



Exploring the Galaxy at TeV energies: Latest results from the H.E.S.S. Galactic Plane Survey.

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Abstract: The High Energy Stereoscopic System (H.E.S.S.) is an array of four imaging atmospheric-Cherenkov telescopes located in Namibia and designed to detect extensive air showers initiated by γ -rays in the very-high-energy domain. It is an ideal instrument for surveying the Galactic plane in search of new sources, thanks to its location in the Southern Hemisphere, its excellent sensitivity, and its large field-of-view. The efforts of the H.E.S.S. Galactic Plane Survey, the first comprehensive survey of the inner Galaxy at TeV energies, have contributed to the discovery of an unexpectedly large and diverse population of over 60 sources of VHE γ -rays within its current range of $\ell = 250$ to 65 degrees in longitude and $|b| \leq 3.5$ degrees in latitude. The population of VHE γ -ray emitters is dominated by the pulsar wind nebula and supernova remnant source classes, although nearly a third remain unidentified or confused.

The sensitivity of H.E.S.S. to sources in the inner Galaxy has improved significantly over the past two years, from continued survey observations, dedicated follow-up observations of interesting source candidates, and from the development of advanced methods for discrimination of γ -ray-induced showers from the dominant background of hadron-induced showers. The latest maps of the Galaxy at TeV energies will be presented, and a few remarkable new sources will be highlighted.

Keywords: H.E.S.S., Galactic Plane Survey, gamma-ray astronomy, supernova remnant, pulsar wind nebula

1 Introduction

At the far end of the energy spectrum accessible to astronomical observations, imaging atmospheric Cherenkov telescopes (IACTs) are employed to detect extended air showers initiated by very-high-energy (VHE; $E > 0.1$ TeV) photons. With the latest generation of IACTs, the detection of VHE γ -rays has turned into a mature astronomical discipline, and more than 120 sources are currently listed in the online TeV γ -ray catalogue TeVCat¹. Here we report on the status and latest results of the Galactic Plane Survey (GPS), undertaken with the High Energy Stereoscopic System (H.E.S.S.). With a sizable fraction of the annual observation budget of H.E.S.S. dedicated to it, the GPS aims at performing a systematic scan of the inner Galaxy, with the main goal of discovering previously unknown emitters of VHE γ -rays. More than 60 Galactic VHE γ -ray sources are now known. The population is dominated by sources that are linked to the final stages in stellar evolution, namely pulsar wind nebulae (PWNe) and supernova remnants (SNRs).

For nearly a third of the sources, however, no plausible counterpart at other wavelengths has been found yet, or the physical origin of the detected emission remains unclear.

H.E.S.S. consists of four identical 12 m diameter IACTs located at an altitude of 1800 m above sea level in the Khomas Highlands of Namibia [1]. Its location in the Southern Hemisphere affords it an excellent view of the inner Galaxy with low energy threshold. Each of the four H.E.S.S. telescopes is equipped with a camera containing 960 photomultiplier tubes and a tessellated mirror with a combined area of 107 m² [2]. The optical design allows for a comparatively large, 5° field-of-view (FoV). The H.E.S.S. array has an angular resolution of $\sim 0.1^\circ$ and an energy resolution of $\sim 15\%$. Its high sensitivity, coupled with the large FoV, permits H.E.S.S. to effectively survey large areas of the Galaxy within a reasonable amount of time.

