H.E.S.S. Unidentified Gamma-ray Sources in a Pulsar Wind Nebula Scenario And HESS J1303-631

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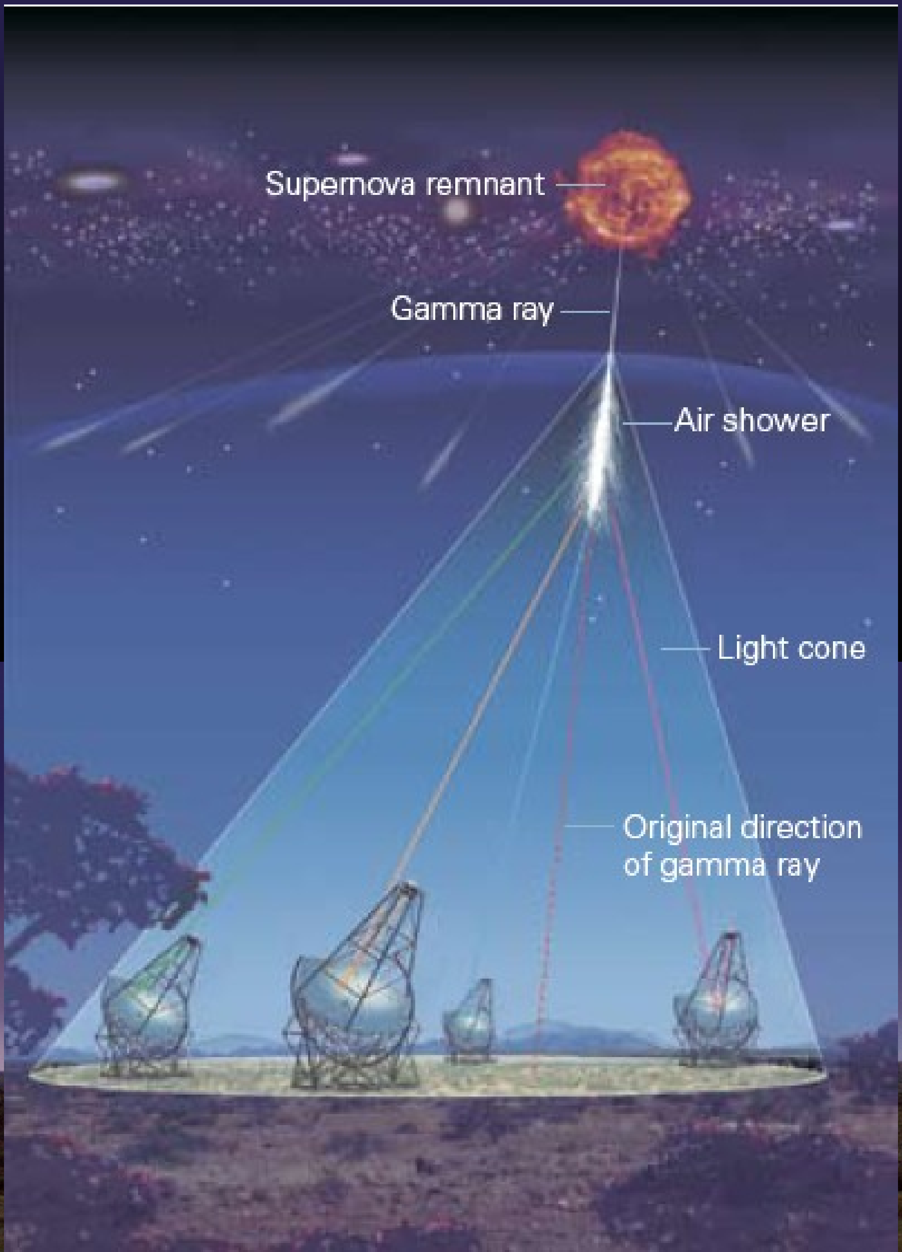
Overview

- The H.E.S.S. Telescopes
- Unidentified Gamma-ray sources as PWNe
- HESS J1303-631

H.E.S.S.



High Energy Stereoscopic System

Gamma-rays produce air showers which are imaged by Cherenkov telescopes

Imaged showers are reconstructed to produce sky maps and spectra of gamma-ray sources

H.E.S.S.

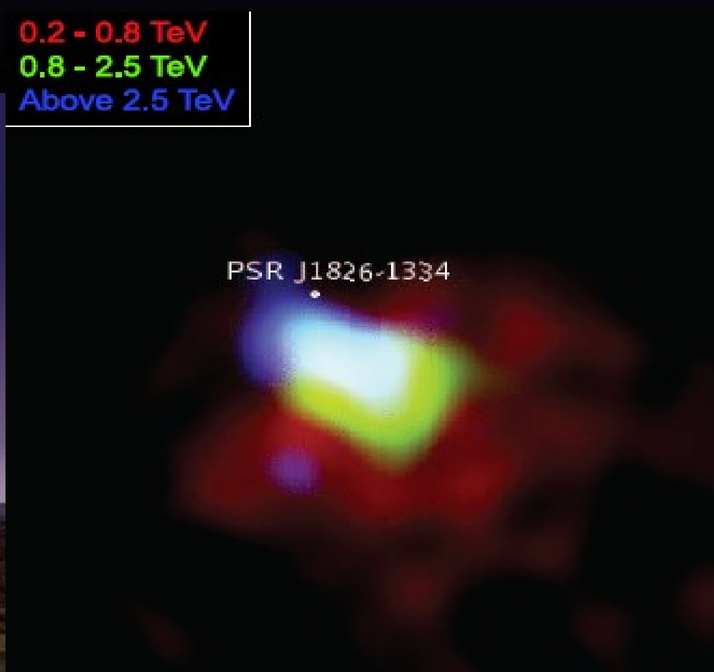
- 4 Telescopes in Namibia
- 13m diameter each
- Gamma-rays from ~100 GeV to ~100 TeV
- Angular Resolution: < 0.08 degrees per event
- 5 degree field of view

Sources Detected with H.E.S.S.

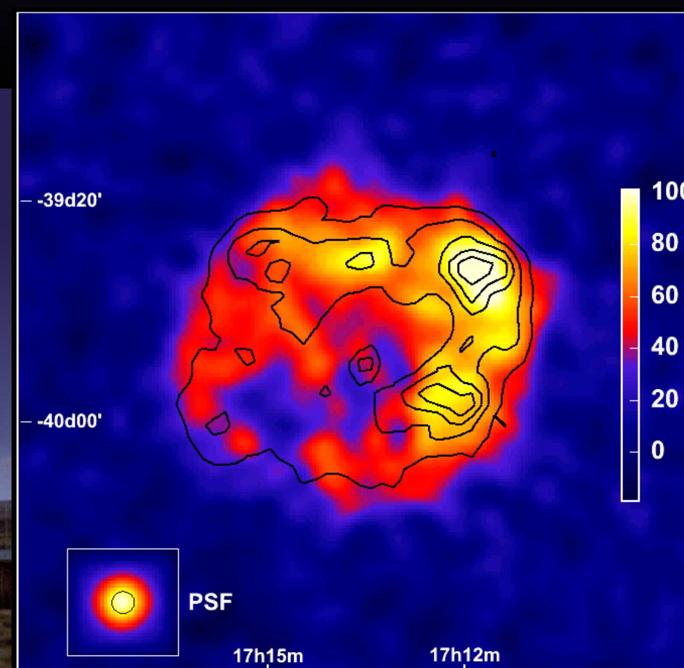
Most of the sources we see are:

- Supernova Remnants
- Active Galactic Nuclei
- Pulsar Binary Systems
- Pulsar Wind Nebulae
- ... or unidentified

PWN: HESS J1825-137



SNR RX J1713.7-3946



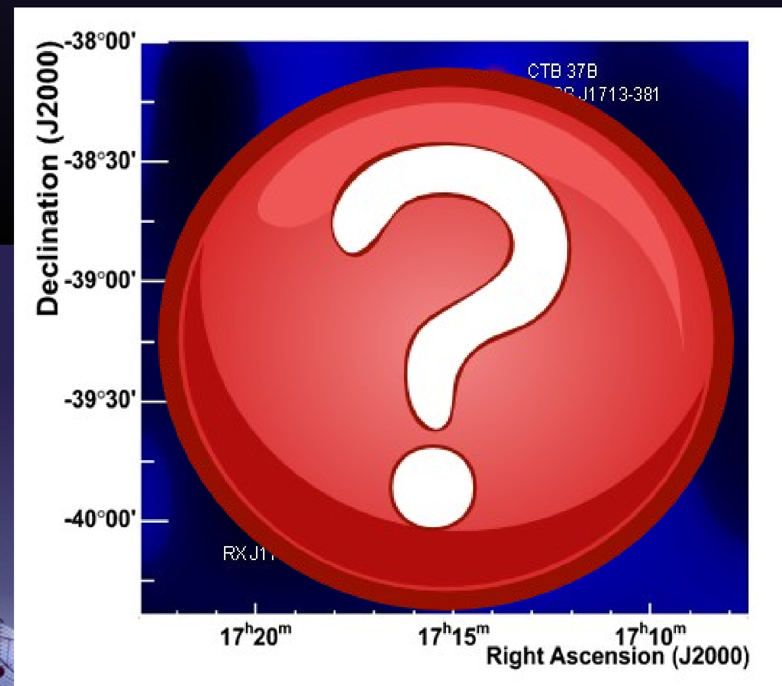
Unidentified Sources

H.E.S.S. has also detected ~24 unidentified sources.

Unidentified Sources

HESS J0632+057	
HESS J1023-575	WR 20a; Westerlund 2; RCW 49
HESS J1303-631	
HESS J1427-608	
HESS J1614-518	
HESS J1616-508	PSR J1617-5055 ?
HESS J1626-490	
HESS J1632-478	IGR J16320-4751 ?
HESS J1634-472	IGR J16358-4726 ?; G337.2+0.1 ?
HESS J1640-465	G338.3-0.0 ?; 3EG J1639-4702 ?
HESS J1702-420	
HESS J1708-410	
HESS J1713-381	CTB 37B (G348.7+0.3) ?
HESS J1714-385	CTB 37A
HESS J1718-385	PSR J1718-3825 ?
HESS J1745-290	Sgr A* / Chan PWN ?
HESS J1745-303	3EG J1744-3011 ?
HESS J1804-216	G8.7-0.1 / W30 ?; PSR J1803-2137 ?
HESS J1809-193	PSR J1809-1917 ?
HESS J1813-178	G12.8-0.02; AX J1813-178
HESS J1834-087	G23.3-0.3 / W41?

