H.E.S.S. Galactic plane survey

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Dataset
H.E.S.S. — HGPS

**HGPS dataset**
- Telescopes: H.E.S.S. I
- Observations: 2004 to 2013
- Total exposure: 3000 hours
- Sky region: $250^\circ < l < 65^\circ$, $-3.5^\circ < b < 3.5^\circ$
- Energy range: 0.2 – 100 TeV
- Resolution (R68): 0.07 deg
Survey region and exposure

Stars: Galactic TeV sources outside HGPS region
Triangles: Galactic GeV sources (1FHL)
Image: Planck CO map

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Energy threshold

- Preliminary
- Maps
- Spectra

Graph showing energy threshold as a function of Galactic longitude for different energy thresholds.

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**Point source sensitivity**

HGPS sensitivity image for an oversample radius of 0.1, assuming a spectral index of 2.3.

Longitude sensitivity profile for 0 of Galactic latitude. Both are displayed in percentage of the Crab unit.

- Compute the point spread function (PSF) (Section 4.4.1) for the highest significance small source and use it for all of the ROI. It was checked that results for other sources in the ROI don’t change much if the PSF is computed for that exact position.
- Model the excess as multiple Gaussian components using a binned likelihood fit to the counts map, taking the background and exposure and PSF into account (Section 4.4.3).
- Many different multi-Gauss solutions are tried by changing the number of sources and the position, extension, normalization start parameters for the fit. For each number of sources (1, 2, 3, …) there is a best-fit solution, sometimes for a given number of sources there are multiple solutions where the fit converged (local likelihood maximum in the parameter space).
- For the catalog the globally most likely solution is chosen where every source satisfies the detection threshold criterion and every pair of sources satisfies the source separation criterion (Section 4.4.4).
- Characterize each source further. Define the “source radius” for spectral analysis. Test if it models the excess well and whether it is elongated.

**4.2. TS maps**

Additionally to the standard significance maps described in sec. 4.4.1 we used so called test statistics (TS) maps during our analysis. Similar to standard Li & Masignificance maps, TS maps give the likelihood ratio of a given source hypothesis compared to the null (i.e. background only) hypothesis, but instead of summing all pixels in a certain region, as done for Li & Masignificance maps, a source model template is fitted at every pixel of the map.

TS maps better reflect the catalog construction procedure. The approach is described in detail in Stewart (2009).

**Why use TS maps instead of Li & Masignificance images?**

In the subsequent presentation of sky maps, TS maps will be used.

Which Figure show TS maps?

Should we discuss the input maps (counts, background, exposure) for the catalog here?

**4.3. Large-scale emission model**

The existence of a diffuse emission component along the Galactic disk has been already demonstrated (Abramowski et al. 2014a). To do so, a mask was build to exclude a fraction of the plane around regions where significant emission was found. The latitude profile of excess events outside this mask clearly shows that some emission is still present. Whether it is due to truly interstellar processes or to unresolved sources emission is an open question.

The presence of an underlying large scale component along the plane is making the Gaussian component extraction unstable: it mimics the presence of degree scale features in some regions of the HGPS and tends to broaden the Gaussian components that describe well defined sources. To precisely extract the sources fluxes and sizes, it is therefore necessary to use a template model of the diffuse emission.

To do so we have build a Gaussian band model: the latitude profile is described by a Gaussian and has three parameters: the peak latitude, the width and the brightness. These parameters are assumed to be constant over a certain longitude range. They can be estimated in a given region of the survey using the maximum likelihood fitting approach. The Gaussian band template can be fitted in a region where no significant signal is measurable on small scales, e.g. outside the exclusion regions defined for the ring background estimation technique.

A simplistic assumption would be that all three parameters are constant with longitude. But whatever the origin of the diffuse component, it is likely to be structured along the plane.
Source catalog
Construction
Morphology model (2013)

ICRC 2013 Figure – Gaussian sources …

… it’s not really that simple …

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Morphology model (2015)

- Cut out SNRs and Galactic centre region (13 sources)
- Large-scale diffuse Gaussian band model
- 100 significant Gaussian components with Poisson likelihood test statistic $TS > 30$
- 64 sources (re-)analysed
- HGPS catalog sources: $77 = 64 + 13$
Gaussian band large-scale emission model

- Gaussian shape in GLAT
- Parameters vary with GLON:
  - Peak Brightness
  - Peak latitude
  - Gaussian width
- Fitted outside exclusion regions, using sliding window with 20 deg width.
Results
For the first time shown in full detail! Will be released as FITS with the paper.
Come see the poster — Session: Poster 3 GA, Track: GA-EX Board #: 54

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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 $\llap{\sim}5$ 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 ($\llap{\sim}5$ pre-trials, and assuming the spectral shape of a power law with index 2.5) is better than 10% Crab.
Source and sensitivity
Galactic latitude distribution

Caveat: these are observed distributions, not taking survey coverage and selection effects into account!

See H.E.S.S. PWN and SNR population studies.
PWN – Klepser et al. GA03 ID=635
SNR – Hahn et al. GA17 ID= 556

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Associations

Systematic association of HGPS sources with nearby PSR, SNR, PWN, GeV sources (3FGL and 1FHL)
Not a population study!

