HESS discovery of VHE γ-ray emission of a remarkable young composite SNR

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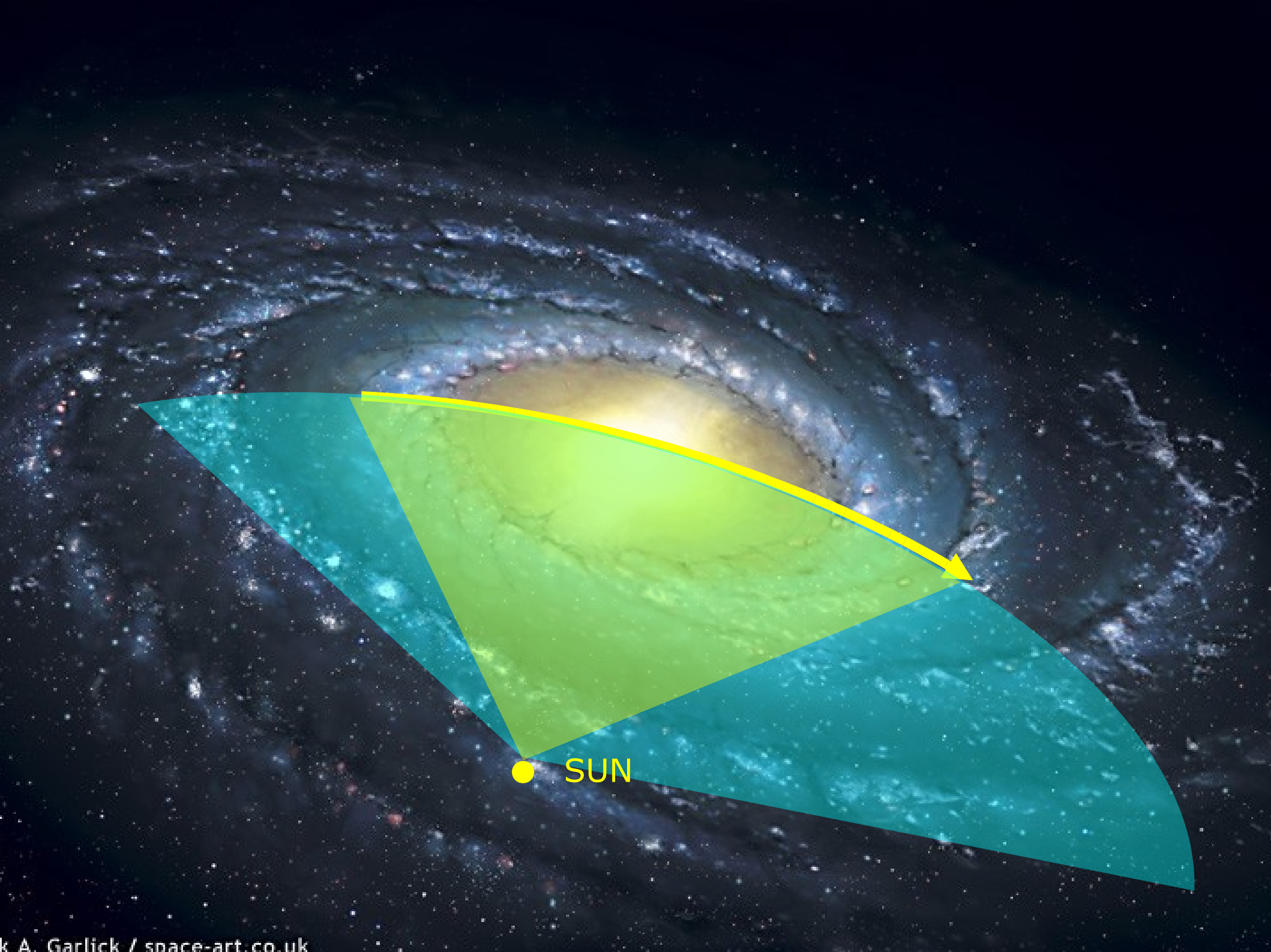
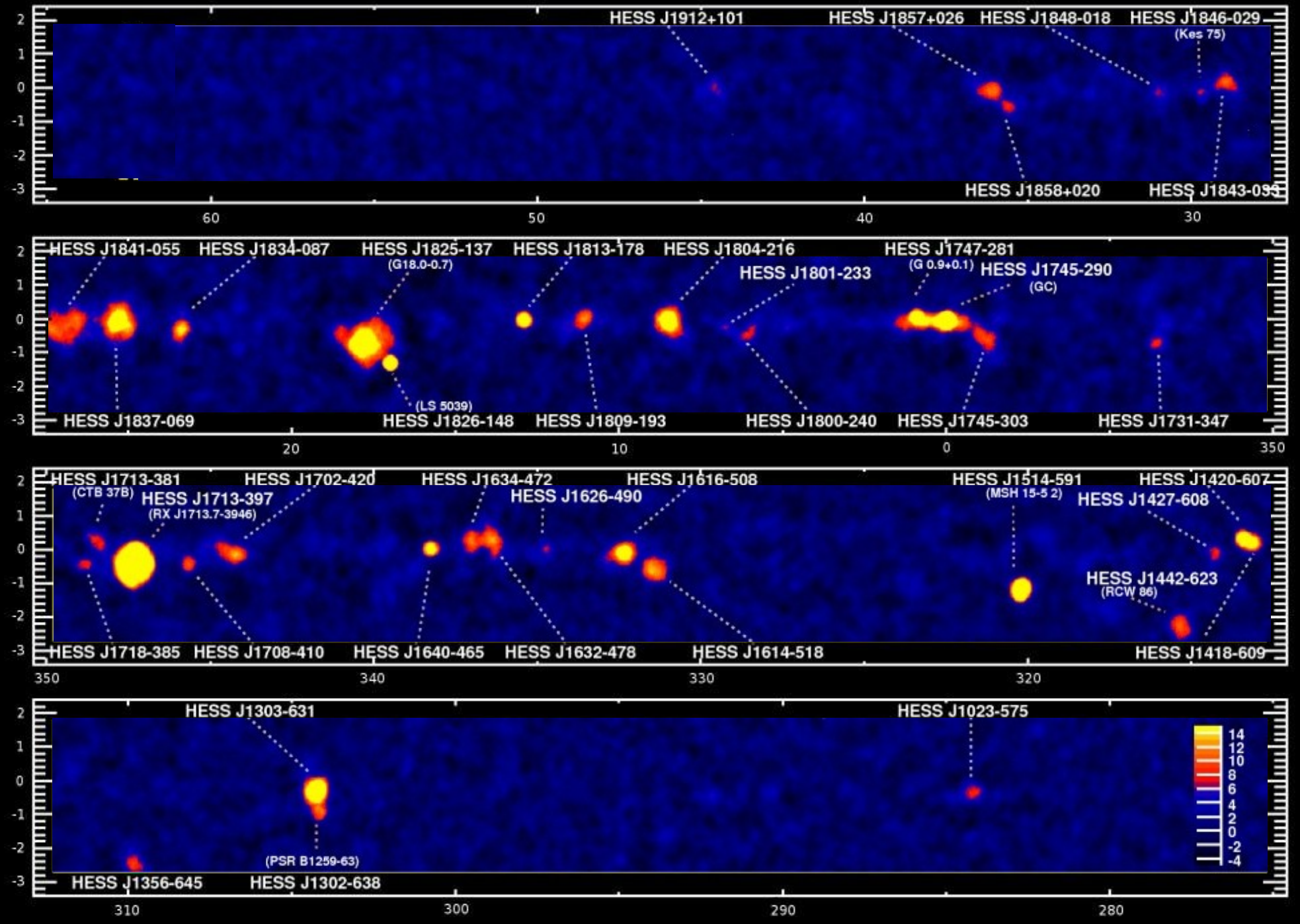
Key location: Namibia