1. <http://tevcat.uchicago.edu/>

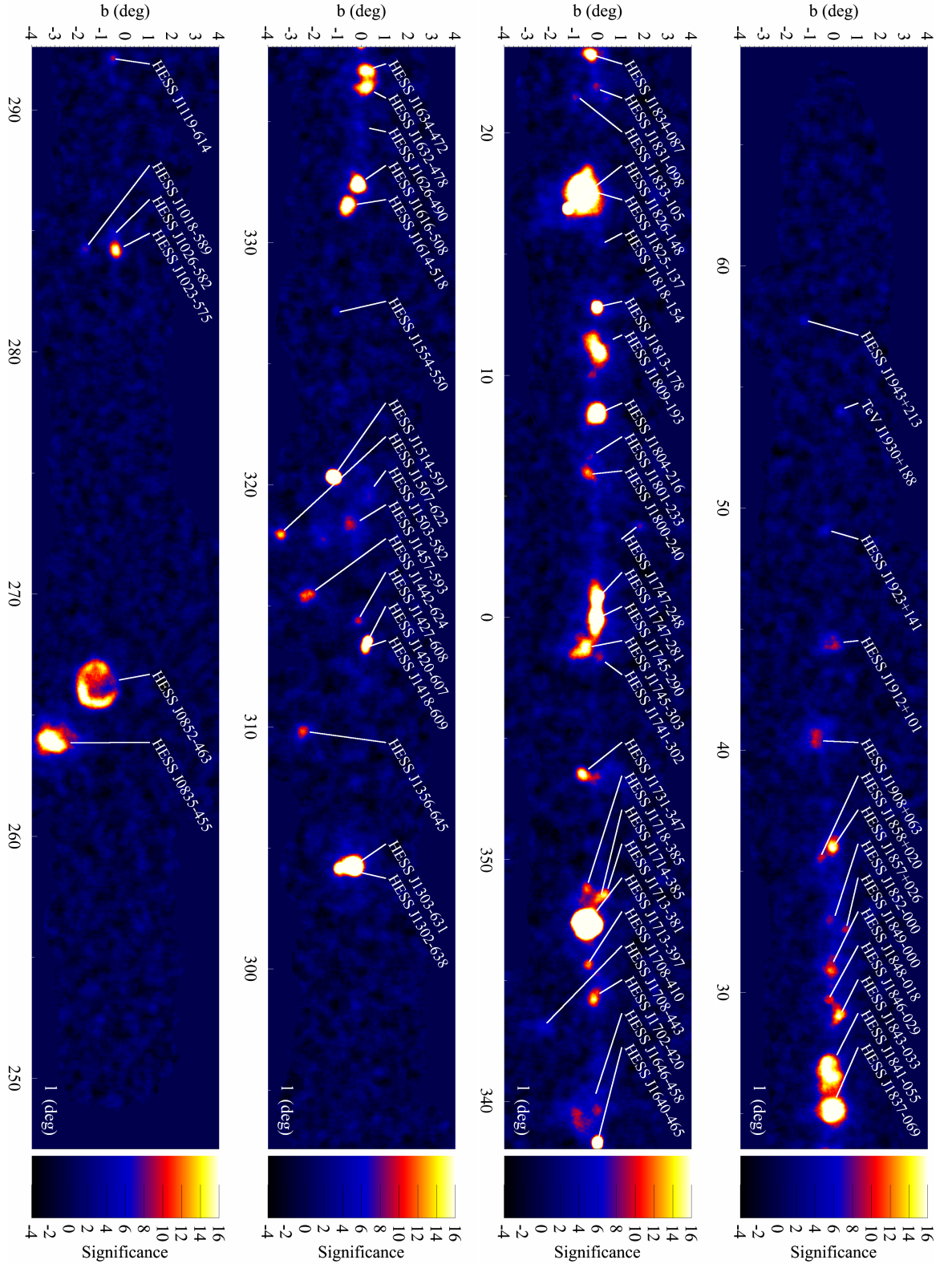


Figure 1: Latest significance map for the H.E.S.S. Galactic Plane Survey. The pre-trials significance for a correlation radius of 0.22° is shown. The colour transition from blue to red corresponds to $\sim 5\sigma$ post-trials significance. The trial factor takes into account the fact that many sky positions are tested for an excess above the background, thus increasing the chance of finding a random upward fluctuation of the background. The map has been filled for regions on the sky where the sensitivity of H.E.S.S. for point sources (5σ pre-trials, and assuming the spectral shape of a power law with index 2.5) is better than 10 % Crab.

