Results from the HESS Array of IACTs

TrevorFest, October 2013

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APC CNRS/IN2P3

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Intensive preparation for this talk

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The H.E.S.S. Observatory

H.E.S.S. I
- 4 telescope system in Namibia
- Field of view 5°
- Energy threshold \( \sim 200 \text{ GeV} \)
- Energy resolution \( \sim 15\% \)
- Angular resolution \( \sim 0.1^\circ \)
- High sensitivity (5\( \sigma \)): 1\% Crab in 25h

H.E.S.S. II
- H.E.S.S. I + single large telescope
- CT5
  - Mirror area 600 \( \text{m}^2 \)
  - Field of view 3.2°
  - Energy threshold O(30 GeV)
H.E.S.S.: 10 years operation in 2012

- Taken 9415 hours of data
  - with 4234 h along the Galactic plane (latitude < 10°) and
  - 5181 h in extragalactic space (latitude > 10°)
- Discovered over ~90 new VHE gamma ray sources (according to TeVCat)
  - ~60 Galactic objects
  - ~30 extra-galactic sources
- Published over 100 scientific papers in reviewed journals, plus numerous conference contributions
- Listed among the 10 most influential astronomical instruments
Most fruitful observations:
H.E.S.S. Galactic Plane Scan

(c) F. Acero & H. Gast

TrevorFest, April 2013
Results from HESS
H.E.S.S. GPS Observations

2800 hours of high-quality data, taken in the years 2004 to 2013.
Longitude \( l = 250 \) to 65 degrees, latitude \( |b| < 3.5 \) degrees
- Sensitivity for point-like sources at the 2\% Crab level or better

Populations:

SNR, PWN, unidentified sources, binaries, one extreme BL Lac, open star cluster, globular cluster, ...

Blue lines: H.E.S.S. horizons for 1\% and 10\% Crab

Dots:
H.E.S.S. Galactic sources
Red: PWNes
Yellow: SNRs
Black: other sources
H.E.S.S. GPS maps

- Pre-trials significance map, correlation radius 0.1°
- Blue-red transition corresponds to ~5σ post trial
H.E.S.S. SNR discoveries

- Young Shell type SNR
  - RX J1713.7-3946, SN 1006, Vela Jr, HESS J1731-347, RCW 86

- Middle aged SNR interacting with molecular clouds:
  - W51C, W49B, W28
Zooms on a couple of SNRs

**RX J1713.7-3946**
First-ever resolved $\gamma$-ray source
Strong correlation with X-rays: $\sim$80%

**RX J0852.0-4622 (Vela jr)**
Thin shell resolved with HESS
Correlation with X-rays: $\sim$65%
+ Correlation with Radio

Angular resolution < 0.1°
The brightest SNR seen: HESS J1640-465

- Most luminous Galactic TeV source
- Distance: 8 – 13 kpc
- Total livetime: 63.4 h
  - ~1800 excess events
- Morphology:
  - Significantly extended: $\sigma = (4.3 \pm 0.3)'$
  - Asymmetric extension towards HII region slightly preferred (by 2$\sigma$)
  - Significant overlap with northwestern SNR shell
Pulsar Wind Nebulae

- Major galactic TeV source population
  - Associated with relatively young (<$10^5$ year old), energetic pulsars
  - Extended sources, 10s of pc
  - Often displaced from pulsar (expansion into inhomogeneous medium)
- Generally believed that we see inverse Compton emission of 1-100 TeV electrons
Energy-dependent Morphology

- HESS J1825-137, HESS J1303-631
- Associated with energetic pulsar
- Spectral steepening seen away from the pulsar
- Very likely this is evidence for cooling of electrons in the Nebula
  - Seen in several X-ray PWN
- A first in gamma-ray astronomy!
- Now seen in several VHE PWNe
**Binaries: LS5039**

- **Binary system**
  - Massive star (20 M☉), UV (17,000 K)
  - Unidentified Compact Object (BH or NS) M = [1.5 – 5] M☉
  - Tight orbit (d = [2 – 4.5] R☉), ~ 0.1 AU
  - Orbital period 3.9 days (from Doppler)
  - Distance ~ 3kpc (9000 light yr)