SUN
k A. Garlick / space-art.co.uk

HESS GPS


HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1858+020
HESS J1843-033
HESS J1841-055
HESS J1834-087
HESS J1825-137
(G18.0-0.7)
HESS J1813-178
HESS J1804-216
HESS J1801-233
HESS J1747-281
(G 0.9+0.1)
HESS J1745-290
(GC)
(LS 5039)
HESS J1837-069
HESS J1826-148
HESS J1809-193
HESS J1800-240
HESS J1745-303
HESS J1731-347
HESS J1713-381
(CTB 37B)
HESS J1713-397
(RX J1713.7-3946)
HESS J1702-420
HESS J1634-472
HESS J1626-490
HESS J1616-508
HESS J1514-591
(MSH 15-5 2)
HESS J1427-608
HESS J1420-607
HESS J1442-623
(RCW 86)
HESS J1718-385
HESS J1708-410
HESS J1640-465
HESS J1632-478
HESS J1614-518
HESS J1418-609
HESS J1303-631
HESS J1023-575
(PSR B1259-63)
HESS J1356-645
HESS J1302-638
14
12
10
8
6
4
2
0
-2
-4

TeV PWNe population

HESS has discovered > 50 Galactic sources
Major galactic population revealed by HESS:
Middle-aged PWNe:

Extended sources with irregular morphology
Associated with pulsars:
young : age < 10^5 yrs
energetic: Edot > 10^{35} erg/s

Nebulae with huge caracteristic sizes ~ few tens of pc
TeV emission = Relic electrons

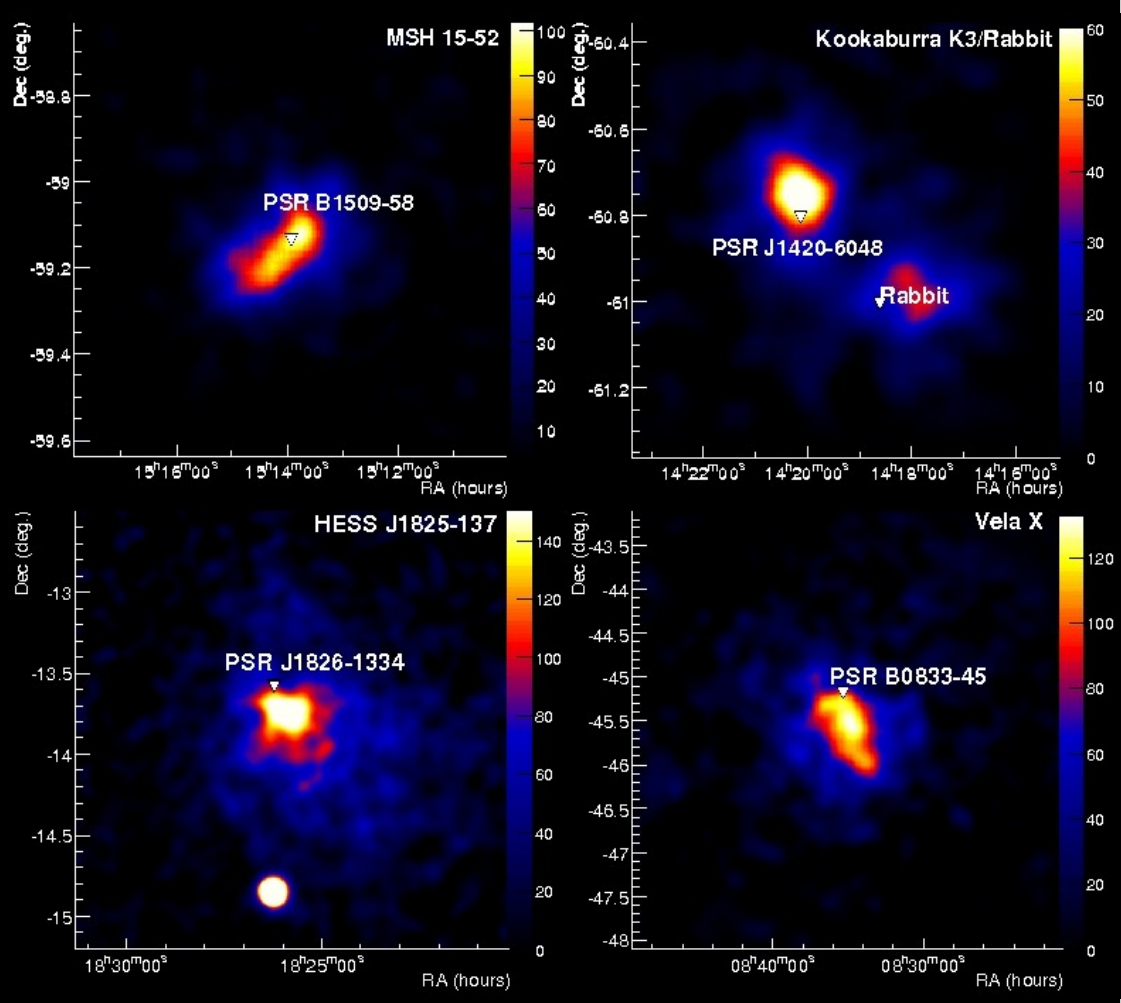
$$\tau(E_X) = (1.2\ \mathrm{kyr}) B_{-5}^{-3/2} E_{\mathrm{keV}}^{-1/2}$$