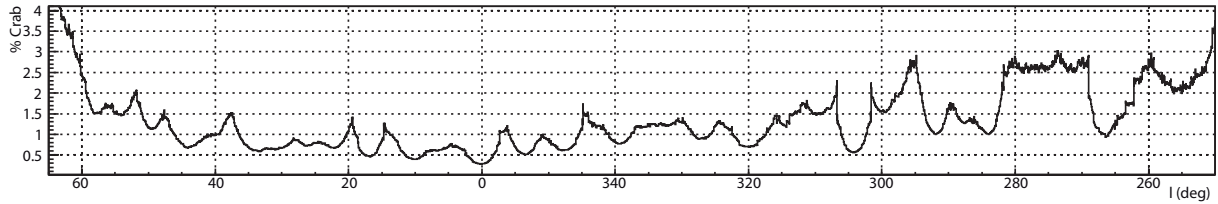


Figure 2: Sensitivity of H.E.S.S. to point-like γ -ray sources with an assumed spectral index of 2.5, for a detection level of 5σ pre-trial, at $b = -0.3^\circ$, the approximate average latitude of Galactic sources. The sensitivity is expressed in units of the Crab integral flux $F(\geq 1 \text{ TeV}) = 2.26 \cdot 10^{-7} \text{ m}^{-2} \text{ s}^{-1}$.

2 The H.E.S.S. Galactic Plane Survey

Most of the available observation time of H.E.S.S. is spent looking at pre-defined targets that seem promising because of their known astrophysical properties. In the H.E.S.S. Galactic Plane Survey, a different approach is followed. Here, the inner Galaxy is systematically scanned using observation positions with overlapping fields-of-view, with the main goal of discovering new γ -ray sources and enabling population studies of Galactic source classes as a consequence. Advanced analysis techniques for background suppression, e.g. [3, 4, 5, 6], play a very important role in this endeavour.

Over the course of its operation, H.E.S.S. has assembled an impressive dataset in the region of the inner Galaxy. In the last major report on the H.E.S.S. Galactic Plane Survey in January 2006 [7], the detection of 17 sources in the range $\ell \pm 30^\circ$ and $b \pm 3^\circ$ was presented using a dataset comprising 230 h of observation time, corrected for read-out dead-time. Since then, this dataset has increased dramatically; it now includes over 2300 h of data covering the longitude range from $\ell = 250^\circ$ to 65° , and more than 60 Galactic sources have been detected as a result. The total dataset that constitutes the Galactic Plane Survey is made up of observations taken with two different strategies: Firstly, in *scan mode*, pointings are distributed systematically along the Galactic plane, usually in three strips in latitude ($b = -1, 0, +1^\circ$) and with spacings of $\sim 0.7^\circ$ in longitude. Deeper, *pointed observations* are taken on promising source candidates, and all other observations that fall within the survey region are included in the dataset, too. For the past and ongoing observation campaigns in 2010 and 2011, the focus of the survey effort has been put on achieving a more uniform exposure in the survey core region ($\ell = 282^\circ$ to 60°), and on deepening the exposure in the region from $\ell = 268^\circ$ to 282° .

Figure 1 shows the latest significance map obtained for the survey region. After calibration and quality selection, a multivariate analysis technique [3] based on shower and image shape parameters is used to discriminate γ -ray events from cosmic ray-induced showers. A minimum image amplitude of 160 p.e. is required. The remaining background is estimated by the ring background technique [1]. Regions on the sky containing known VHE γ -ray sources are excluded from the ring, and the ring radius is adaptively

enlarged where a large fraction of the ring area overlaps with an excluded region. The significance value for each position is then calculated [8], by summing the candidate events within a fixed and pre-defined correlation radius of 0.22° , suitable for extended sources, and comparing to the estimated background level at that position. The map now covers the full longitude range of the GPS, and in particular, the extensions above $\ell = 60^\circ$ and below $\ell = 275^\circ$, that are presented here for the first time.

Figure 2 depicts the current sensitivity to γ -ray sources, as an example for point-like sources emitting a simple power-law spectrum with index $\Gamma = 2.5$ and located at a Galactic latitude of $b = -0.3^\circ$, the approximate average among known Galactic sources. The sensitivity is at the few-permille Crab level for the deepest exposures and is below 2% Crab for practically all of the longitude range $\ell = 283^\circ$ to 59° at this latitude. Note that in crowded regions, especially close to the Galactic plane, the detection of new faint sources is complicated by the foreground emission from stronger sources. The official H.E.S.S. source catalogue containing all sources published in refereed journals is available online at www.mpi-hd.mpg.de/hfm/HESS/.

3 New discoveries

In this section, we briefly spotlight some of the recent additions to the list of Galactic H.E.S.S. sources, many of which are presented at this conference for the first time.

