# New unidentified H.E.S.S. Galactic sources

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*Abstract.* **H.E.S.S. is one of the most sensitive instruments in the very high energy (VHE; > 100 GeV) gamma-ray domain and has revealed many new sources along the Galactic Plane. After the successful first VHE Galactic Plane Survey of 2004, H.E.S.S. has continued and extended that survey in 2005–2008, discovering a number of new sources, many of which are unidentified.**

**While some of the unidentified H.E.S.S. sources have several positional counterparts and hence several different possible scenarios for the origin of the VHE gamma-ray emission, their identification remains unclear. Others have so far no counterparts at any other wavelength. Particularly, the lack of an X-ray counterpart puts serious constraints on emission models.**

**Several newly discovered and still unidentified VHE sources are reported here.**

*Keywords***: Astronomical Observations; High Energy Gamma rays; Cosmic Rays.**

## I. INTRODUCTION

Very high energy (VHE, > $10^{11}$ eV) particles can be traced within our Galaxy by a combination of non-thermal X-ray emission and VHE gamma-ray emission via leptonic (i.e. Inverse Compton scattering of electrons, Bremsstrahlung and synchrotron radiation) or hadronic (i.e. the decay of charged and neutral pions, due to interactions of energetic hadrons) processes.

H.E.S.S. detects VHE $\gamma$-rays above an energy threshold of ∼100 GeV and up to ∼100 TeV with a typical energy resolution of 15% per photon. The angular resolution is ∼ 0.1° per event, allowing a positional error better than 40" for a point source detected with a statistical significance 6 $\sigma$. The H.E.S.S. field of view is almost 5° in diameter with a point source sensitivity of < 2.0 × $10^{-13}$ ergs cm$^{-2}$ s$^{-1}$ (∼1% of the Crab Nebula) for a 5 $\sigma$ detection in 25 hours of observations [1].

We report evidence for new extended sources detected in the extension [2] of the successful VHE Galactic Plane Survey of 2004 [3].

## II. NEW UNIDENTIFIED H.E.S.S. SOURCES

After the successful first survey of 2004 [3], H.E.S.S. extended the survey in 2005-2008, leading to the discovery of several new VHE gamma-ray sources. Of these, several have been associated with Supenovae Remnants (SNRs; such as CTB 37A, CTB 37B, RCW 86, Kes 75 and SN 1006), some of them are candidate PWNe (such as HESS J1356-654 and HESS J1849-000), however the rest remain unidentified.

In this section, five recently discovered VHE gamma-ray sources, that are still unidentified, will be discussed, showing their morphology, their spectrum and providing evidence for possible counterparts. A particular emphasis is dedicated to the new sources in the Galactic Center region, which is very important for *Fermi* LAT studies of diffuse emission or dark matter.

### A. HESS J1507-622

HESS J1507-622 is one of the most interesting newly discovered sources, the discovery of which is presented here and will be followed shortly by a more complete article. HESS J1507-622 is among the brightest (∼8% of Crab Flux) newly discovered sources and it is so far without plausible counterparts (similar to HESS J1427-608, HESS J1708-410, HESS J1858+020 [4] and HESS J1616-508 [5]). While all unidentified VHE sources that have been discovered in the H.E.S.S. Galactic plane scan so far are located in a quite narrow angular band of ±1° around the Galactic plane, HESS J1507-622 is unique in this respect since it lies ∼3.5° offset from the Galactic plane, ∼ 3° away from RCW 86 and from MSH 15-52. If truly offset from the plane and not simply a nearby source, it would be even more surprising to not find any trace of counterparts at any wavelength, considering the comparably lower $n_H$ at 3.5° off the plane and, hence, the lower Galactic absorption in X-rays and the reduced background emission.