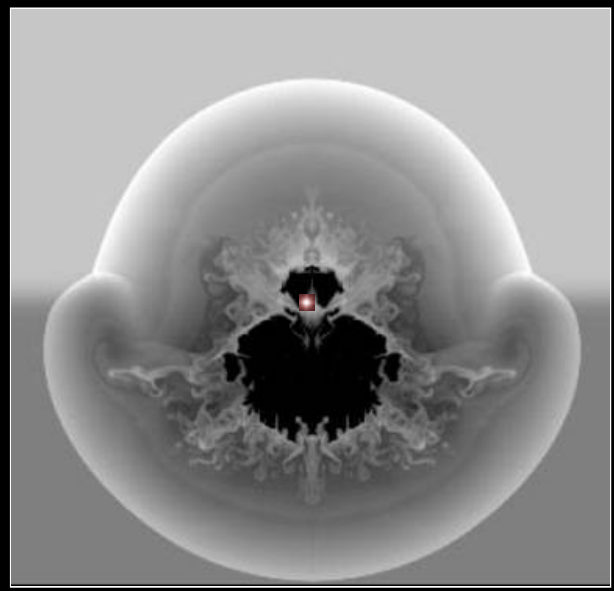
$$\tau(E_\gamma) \sim (4.8\ \mathrm{kyr}) B_{-5}^{-2} E_{\mathrm{TeV}}^{-1/2}$$

Mostly displaced TeV emission wrt pulsar position: “Crushed nebulae”

SN Explosion in inhomogeneous medium
Reverse shock pushes the nebula
[Blondin et al. 2001]

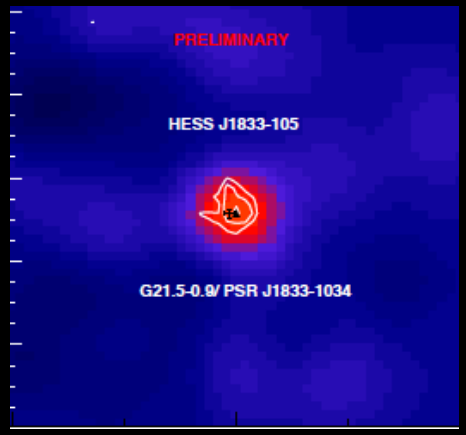
A handful of young/composite PWNe





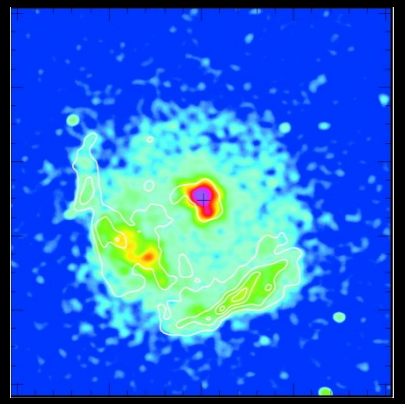
Young/composite TeV PWNe

G21.5-0.9 : HESSJ1833-105



- Distance 4.7 kpc ~ d_5=5 kpc
- 2.5' radius shell → R_{SNR}~6 d_5 pc
- (was) 2nd Strongest Pulsar in MW : PSR J1833-1034
- Edot=3.3 x10^{37} ergs/s, P=61.5ms, τc=4.7 kyr
- True age T ≤ 1kyr
- VLA →PWN expansion T=870 ±200 yr
- HESS J1833-105 : point-like
- Lx(1-10 keV)=1.8x10^{35} erg/s
- Γx = 1.91 {1.5-2}
- Lγ(1-10 TeV) =3.7x10^{33} erg/s
- Γγ = 2.2 > Γx
- Shell Contribution to TeV emission : unlikely
  - → 2σ U.L of 1.8' on size < shell radius
  - → low ρ_{gas} : irrealistic total CR E=4x10^{51} erg

Kes75 : HESSJ1846-026

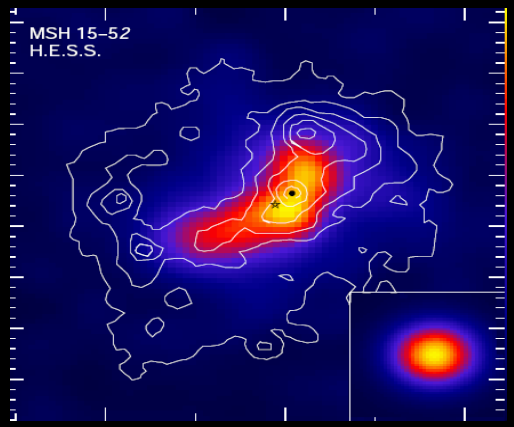


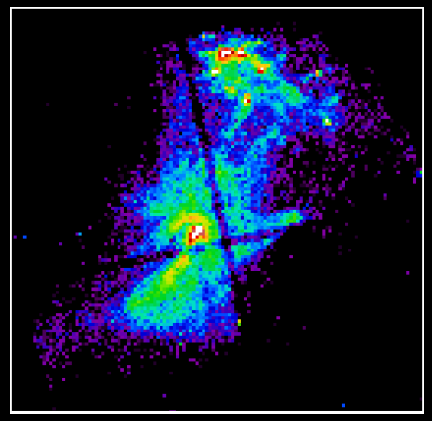
- Distance d_6=6 kpc (revised from 19 kpc)
- 1.75' radius shell → R_{SNR}~3 $d_6$pc
- PSR J1846-0258 B_{surf}~4.8x10^{13} @ Magnetar limit
- Edot=8.3 x10^{36} ergs/s, P=340ms, τc=723 yr
- True age T ≤ 834 yr
- HESS J1846-026 : point-like
- Lx(1-10 keV)=1.4x10^{35} erg/s
- Γx = 1.9 {1.6 for jet}
- Lγ(1-10 TeV)=6.0x10^{33} erg/s
- Γγ = 2.29 > Γx