Thanks to Samar Safi-Harb and Gilles Ferrand for SNRcat!
http://www.physics.umanitoba.ca/snr/SNRcat/
Firm identifications

- 12 PWN
- 6 Composite
- 6 SNR
- 3 Binary
- Unidentified: 50

Mostly sources with multiple associations

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New H.E.S.S. sources!
Summary

• H.E.S.S. Galactic plane survey (HGPS) is completed

• Can be the basis for new studies, e.g. by H.E.S.S.
  - PWN population study (Stefan Klepser et al.)
  - SNR population study (Joachim Hahn et al.)

• Several new sources discovered

• Paper and legacy data release coming soon (fall 2015)

• FITS maps and source catalog (morphology & spectra)

• Come see the HGPS poster (Axel Donath et al.) and talk to us!
Backup slides
HGPS firm identifications

(see pie chart on slide 17)

| Source Name          | Associated object | Class       | Evidence       | Reference                                      |
|----------------------|-------------------|-------------|----------------|-----------------------------------------------|
| HESS J1018–689A      | IFGL J1018.6–5856 | Binary      | Variability    | H. E. S. S. Collaboration et al. (2015a)     |
| HESS J1302–638       | PSR B1259–63      | Binary      | Variability    | Aharonian et al. (2005a)                      |
| HESS J1826–148       | LS 5039           | Binary      | Variability    | Aharonian et al. (2006c)                      |
| HESS J0852–363       | Vela Junior       | SNR         | Morphology     | Aharonian et al. (2005b)                      |
| HESS J1442–624       | RCW 86            | SNR         | Morphology     | Aharonian et al. (2009)                       |
| HESS J1534–571       | G323.7+01.0       | SNR         | Morphology     | H.E.S.S. SNR shell paper (2015)               |
| HESS J1713–397       | RX J1713.7–3946   | SNR         | Morphology     | Aharonian et al. (2004)                       |
| HESS J1731–347       | G353.6–0.7        | SNR         | Morphology     | H.E.S.S. Collaboration et al. (2011b)        |
| HESS J1800–240       | W 28              | SNR         | Position       | Aharonian et al. (2008)                       |
| HESS J0835–455       | Vela X            | PWN         | Morphology     | Aharonian et al. (2006a)                      |
| HESS J1303–631       | PSR J1301–6305    | PWN         | ED Morph.      | H.E.S.S. Collaboration et al. (2012)          |
| HESS J1514–591       | MSH 15–52         | PWN         | Morphology     | Aharonian et al. (2005a)                      |
| HESS J1826–137       | PSR J1826–1334    | PWN         | ED Morph.      | Aharonian et al. (2006d)                      |
| HESS J1356–645       | PSR J1357–6429    | PWN         | Position       | H.E.S.S. Collaboration et al. (2011a)        |
| HESS J1418–609       | PSR J1418–6058    | PWN         | Position       | Aharonian et al. (2006b)                      |
| HESS J1420–607       | PSR J1420–6048    | PWN         | Position       | Aharonian et al. (2006b)                      |
| HESS J1554–550       | G327.1+01.1       | PWN         | Morphology     | Section 5.7.5                                |
| HESS J1747–281       | G0.9+0.1          | PWN         | Morphology     | Aharonian et al. (2005b)                      |
| HESS J1818–154       | G015.4+00.1       | PWN         | Morphology     | H. E. S. S. Collaboration et al. (2014)       |
| HESS J1849–900       | PSR J1849–0001    | PWN         | Position       | Section 5.7.15                               |
| HESS J1837–069       | PSR J1838–0655    | PWN?        | Morphology     | Marandon et al. (2008)                        |
| HESS J1640–465       | G338.3+0.0        | Composite?  | Position       | Abramowski et al. (2014b), Gotthelf et al. (2014) |
| HESS J1119–614       | PSR J1119–6127    | Composite   | Position       | Section 5.7.1                                |
| HESS J1813–178       | PSR J1813–1749    | Composite   | Position       | Funk et al. (2007), Gotthelf & Halpern (2009) |
| HESS J1839–105       | G21.5–0.9         | Composite   | Position       | Section 5.7.10                               |
| HESS J1846–029       | PSR J1846–0258    | Composite   | Position       | Section 5.7.13                               |
| HESS J1930+186       | G54.1+0.3         | Composite   | Position       | Acciari et al. (2010), Section 5.5           |

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Exclusion regions and regions of interest
• Position:
  \((l, b) = (17.31, 2.49) \text{ deg}\)
  \((\alpha, \delta) = (273.34, -12.69) \text{ deg}\)

• Extension: 0.21 deg

• Flux: 4.2% Crab
• Position: 
  \((l, b) = (18.48, -0.39)\) deg
  \((\alpha, \delta) = (276.51, -13.02)\) deg
• Extension: 0.15 deg
• Flux: 3.3% Crab
- Position: 
  \((l, b) = (21.49, 0.38)\) deg 
  \((\alpha, \delta) = (277.25, -9.99)\) deg

- Extension upper limit: 
  < 0.07 deg

- Flux: 1.7% Crab
• Position: 
  \((l, b) = (23.21, 0.29)\) deg 
  \((\alpha, \delta) = (278.13, -8.51)\) deg 

• Extension upper limit: 
  < 0.05 deg 

• Flux: 0.8% Crab
• Position:
  \((l, b) = (29.41, 0.09)\) deg
  \((\alpha, \delta) = (281.17, -3.10)\) deg

• Extension upper limit:
  \(< 0.05\) deg

• Flux: 1.0\% Crab