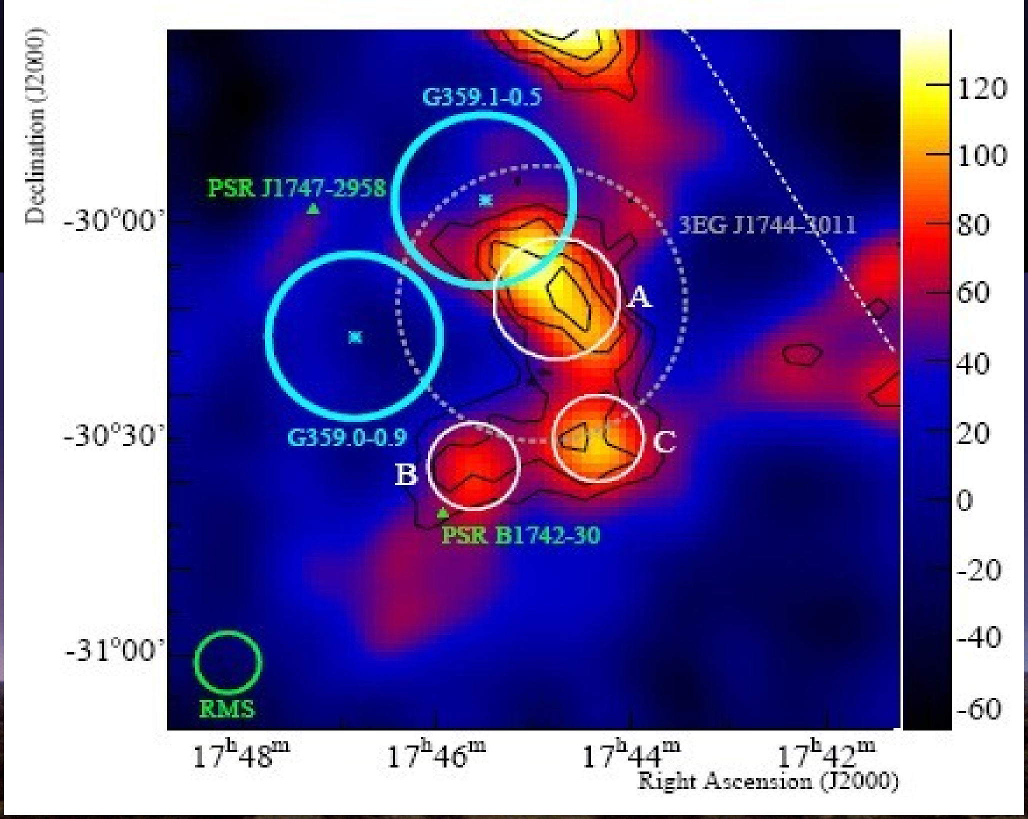
What could it be a PWN?



Unidentified Sources

Type 1: Multiple and complex:

HESS J1745-303 appears to be numerous emission regions with several possible emission mechanisms.

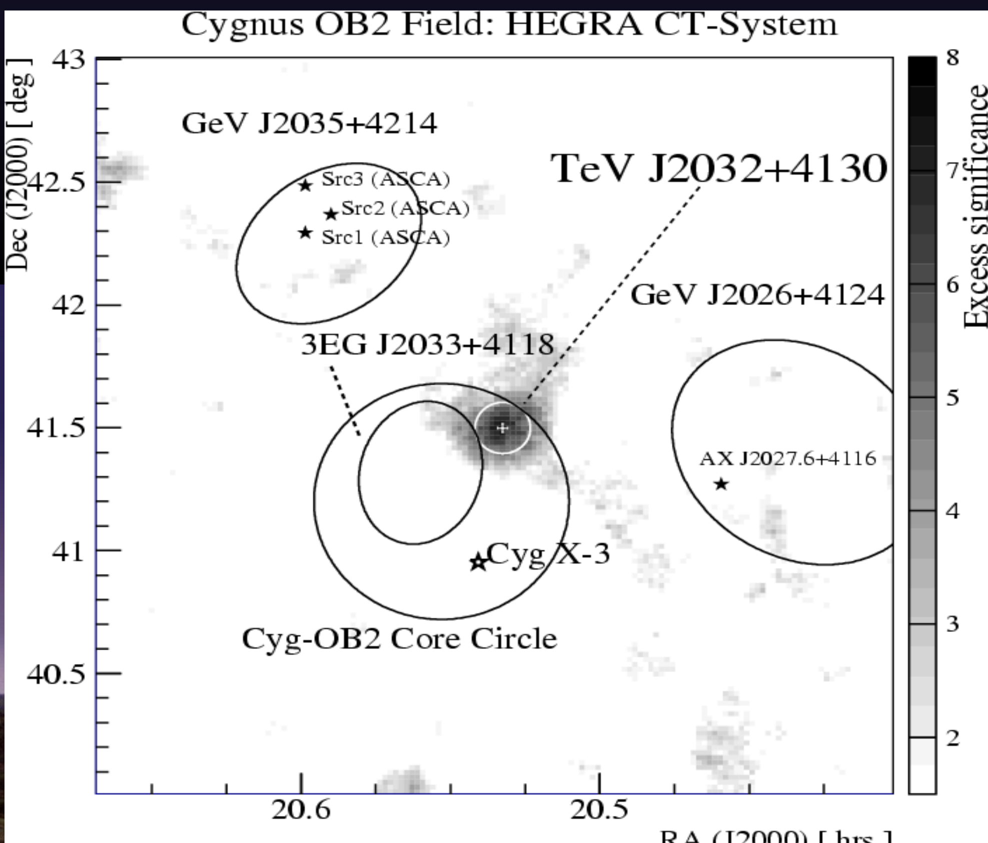


Possible Associations:
EGRET 3EG J1744-3022
SNR G359.1-0.5
PSR B1742-30

Unidentified Sources

Type 2: “Dark” Sources

Gamma-ray sources without obvious, extended counterparts at other wavelengths. Typically extended galactic sources.



First example discovered by HEGRA: TeV J2032+4130

Many more discovered by H.E.S.S.

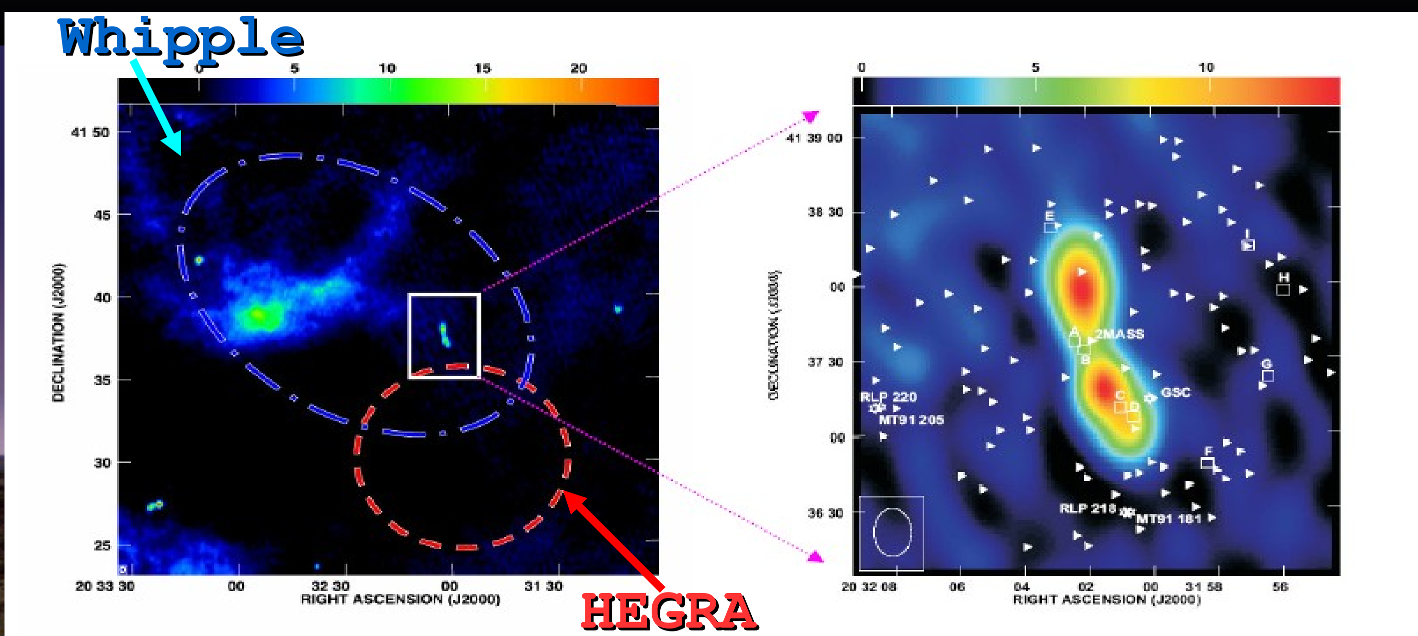
Could be a new kind of source, a “dark” accelerator?

Unidentified Sources

TeV J2032+4130 Update:

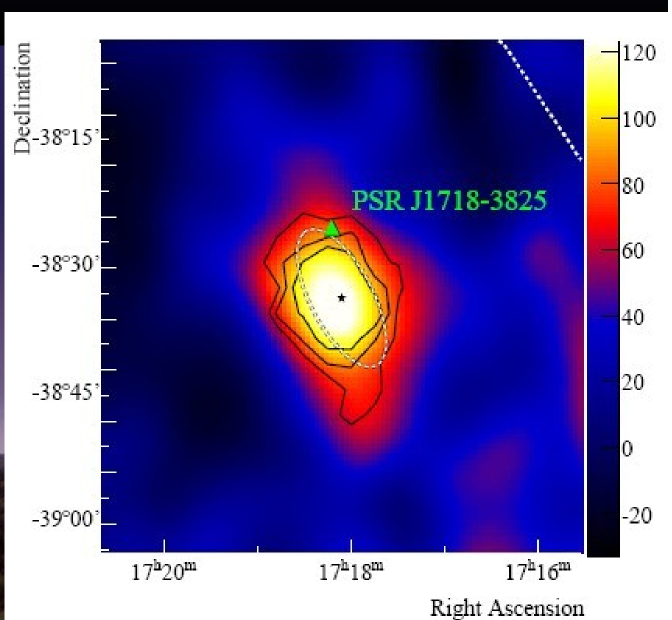
Deep observations have revealed faint but extended radio and X-ray sources which may be associated to the very high energy emission making this a "Not-so-dark" source, also the discovery by Fermi of a gamma-ray only pulsar may indicate a PWN scenario.

