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# THE W49 REGION AS SEEN BY H.E.S.S.

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**Abstract.** The W49 region hosts a star forming region (W49A) and a supernova remnant interacting with molecular clouds (W49B). The $10^6$ $M_\odot$ Giant Molecular Cloud W49A is one of the most luminous giant radio HII region in our Galaxy and hosts several active, high-mass star formation sites. The mixed-morphology supernova remnant W49B has one of the highest radio surface brightness of all the SNRs of this class in our Galaxy. Infrared observations evidenced that W49B is interacting with molecular clouds and Fermi recently reported the detection of a coincident bright, high-energy gamma-ray source. Observations by the H.E.S.S. telescope array resulted in the significant detection of VHE gamma-ray emission from the W49 region, compatible with gamma-ray emission from the SNR W49B. The results, the morphology and the origin of the VHE gamma-ray emission are presented in the multi-wavelength context and the implications on the origin of the signal are discussed.

Keywords: gamma rays, W49, H.E.S.S.

## 1 Introduction

The W49 region is a prime candidate to observe with ground-based Cherenkov telescopes such as H.E.S.S. since it hosts a star forming region (W49A) and a mixed morphology supernova remnant interacting with molecular clouds (W49B).

W49A is one of the most luminous giant HII region in the Galaxy (Smith et al. 1978). In the core ($\sim$ 15 pc) of this $10^6$ $M_\odot$ Giant Molecular Cloud of 100 pc in total extension (Simon et al. 2001), $\sim$ 30 ultra-compact HII regions, each hosting at least one massive star (earlier than B3) are resolved in radio (de Pree et al. 1997). From the proper motion of the strong $H_2O$ masers it hosts, the distance of W49A is estimated to be $11.4 \pm 1.2$ kpc (Gwinn et al. 1992).

The progenitor of W49B is thought to be a super-massive star that created a wind-blown bubble in a dense molecular cloud in which the explosion occurred (Keohane et al. 2007) as revealed by IR and X-ray observations. The detection of Mid-IR lines from shocked molecular hydrogen is an evidence that W49B is interacting with molecular clouds (Reach et al. 2006). From HI absorption analyses, its distance was estimated to be $\sim$ 8 kpc (Radhakrishnan et al. 1972). More recent VLA observations show that W49B could be associated with W49A (Brogan & Troland 2001), extending the range of possible distances for this object (8 kpc $< D <$ 12 kpc). Its age is estimated to be between 1 kyr and 4 kyrs (Pye et al. 1984; Hwang et al. 2000). In Radio, the supernova remnant shell is resolved with a size of $\sim 4'$. W49B is also detected by the Fermi-LAT at a level of $38\sigma$ with 17 months of data (Abdo et al. 2010).

The discovery of VHE $\gamma$-rays from the W49 region is reported in the next section. These preliminary results are then discussed.

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## 2 H.E.S.S. Observations and Analysis Results

H.E.S.S. is an array of four 13 m diameter imaging Cherenkov telescopes situated in the Khomas Highlands in Namibia at an altitude of 1800 m above sea level (see e.g. Bernlöhr et al. 2003; Funk et al. 2004). The standard H.E.S.S. run selection procedure was used to select observations taken under good weather conditions. This resulted in a dataset comprising 60 hours of observations (live time) on W49B and W49A. Data were analysed using the *Model Analysis* as described in de Naurois & Rolland (2009). This analysis was performed on W49A and W49B, using the standard cuts which include a minimum charge of 60 photoelectrons resulting in an energy threshold of $\sim$ 260 GeV. The analysis regions were defined a-priori as circles of 0.1° centered on the nominal position of W49A ($l = 43.17°, b = 0.0°$) and W49B ($l = 43.27°, b = -0.19°$). The results presented below were also confirmed by independent analyses such as those described in Ohm et al. (2009) or Becherini et al. (2011).

Figure 1 shows the resulting excess map smoothed to the H.E.S.S. Point Spread Function (PSF) (68% containment radius $R_{68} = 0.066°$). An excess of 191 VHE $\gamma$-rays is detected towards W49B by H.E.S.S. with a statistical significance of 8.8$\sigma$ using an integration radius of 0.1°. An excess of VHE $\gamma$-rays is also detected in the direction of W49A with a significance of more than 4.4$\sigma$. The best fit position of the TeV emission is found to be ($l = 43.258° \pm 0.008°, b = -0.188° \pm 0.01°$) assuming point-like emission. As shown on Figure 2, this is well coincident with the brightest radio part of the W49B remnant and with the GeV emission fitted position ($l = 43.251° - b = -0.168°$, with an error radius of 0.024° at 95% C.L.(Abdo et al. 2010)).

The TeV excess visible towards W49A is in good coincidence with the densest part of the molecular cloud as observed by the $^{13}CO$ Galactic Ring Survey (Jackson et al. 2006) as can be seen on Figure 2.

