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

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I. INTRODUCTION

Very high energy (VHE, > 1011 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 γ-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 σ. 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 σ detection in 25 hours of observations [1].

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

After the successful first survey of 2004 [2], H.E.S.S. extended the survey in 2005-2008 [3], leading to the discovery of several new VHE gamma-ray sources. Of these, several have been associated with Supernovae Remnants (SNRs; such as CTB 37A, CTB 37B, RCW 86, Kes 75), 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. One of the sources, HESS J1507-622, is reported for the first time, whereas the others were covered in recent publications [5], [4], [6], [7].

A. HESS J1507-622

HESS J1507-622 (Figure 1) is one of the most interesting newly discovered sources. 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 [8] and HESS J1616-508 [9]). While all unidentified VHE sources that have been discovered in the H.E.S.S. Galactic Plane Survey 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, offset 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, 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 [10], is 8.2 σ (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 results on HESS J1507-622 are still preliminary: Figure 1 shows the uncorrelated excess count map (smoothed with Gaussian of 0.07°), using

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.

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.

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hard cuts [1] and the Ring background method [11]. 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 [11]. Using standard cuts [1] and hence a lower energy threshold (∼ 500 GeV), the observed spectrum is well fit by a power-law \( dN/dE = k(E/1 \text{ TeV})^{-\Gamma} \) with photon index \( \Gamma = 2.20 \pm 0.21_{\text{stat}} \pm 0.20_{\text{sys}} \), the integral flux (above 1 TeV) is \((1.5 \pm 0.5_{\text{stat}} \pm 0.3_{\text{sys}}) \times 10^{-12} \text{ TeV}^{-1} \text{ cm}^{-2} \text{ s}^{-1}\). Using hard cuts (energy threshold ∼ 1 TeV) and hence a better gamma-hadron separation [1], the observed spectrum is well fit with a power-law with photon index \( \Gamma = 2.46 \pm 0.20_{\text{stat}} \pm 0.20_{\text{sys}} \), the integral flux (above 1 TeV) is \((2.0 \pm 0.6_{\text{stat}} \pm 0.4_{\text{sys}}) \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}\). The data points are compatible; the difference in flux arises from the difference in slopes and from the extrapolation to 1 TeV.

B. HESS J1503-582

The VHE gamma-ray emitter HESS J1503-582 (Figure 2) has been recently discovered by H.E.S.S. [4], 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 [13]. 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 Figure 2, shows significance of ∼6σ in ∼24 hours of effective exposure. The spectrum can be fit well by a power law with index \( \Gamma = 2.4 \pm 0.4_{\text{stat}} \pm 0.2_{\text{sys}} \) with a flux above 1 TeV of \( \sim 6 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1} \) (∼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 ∼9σ in ∼50 hours of effective exposure [5]. Figure 3 shows the significance map of the recently discovered source HESS J1848-018 [5]. Its differential energy spectrum is well fit by a power law with index \( \Gamma = 2.8 \pm 0.2_{\text{stat}} \) and it has an integrated flux above 1 TeV of \( \sim 2 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1} \), corresponding to ∼8% 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 2 [14], of VHE gamma-ray emission associated with a star-forming region and WR star. The complex, multi-wavelength morphology of HESS J1848-018 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 relevant for the studies about of the role of diffuse Galactic emission versus resolved sources in this region.

1) **HESS J1745-303**: HESS J1745-303 is not a new source \[8\], but it has been recently observed in VHE gamma-rays in detail by H.E.S.S. and in X-rays by XMM-Newton \[6\].

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 4σ, 5σ, 6σ, 7σ of significance.

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

The region labeled A in Figure 4 is thought to be associated with the interaction of the SNR G359.1-0.5 \[16\] with $^{12}\text{CO}$ molecular clouds \[17\] 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 ($\dot{E}/D^2 = 2 \times 10^{33} \, \text{erg} \, \text{s}^{-1} \, \text{kpc}^{-2}$), 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 \[15\]:

2) **HESS J1741-302**: The discovery of a faint ($\sim 1\%$ of the Crab flux) source, HESS J1741-302, has been recently announced \[7\], one of the faintest newly discovered sources, at the lower end of H.E.S.S. sensitivity. The discovery peak significance is 8.1σ in 143.5 hours of observations. With standard analysis cuts \[11\], HESS J1741-302 appears as an irregular blob. With hard analysis cuts (200 p.e.) \[11\] 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 \[7\] 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 $\Gamma = 2.78 \pm 0.24_{\text{stat}} \pm 0.20_{\text{sys}}$ with a flux above 1 TeV of $(6.3 \pm 1.3_{\text{stat}} \pm 1.1_{\text{sys}}) \times 10^{-13} \text{cm}^{-2} \text{s}^{-1}$.

In other sources in the galactic center region (e.g. HESS J1745-303 [6] 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 powered by the somewhat offset source [21]. A weak molecular emission is coincident with the H.E.S.S. source HESS J1745-303 [6] and the GC diffuse emission [20], which have typical VHE fluxes of $\sim 10^{-12}$ (spin-down luminosity $7.7 \times 10^{33} \text{erg s}^{-1}$). 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 $\sim 10^{-12}$ of the Crab. Given that the estimated flux of HESS J1741-303 is approximately 1% of the Crab, a weak PWN scenario is plausible. The brightest hot spot is spatially coincident with the pulsar PSR J1741-3016 [19], which is, however, probably too faint (spin-down luminosity $2.1 \times 10^{30} \text{erg s}^{-1}$) to sustain a PWN scenario.

III. CONCLUSIONS

Five recently discovered H.E.S.S. unidentified sources and their possible counterparts have been discussed. All the sources are located in the Galactic plane (or slightly off the plane) and appear extended in VHE gamma rays. 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.

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