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Results from the H.E.S.S. Galactic Plane survey

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The H.E.S.S. experiment (High Energy Stereoscopic System) is an array of imaging Cherenkov telescopes for the detection of γ-rays in the energy domain above 100 GeV. Its improved sensitivity and angular resolution in comparison to previous instruments and the large field of view of 5 degrees makes H.E.S.S. perfectly suited for a survey of the galactic plane. We report on a scan of the inner part of the Galactic plane in very high energy γ-rays with the H.E.S.S telescope system. The Galactic plane between longitude 330 deg and 30 deg and Galactic latitude -3 deg to +3 deg was observed for a total of 230 hours, reaching an average flux sensitivity of 3% of the Crab Nebula at energies above 200 GeV. Several unknown sources of very high energy γ-ray emission were found at a high statistical significance. We will present results for these new sources, along with a discussion on possible counterparts in other wavelength bands.

1. Introduction

Very high energy (VHE, defined here as $E > 10^{11}$ eV) γ-rays provide the most direct view currently available of extreme environments in the local universe. As γ-rays are produced by interactions of relativistic particles they represent a good probe of non-thermal astrophysical processes. Relativistic electrons can produce γ-rays by non-thermal bremsstrahlung or by inverse Compton scattering on background radiation fields, whereas protons (and atomic nuclei) can generate γ-rays via the decay of π^0s produced in hadronic interactions with ambient material. VHE γ-radiation is therefore expected from the acceleration sites of particles with energies above 1 TeV (10^{12} eV). In particular, γ-rays can be seen as a probe of sources of nucleonic cosmic rays in our Galaxy and may thus provide part of the solution to the century-old puzzle of the origin of this radiation.

Theoretically predicted particle accelerators in the Galaxy include pulsars and their pulsar wind nebulae (PWN), supernova remnants (SNR), microquasars, and massive star forming regions. Detected sources of very high energy γ-rays in the Galaxy include PWN, SNRs and objects with no identified counterpart in other wavebands. Most potential galactic γ-ray sources are associated with massive star formation and therefore cluster along the Galactic Plane, concentrated in the direction towards the centre of the Galaxy. From catalogues, it is known that 91 SNRs and 389 pulsars are located within the inner 60° in galactic longitude and 6° in galactic latitude [2, 3]. A systematic survey of the Galactic plane thus provides a promising way to investigate properties of source classes and to search for as-yet unknown types of Galactic VHE γ-ray emitters. Until the completion of the High Energy Stereoscopic System (H.E.S.S.) [4] in early 2004, no systematic VHE γ-ray survey of the southern sky, or of the central region of the Galaxy had been performed. Here we report on a survey of this region conducted with H.E.S.S. in 2004, at a flux sensitivity of 3% of the Crab flux. H.E.S.S. is an array of telescopes using the stereoscopic imaging Cherenkov technique. H.E.S.S. consists of four atmospheric Cherenkov telescopes and has the largest field of view (5° diameter) of all presently operating imaging Cherenkov telescopes, which yields a considerable advantage for surveys. The angular resolution for individual γ-rays is better than 0.1°, allowing a source position error of $30''$ to be achieved, even for relatively faint sources.

