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Discovery of An Extended X-ray PWN Counterpart to the VHE Gamma-ray Source HESS J1303-631

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Overview

- The H.E.S.S. Telescopes
- Original "dark source" HESS J1303-631 now identified as PWN
- Discovery of "tiny" X-ray PWN with XMM
- Synchrotron Underluminous PWN

H.E.S.S.

- Imaging Atmospheric Cherenkov Telescopes
- 4 Telescopes in Namibia
- 13m diameter each
- Gamma-rays from ~100 GeV to ~100 TeV
- Angular Resolution: < 0.08 degrees per event</p>
- 5 degree field of view



Unidentified HESS J1303-631

Serendipitously discovered by H.E.S.S. In 2004 during observations of the binary system PSR B1259-63

Extended: ~0.18 deg Powerful: ~17% Crab Flux



No Extended Counterparts

843 MHz SUMSS Radio Map No extended sources within the TeV emission region Chandra X-ray Observation in 2004 Mukherjee, Halpern 2005 No plausible counterpart Four point sources detected None of the pulsars detected



Association with PSR J1301-6305?

High spin-down power pulsar: 1.7e36 erg/sec Young pulsar: 11,000 years Dispersion Measure (DM): 374 cm^{^-3} pc DM Distance: 6.6 kpc (NE2001, Cordes & Lazio) At this distance, Gamma-rays represent only 3.7% of pulsar spin down power (i.e. Gamma-ray efficiency)



HESS J1303-631: Gamma-rays

Constant morphology hypothesis gives p-value 4e-7 Detection of energy dependent morphology implies PWN

Highest energies located near the pulsar, lower energy photons, likely from older "colder" electrons farther <u>from</u> the pulsar.



2 XMM Observations

July 13, 2005: Obs 0101 Rev 1024: 30ksec July 15, 2005: Obs 0101 Rev 1025: 30ksec

Red: Obs 1 Blue: Obs 2 Green: HESS J1303 significance contours

Obs 2 farther off axis For pulsar



XMM Newton observation of the source reveals an extended X-ray emission region near to the pulsar Flux map smoothed with Gaussian kernel of 40" HESS 8, 14 and 20 sigma significance contours shown in white.



Observation 2 appears to show extension toward East-South East while Observation 1 does not. Surprising because observation 1 has pulsar closer to on-axis.

Observation1

Observation2



Black lines show the Chip edges for each camera pointing. Observation1 is not suitable for the search for extended PWN because chip edges obscure the extended region in all 3 cameras



Direction of X-ray Extension

Direction of extension is determined by an annular projection. The direction is found to be consistent with one identified object within TeV emission region:

star forming region IRAS 13010-6254

120E

110F

100Ē

80 70



<u>HESS J1303-631: X-rays</u>

Simultaneously fit on and off slices Integrate from pulsar to chip edge (indicated by red bin) On-counts: 950 BG counts: 689 \rightarrow excess of 261 around high velocity pulsar? \rightarrow 6.5 sigma (Li, Ma). Extension ~140 arcsec



Lumpy structure due to turbulent flow



X-ray spectrum: avoid soft source 2XMM J130141.3-630535 (10" exclusion) HR2, (1-2 keV / 0.5-1 keV) is 0.12 compared to 0.76 for pulsar point source $\Gamma = 2.7$ NH ~ (3.6 +/- 1.4) X 10^22/cm^2 1 sigma larger than total integrated column density: 1.9 X 10^22/cm^2



Column Density and Distance

NH ~ $(3.6 + / - 1.4) \times 10^{22}/\text{cm}^2$ Total integrated column density: 1.9 X 10^22/cm^2 NH/DM = 31, much higher than typical 5-10

Gaensler et al (2004) argued that a value of 85 for the mouse implied a much larger distance to that pulsar.

DM distance to PSR J1301-6305: 6.6 kpc (NE2001, Cordes & Lazio) Previous model of the electron distribution (TC93) in the Galaxy gave a DM of 16 kpc, one of the most significant changes is pulsar distance in the new model.

Alternative distance from star forming region: IRAS 13010-6254 33 km/s \rightarrow ~12 kpc Would imply high gammaray efficiency: ~28% Requires larger age than characteristic by factor ~3 (like PSR B1757-24, Zeiger, 2008) and one of the highest velocity, ~1,500 km/s

High velocity may effect X-ray production efficiency and therefore synchrotron cooling efficiency and Gamma-ray production efficiency.

Pulsar born in star forming region?

The direction of the X-ray extension is consistent with the position of the star forming region IRAS 13010-6254



HESS J1303-631: Radio

Radio observations from PMN at



Green contours: H.E.S.S. gammarays

Black contours: XMM X-ray

White contours: PMN Radio

Feature not significant used as upper limit

HESS J1303-631: SED

The spectral energy distribution of HESS J1303-631 in an electron scenario.

A "one zone" model where the same electrons produce synchrotron radio/Xrays and inverse Compton gamma-rays



Using spectra from H.E.S.S. and XMM as well as the flux upper limit from PMN, the data is consistent with a PWN scenario with a B field of 0.9 mu G



Conclusions

Energy dependent Morphology found in HESS J1303-631

X-ray PWN identified

HESS J1303-631 can now be identified as a synchrotron underluminous PWN, paper to be published soon!

Outlook

Proposal for ATCA deep radio observations recently submitted by the H.E.S.S. Collaboration to gain better understand the new class of "synchrotron underluminous" PWNe.