The discovery peak significance, calculated following the method of Eq. (17) in [6], is 8.2 $\sigma$ (employing a 0.22° oversampling radius, which is the standard radius used in source searches in the H.E.S.S. Galactic Plane Survey). The preliminary analysis of HESS J1507-622
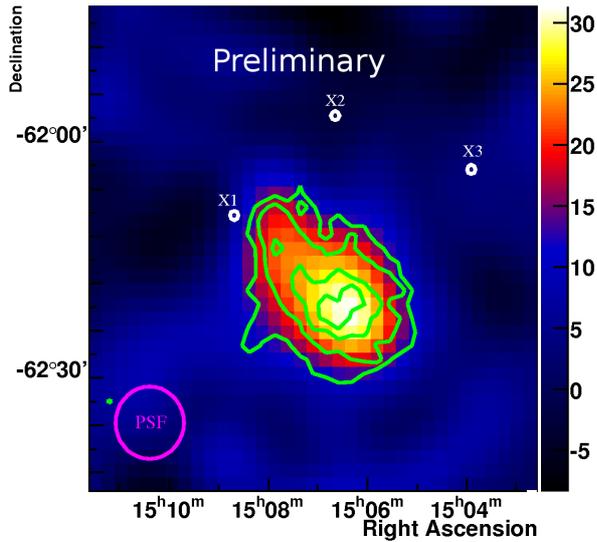
Fig. 1. Excess count map (smoothed with Gaussian of 0.07° radius) of HESS J1507-622. The contours show $3\sigma$, $4\sigma$, $5\sigma$, $6\sigma$ of significance respectively for an integration radius of 0.12°. The white circles represent the position of three faint RASS [8] sources: X1 indicates 1RXS J150841.2-621006, X2 indicates 1RXS J150639.1-615704 and X3 indicates 1RXS J150354.7-620408. The Point Spread Function (PSF) of the instrument for these observations is superimposed in left lower corner.



Fig. 2. Significance map (0.3° correlation radius) of HESS J1503-582 [9]. The black dashed line represents the Galactic Plane. Superimposed there are 2 other possible counterparts: the X-ray source AX J150436-5824 tentatively classified as a Cataclysmic Variable and the pulsar PSR J1502-5828, which has a very low spin-down luminosity $(3.3 \times 10^{31}(d/12\mathrm{kpc})^{-2}\mathrm{erg/s\ kpc}^2)$, that is not enough powerful to explain a PWN scenario.

is presented: Figure 1 shows the uncorrelated excess count map (smoothed with Gaussian of 0.07°), using *hard cuts* [1] and the *Ring* background method [7]. The best fit position is at RA = 226.72° ± 0.06°, Dec = −62.32° ± 0.03°, and the source is slightly extended with an intrinsic size (not including the PSF) of 0.11°.

The preliminary energy spectrum is reconstructed (0.22° extraction radius) with the method presented in [1] with the background subtracted using the *Reflected-Region* background method [7]. Using *standard cuts* [1] and hence a lower energy threshold ($\sim$ 500 GeV), the observed spectrum is well fit by a power-law $dN/dE = k(E/1\ \mathrm{TeV})^{-\Gamma}$ with photon index $\Gamma = 2.20 \pm 0.21_{stat} \pm 0.20_{sys}$; the integral flux (above 1 TeV) is $(1.5 \pm 0.5_{stat} \pm 0.3_{sys}) \times 10^{-12}\ \mathrm{TeV}^{-1}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. Using *hard cuts* (energy threshold $\sim$ 1 TeV) and hence a better gamma-hadron separation [1], the observed spectrum is well fit with a power-law with photon index $\Gamma = 2.46 \pm 0.20_{stat} \pm 0.20_{sys}$; the integral flux (above 1 TeV) is $(2.0 \pm 0.6_{stat} \pm 0.4_{sys}) \times 10^{-13}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. The data points are compatible; the difference in flux arises from the difference in slopes and from the extrapolation to 1 TeV.

New data are now available on HESS J1507-622, hence it is worthwhile to emphasize that the analysis presented here is preliminary.

### B. HESS J1503-582

The VHE gamma-ray emitter HESS J1503-582 has been recently discovered by H.E.S.S. [9], it is still unidentified, i.e. it did not have any of the typical counterparts at lower energies (e.g. SNRs, energetic
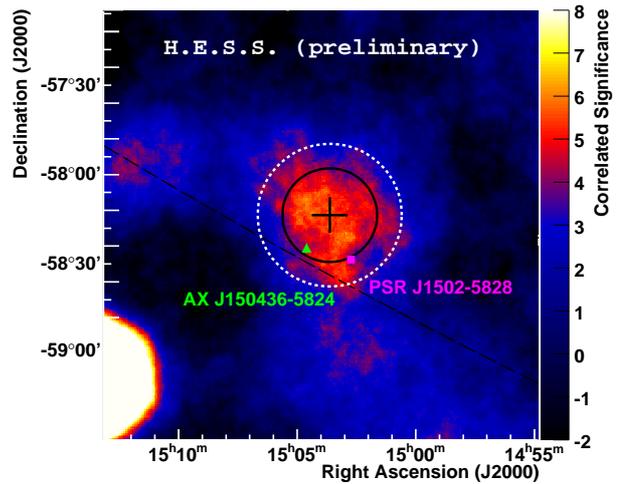
pulsars, or bright *Fermi* gamma-ray sources). However, it is now considered unique in that it is the first VHE gamma-ray source that appears to be associated with a *forbidden-velocity wing* (FVW). FVWs are faint HI 21 cm emission line structures which are visible at velocities which deviate from the canonical Galactic rotation curve, suggesting associated dynamical phenomena [10]. Deeper observations of HESS J1503-582 are scheduled for 2009 in order to further investigate this new source of VHE gamma-rays.