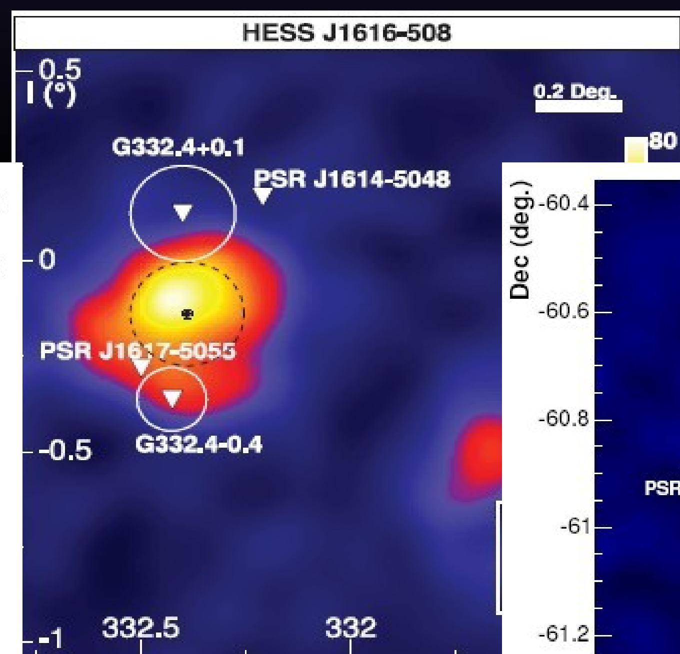
1.4 GHz Radio WSRT Map

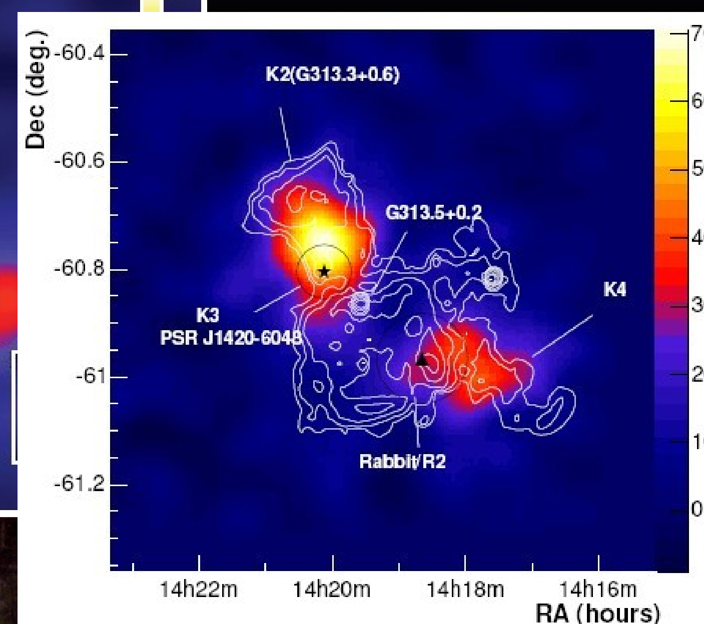


Could they be PWN?

Many of the unidentified H.E.S.S. Sources have a powerful pulsar located near the edge of the emission region. With deep enough observations, it's likely that many of these will be added to the category of "not-so-dark" pulsar wind nebulae.





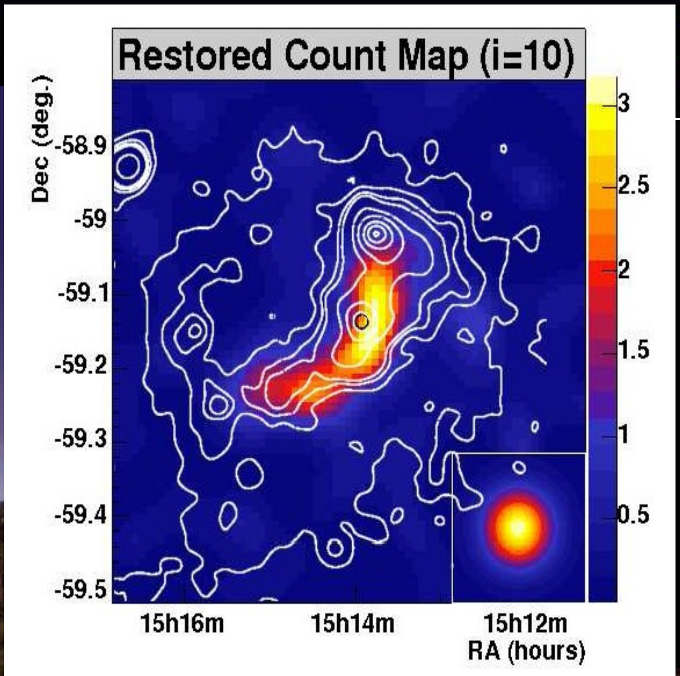


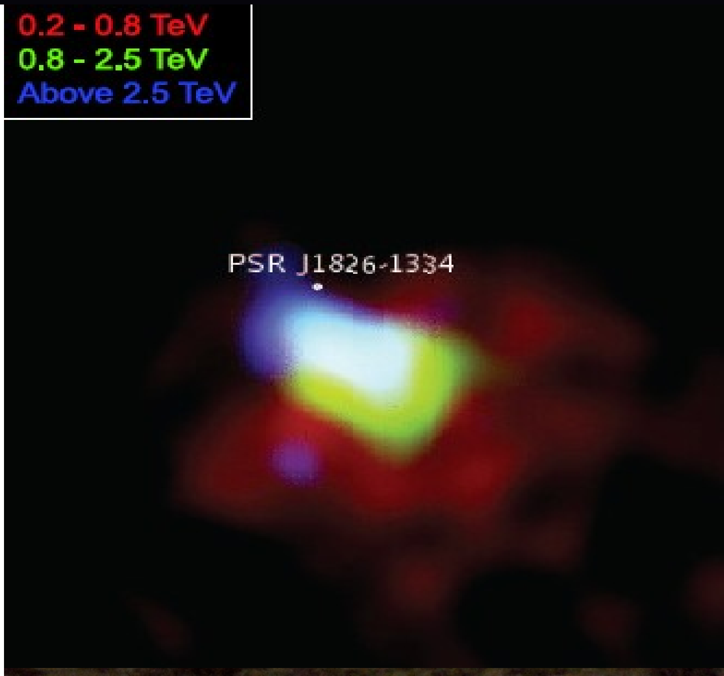
Offset Pulsar Wind Nebulae

Virtually very extended PWN detected by H.E.S.S. is an "offset PWN", i.e. the pulsar lies at the edge of the emission region.

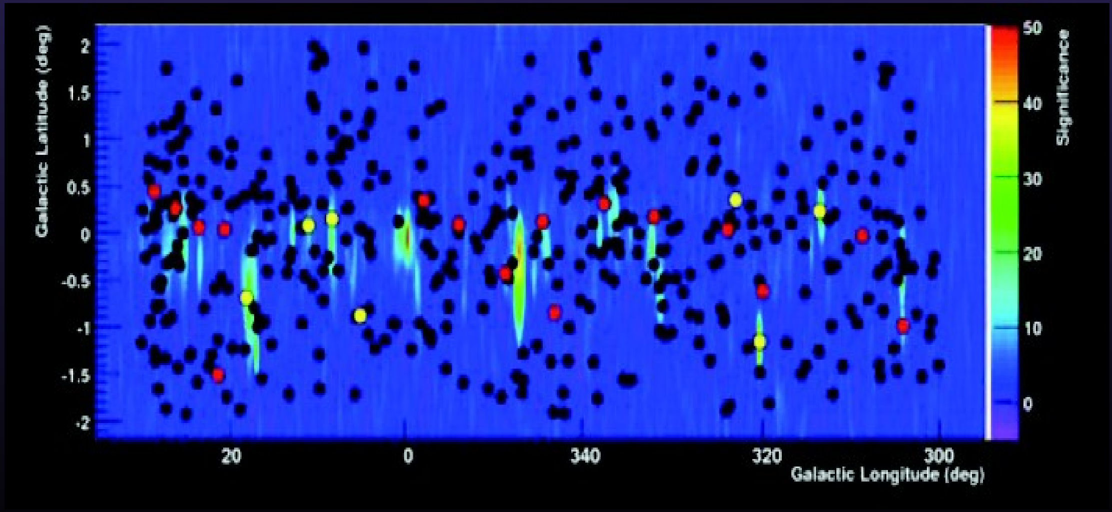
Two possibilities:

- "Crushed" PWN: inhomogeneity in the interstellar medium density prefers expansion in one direction.
- Supersonic Pulsar: pulsar space velocity is greater than electron diffusion rate.