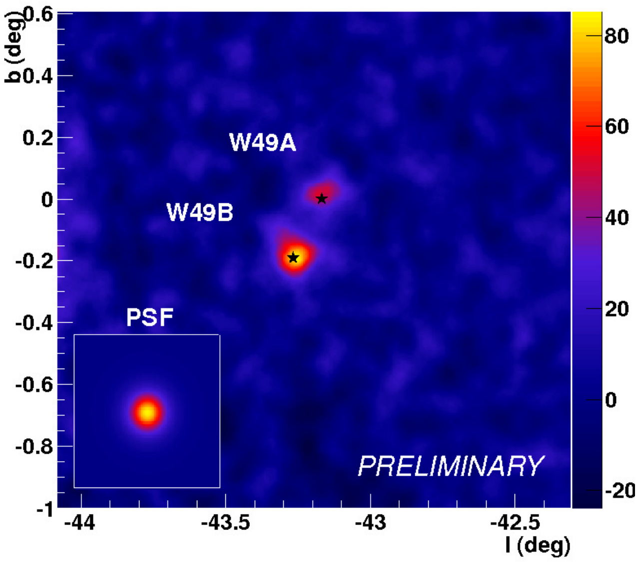


**Fig. 1.** H.E.S.S. excess map of the W49 region obtained with the Model Analysis. The map is smoothed to the H.E.S.S. PSF shown in the caption. The stars marks W49B and W49A nominal positions.

The differential energy spectrum of the VHE $\gamma$-ray emission towards W49B was derived above the energy threshold of 260GeV selecting the events inside a circular region of 0.1° around the supernova remnant nominal position. The spectrum obtained for W49B is well described ($\chi^2/dof = 39.6/38$) by a power-law model defined as $dN/dE = N_0(E/1TeV)^{-\Gamma}$ with $\Gamma = 3.1{\pm}0.3_{stat}{\pm}0.2_{syst}$ and $N_0 = 2.3{\pm}0.4_{stat}{\pm}0.6_{syst}10^{-13}$ cm$^{-2}$s$^{-1}$TeV$^{-1}$. This corresponds to an integral flux above 1TeV of $1.1 \pm 0.3_{stat} \pm 0.3_{syst}10^{-13}$ cm$^{-2}$s$^{-1}$, equivalent to $\sim$ 0.5% of the Crab nebula flux above the same energy. As can be seen on Figure 3, the GeV (Abdo et al. 2010) and TeV gamma-ray spectra are in remarkably good agreement.

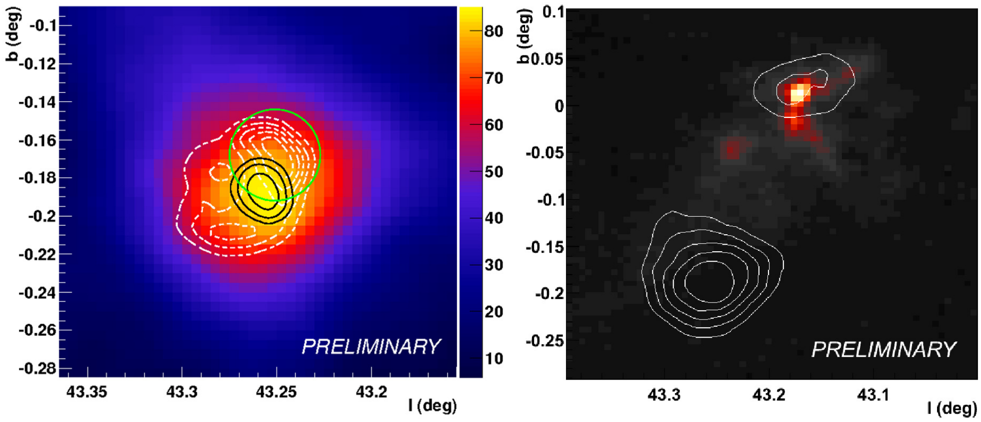


**Fig. 2. Left**: Detail of Figure 1 centered on W49B. The black contours are the error contours at 68%, 95% and 99% of the fitted position assuming point-like emission. The green circle is the Fermi-LAT fitted position at 95% C.L. The white contours show the radio emission as seen by NVSS. **Right**: Integrated Map of the $^{13}CO(J = 1 - 0)$ Galactic Ring Survey between $v_{LSR}$ = 0 km/s and 20 km/s. This velocity range corresponds to the distance to W49A. The white contours are from the H.E.S.S. excess map shown in Figure 1.