HESS J1503-582, visible in Fig. 2, shows significance of $\sim$6 $\sigma$ in $\sim$24 hours of effective exposure. The spectrum can be fit well by a power law with index $\Gamma = 2.4 \pm 0.4_{stat} \pm 0.2_{syst}$ with a flux above 1 TeV of $\sim$ $6 \times 10^{-12}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ ($\sim$6 % of the Crab flux).

### C. HESS J1848-018

HESS J1848−018 is an extended VHE gamma-ray source which was recently detected in the H.E.S.S. Galactic Plane Survey with a statistical significance of $\sim$9 $\sigma$ in $\sim$50 hours of effective exposure [11]. Figure 3 shows the significance map of the recently discovered source HESS J1848-018 [11]. Its differential energy spectrum is well fit by a power law with index $\Gamma = 2.8 \pm 0.2_{stat}$ and it has an integrated flux above 1 TeV of $\sim$2 $\times$ $10^{-12}\ \mathrm{erg\ cm}^{-2}\ \mathrm{s}^{-1}$, corresponding to $\sim$2% that of the Crab nebula. HESS J1848−018 is located along the Scutum-Crux spiral arm tangent and is in the direction of, but slightly offset from, the star-forming region W 43, which hosts a giant HII region (G30.8−0.2), a giant molecular cloud, and the Wolf-Rayet (WR) star WR 121a in the central stellar cluster. If HESS J1848−018 is indeed associated with W 43, it would be only the second known case, after Westerlund
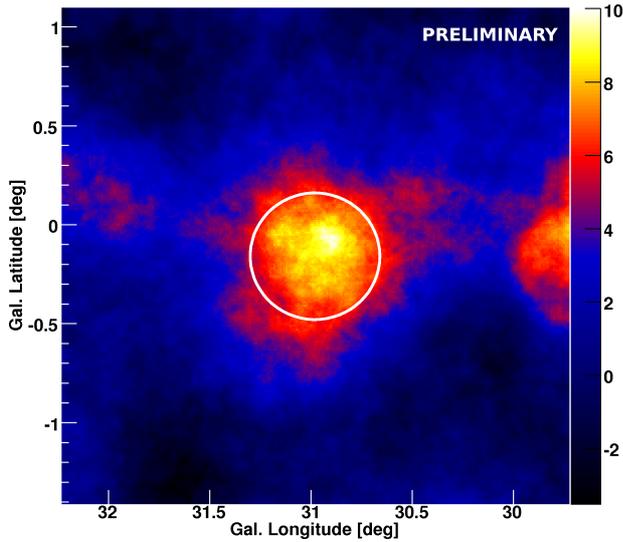
Fig. 3. H.E.S.S. image of the correlated significance (0.3°) of HESS J1848−018. The white circle denotes the source's intrinsic rms size of 0.32° ± 0.02°. The bright VHE gamma-ray source to the right is the SNR Kes 75 [11].



Fig. 4. Excess count map (smoothed with Gaussian of 0.07° radius) and significant contours of HESS J1745-303 [13]. The white dashed line represents the Galactic Plane. Superimposed there are the two SNRs G359.1-0.5 and G359.0-0.9, the two pulsars PSR B1742-30 and PSR J1747-2958, and the EGRET source 3EG 1744-3011.

2 [12], of VHE gamma-ray emission associated with a star-forming region and WR star.

The complex, multi-wavelength morphology is currently under investigation.

### D. Galactic Center region: HESS J1745-303 and HESS J1741-302

The discovery of new VHE sources close to the Galactic Center is very important for the studies about diffuse Galactic emission and dark matter and will play a crucial role in the outcoming *Fermi* LAT studies.

*1) HESS J1745-303:* HESS J1745-303 is not a new source [3], but it has been recently observed in VHE gamma-rays in detail by H.E.S.S. and in X-rays by *XMM-Newton* [13].