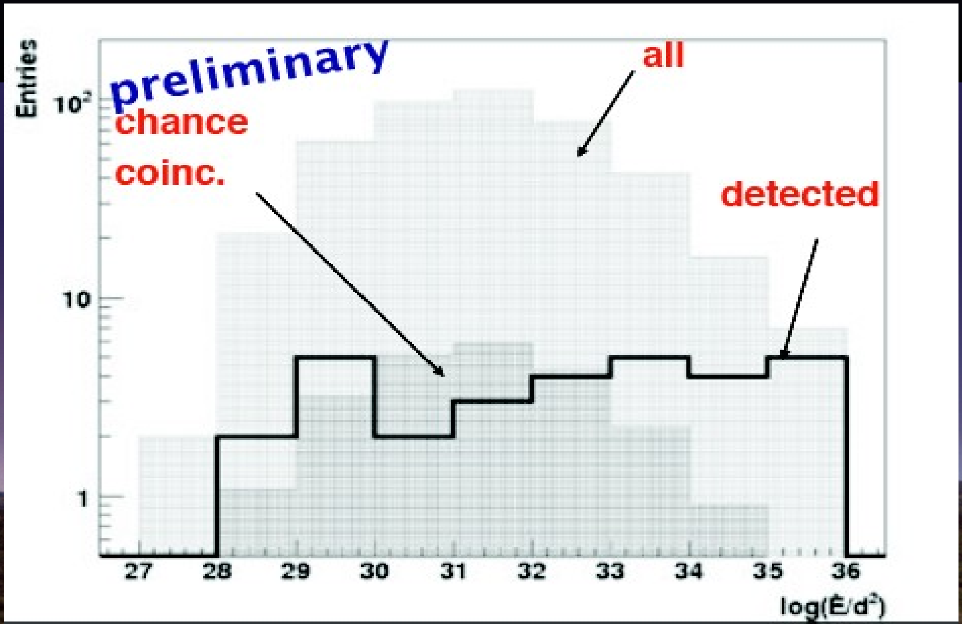




Pulsar Correlation Study



Correlate HESS sources with PSRs from Parkes Survey

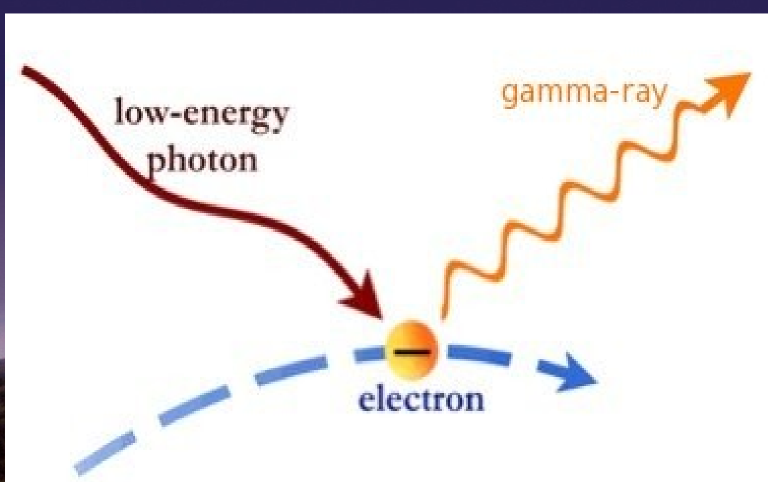


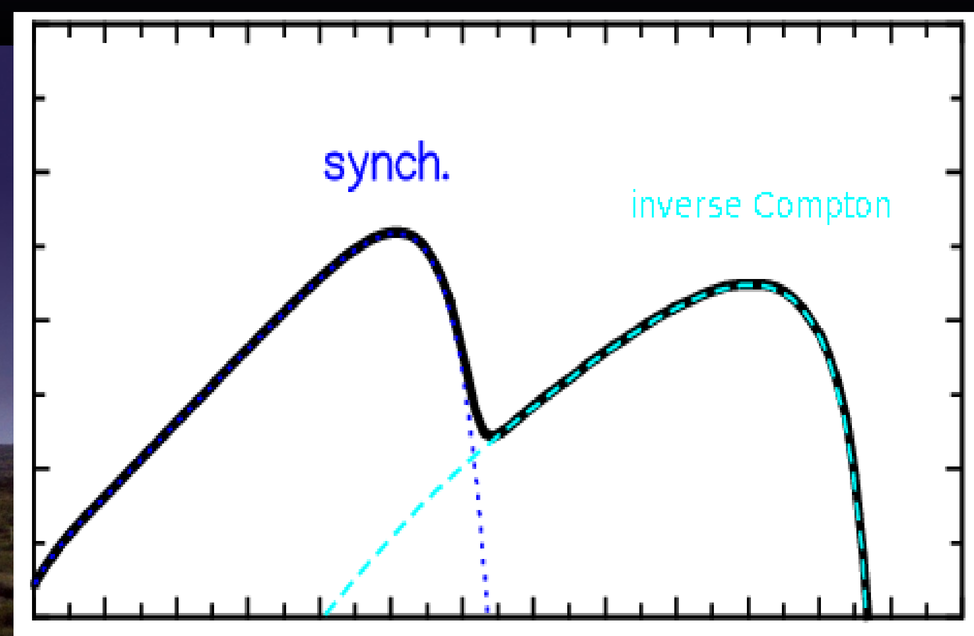
At high Edot/d^2 very low probability of chance coincidence can start to predict which PSRs will make gamma PWNe

Inverse Compton Gamma-Rays

High Energy Electrons scatter CMB photons through the inverse Compton effect to produce Gamma-rays

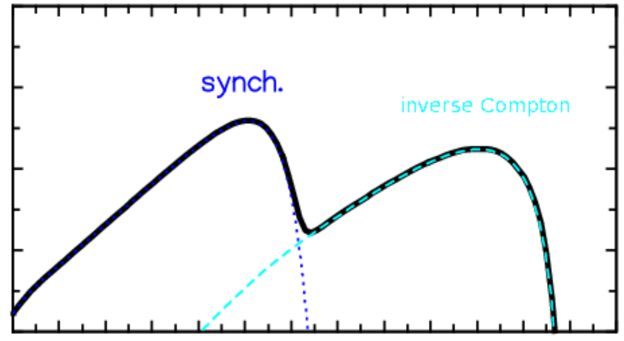
The same electrons produce X-rays and Radio via synchrotron scatter in a local magnetic field

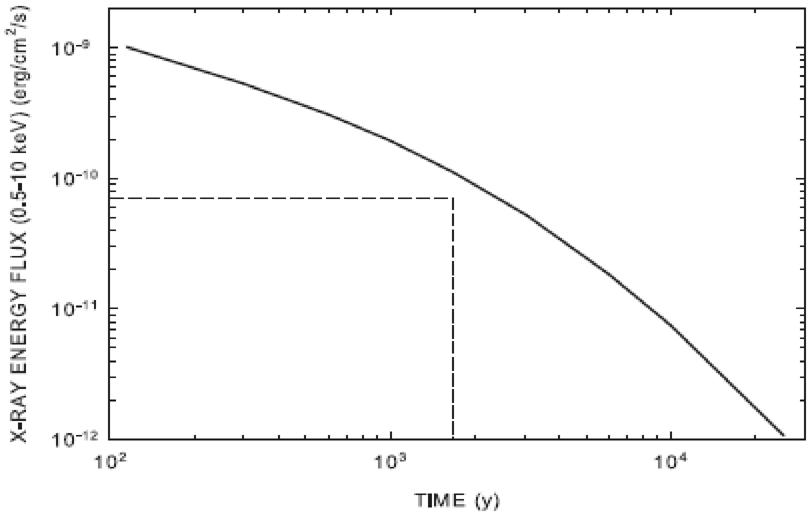




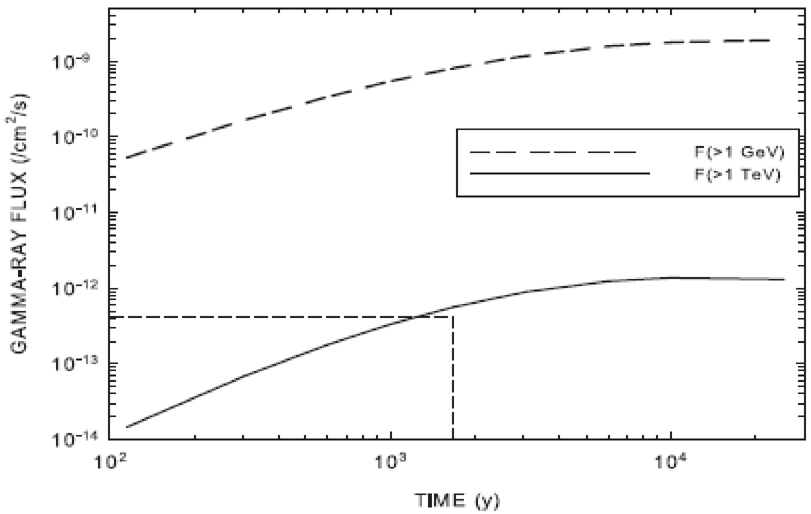
Unidentified Gamma-ray Sources as PWNe

O.C. De Jager et. al. (2009) Found that as a PWN expands, the average magnetic field drops as t^-1.3. Then, the radio/x-ray synchrotron peak will drop but inverse Compton gamma-rays remain nearly constant for many kiloyears.





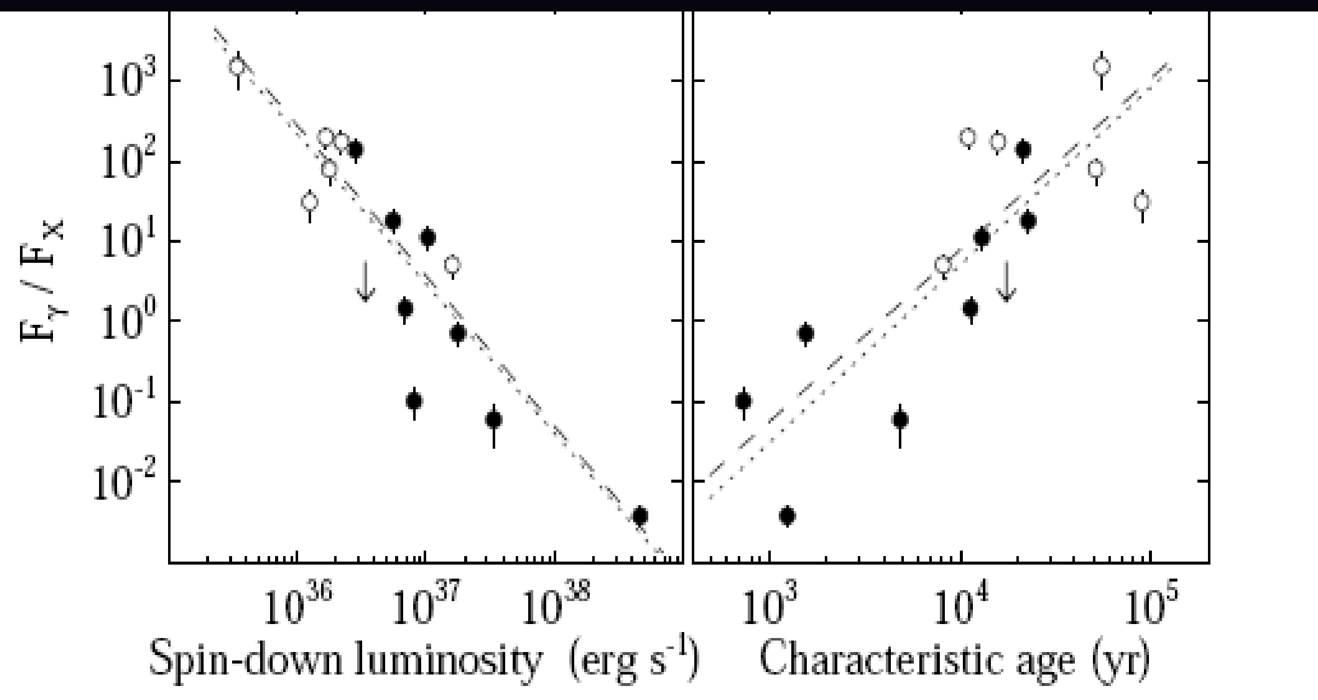
(a) X-rays



(b) GeV and TeV

Gamma/X Ratio

F.Mattana, et. al. Compared ratios of the Gamma-ray/X-ray ratio for PWN associations as a function of time and found a strong correlation, mainly due to falling X-ray components



