Exploring the Galaxy at VHEs with H.E.S.S.

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Exploring the Galaxy at VHEs with H.E.S.S.

outline

- the H.E.S.S. telescopes
- Galactic highlights
 - H.E.S.S. I
 - H.E.S.S. II
- summary









The Cherenkov technique in a nutshell



The stereo Cherenkov technique in a nutshell





Technical specs: snapshot

Telescopes: 4 Mirrors: 12 m diameter Area: 107 m² **FoV: ~5° diameter** Camera: 960 pixels (PMTs) Angular resolution $\ge 0.06^{\circ}$ (5') Electronics: fast ~1 ns Energy range: ~100 GeV to ~100 TeV Energy resolution ~15% Background rejection > 99% Duty cycle 10%





The High Energy Stereoscopic System of Cherenkov telescopes







• >2800h obs (2004-2013), 65° < / < 250°, 1*b*l < 3.5°, [0.2 - 100] TeV, ~2% Crab, 77 sources





- adaptive ring bkg estimation with exclusion region masks
- semi-automated, MLE-based source detection & morphology fitting
- model sources as Gaussian plus an underlying "diffuse" component





P. Bordas, HESS Galactic, JPS-2015



- one of the hardest gamma-ray spectra ever found at VHEs (Γ = 2.07)
- detected only above few TeVs (contamination by nearby HESS J1640)
- no signature of cut-off, pp-preferred... PeVatron? (protons >100 TeV 99% CL)



H.E.S.S. Collaboration (2006)

Fermi-LAT Collaboration (2011)

still, many questions remain...

- spectral cut-off shape? —> electrons vs. protons
- spatially-resolved spectra w/ unprecedented resolution —> resolve physical properties
- morphology & radial profiles + comparison to X-rays —> particle diffusion + escape?

H.E.S.S. high-precision measurements of RXJ1713-3946



H.E.S.S. Collaboration (2015, in prep.)

- exposure: 170 h
- angular resolution: 0.05 deg
- energy threshold: 250 GeV



H.E.S.S. high-precision measurements of RXJ1713-3946 The X-ray hotspots









H.E.S.S. high-precision measurements of RXJ1713-3946



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The Fermi-LAT and H.E.S.S. Views of the Supernova Remnant W49B



Fermi-LAT and H.E.S.S. Collaboration (2015, in prep.)

- H.E.S.S.:
 - 75h live-time (2004-2013, no CT5)
 - *Model* analysis, std cuts (E_{th} ~ 290 GeV)
 - W49B detected at 12.9 stat. level
 - morphology: point-like (PSF ~ shell size)

, The Fermi-LAT and H.E.S.S. view of the supernova remnant ICRC 2015 - The Hague, 05/08/2015

- Fermi-LAT:
 - 5 years of data (Pass7)
 - morphology: point-like (PSF ~ shell size)
 - slight offset position w.r.t. H.E.S.S

SNRs: new TeV shells



H.E.S.S. Collaboration (2015, in prep.)

- goal: extend small population of known TeV shells
 - some sources may be faint in X-rays (intrinsically or due to absorption)
 - -shell morphology: particles confined albeit high-E may have escaped
- method: look for new shell candidates in the HGPS
- results: two new shell-candidates resolved, few more candidates...

H.E.S.S. Observations of the LMC



PWN N157B:

- Crab LMV "counter-part"
- but lower B-field (45 μG) and efficiency
- no GeV emitter (so far)

30 Dor C

- 1st detection superbubble in γ-rays
- shell-bright in X-rays, TeV also there?

N 132D

- one of oldest TeV emitting SNRs
- first individual cosmic-ray sources in external galaxy \rightarrow Science **347**:6220 (2015)
- just the "tip of the iceberg"? -> future observations with CTA

Pulsations from the Vela Pulsar down to 20 GeV with H.E.S.S. II



- High significance detection of the P2 pulse from the Vela PSR with H.E.S.S.II
- CT5 able to operate down to 20 GeV
- Excellent agreement with Fermi-LAT: crosscalibration check for CT5



H.E.S.S. Collaboration (2015, in prep.)