Shell Contribution to TeV emission : possible
→ large ρ_{gas} ; but would rather inefficient shell

Young/composite TeV PWNe

MSH 15-52 : HESSJ1514-591

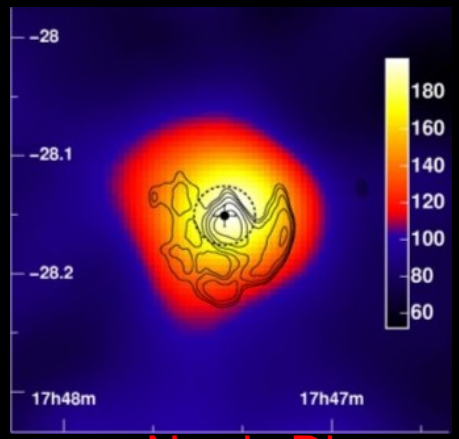


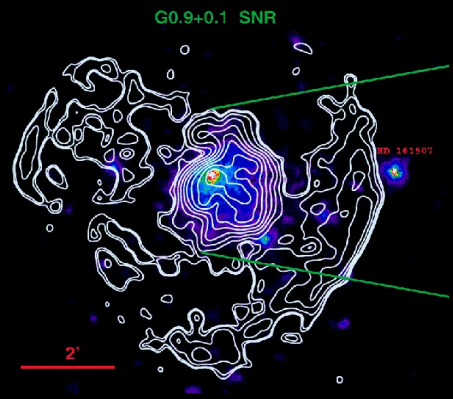


- Distance d_5=5 kpc
- 35' radius (complex) shell → R_{SNR}~50 d_5 pc
- PSR 1509-58 B_{surf}~1.5x10^{13}
- Edot=1.8 x10^{37} ergs/s, P=150ms, τc=1700 yr
- True Age T ? expansion in under-dense cavity?
- Or T> 1700 yr [3]; if so not in same category...
- HESS J1514-591 : extended 6.4'x2.3' (s.d.)
- Lx(1-10 keV)~4.2 x10^{35} erg/s
- Γx = 2.08
- Lγ(1-10 TeV)~4.0x10^{34} erg/s
- Γγ = 2.27 > Γx

Shell Contribution to TeV emission : excluded by the TeV source size

G0.9+0.1 : HESSJ1747-281





Newly Discovered PSR similar to that of G21.5-0.9

- Distance $d_{8.5}$=8.5 kpc
- 4' radius shell → R_{SNR}~10 d_5 pc > G21.5 shell
- PSR J1747-2809 B_{surf}~2.9x10^{12}
- Edot=4.3 x10^{37} ergs/s, P=52ms, τc=5.3 kyr
- True Age T ?
-
- HESS J1747-281 : point-like
- Lx(2-10 keV)~6.5 x10^{34} erg/s
- Γx = 1.9
- Lγ(1-10 TeV)~2.0x10^{34} erg/s
- Γγ = 2.40 > Γx (star-light+dust)

Shell Contribution to TeV emission : excluded by the TeV source size

VHE emission detected by HESS in G 292.2-0.5

First observations as part of the HESS Galactic Scan in l $\in$ [270°-300°]

Total observation live time ~ 50h

Extended emission size ~ 0.1°
to the W-SW of the SNR

Excess: 220 (hard cuts)

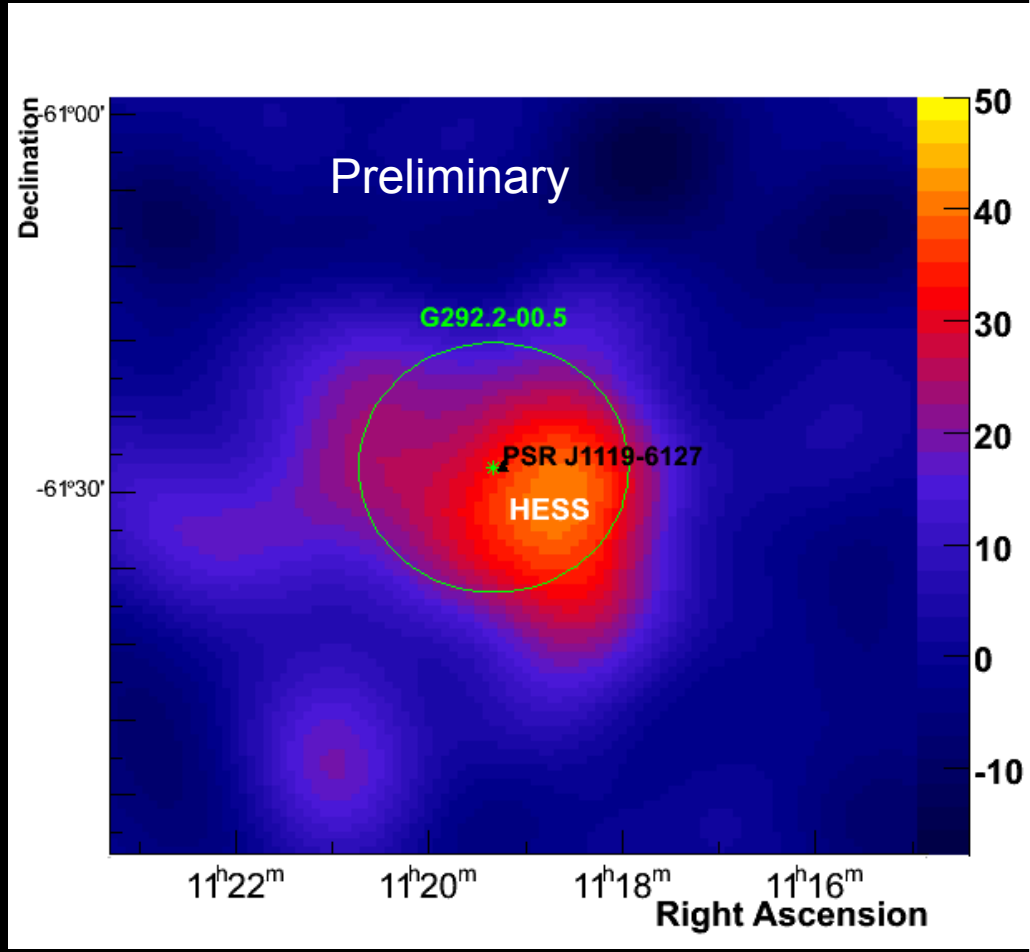
Significance: 8.9 σ
for an integration radius = 0.2°

