Morphological and spectral measurements of 2HWC J1928+177 with HAWC and H.E.S.S.

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High Altitude Water Cherenkov

- Located in Sierra Negra (Mexico)
- **4100 m** above sea level
- 300 tanks
- 200 kL water each
- 22 000 m² **area** w. 57% coverage
- 15-20 kHz **trigger rate**
- **FoV** ~ 2 sr
- **Energy range** 0.1 - 100 TeV
- **Angular resolution** ~ 0.2°-1°
- **Duty cycle** > 95%
High Energy Sterescopic System

- Located in Namibia
- **1800 m** above sea level
- 4 12-m diameter telescopes
- 1 28-m diameter
- **Energy range** 0.05 - 100 TeV
- **Angular resolution** $\sim < 0.1^\circ$
Region around SNR G054.1+00.3

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2HWC J1930+188
(SNR G054.1+00.3) -> TeV association

- 2HWC J1928+177
- Brighter than SNR G054
- VHE gamma-ray emission coincident with PSR J1928+1746
- VERITAS point-like upper limit ~1.4% of Crab (E>1 TeV)
HAWC Results (~2 years)

- HAWC skymap with three regions of emission
- Contours starting at 5σ and increasing by 2σ
- Region very complex with many emission blobs
HAWC-HESS comparison

- Green: HESS 80% containment of SNR G054.1+00.3 (HESS J1930+188).
- Top: HAWC (~>10 TeV) with contours in black. Compatible with the PSF.
- Bottom: HESS, Map above ~750 GeV using 0.2 deg integration radius.
  - HAWC contours in white.
Multiwavelength view

- The source is really DARK.
- No PWN/SNR detected at any other wavelength
PSR J1928+1746

- Radio pulsar discovered in the ALFA survey
  - Age = 83 kyr
  - $E_{\dot{\nu}} = 1.6 \times 10^{36}$ erg s$^{-1}$
  - Distance = 5.8 kpc
  - $P = 68.7$ ms, $P_{\dot{\nu}} = 1.32 \times 10^{-14}$ s/s

- Observed but undetected in X-rays by Chandra -> U.L. at a $5.8 \times 10^{-15}$ erg/s/cm$^2$

- No pulsed emission has been detected at gamma rays, but:
  - EGRET discovered a source coincident with the pulsar position (3EG J1928+1733).
  - Fermi also reported emission from that region (3FGL J1928.9+1739).
  - Saz Parkinson et al. (2016) associates 3FGL J1928.9+1739 emission with that of a pulsar using Machine Learning techniques
2HWC J1928+177

HAWC:
\[ \frac{dN}{dE} = f_0 \left( \frac{E}{7 \text{ TeV}} \right)^{-\Gamma} \]
\[ f_0 = (1.06 \pm 0.12) \times 10^{-14} \, \text{TeV}^{-1} \text{cm}^{-2} \text{s}^{-1} \]
\[ \Gamma = 2.60 \pm 0.09 \]

HESS upper limits above 750 GeV for 0.1 and 0.4 integration radius.
Modeling

**Electrons**
- Photon fields for IC:
  - CMB: 0.25 eV/cm³
  - FIR [20 K]: 0.3 eV/cm³
- We need $W_e=4.9 \times 10^{47}$ erg of electrons above 1 TeV to produce this emission.
- Total energy injected by the pulsar: $\sim 10^{51}$ erg

**Protons**
- Density assumed $n=1$ cm⁻³
- The energy injected into protons of $E>1$ TeV needs to be $>10^{50}$ erg -> Energetically challenging.

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**Particles**

**Gammas**

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Comparison with PWN population

TeV efficiency

TeV luminosity

Characteristic age

Spin-down power
Comparison to SNRs

From Funk, S. 2015
Conclusions

• Morphology:
  • HAWC at the highest energies is compatible with the PSF -> Extension at these energies might be up to ~0.2 deg (HAWC PSF)
  • For lower energies, the morphology is not so clear due to larger PSF and contamination

• Spectrum is best fit by a single power-law between ~few TeV and ~80 TeV

• Leptonic scenario favored

• PWN hypothesis is consistent with the rest of the PWN population

• Comparison to SNR detected at TeV show an unseen hard spectrum at TeV energies.
Backup
Thanks!