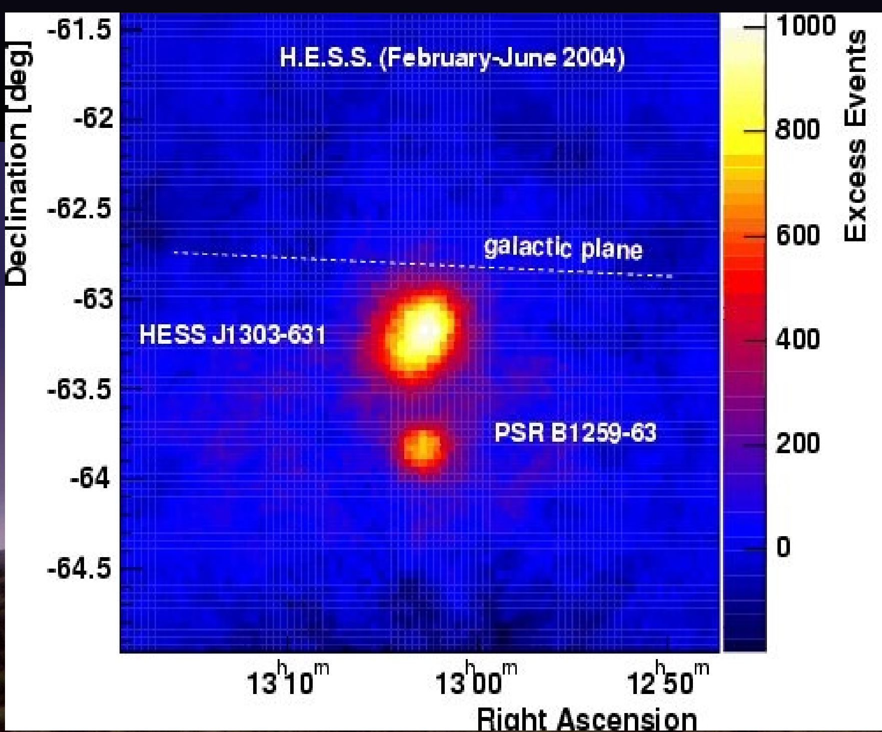
Known PWN associations: closed circles

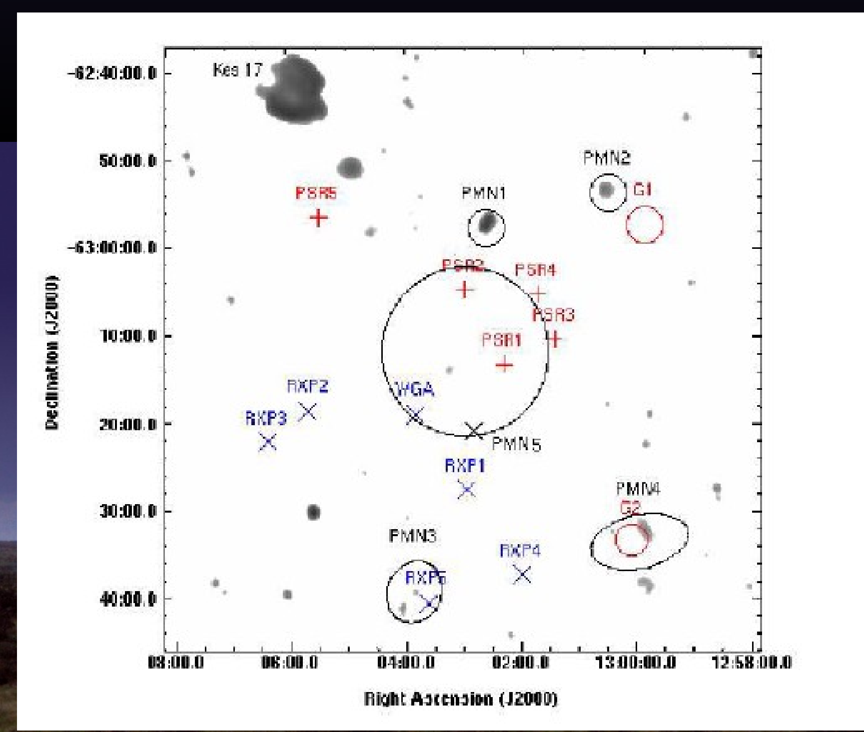
Proposed associations: open circles

Unidentified HESS J1303-631

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

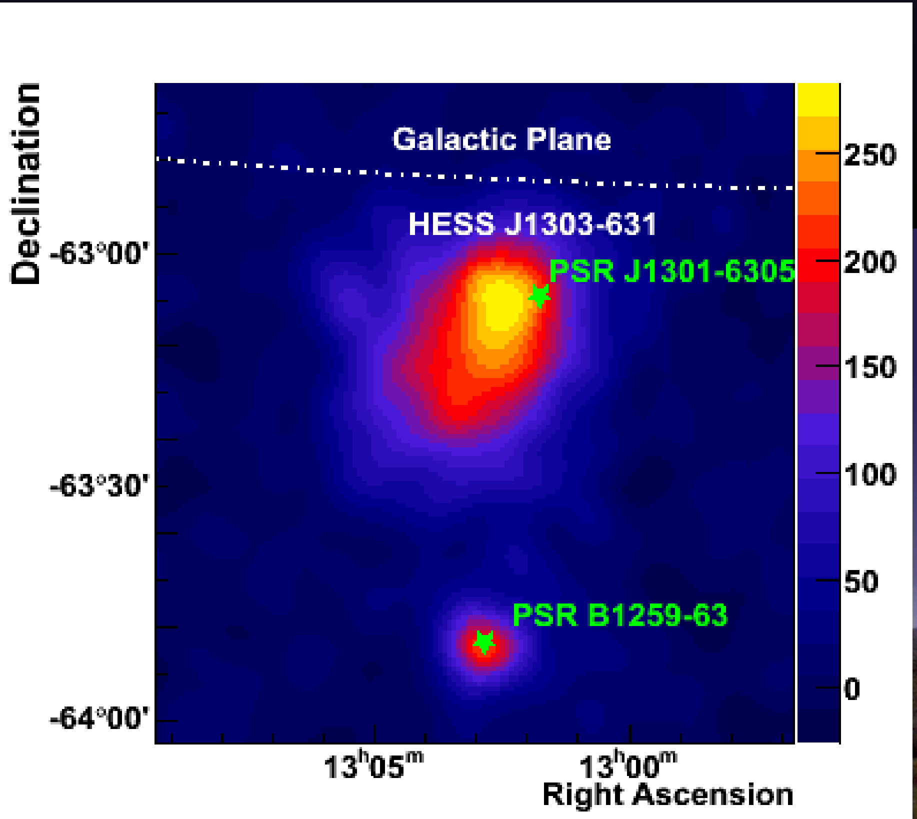
No extended radio sources found in emission region and follow-up observations in X-rays by Chandra yielded no plausible counterpart
Most likely counterpart: PSR J1301-6305





