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The Galactic Sky seen by H.E.S.S.

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Abstract

The H.E.S.S. experiment is an array of four imaging Cherenkov telescopes located in the Khomas Highlands of Namibia. It has been operating in its full configuration since December 2003 and detects very-high-energy (VHE) γ rays ranging from 100 GeV to ~50 TeV. Since 2004, the continuous observation of the Galactic Plane by the H.E.S.S. array of telescopes has yielded the discovery of more than 50 sources, belonging to the classes of pulsar wind nebulae (PWN), supernova remnants (SNR), γ ray binaries and, more recently, a stellar cluster and molecular clouds in the vicinity of shell-type SNRs. Galactic emission seen by H.E.S.S. and its implications for particle acceleration in our Galaxy are discussed.

Keywords: Gamma-ray astronomy; Imaging atmospheric telescopes; H.E.S.S.; Supernova remnants; Binary systems; Pulsar wind nebulae

1. Introduction

In the last decade, the third generation of imaging atmospheric Cherenkov telescope (H.E.S.S., VERITAS, MAGIC and CANGAROO-III) came into operation and opened up a previously largely unexplored window on the very-high-energy (VHE) Universe. Since the pioneering Whipple experiment in 1989, the sensitivity has been increased by a factor of 100, leading to a detection time of ~25 s for a source of the intensity of the Crab Nebula compared to 50 h for the original detection (Weekes et al., 1989). The TeV source catalogue now comprises more than 100 sources.[1] This scientific breakthrough was made possible by the combination of telescopes with large mirrors, cameras with fast photo-detectors and fine pixelation and the sterescopic observation technique which, by combining several views of the same shower seen from different telescopes, allows a simple geometric reconstruction of the direction of the primary gamma ray and a significant improvement of the angular resolution and rejection capabilites. The High Energy Stereoscopic System (H.E.S.S.), an array of four imaging atmospheric Cherenkov telescopes situated in the Khomas Highland of Namibia (Aharonian et al., 2006a), played a major role in the opening up of this field, with in particular a very successful systematic survey of the inner parts of the Galactic Plane starting in 2004 and extended continuously since then (Aharonian et al., 2005b, 2006b; Chaves, 2009). The angular resolution of H.E.S.S. is better than 0.1° at all the accessible energies from ~120 GeV to several tens of TeV and the energy resolution is about 15% for a threshold varying from ~120 GeV at zenith to about 700 GeV at a zenith angle of 60°. The sensitivity of the H.E.S.S. instrument was recently improved by a factor of ~2 by the development of more sophisticated analysis techniques (Ohm et al., 2009b; Dubois et al., 2009; de Naurois and Rolland, 2009; Naumann-Godó et al., 2009; Fiasson et al., 2010), some of which also yielded an angular resolution improved by about 30%.

The H.E.S.S. Galactic Plane survey now covers most of the Galactic Plane as seen from the Southern Hemisphere, and led to the discovery of a rich population of more than 50 Galactic sources, belonging to the classes of pulsar wind

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[1] See TeVCat, an online TeV γ-ray catalog, at http://tevcat.uchicago.edu/.

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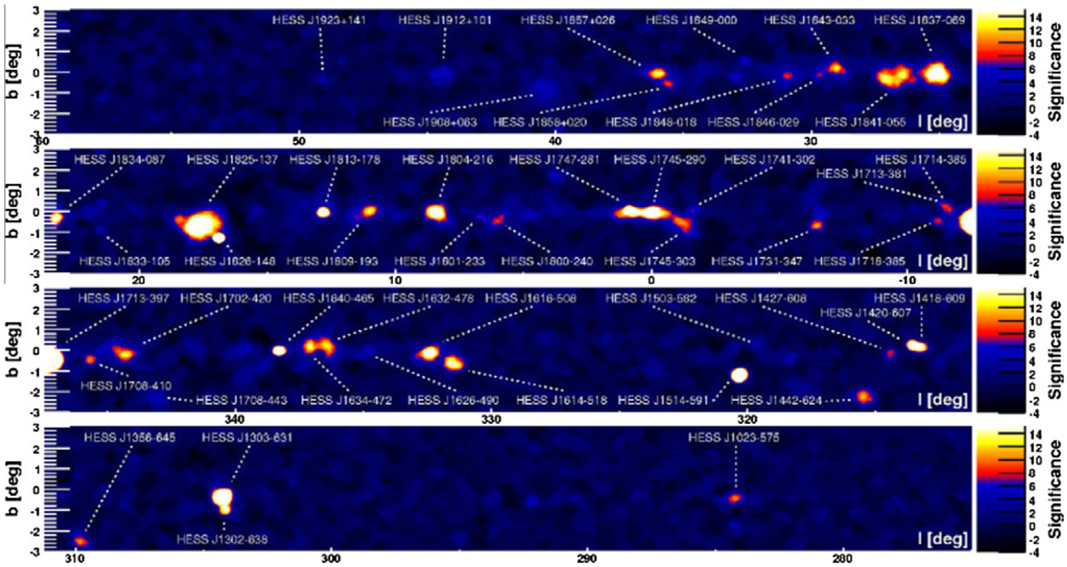