- **H.E.S.S. discovery, First Periodic VHE source:**
  - Best fit period 3.90577 ± 0.00013 (11 seconds precision!)
  - Optical period is 3.90603 days (MJD0 = 51942.59): 2σ away
  - Folded light-curve shows features to be explained and orbital phase-resolved spectra
Binaries: 1FGL J1018.6-5856 / HESS J1018-589A

- **HE gamma-rays:**
  - “genuine” γ-ray binary: Fermi discovery
  - Periodic modulation = 16.58 days
- **Optical:**
  - O6V((f)) companion star
- **X-rays:**
  - periodicity seen also in X-rays, with a double peak structure in the phase-folded light-curve
- **Radio:**
  - flux variability, but no peak at $\phi \sim 0$

- **H.E.S.S.:**
  - Two sources, point-like (1FGL J1018?) + extended (PSR J1016?)
  - Search for variability in H.E.S.S.
  - $\Rightarrow$ Similar orbital variation as Fermi: peak at phase 0(3.1σ).

Abramowski et al. (2012)
Extragalactic: Active Galactic Nuclei ... +

Radio Galaxies:
- M 87
- Centaurus A

FSRQ(s):
- PKS 1510-089

BL Lacs:
- SHBL J001355.9-185406
- Markarian 421
- RGB J0152+017
- 1ES 1312-423
- 1ES 0229+200
- AP Librae
- 1ES 0347-121
- PG 1553+113
- 1ES 0414+009
- HESS J1943+213
- PKS 0447-439
- PKS 2005-489
- PKS 0548-322
- PKS 2155-304
- 1RXS J101015.9-311909
- H 2356-309
- 1ES 1101-232
  (new) KUV 00311-1938
  (new) PKS 0301-243
  (new) PKS 1440-389

... but also non AGN, starburst galaxy NGC 253

Beckmann & Shrader (2012); graphic by Marie-Luise Menzel
Extragalactic: Active Galactic Nuclei ...

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Updated in June 2013
Old faithful: PKS 2155-309

- Rich source, bright, flaring
- Not HESS-discovery
- 9 H.E.S.S. papers so far!

“Big Flare”
- Best measured rise-time: $173 \pm 28$ s
- Two orders of magnitude brighter than typical
- Time-scale probes size of emitting region if causality
- Also used to test Quantum Gravity

- VHE/X-ray correlation seen during flaring epoch
- Some link between long term optical/radio level & VHE flaring
- One zone SSC models only fit SED during low states
New AGN: PKS 0447-439

- H.E.S.S. discovery
- 15σ after 13h in 2009 exposure
- VHE variability from days to months

- H.E.S.S. firm UL for currently-unknown redshift, z <~ 0.4
- Broad-band SED overall fit by one-zone SSC, but ...
- No exact correlations between VHE, HE, X-ray, Optical ⇒ Challenging one-zone SSC

Quasi simultaneous SED (2009)

The H.E.S.S.-II Telescope, CT5

Dish
Total mirror area 614 m²
Focal length 36 m

Camera
2048 PMTs
Field of 3.2°
First H.E.S.S.-II preliminary mono results

- First data from the Crab Nebula taken with the new H.E.S.S. telescope
  - Zenith angle: 46°
  - Preliminary mono-analysis

- Excess map with $E > 50$ GeV
  (for preliminary mono-analysis, vs. 400 GeV threshold H.E.S.S.-I)
Conclusions

• HESS-I
  - Technical Inheritance from Whipple + HEGRA + CAT
  - Know-how inheritance from Whipple (via Artemis & CAT) & HEGRA stereo

⇒ Rich harvest of results, better than hoped for,
  building on the Whipple Observatory & Trevor Weekes' foundations
  - Now, simple detections of PWNe / AGNs
    are relegated to conference posters or research notes!

• Near future, with HESS-II
  - But slow start, low-energies and mono are hard, especially combined!
  - Stay tuned …

• Farther on the horizon: CTA
Notable Mechanical / Optical characteristics
- 17.8 m² mirror area (16 m² after shadowing), 5m Ø, 90 x 50cm Ø facets
- Focal length 6m → high F/D ~ 1.2 (for fast timing)

Characteristics concerning camera (some → HESS):
- Very fine pixel camera, 600 PMs, most <0.13° (some guard rings)
- Fast (small) PMs, low TTS (transit time spread)
- Fast electronics
- “Semi-integrated” camera
  - All pre-amps, trigger logic electronics in camera
  - External integration gate in counterweight
  - ADCs, DAQ, HVs in counterweight
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