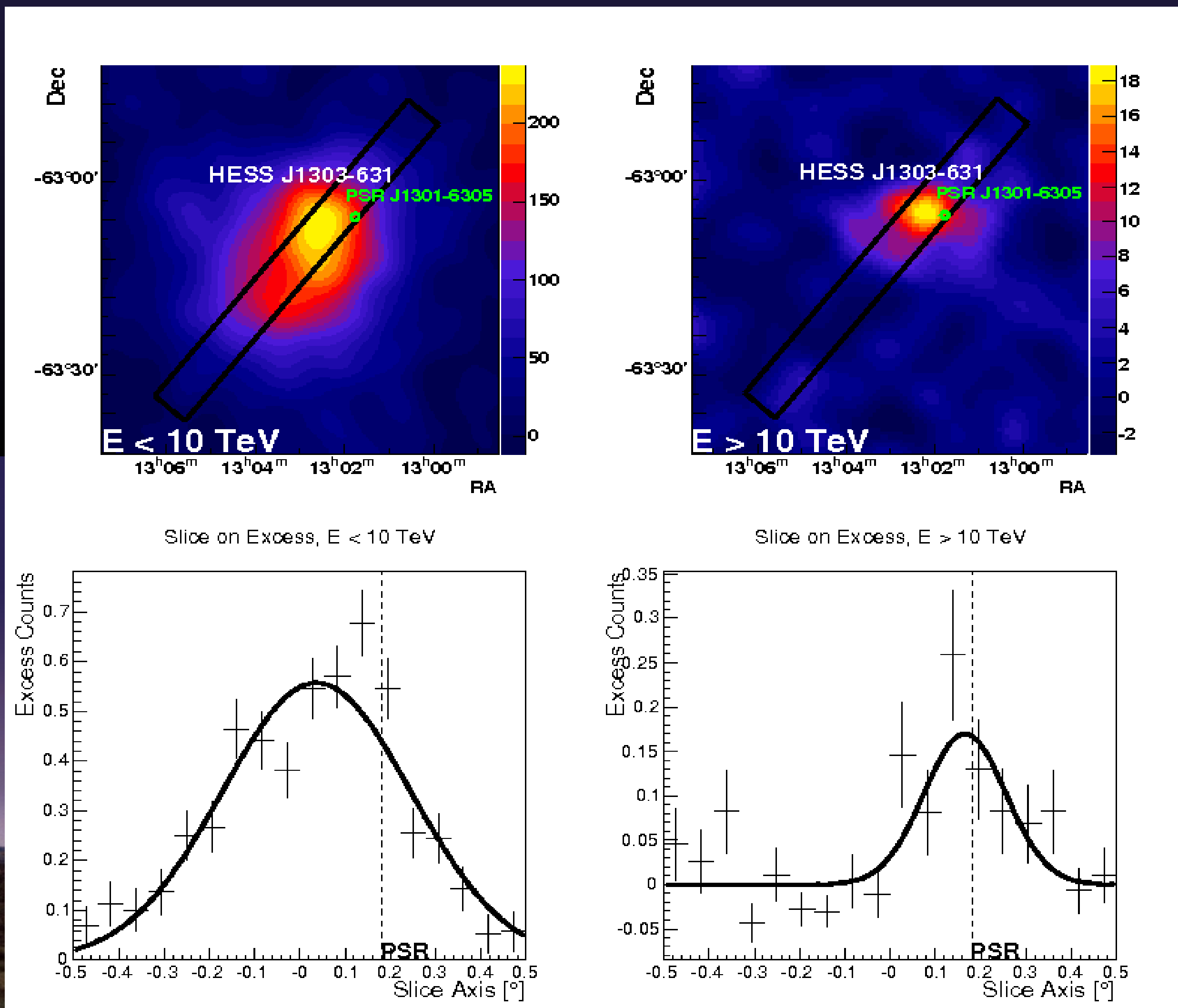
Unidentified HESS J1303-631

PSR J1301-6305:
High spin-down power: 1.7e36 erg/sec
Young pulsar: 11,000 years
Distance = 6.6 kpc
Gamma-rays represent only a few percent of current spin-down power: typical for PWNe



Unidentified HESS J1303-631

Morphology detected at 7 sigma significance Between E<10 TeV and E>10 TeV



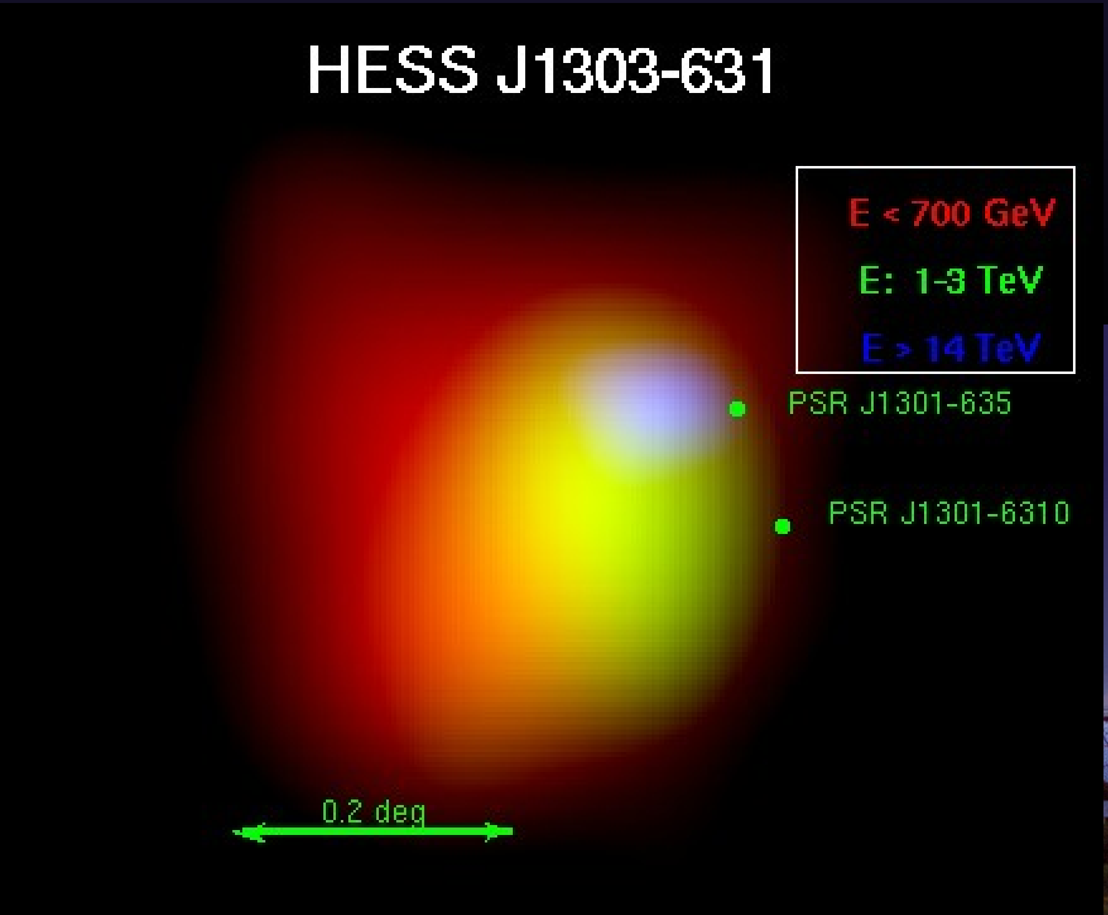
Intrinsic gaussian width falls from 0.2 to 0.1 deg

Center of emission moves ~0.1 degrees

Still significantly extended above 10 TeV

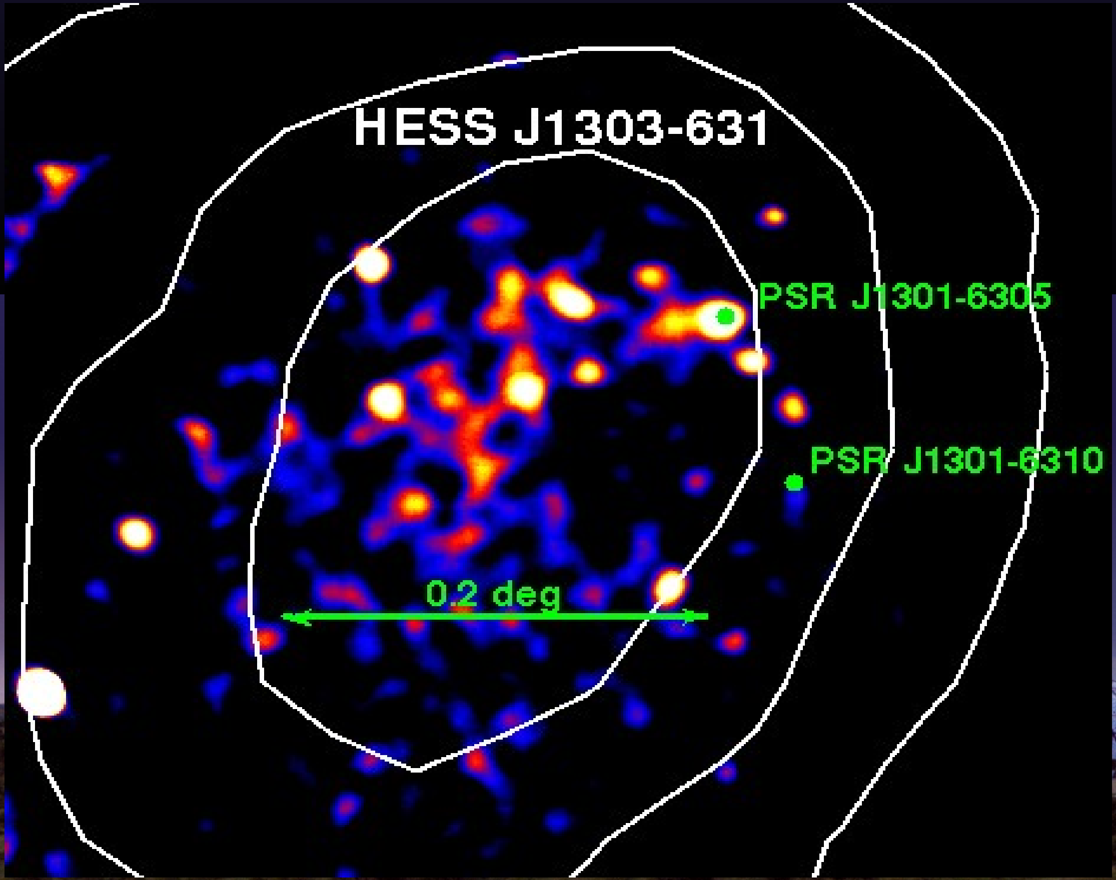
HESS J1303-631: Gamma-rays

The highest energies near the pulsar, lower energies farther from pulsar suggests a pulsar association.



HESS J1303-631: X-rays

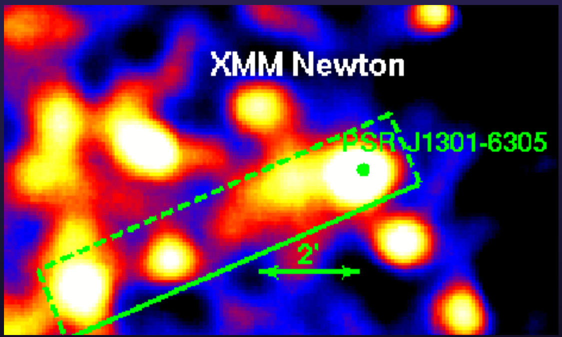
XMM Newton observation of the source region reveals a slightly extended X-ray source associated to the pulsar



Count map
ObsID 0302340101
~30 ksec

ObsID 0303440101
Is unfortunately not suitable since extended region lies on the edges of the chips in all three cameras.

