



The H.E.S.S. survey of the inner Galactic plane

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Abstract: The High Energy Stereoscopic System (H.E.S.S.), located in the Khomas Highlands of Namibia, is an array of four imaging atmospheric-Cherenkov telescopes designed to detect γ -rays in the very high energy (VHE; > 100 GeV) domain. Its high sensitivity and large field-of-view (5°) make it an ideal instrument to perform a survey within the Galactic plane for new VHE sources. Previous observations in 2004/2005 resulted in numerous detections of VHE gamma-ray emitters in the region $l = 330^\circ - 30^\circ$ Galactic longitude. Recently the survey was extended, covering the regions $l = 280^\circ - 330^\circ$ and $l = 30^\circ - 60^\circ$, leading to the discovery of several previously unknown sources with high statistical significance. The current status of the survey will be presented.

Introduction

The majority of the newly discovered sources of very high energy (VHE; > 100 GeV) γ -rays are related to late phases of stellar evolution, either directly to massive stars or to the compact objects they form after their collapse. The possible associations include pulsar wind nebulae (PWN) of high spin-down luminosity pulsars such as G 18.0–0.7 [1], supernova remnants like RX J1713.7–3946 [2], and open star clusters like Westerlund 2 [3]. As these objects cluster closely along the Galactic plane, a survey of this region is an effective approach to discover new sources and source classes of VHE γ -ray emission.

The H.E.S.S. experiment and its Galactic plane survey

The High Energy Stereoscopic System (H.E.S.S.) is an array of four imaging atmospheric-Cherenkov telescopes located 1800 m above sea level in the Khomas Highlands in Namibia [4]. Each of the telescopes is equipped with a camera comprising 960 photomultipliers and a tessellated mirror with an area of 107 m^2 , resulting in a comparatively large field-of-view of 5° in diameter. The H.E.S.S. array can detect point sources at flux levels of

about 1% of the Crab nebula flux near zenith with a statistical significance of 5σ in 25 hours of observation. This high sensitivity and the large field-of-view enable H.E.S.S. to survey large celestial areas – such as the Galactic plane – within a reasonable time.

The H.E.S.S. Galactic plane survey began 2004 and has been a major part of its observation program since. In the years 2004/2005 the survey was conducted in the Galactic longitude band $\pm 30^\circ$ around $l = 0^\circ$, covering most of the inner part of the Galactic plane from the tangent of the Norma arm to the tangent of the Scutum arm. Observations of 28 minutes duration each were taken at pointings with a spacing of 0.7° in longitude in three strips in Galactic latitude, covering an approximately 6° broad region along the Galactic plane. 95 h of data were taken in pure survey mode. Promising source candidates were re-observed in dedicated observations, comprising 30 h of data. In addition dedicated observations in this region were taken on known or assumed VHE γ -ray sources. The total amount of good quality data in this region was 230 hours, Fig. 1 (blue). This first stage of the H.E.S.S. Galactic plane survey resulted in the discovery of eight previously unknown sources of VHE γ -rays at a significance level greater than 6σ after accounting for all trials involved in the search (post-trials) [5]. Additionally, six likely sources were

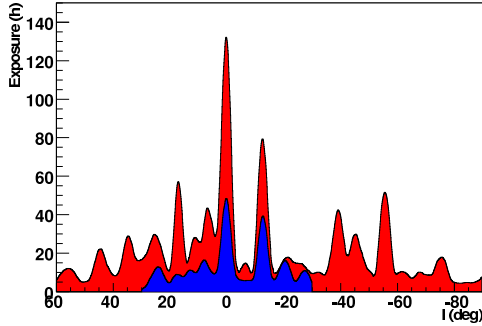


Figure 1: Acceptance corrected livetime (equivalent time spent at an offset of 0.5°) along the Galactic plane. All observations passing quality selection are considered, including survey-mode observations, re-observations of promising source candidates, and dedicated observations of known or expected VHE γ -ray sources. *Blue*: Observations taken in 2004/2005, published in [6]. *Red*: Present status of data taking near the Galactic plane.

found with significances above 4σ [6].