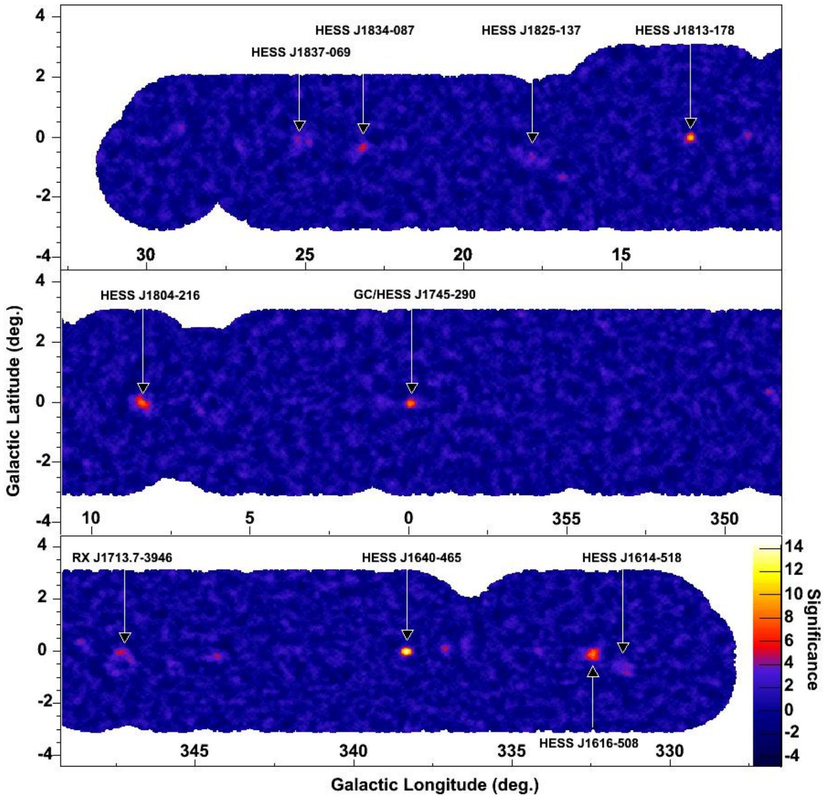

Figure 1. Significance (pre-trial) map of the H.E.S.S. 2004 Galactic plane scan. Re-observations of candidates from the initial scan are included here. The background level was estimated using a ring around the test source position. On-source counts are summed over a circle of radius θ, where $\theta^2 = 0.02$ degrees^2, a cut appropriate for point-like sources.

2. The H.E.S.S. Galactic plane survey

The inner part of the Galactic plane (Galactic longitude -30°$<$l$<$30° and latitude -3°$<$b$<$3°) was scanned with H.E.S.S. from May to July 2004 in observations of 28 minute duration. Individual observations were spaced by $0.7°$ in longitude and $1°$ in latitude for a total observation time of 112 hours. An average 5 standard deviation detection sensitivity of 3×10^{-11} photons cm^{-2} s^{-1} above 100 GeV (≈3% of the Crab Flux) was reached for points on the Galactic plane. Seven promising candidate sources from the survey were re-observed from July to September for typically 3.5 hours per source. Eight unknown VHE sources were detected at the level of larger than 6 standard deviations after accounting for all trial factors (see Fig. 1). The new Galactic VHE γ-ray sources cluster along the Galactic plane (with a mean b of -0.25° and an rms of 0.25° in the latitude distribution). This is a clear indication that we see a population of Galactic (rather than extragalactic) sources. All of the sources are significantly extended beyond the size of the H.E.S.S. point spread function. A search for counterparts for the new γ-ray sources has been conducted in other wavelength bands. Fig. 2 shows the γ-ray emission from the region around each of the new sources together with potential counterparts.

