ray source AX J1838.0−0655, 6arcmin to the west of the peak of the TeV emission. An INTEGRAL observation by Malizia et al. (2005) shows that it has a hard spectrum extending to 300 keV.

The only significant radio emission in our observed fields are from the W42 star formation region, a point source GPSR5 25.266−0.161 and a linear non-thermal source designated GPSR5 25.252−0.139 and GPSR5 25.237−0.150. W42, of which the brightest radio feature is the HII region G25.38−0.18, is at the edge of the TeV source and probably too far from its peak to

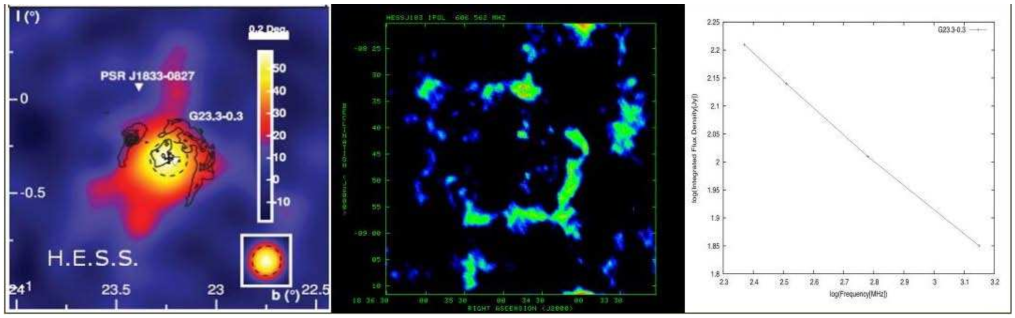

Figure 2. Left: HESS J1834−087 with VLA 90 cm radio contours (black); Middle: GMRT map at 610 MHz; Right: radio spectrum.

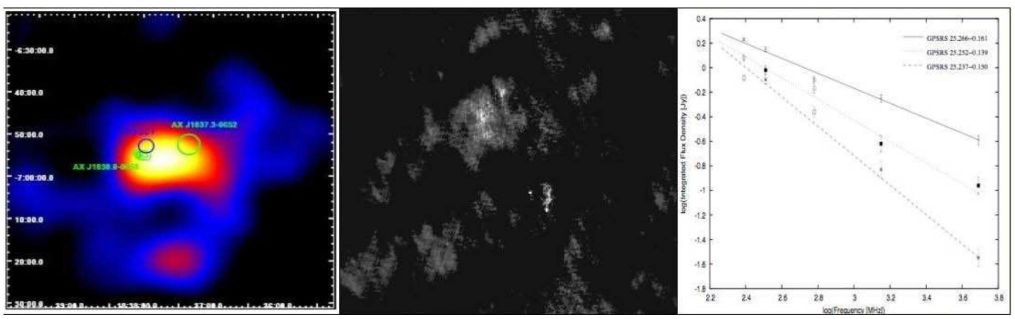

Figure 3. Left: HESS J1837−069 with two ASCA sources (green contour); Middle: GMRT map at 610 MHz; Right: radio spectrum.

generate the gamma-rays. The linear non-thermal source lies 8arcmin nearer to the peak of the TeV emission. Figer et al. (2006) report a 4arcmin diameter, very massive, young stellar cluster, directionally coincident with this source. The cluster contains 14 red supergiants at an estimated distance of 6.6 kpc. Trejo & Rodriguez (2006) have shown from VLA archive data that the linear source and the adjacent point source have H absorption at negative LSR velocities which indicate that they are at least around 20 kpc from the Sun on the far side of the Galaxy. It is now generally assumed that they are extragalactic.

The currently most convincing explanation of the TeV emission arises from the Chandra 0.3 - 12 keV observation of the region. Two ASCA sources, AX J1837.3−0652 and AX J1838.0−0655, are each resolved into a point source with a surrounding nebula, suggesting a pulsar and its PWN. The latter is the brighter by a factor of 10; its nebula has a diameter of 2arcmin. RXTE 2−20 keV observations (Gotthelf & Halpern 2008) confirmed the presence of pulsar PSR J1838−0655, of period 70.5 ms, characteristic age 22.7 kyr and spin-down luminosity 5.5×10^{36} erg s^{-1}. If the pulsar is a product of the nearby massive star cluster and therefore at a distance of 6.6 kpc the luminosity in gamma-rays above 0.2 TeV is 1.58×10^{35} erg s^{-1}. This requires a conversion efficiency from spin down energy to gamma-rays of 3%, a value similar to that required for HESS J1825−137 from a pulsar of a similar age. The morphologies of these two sources are also similar with the asymmetry of the TeV PWN being put down to the effect of a reverse shock following the expansion of the initial SNR into an inhomogeneous medium.

3. Discussion

Radio counterparts for two TeV emitting SNRs HESS J1813−178 and HESS J1834−087 have been successfully identified and resolved using the GMRT. In both the cases it is inferred that the gamma-rays originate in a PWN or in the SNR shell. The multi-wavelength association is well explained by the synchrotron + IC mechanism. No direct radio counterparts were detected in the case of HESS J1825−137 and HESS J1837−069; the multi-wavelength data, however, strongly implies that both the sources are TeV PWN of a pulsar.

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