Flux ~ 4% Crab nebula

Lγ(0.5-10 TeV) ~ 3.5 10^{34} $(d_{8.4})^2$ erg/s

γ-ray efficiency ~ 1.5% 10-10^2 larger

Evidence of a steeper spectrum than for other young TeV PWNe
(photon index Γ>2.2)



G292.2-0.5/ PSR J1119-6127

PSR J1119-6127 [Camilo et al. 2000]
Large P= 408 ms
Although τc=1.6 kyr, Edot= 2.3e+36 erg/s
One of 5 pulsars with known braking index : n=2.91±0.05

B=4.1x10^{13} G, at the limit of Magnetars and similar to the 0.3 s X-ray pulsar PSR J1846-0258 in Kes 75 (723yrs, B~5x10^{13} G)

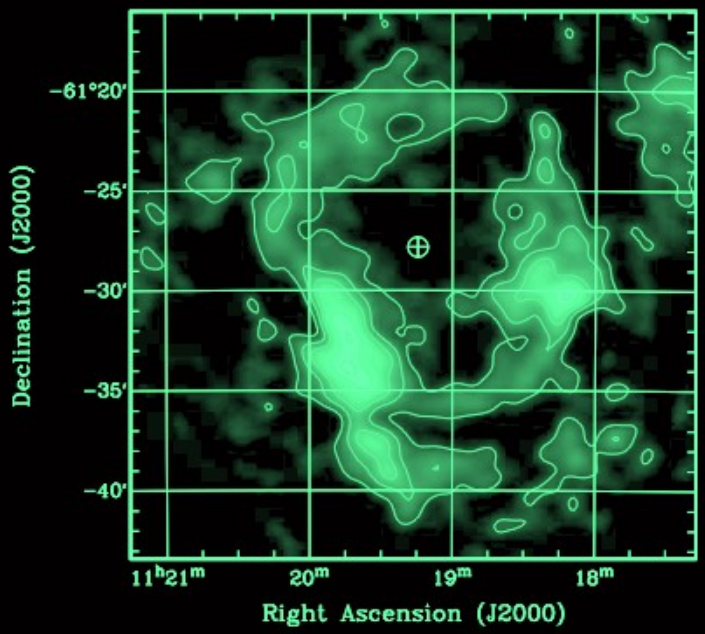
ATCA deep measurements revealed the 15' SNR Shell [Crawford et al 2001]

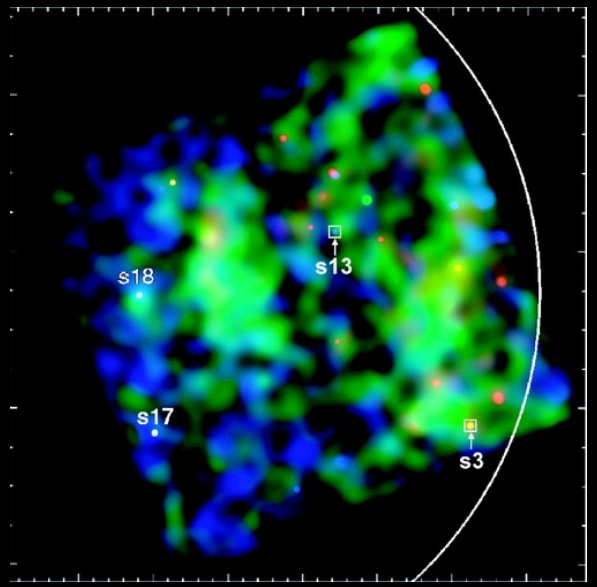
But no radio emission from PWN

X-rays Rosat + ASCA [Pivovaroff 2001]

Chandra : Evidence for a 3"x3" X-ray PWN [Gonzalez & Safi-Harb 2003]

PWN+Jet confirmed [Safi-Harb & Kumar 2008]





X-ray Picture

Very faint PWN:
Lx~ 1.6 10^{32} erg/s; Γ=1.1 (+0.9,-0.7)
Southern Jet:
Lx~ 2.1 10^{33} erg/s; Γ=1.4 (+0.8,-0.9)
Lx/Edot = 0.001 << kes75 (~2%)

[Safi-Harb & Kumar; this conf.]:

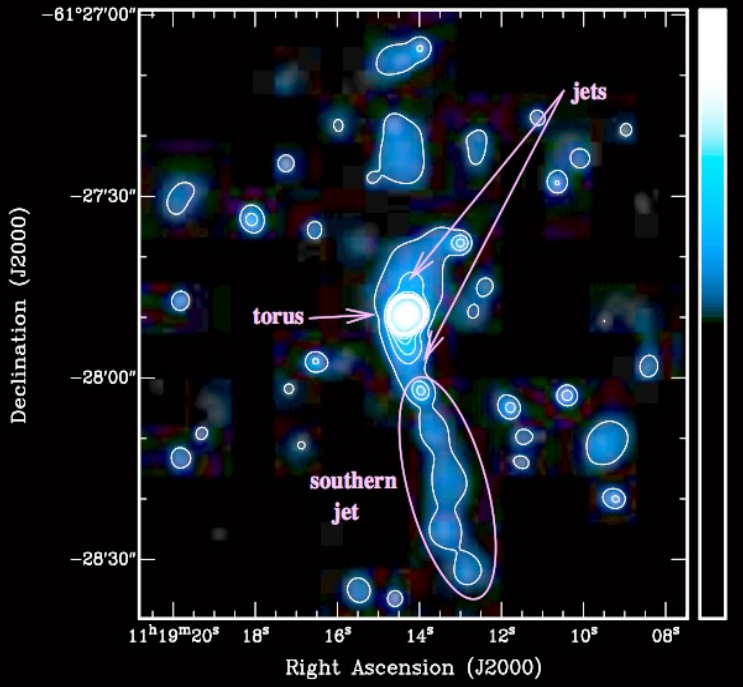
PSR West: best fit VP+PL

-mix of non-thermal+ thermal

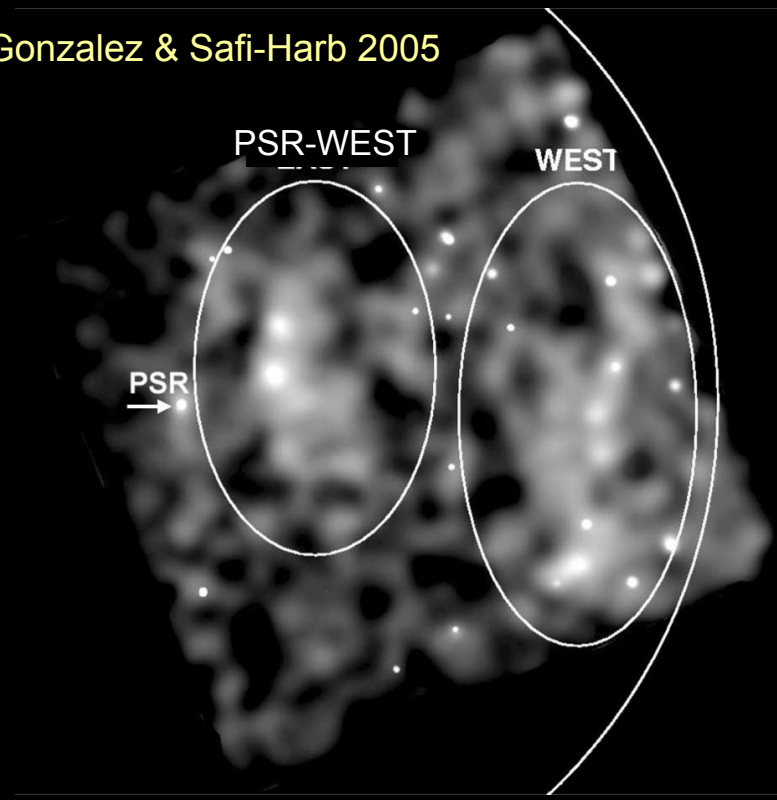
-Lx~ 5.6 10^{34} erg/s Γ=1.5 (+0.5,-0.2)