Figure 4 shows the image of gamma-ray excess counts of HESS J1745-303 smoothed with a radius of 0.07°. Overlaid on the image are the contours of $4\sigma$, $5\sigma$, $6\sigma$, $7\sigma$ of significance.

HESS J1745-303 is detected with a significance of $10.2\sigma$ in 79 hours of observation. The spectrum can be fit well by a power law with index $\Gamma = 2.7 \pm 0.1_{stat} \pm 0.2_{sys}$ and a flux above 1 TeV of $(1.63 \pm 0.16) \times 10^{-12}$ cm$^{-2}$ s$^{-1}$.

The region labeled A in Figure 4 is thought to be associated with the interaction of the SNR G359.1-0.5 [15] with $^{12}$CO molecular clouds [16] spatially coincident with the peak of the VHE gamma-ray emission. The part labeled B in Figure 4 is more likely to be a PWN powered by the pulsar PSR B1742-30 ($\dot{E}/D^2 = 2 \times 10^{33}$ erg s$^{-1}$ kpc$^{-2}$), which requires a conversion efficiency from rotational kinetic energy to gamma-ray of $\sim 32\%$ to produce the entire VHE emission. HESS J1745-303 is also spatially coincident with the EGRET source 3EG 1744-3011 [14]:
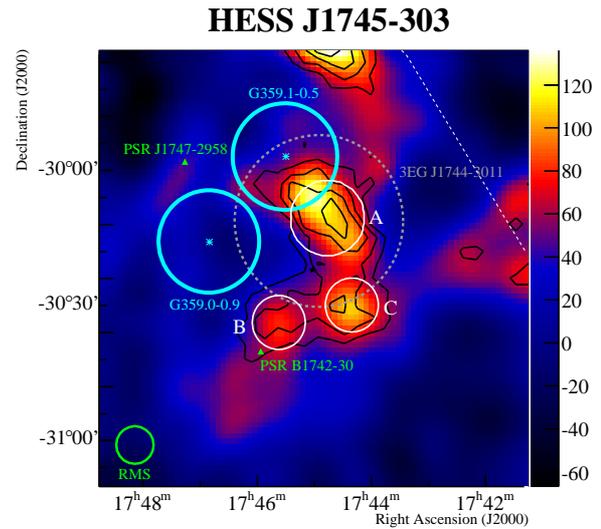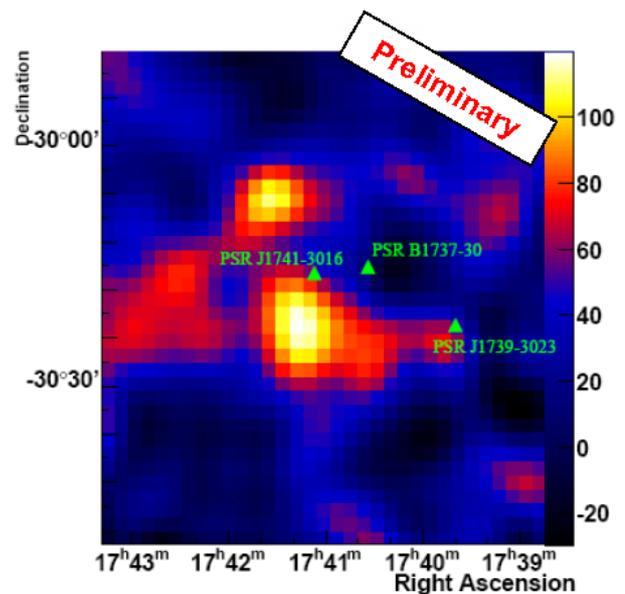


Fig. 5. Gamma-ray acceptance corrected skymap of HESS J1741-302 [17], obtained with *hard analysis cuts* and a Gaussian smoothing radius of 0.05°, with superimposed the positions of PSR B1737-30 [18] and PSR J1741-3016 [19].

*2) HESS J1741-302:* The discovery of a faint ($\sim 1\%$ of the Crab flux) source, HESS J1741-302, has been recently announced [17], one of the faintest newly discovered sources, at the lower end of H.E.S.S. sensitivity.