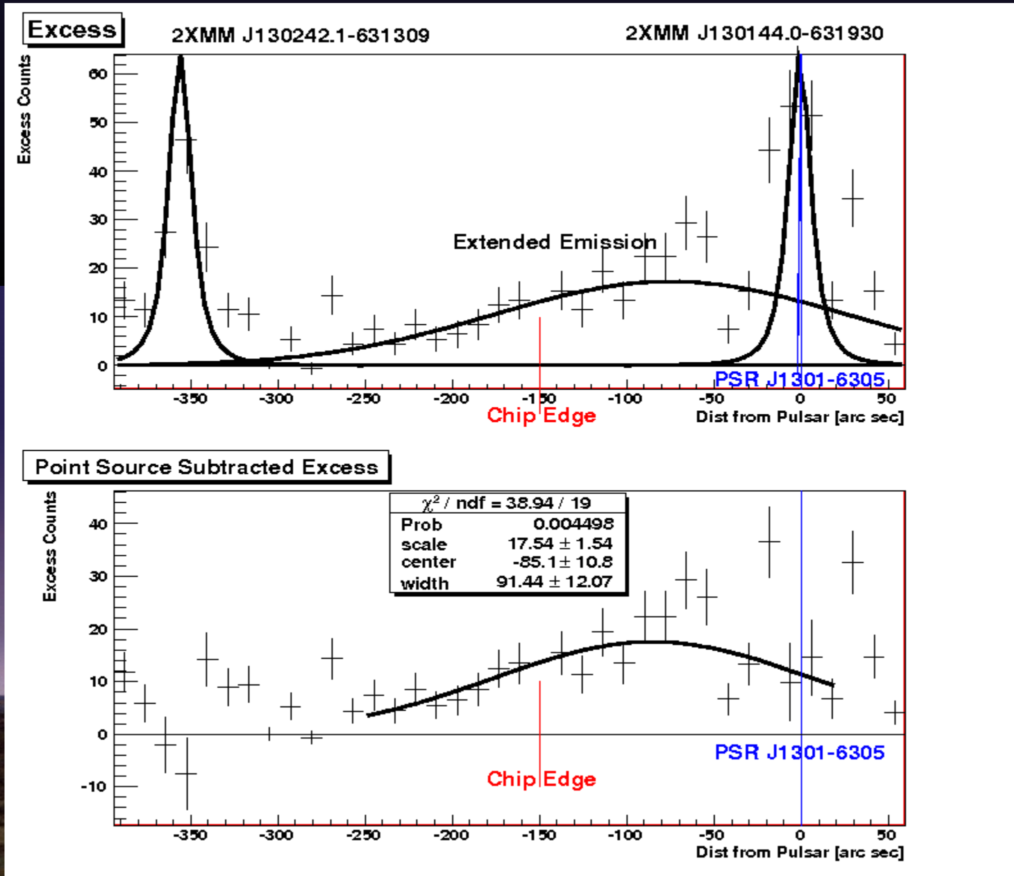
HESS J1303-631: X-rays



Slice on XMM X-ray source associated to the pulsar

Width ~90 arc sec
8 sigma

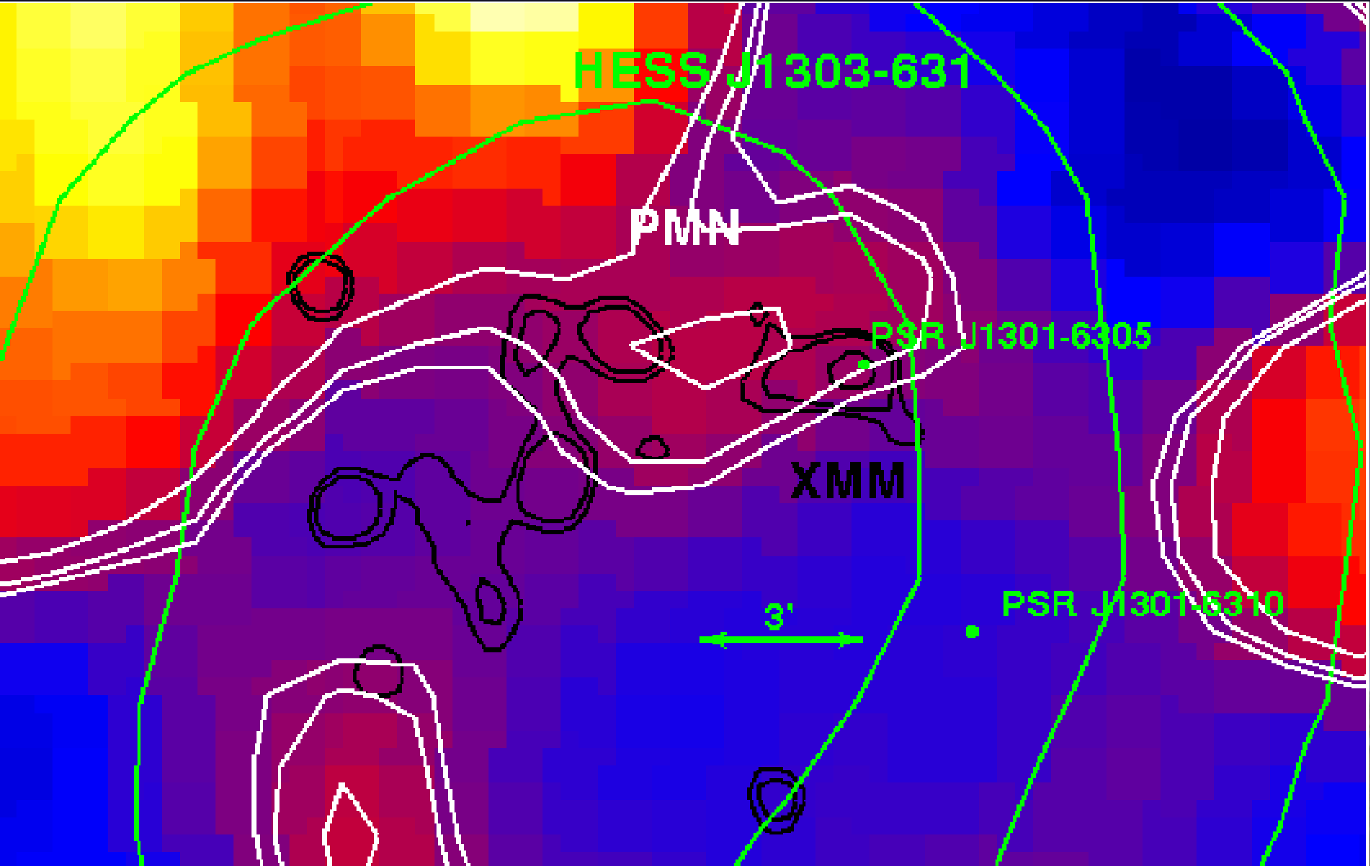
Absorbed Powerlaw fit:
PhoIndex 2.75
Flux(2-10kev)= 1.2e-13 erg/cm2/s



HESS J1303-631: Radio

Radio observations with PMN at 4.8 GHz

Some evidence for a radio counterpart at the detection limit with flux ~29 mJ, so not significant.



Green contours: H.E.S.S. gamma-rays

Black contours: XMM X-ray

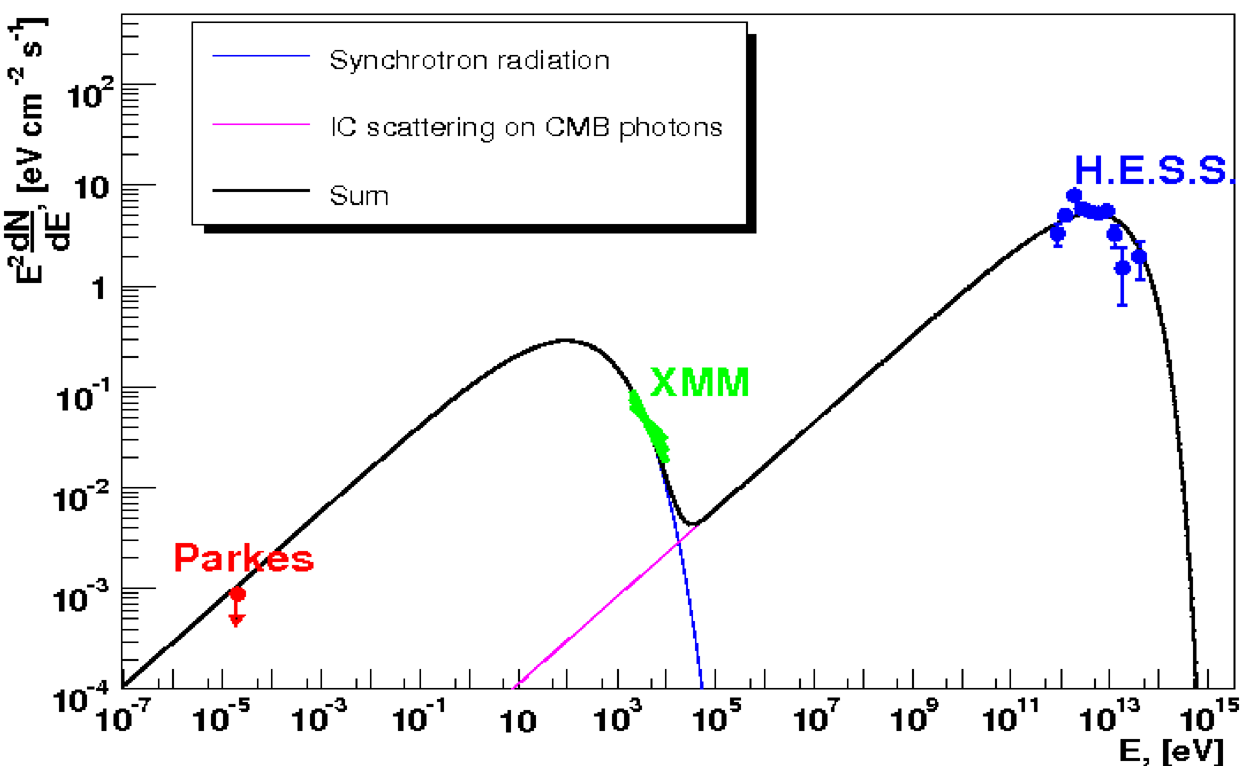
White contours: PMN Radio

HESS J1303-631: SED

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

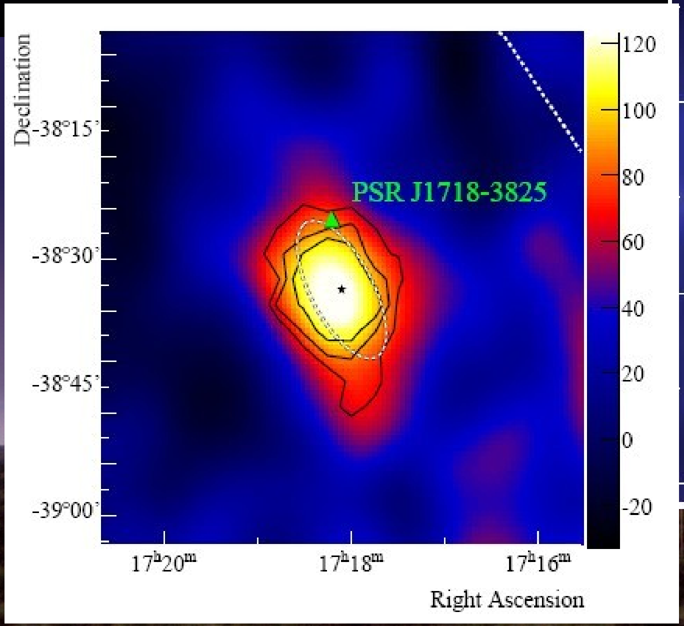
A "one zone" model where the same electrons produce synchrotron radio/X-rays and inverse Compton gamma-rays
-Iurii Sushch