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Observations of Sgr A* with H.E.S.S. II



- GC with the H.E.S.S. II array down to ~100 GeV
- Detection of central source (40σ), PWN G0.9+0.1, HESS J1745-303 + diffuse emission
- smooth continuation from spectrum seen in H.E.S.S. I
- E-threshold not low-enough to fully describe Fermi-LAT-H.E.S.S. spectral break
- +50h obs. time coming soon (blinded for dark matter searches...) vs 58h so far...

PSR B1259-63: a pulsar γ-ray binary system

- pulsar (P 48ms, L_{sd}= 8 ×10³⁵ erg/s) + O9.5Ve star (L_{star}= 2.3 × 10³⁸ erg/s) + circ. disk
- binary system: D = 2.3, P_{orb}= 3.4 years, eccentricity = 0.87, orbital inclination i ~24°
- variable/periodic emission in radio, optical, X-rays, GeV and TeV γ-rays
- pulsations seen only in radio (and away from periastron)
- GeV flare in 2011; happening again in 2014



PSR B1259-63, credits: NASA archive



H.E.S.S. Observations of PSR B1259-63 during its 2014 periastron passage



H.E.S.S. Collaboration (2015, in prep.)

- Long-term H.E.S.S. monitoring campaign to cover 2014 periastron
- coordination with MWL observatories for simultaneous observations
- More than 57 hours of live-time analysed with STEREO and MONO analysis chains
- Source detected at 40σ level, HESS J1303-638 also detected

H.E.S.S. Observations of PSR B1259-63 during its 2014 periastron passage



- analysis of both 2014 and previous data with new software tools
- confirmed double-peak pattern observed in the long-term light curve
- Local minimum at the periastron passage
- Source still active at VHEs at 40-50 days after periastron
- Differences between light curves w.r.t previous periastron events

H.E.S.S. Observations of PSR B1259-63 during its 2014 periastron passage



- Comparison of results from H.E.S.S., Fermi-LAT and Swift-XRT simultaneous observations
- X-rays: highest-ever flux recorded in 2014 (2nd disk crossing). Hints of variability during GeV flare?
- Fermi-LAT: reappearance of the gamma-ray flare (slight differences), marked variability
- H.E.S.S. (CT5): high emission state at VHEs during the GeV flare

H.E.S.S. Collaboration (2015, in prep.)

LS 5039

LS 5039: the "swiss-clock" gamma-ray binary

- First binary @ TeV (Aharonian et al. 2005)
- C.O.: 3.7 +/-1.5 M_{sun}, O6.5V companion, P_{orb}= 3.9d
- long-term stability at VHEs (the exception)
- illustrates variability in VHE light-curves and spectra





P. Bordas, HESS Galactic, JPS-2015

LS 5039 - update of H.E.S.S - I data-set (2006-2012)

- excellent agreement with 2006 published results (swiss-clock)
- detection in every orbital phase (0.1 width)
- spectral features in some phase-bins
- broken PL preferred for INFC w.r.t. exp-cutoff-PL



LS 5039

LS 5039 - new H.E.S.S - II observations (2013-2015)



H.E.S.S. Collaboration (2015, in prep.)

Summary (I)

- 12 years of extremely successful H.E.S.S. operations
 - > effectively opening up the VHE window as a new astro-particle physics discipline
 - constraining the origin of Galactic cosmic-rays
 - testing the paradigm of **SNRs**: spectral cutoffs at TeV energies
 - through single new accelerators + diffuse emission: **PeVatrons**!

revealing VHE properties in powerful Galactic accelerators:

- properties of SNRs, **PWNs**, **binaries**, **stellar-clusters**... at the highest energies
- yet many unidentified -> discovery of **new source** types?



Summary (II)

- H.E.S.S.-II in operation since 2013
 - first true "hybrid system" of Cherenkov telescopes (rather challenging!)
 - Iowering E-threshold down to ~ 50-100 GeV
 - entering the *Fermi*-LAT regime (but with **10^5 times collection area**)
 - well-suited for variable phenomena (~hours-days) given high-statistics
 - no real analog system in the horizon: CTA offers 24m, northern hemisphere
 - hardware/software can be further improved => a true transients hunter!



BACKUP