In the years 2005–2007, the survey region was extended further along the Galactic Plane. The scan region now covers $-85^\circ < l < 60^\circ$, $-3^\circ < b < 3^\circ$, containing the Carina-Sagittarius arm and part of the Perseus arm. In total, ~ 325 h of data were taken in survey mode within this region, together with 625 h of pointed observations, which include re-observations of source candidates and dedicated observations of known or assumed VHE γ -ray emitters. Figure 1 shows the present (red) and past (blue) exposure of the H.E.S.S. Galactic plane scan.

New sources of VHE γ -rays

In the continuation of the H.E.S.S. Galactic plane survey, >14 new VHE γ -ray sources were discovered so far at statistical significances larger than 5σ post-trials. The possible associations range from young pulsars such as PSR J1846–258 (Kes 75), over middle-aged pulsars (PSR J1913+1011) to a source first discovered at TeV energies by the Milagro collaboration (MGRO J1908+06). A non-negligible fraction of the sources, however, have no obvious counterparts.

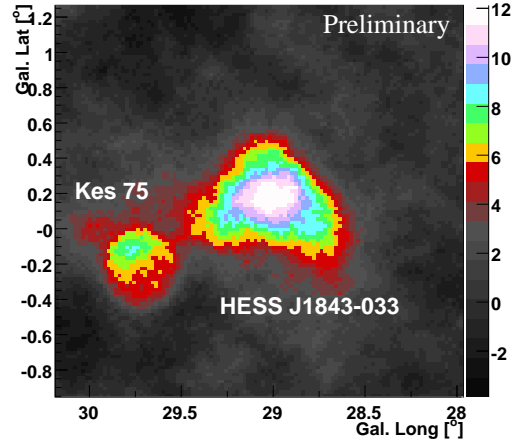


Figure 2: γ -ray significance map of the region containing Kes 75, obtained by counting γ -rays within 0.22° from a given location. The integration radius is part of the standard survey analysis, chosen a-priori and therefore not adjusted to the individual source sizes. Shown significance values do not take the statistical trials involved in the survey into account.

PSR J1846–0258 and Kes 75

The young shell-type supernova remnant (SNR) Kes 75 is in many ways similar to the well-studied Crab SNR. It contains the central pulsar PSR J1846–0258, which powers an extended radio and X-ray core, and is therefore another example of a centre-filled SNR, or plerion. Its distance is estimated as ~ 19 kpc [7]. PSR J1846–0258 has a rotation period of 325 ms and a spin-down age of 728 yrs [8], which apparently makes it the youngest rotation-powered pulsar yet discovered [9]. The extensions of the core and the shell are $30''$ and $3.5'$ respectively [7]. Like from the Crab nebula, a point-like source of VHE γ -ray emission is detected, coincident with the position of Kes 75, at a significance level of more than 8σ post-trials. For details concerning the H.E.S.S. detection of this object see [10]. In the same field of view, an extended source HESS J1843–303 was discovered with a statistical significance of more than 11σ post-trials. In contrast to Kes 75, no obvious counterpart for this source was found yet, but a detailed archival search is still ongoing.

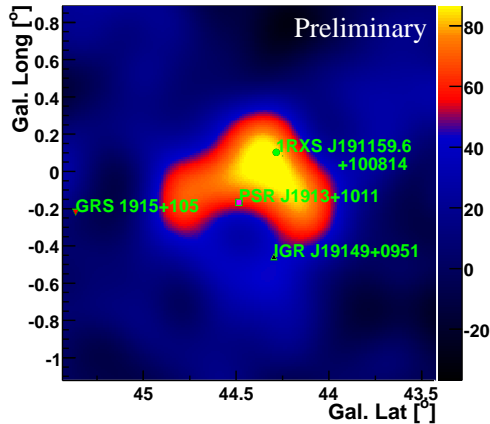


Figure 3: Image of the VHE γ -ray excess from HESS J1912+101, smoothed with a Gaussian profile of width 0.13° . The positions of the pulsar PSR J1913+1011, the ROSAT source 1RXS J191159.6+100814, the INTEGRAL source IGR J19149+0951 and the microquasar GRS 1915+105 are marked.