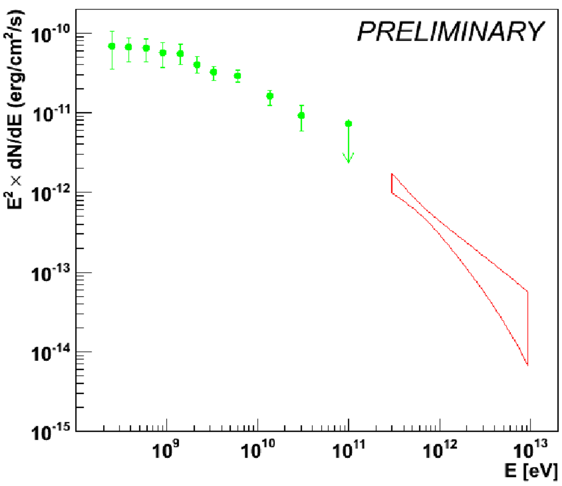


**Fig. 3.** Combined GeV and TeV energy spectrum obtained by the Fermi-LAT (green) and H.E.S.S. (red). The H.E.S.S. spectrum was extracted from a circular region of 0.1° around the nominal position of W49B.

## 3 Interpretations

### *3.1 W49B*

The most straight forward interpretations for the origin of the signal are particle acceleration either by a pulsar or by the SNR shock. No observations suggest the presence of a pulsar or pulsar wind nebula in W49B. The spatial coincidence of the TeV emission with the brightest part of the radio shell and GeV emission points toward emission from particle accelerated at the shock as predicted, for instance by the diffusive shock acceleration theory (DSA) (e.g. Drury 1983)

Since the shock is observed to be interacting with the molecular cloud in which the supernova exploded, very-high energy $\gamma$-ray emissions from the decay of $\pi^0$ mesons is expected to be enhanced proportionnaly to the target mass. Furthermore, the large GeV gamma-ray luminosity (Abdo et al. 2010) of $\sim 10^{36}$ erg s$^{-1}$ seems to be difficult to explain with IC scattering only. The detection of W49B at GeV and TeV emission is therefore a rather compelling argument in favour of a hadronic nature of the accelerated particles. More detailed studies are in progress to understand and constrain the emission processes in W49B.

### 3.2 W49A

Star forming regions are potential acceleration sites of VHE particles. This can, for instance, occur at the shocks created by the strong winds of the numerous massive stars they generally host. Recently, the presence of two expanding shells as well as gas ejections were found in W49A (Peng et al. 2010). The shells seem to have a common origin in the cloud core and a total kinetic energy of $\sim 10^{49}$ ergs. The gas ejections are likely to have the same origin as the expanding shells and a total energy of $\sim 10^{50}$ ergs.

## 4 Conclusion

The W49 region was observed by the H.E.S.S. telescope array, yielding $\sim$ 60h of good quality data. This led to the significant detection of TeV gamma-ray emission coincident with the supernova remnant W49B at a significance level of $8.8\sigma$. The position of the emission is compatible with the brightest part of the radio emission from the SNR as well as with the GeV emission. Energy spectra in the GeV and TeV bands are in very good agreement. Given the very high GeV luminosity and the fact that the SNR is interacting with dense material, a hadronic scenario is favored.

These observations also resulted in evidence for gamma-ray emission in the direction of the star forming region W49A. Analyses are still ongoing in order to confirm this promising preliminary result.

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## References

Abdo, A. A., Ackermann, M., Ajello, M., et al. 2010, ApJ, 722, 1303

Becherini, Y., Djannati-Ataï, A., Marandon, V., Punch, M., & Pita, S. 2011, Astroparticle Physics, 34, 858

Bernlöhr, K., Carrol, O., Cornils, R., et al. 2003, Astroparticle Physics, 20, 111

Brogan, C. L. & Troland, T. H. 2001, ApJ, 550, 799

de Naurois, M. & Rolland, L. 2009, Astroparticle Physics, 32, 231

de Pree, C. G., Mehringer, D. M., & Goss, W. M. 1997, ApJ, 482, 307

Drury, L. O. 1983, Reports on Progress in Physics, 46, 973

Funk, S., Hermann, G., Hinton, J., et al. 2004, Astroparticle Physics, 22, 285

Gwinn, C. R., Moran, J. M., & Reid, M. J. 1992, ApJ, 393, 149

Hwang, U., Petre, R., & Hughes, J. P. 2000, ApJ, 532, 970

Jackson, J. M., Rathborne, J. M., Shah, R. Y., et al. 2006, ApJS, 163, 145

Keohane, J. W., Reach, W. T., Rho, J., & Jarrett, T. H. 2007, ApJ, 654, 938

Ohm, S., van Eldik, C., & Egberts, K. 2009, Astroparticle Physics, 31, 383

Peng, T.-C., Wyrowski, F., van der Tak, F. F. S., Menten, K. M., & Walmsley, C. M. 2010, A&A, 520, A84+

Pye, J. P., Becker, R. H., Seward, F. D., & Thomas, N. 1984, MNRAS, 207, 649

Radhakrishnan, V., Goss, W. M., Murray, J. D., & Brooks, J. W. 1972, ApJS, 24, 49

Reach, W. T., Rho, J., Tappe, A., et al. 2006, AJ, 131, 1479

Simon, R., Jackson, J. M., Clemens, D. P., Bania, T. M., & Heyer, M. H. 2001, ApJ, 551, 747

Smith, L. F., Biermann, P., & Mezger, P. G. 1978, A&A, 66, 65