Discovery of VHE emission towards the direction of SNR G284.3-1.8

After 40 h of observations, H.E.S.S. has detected significant emission (HESS J1018-589) from the direction of SNR G284.3-1.8, an incomplete radio shell with nonthermal spectrum and interacting with molecular clouds [9]. An association with the Vela-like pulsar PSR J1016-5857 can be made if distance measurements of the SNR and the pulsar as well as the large offset between the centre of the shell and the pulsar can be reconciled.

Detection of High and Very High Energy γ -rays from the direction of SNR G318.2+0.1

An extended source of VHE γ -rays (HESS J1457-593)

was recently discovered [10] in the direction towards the shell-type SNR G318.2+0.1, with a hard spectrum extending beyond 20 TeV. The VHE γ -ray emission overlaps the southern rim of the SNR and extends roughly 0.3° outward from the shell. In the most likely scenario, cosmic rays accelerated in the shock-front of the SNR interact with the target material in a spatially coincident giant molecular cloud seen in ^{12}CO line data and produce γ -rays from pion decay. This scenario is supported by public Fermi-LAT data revealing γ -ray emission at the position of the H.E.S.S. source and extending towards the western rim of the SNR.

A newly discovered VHE γ -ray PWN candidate around PSR J1459-6053

Survey observations have revealed a significant VHE γ -ray excess from the direction of PSR J1459-6053, a rather old γ -ray pulsar (64 kyr) with a spindown energy of $9 \cdot 10^{-35} \text{ erg/s}$, discovered by Fermi-LAT in high-energy γ -rays [11]. The X-ray pulsar counterpart has been recently detected using the Suzaku satellite. The source is located in a region of the sky highly populated with VHE sources, with at least two other confirmed VHE γ -ray sources (PWN and SNR) within less than 2 degrees.

Detection of VHE γ -ray emission from the intriguing composite SNR G327.1-1.1

SNR G327.1-1.1 belongs to the category of SNRs hosting a PWN (known as composite SNRs) and exhibits a shell and a bright central PWN, both seen in radio and X-rays. Interestingly, radio observations of the PWN show an extended blob of emission and a curious narrow finger structure pointing towards the offset compact X-ray source (the pulsar candidate) indicating a possible fast moving pulsar in the SNR or an asymmetric passage of the reverse shock. Observations of the SNR G327.1-1.1 with the H.E.S.S. telescope array resulted in the detection of significant TeV γ -ray emission in spatial coincidence with the PWN (HESS J1554-550) [12].

VHE γ -ray emission from the direction of Terzan 5

H.E.S.S. has discovered a new VHE γ -ray source (HESS J1747-248), located in the immediate vicinity of the Galactic globular cluster Terzan 5 [13]. The source appears extended and off-set from the cluster core but overlaps significantly with Terzan 5. A random coincidence with the globular cluster is unlikely ($\sim 10^{-4}$) but this possibility cannot firmly be excluded. With the largest population of identified millisecond pulsars, a very large core stellar density and the brightest GeV-range flux as measured by Fermi-LAT, Terzan 5 stands out among Galactic globular clusters. Interpretation of the available data accommodates several possible origins for this VHE γ -ray source.

Discovery of VHE γ -ray emission from the shell-type SNR G15.4+0.1 with H.E.S.S.

Statistically significant emission of VHE γ -rays (HESS

J1818-154) has now been detected from the direction of the shell-type SNR G15.4+0.1 [14] which was recently discovered at radio wavelengths by VLA. The VHE γ -ray emission is extended beyond the H.E.S.S. PSF ($\sim 6'$), though significantly less than the shell of the SNR as seen in radio.

Discovery of VHE γ -ray emission near PSR J1831-0952

During survey operations, H.E.S.S. has detected an extended source (HESS J1831-098) near the 67 ms pulsar PSR J1831-0952 [15]. The source's spectrum is hard with a photon index of 2.1 ± 0.08 and with a flux of $\sim 4\%$ of the Crab nebula. Adopting the dispersion measure distance of the pulsar (4.3 kpc), less than 1 % of its spin-down energy would be required to provide the observed luminosity of the VHE source. The analysis of Fermi data shows no significant emission above 10 GeV in coincidence with the H.E.S.S. source.

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