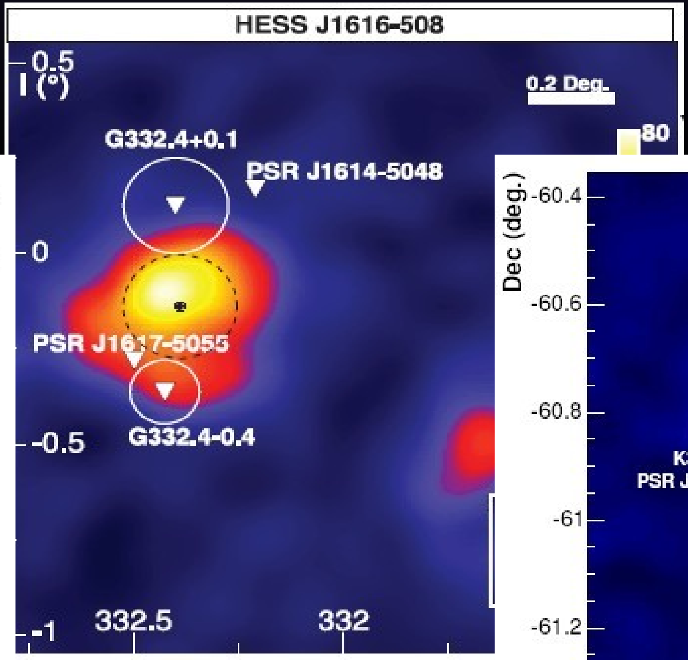
Using spectra from H.E.S.S. And XMM as well as the flux upper limit from PMN, the data is consistent with a PWN scenario with average B field of 0.4 \mu G
Electron index 2.2
Emax 113 TeV

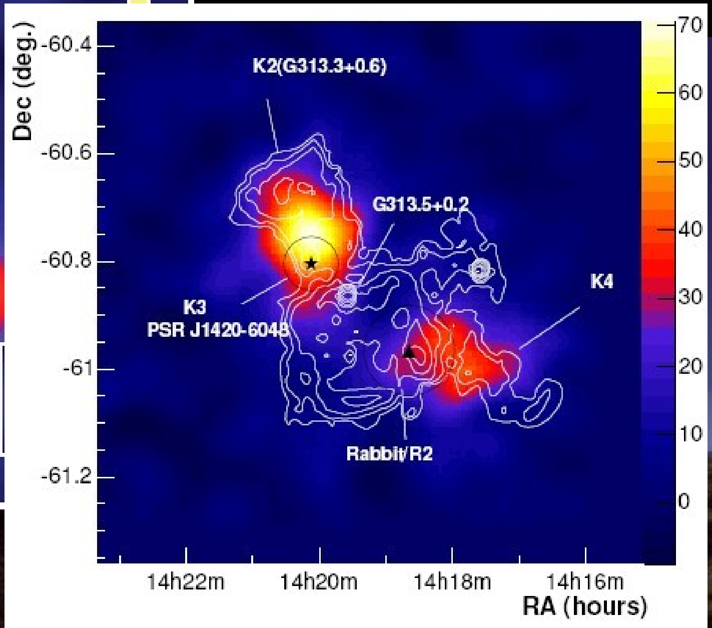


And the other Unidentifieds?

Many of the unidentified H.E.S.S. Sources have a powerful pulsar located near the edge of the emission region. With deep enough observations, it's likely that many of these will be added to the category of “not-so-dark” pulsar wind nebulae.



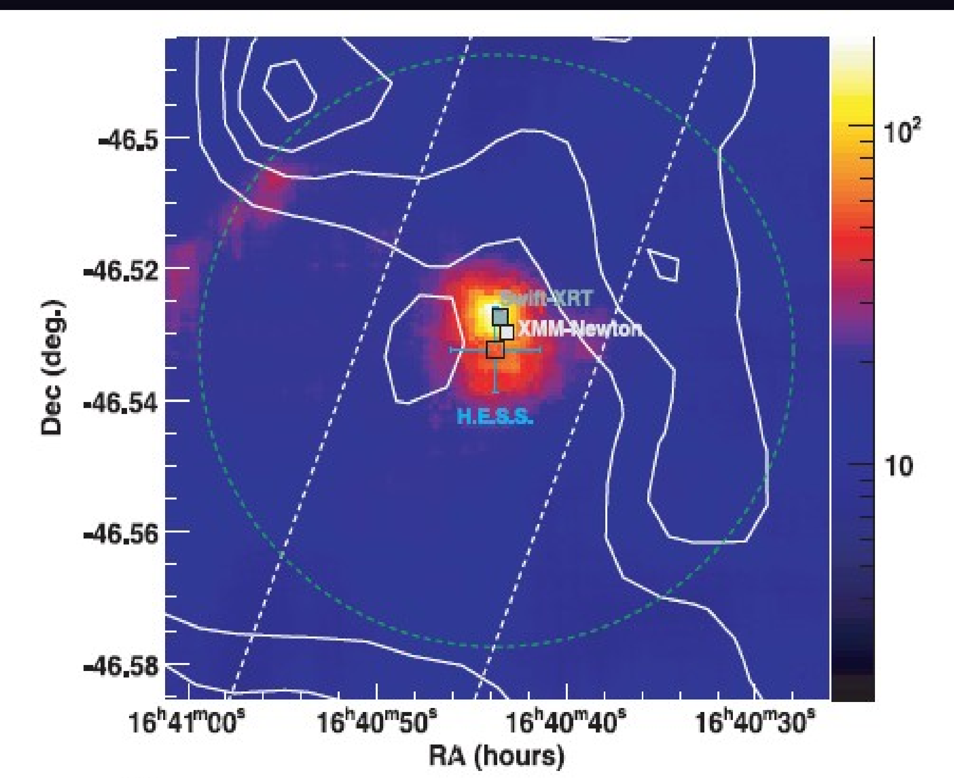




HESS J1640-465

No pulsar found near bye, but hard point source in X-rays may represent neutron star responsible for Gamma-ray emission.

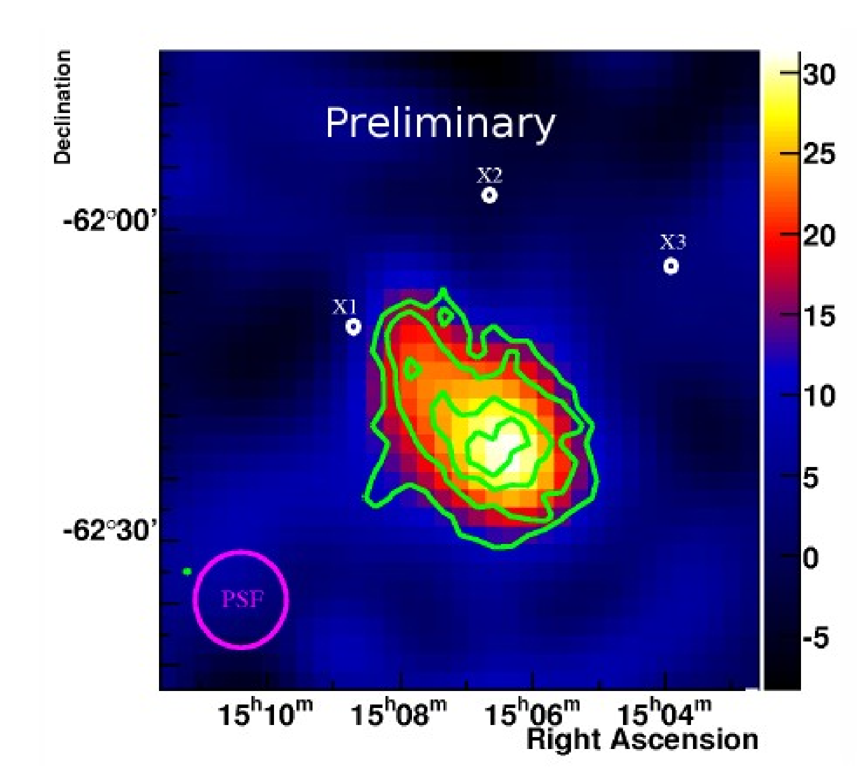
XMM X-ray: E > 2 keV
White: MOST Radio shell of G338.3-0.0
Cross shows HESS best fit position



XMMU J16445.4-463131
Index 1.74 +/- 0.1
F(2-10keV) = 6.6 e-13 erg/cm2/s
Significance = 11

HESS J1507-622

8% of Crab flux
Photon Index 2.2
3.5 deg from Galactic Plane
Surprisingly, no plausible counterparts or pulsars although far from GP where absorption is low!



Gamma-ray excess from H.E.S.S.

Conclusions

- With energy dependent morphology, X-ray counterpart and potential radio counterpart, the evidence seems strong enough now to identify HESS J1303-631 as a “not-so-dark” PWN
- Many other unidentified sources appear to be “not-so-dark” PWNe
- It is possible that most/all unidentified sources will eventually be identified as “not-so-dark” PWNe
- With continued Multi-Wavelength observations we can better understand this new class of PWNe