HESS J1912+101

Another possible example of VHE γ -ray emission from a PWN of a high spin-down luminosity pulsar is HESS J1912+101, located at $l = 44.4^\circ$ and $b = -0.1^\circ$, detected at a post-trials significance of more than 5σ . The corresponding pulsar, PSR J1913+1011, is rather old, with a spin-down age of $t_c = 1.7 \times 10^5$ yrs, and nearby, at a distance of ~ 4.5 kpc [8]. In contrast to PSR J1846–0258 mentioned earlier, no PWN was detected during a dedicated Chandra observation of the pulsar. The H.E.S.S. source is offset from the position of PSR J1913+1011, which can be explained by either the proper motion of the pulsar, or by an expansion of the PWN in an inhomogeneous medium [11]. The latter explanation seems plausible as clumpy molecular material was found close to the pulsar position in $^{13}\text{CO}(J=1\rightarrow 0)$ line measurements [12]. The scenario of an asymmetric PWN would make HESS J1912+101 similar to HESS J1825–137 [1].

MGRO J1908+06

The Milagro collaboration, operating a ground-based air shower detector near Los Alamos, announced the detection of several new candidate emitters of TeV γ -rays in the Galactic plane [13]. Compared to the H.E.S.S. array, Milagro has a higher energy threshold - the median energy of detected events is about 20 TeV - and a reduced angular resolution of about 1° . The Milagro coverage of the Galactic plane extends from about 30° longitude towards higher longitudes. Four sources are detected at sufficient significance, the Crab Nebula and the new sources MGRO 2019+37, MGRO 1908+06 and MGRO 2031+41. Of these, only MGRO 1908+06, with a flux of 80% of the Crab flux and a diameter of up to 2.6° , located at around 40° longitude is also contained within the H.E.S.S. Galactic plane survey. Confirming the Milagro result, a γ -ray source is detected with a significance of more than 5σ post-trials. The H.E.S.S. source is located at $l = 40.45^\circ$ and $b = -0.80^\circ$, consistent with the Milagro position of $l = 40.4^\circ$ and $b = -1.0^\circ$, with an error radius on the Milagro position of 0.24° . The rms size of the H.E.S.S. source is about 0.2° . For more details on the H.E.S.S. result see [14].

Unidentified sources

A significant fraction of the recently discovered sources of VHE γ -rays within the Galactic plane lack obvious counterparts. For seven of these sources extensive archival searches in multi-wavelength data and standard catalogues were performed to search for associated objects in the radio, X-ray and GeV γ -ray domains. While some of them are partially coincident with known or unidentified X-ray sources, none provide a clear counterpart which matches all of the observed characteristics of the VHE emission. The lack of a lower-energy counterpart challenges VHE emission scenarios, both leptonic and hadronic. More details are given in a separate contribution to this conference [15].

Summary

The H.E.S.S. Galactic plane survey, which started in the year 2004, now reaches from -85° longitude to 60° longitude, and covers an approximately 6° broad band around latitude $b = 0^\circ$. In total, more than 950 hours of data were taken in this region, including survey mode observations, re-observations of source candidates and dedicated observations of known or suspected γ -ray sources. The first stage of the survey, covering the inner 60° of the Galactic plane, has increased the number of known VHE γ -sources within this region from three at the beginning of 2004 to seventeen. Further follow-up observations within this region and the extension of the survey along the Galactic plane resulted in the discovery of even more additional VHE γ -ray emitters. Most of them were presented during this conference. Multi-wavelength follow-up observations and archival searches have already begun, and will be crucial for understanding the underlying processes at work in these astrophysical objects.

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