SNR West: best fit VP : Shocked ISM

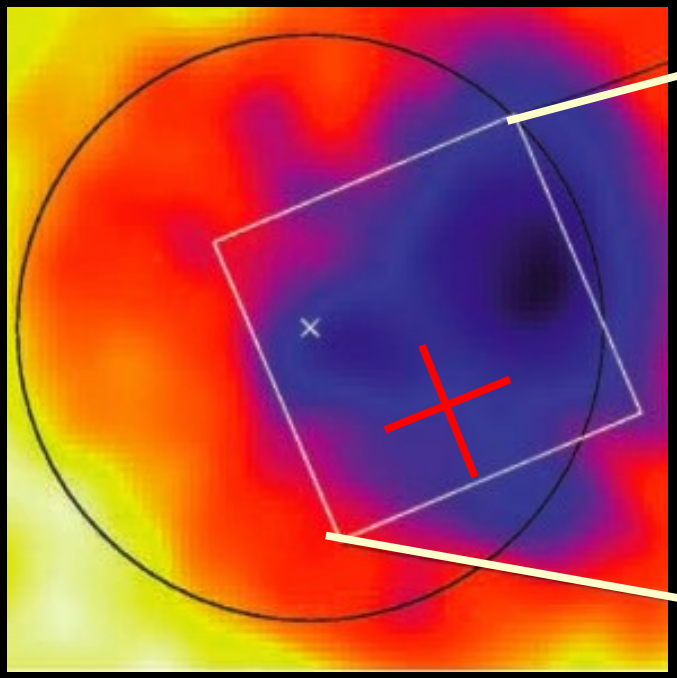
Safi-Harb & Kumar 2008



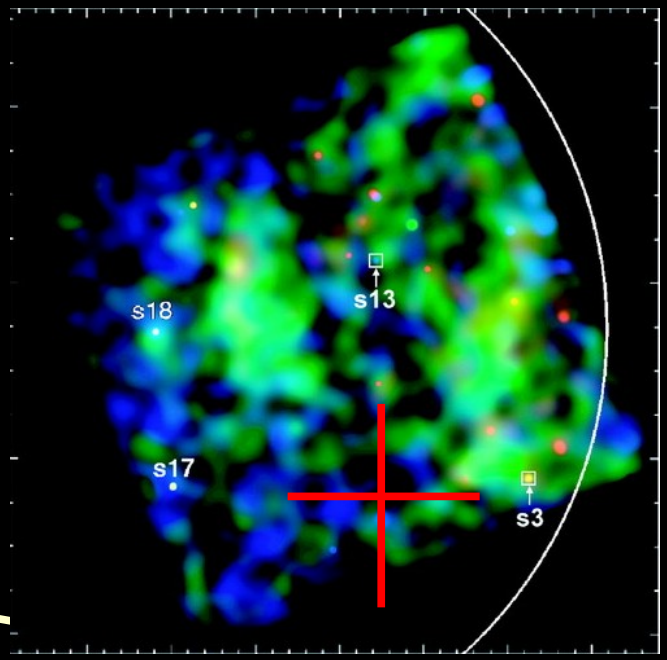
Gonzalez & Safi-Harb 2005



TeV emission within G292.2-0.5

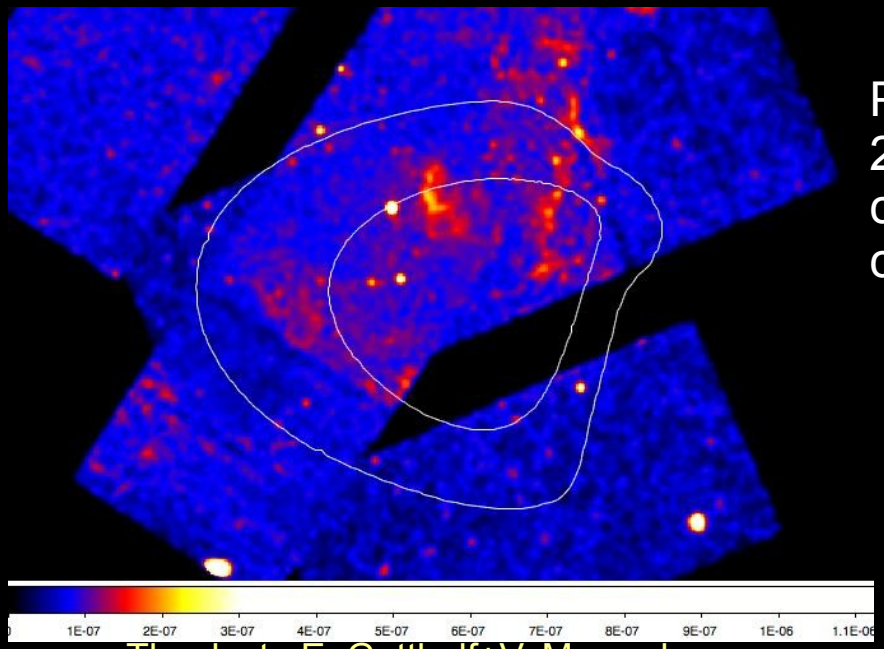


ASCA/ Cross: TeV approx centroid



Chandra/
Cross: TeV approx centroid

TeV centroid clearly to the W of PSR J1119-6127
Between PSR W & SNR W



Preliminary
2 & 3 sigma TeV centroid position contours

Thanks to E. Gotthelf+V. Marandon

TeV Origin? (I)

Association to the compact PWN:
Very faint: Lx/Lγ~ 510^{-3} unrealistic B
Add south-jet Lx/Lγ~ 0.06 dosen't help

Γx<2 too hard wrt Γγ> 2.2
But clearly not same zone/populations @ play

Association to PSR West: PWN-like IC emission by the non-thermal component:
Lx (0.5-10keV)~ 1.2 10^{34} erg/s;

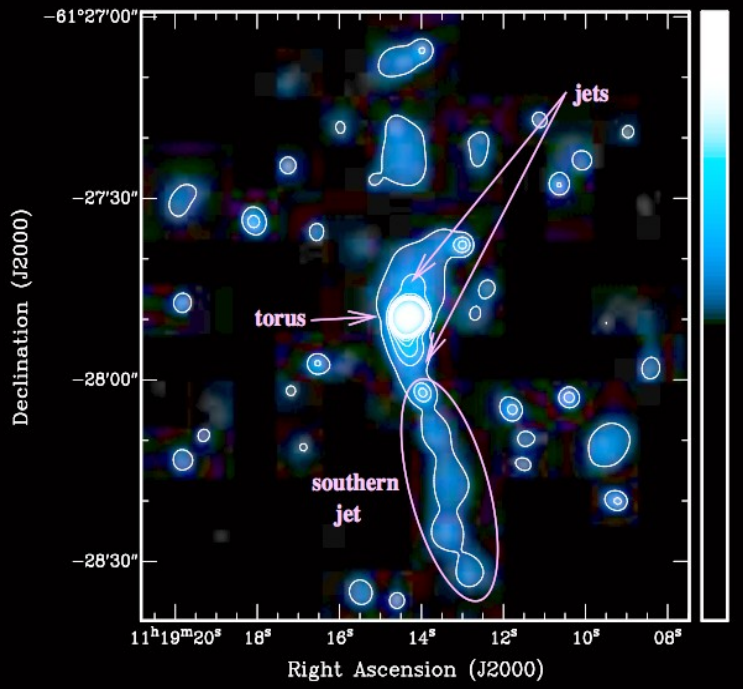
Lx/Lγ~ 0.34

Bn >~ (3 μG)$(Lx/Lγ)^{1/2}$ ~ 2 μG

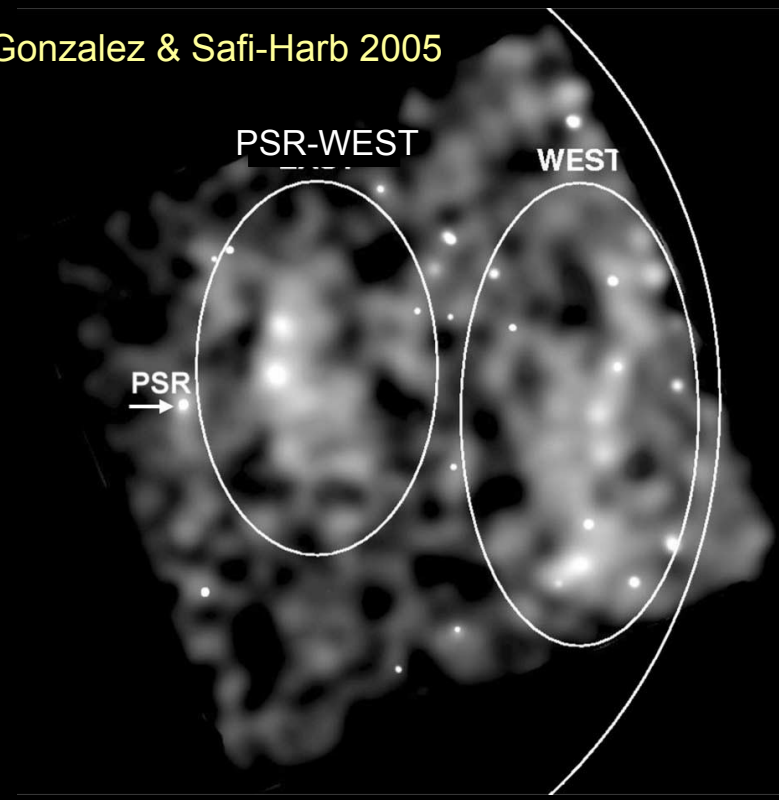
Would need a significant contribution of dust-IR (to explain also steeper Γγ)

Far from equipartition (as for other TeV nebulae): would imply a particle dominated wind