The discovery peak significance is 8.1 $\sigma$ in 143.5 hours of observations. With *standard analysis cuts* [7], HESS J1741-302 appears as an irregular blob. With *hard analysis cuts* (200 p.e.) [7] resulting in improved angular resolution, improved background rejection and higher energy threshold, two apparent hot spots start to appear in the map (Figure 5); however, Figure 4 in [17] shows

that current statistics do not allow detailed statements about source morphology, and that the hot spots are consistent with statistical fluctuations within the source. The preliminary spectrum can be fit well by a power law with index $\Gamma = 2.78 \pm 0.24_{stat} \pm 0.20_{sys}$ with a flux above 1 TeV of $(6.3 \pm 1.3_{stat} \pm 1.1_{sys}) \times 10^{-13}$ cm$^{-2}$ s$^{-1}$.

In other sources in the galactic center region (e.g. HESS J1745-303 [13] and the GC diffuse emission [20]), there is evidence that interactions of cosmic rays with Molecular Clouds (MCs) play a role in VHE gamma-ray production. Such an association in this case is not clear, though in some velocity ranges there is some weak molecular emission coincident with the H.E.S.S. source [21]. Another suitable scenario could be an offset Pulsar Wind Nebula, where an undiscovered SNR (or a dense MC) would be powered by the somewhat offset but relatively powerful pulsar PSR B1737-30 [18] (spin-down luminosity $7.7 \times 10^{33}$ $\frac{erg}{s \cdot kpc^2}$). This pulsar has a spin-down luminosity that is almost one order of magnitude fainter than other VHE gamma-ray emitting pulsars (e.g. like HESS J1825-137 [22]), which have typical VHE fluxes of $\sim$10% of the Crab. Given that the estimated flux of HESS J1741-303 is approximately 1% of the Crab, a weak PWN scenario is plausible. Moreover the brightest hot spot is spatially coincident with the pulsar PSR J1741-3016 [19], which is very faint (spin-down luminosity $2.1 \times 10^{30}$ $\frac{erg}{s \cdot kpc^2}$). Even if very unlikely, one could imagine a PWN scenario that involves this very faint pulsar.

## III. CONCLUSIONS

Five recently discovered H.E.S.S. unidentified sources and their possible counterparts have been discussed. All the sources located in the Galactic plane (or slightly off the plane) and appear extended in VHE, however since these sources have so far no clear counterpart in lower-energy wavebands, further multi-wavelength studies are required in order to understand the emission mechanism powering them.

## IV. ACKNOWLEDGEMENTS

## REFERENCES

[1] F. Aharonian et al., (H.E.S.S. Coll.), *A&A*, **457**, 899 (2006).
[2] R. C. G. Chaves (H.E.S.S. Coll.), these proceedings.
[3] F. Aharonian et al., (H.E.S.S. Coll.), *Science*, **307**, 1839 (2005).
[4] F. Aharonian et al. (H.E.S.S. Coll.), *A&A*, **477**, 353 (2008).
[5] F. Aharonian et al. (H.E.S.S. Coll.), *ApJ*, **636**, 777 (2006).
[6] T. Li and Y. Ma, *ApJ*, **272**, 317 (1983).
[7] D. Berge et al., *A&A*, **466**, 1219 (2007).
[8] W. Voges et al., *IAU Circ.*, **7432**, 1 (2000).
[9] M. Renaud et al., (H.E.S.S. Coll.), *AIP*, **1085**, 281 (2008).
[10] J. H. Kang and B. C. Koo, *ApJSS*, **173**, 85 (2007).
[11] R. C. G. Chaves et al. (H.E.S.S. Coll.), *AIP*, **1085**, 372 (2008)
[12] F. Aharonian et al. (H.E.S.S. Coll.), *A&A*, **467**, 1075 (2007).
[13] F. Aharonian et al., (H.E.S.S. Coll.), *A&A*, **483**, 509 (2008).
[14] R. C. Hartman et al., *ApJSS*, **123**, 79 (1999).
[15] D. Downes et al., *A&AS*, **35**, 1 (1979).
[16] M. Bitran et al., *A&AS*, **125**, 99 (1997).
[17] O. Tibolla et al. (H.E.S.S. Coll.), *AIP*, **1085**, 249 (2008).
[18] T. R. Clifton and A. G. Lyne, *Nature*, **320**, 43 (1986).
[19] D. J. Morris et al., *MNRAS*, **335**, 275 (2002).
[20] F. Aharonian et al., (H.E.S.S. Coll.), *Phys. Rev. Lett.*, **97**, 221102 (2006).
[21] T. Dame et al., *ApJ*, **547**, 792 (2001).
[22] F. Aharonian et al., (H.E.S.S. Coll.), *A&A*, **460**, 365 (2006).