Fig. 1. Pre-trial significance in the H.E.S.S. Galactic Plane Survey. Significance is truncated above 15 σ to increase visibility. Figure reproduced from Chaves (2009).

nebulae (PWN), supernova remnants (SNR), γ ray binaries and, more recently, stellar clusters and molecular clouds in the vicinity of shell-type SNRs.

Outside of the Galactic Plane, more than 30 point-like sources have been discovered and associated with active galactic nuclei (AGN), mostly objects of the BL Lacertae type (BL Lac).

2. Survey of the Galactic Plane

The H.E.S.S. Galactic Plane survey (GPS) has been a core component of the observation program since 2004. The original GPS (Aharonian et al., 2005b), consisting of $\sim$230 h of observation after standard run-quality selection, covered the inner part of the Galaxy, from the Norma to the Scutum-Crux spiral arms tangent ($l \pm 30°$ in longitude and $b \pm 3°$ in latitude). It resulted in the firm discovery of eight previously unknown sources of VHE γ rays with a statistical significance above 6σ (post-trials[2]) and six likely sources above 4 σ, all of them confirmed by subsequent deeper observations.

Between 2005 and 2009, the GPS was extended significantly in longitude, from $l \sim -60°$ to $l \sim 275°$ (Chaves, 2009). In addition, the overall exposure along the Galactic Plane was significantly increased with more than 1400 h of accumulated data (representing roughly one third of the total H.E.S.S. data set). The H.E.S.S. exposure inside the Galactic Plane varies from a few hours on the less observed area to more than 100 h in the deep exposure regions centered around targets of specific interest such as Sgr A*, RX J1713.7-3946, or LS 5039, leading to a sensitivity varying between less than 1% to about 10% of the Crab Nebula flux.

The pre-trials significance map of the Galactic Plane, reproduced from Chaves (2009) and calculated using the ring-background subtraction technique (Aharonian et al., 2006a) and *hard* cuts, is shown in Fig. 1. A total of 56 Galactic sources are detected in the GPS. The major population consists of PWN (29 identified sources) followed by SNR (9 associations) and binary systems (3 systems).

Most of the Galactic VHE sources are found to be significantly extended, with sizes greater than the $\sim$0.1° H.E.S.S. point spread function (PSF). The few sources in the Galactic Plane that appear point-like are associated with young pulsar wind nebulae (PWN), including the Crab Nebula (Aharonian et al., 2006a), or with VHE γ ray emitting high-mass X-ray binaries (HMXB) which include the very well established binaries PSR B1259-63 (Aharonian et al., 2005d) and LS 5039 (Aharonian et al., 2005c). The point-like VHE source HESS J0632+057 is now a strong candidate for a HMXB system following a recent multi-wavelength campaign (Aharonian et al., 2007c; Hinton et al., 2009).

After excluding five sources well off the Galactic Plane, with $|b| > 2°$ (HESS J1356-645, HESS J1442-624, HESS J1507-662, HESS J1514-591, and SN 1006), the latitude distribution of the Galactic sources is very narrow ($\langle b \rangle = -0.26°$ with an RMS of 0.40°). This scale is significantly smaller than the width of the region of significant H.E.S.S. exposure (of the order of $\sim$2° in RMS), and similar to the scale of the molecular gas distribution. The latitude distribution is, at the first glance, compatible with what is the presumably parent populations of SNRs (Green, 2004) and high spin-down luminosity pulsars ($\dot{E} > 10^{34}$ ergs s^{-1}) from Manchester et al. (2005).

[2] Since the GPS contains a large number of test positions, the significance has to be corrected according to a "trial factor." This trial factor accounts for the increased probability of finding a fake signal with an increased number of test positions for which a significance is calculated. A Monte Carlo simulation is used to correct for the number of trials.