Safi-Harb & Kumar 2008



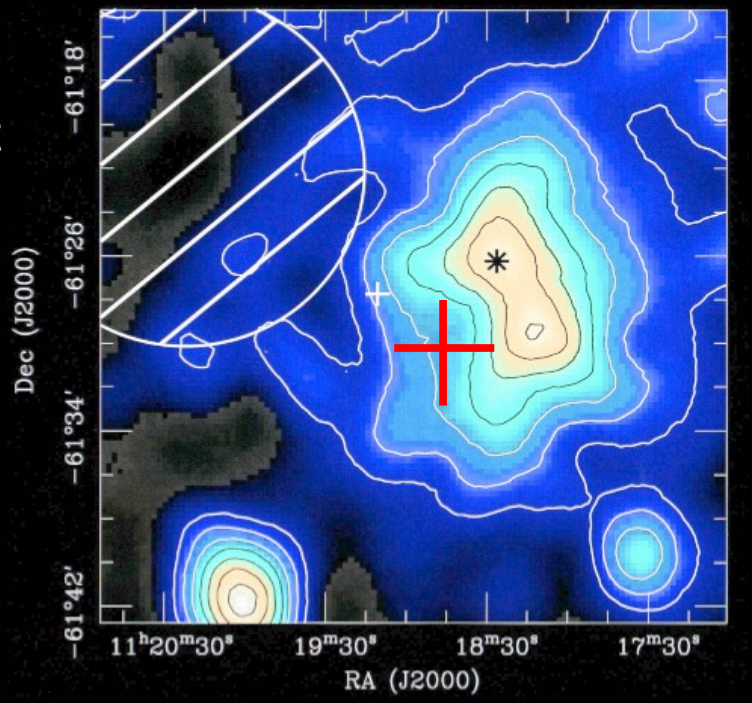
Gonzalez & Safi-Harb 2005



TeV Origin? (II)

Dark cloud to the East

Pivovaroff 2001



Association to PSR West (contin'd):

Mixing of electrons with ejecta due to passage of reverse shock? East-West asymmetry?

Displaced nebula after crushing by an asymmetrical reverse shock due to the dark cloud to the N-East. (1700 yrs ?)

Properties of the cloud?

What about the similar PSR East X-ray emission reported by H. Kumar?

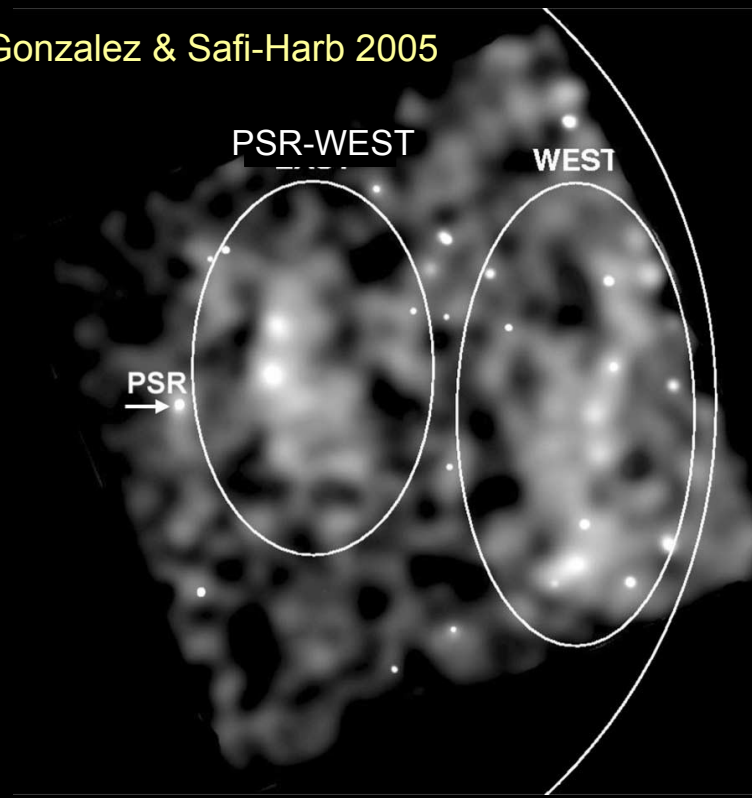
Association to Thermal X-rays (thermal PSR-West+SNR-West)

Assume ε=20% efficiency for accelerator

$L_\gamma(0.5\text{-}10\text{TeV}) \sim 8.2\times10^{33}(\varepsilon/0.2)(n/1\ \text{cm}^{-3})$ erg/s

Would need higher density n or ε. Preliminary value (Kumar & Safi-Harb) $n < 0.1\ \text{cm}^{-3}$ not favouring this scenario...

Gonzalez & Safi-Harb 2005



Summary

An extended (~0.1°) TeV γ-ray source is discovered in G292.2-0.5

The γ-ray luminosity is $L_\gamma(0.5\text{-}10\ \text{TeV}) \sim 3.5\ 10^{34}\ (d_{8.4})^2$ erg/s; that is 1.5% Edot

L_γ is higher than e.g. HESS J1846-026 in Kes75 or HESS J1833-105 in G21.5-0.9 (few 10^{33} erg/s) and γ-ray efficiency 10-10^2 larger; X-ray efficiency is << Kes75.

The spectrum is steeper than other young PWNe ($\Gamma_\gamma > 2.2$)

The VHE emission is clearly to the W-SW of the PSR/SNR, compatible both with "PSR-West and SNR-West [Kumar& Safi-Harb]" in X-rays

PSR J1119-6127 is particular, large period and B_s similar to PSRJ1846-0258/Kes75

But very faint PWN Lx/Edot = 0.001, whereas Kes75 very bright: Lx/Edot ~2%

Origin of TeV emission:

Electrons mixed with ejecta due to passage of an asymmetrical reverse shock?

Cosmic-ray acceleration @ play + p-p interactions? Need ambiant density O(1cm^{-3})

Further investigations: TeV spectrum, morphology, density of environ. matter,...

Number of TeV emitting young and composite SNRs is increasing, similarites do exist but still many variations (central engine, B/X-ray efficieny/Lx/Lγ,...) to be understood.

Thank You

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Vol 460 | Issue no. 7251 | 2 July 2009

We are all Iranians

Iran's endogenous civil-rights movement needs international solidarity, not political meddling. Academics, universities and non-governmental organizations can help.