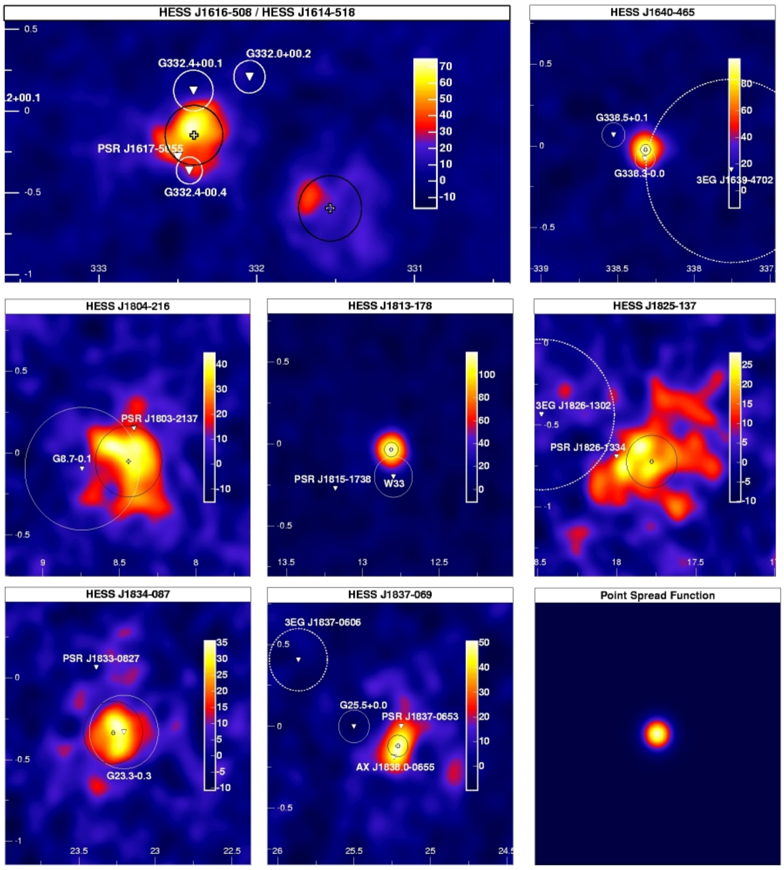

Figure 2. Smoothed excess maps in units of counts of the regions around each of the eight new sources in Galactic coordinates in degrees. A Gaussian of rms 0.05° is used for smoothing to reduce the impact of statistical fluctuations. The best-fit centroids for the γ-ray emission are shown as crosses, and the best-fit rms size as a black circle. Possible counterparts are marked by white triangles, with circles indicating the nominal source radius (or the position error in the case of EGRET sources). The lower right panel indicates the simulated point spread function of the instrument for these data, smoothed in the same way as the other panels.

3. Discussion of possible counterparts

3.1 SNR candidates

The chance probability for coincidences with SNR in the whole scan region is 6%. Four plausible associations exist with an SNR: for HESS J1640-465, HESS J1834-087 and HESS J1804-216 and recently discovered also HESS J1813-178. HESS J1640-465 is spatially coincident with the SNR G338.3-0.0, which is a broken shell SNR lying on the edge of a bright ultra-compact HII region. The unidentified EGRET source 3EG J1639-4702 lies 35′ away and could also be connected to HESS J1640-465, given the position uncertainty of 34′ of the EGRET source. HESS J1834-087 is spatially coincident with SNR G23.3-0.3 (W 41), a 27′ diameter shell-type SNR. HESS J1813-137 is spatially coincident with the recently published radio SNR candidate G12.8–0.0 [5], that was also detected in soft γ-rays by the INTEGRAL satellite [6]. HESS J1804-216 coincides with the southwestern rim of the shell-type SNR G8.7-0.1 (W30) of radius $26'$.

3.2 Pulsar wind nebula candidates

HESS J1804-216 is also one of three plausible associations with nebulae powered by sufficiently energetic young pulsars. The others are HESS J1825-137 and HESS J1616-508. HESS J1825-137 lies $13'$ from the pulsar PSR J1826-1334 which has been associated with the close-by unidentified EGRET source 3EG J1826-1302. A $5'$ diameter diffuse emission region extending asymmetrically to the south of the pulsar was detected using XMM [7]. This diffuse emission is interpreted as synchrotron emission produced by a pulsar wind nebula (PWN). The VHE emission is similarly located south of PSR J1826-1334, and could be coincident with the PWN. The conversion efficiency implied from spin down power to VHE γ-rays is less than 1%. HESS J1616-508 is located $9'$ from the young hard X-ray pulsar PSR J1617-5055. The VHE γ-ray flux is again less than 1% of the spin-down luminosity of the pulsar.

3.3 Other sources

For HESS J1837-069 a potential counterpart is the diffuse hard X-ray source G25.5+0.0, which is $12'$ across and was detected in the ASCA Galactic plane survey [8]. The nature of this bright X-ray source is unclear but it may be an X-ray synchrotron emission dominated SNR such as SN 1006 or a PWN. The brightest feature in the ASCA map (AX J1838.0-0655), located south of G25.5+0.0, coincides with the centre of gravity of the VHE emission and is therefore the most promising counterpart candidate. This still unidentified source was also serendipitously detected by BeppoSAX and also in the hard X-ray (20-100 keV) band in the Galactic plane survey of Integral. HESS J1614-518 so far has no plausible SNR or pulsar counterpart. This source is in the field of view of the nearby HESS J1616-508.

4. Summary

Four of the eight newly discovered sources are potentially associated with supernova remnants, two with EGRET sources. In three cases an association with pulsar-powered nebulae is not excluded. In conclusion, we have on the basis of the survey generated a first unbiased catalogue of very high energy γ-ray sources in the central region of our Galaxy, extending our knowledge of the Milky Way into the VHE domain.

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