H.E.S.S. TeV Gamma-ray Sources Associated with Pulsar Wind Nebulae

Christoph Deil (MPI for Nuclear Physics, Heidelberg)
R.C.G. Chaves, M. Dalton, A. Djannati-Atai, F. Dubois, A. Foerster, Y.A. Gallant, B. Glueck, J.A. Hinton, S. Hoppe, O.C. de Jager, D. Keogh, B. Khelifi, G. Lamanna, Nu. Komin, K. Kosack, A. Lemiere, V. Marandon, M. Renaud, O. Tibolla **for the H.E.S.S. Collaboration**

HESS J1923+141
HESS J1912+101
HESS J1857+026
HESS J1849-000
HESS J1843-033
HESS J1837-069
HESS J1908+063
HESS J1858+020
HESS J1848-018
HESS J1846-029
HESS J1841-055
b [deg]
l [deg]

HESS J1834-087
HESS J1825-137
HESS J1813-178
HESS J1804-216
HESS J1747-281
HESS J1745-290
HESS J1741-302
HESS J1714-385
HESS J1713-381
HESS J1833-105
HESS J1826-148
HESS J1809-193
HESS J1801-233
HESS J1800-240
HESS J1745-303
HESS J1731-347
HESS J1718-385
b [deg]
l [deg]

HESS J1713-397
HESS J1702-420
HESS J1640-465
HESS J1632-478
HESS J1616-508
HESS J1503-582
HESS J1427-608
HESS J1418-609
HESS J1420-607
HESS J1708-410
HESS J1708-443
HESS J1634-472
HESS J1626-490
HESS J1614-518
HESS J1514-591
HESS J1442-624
b [deg]
l [deg]

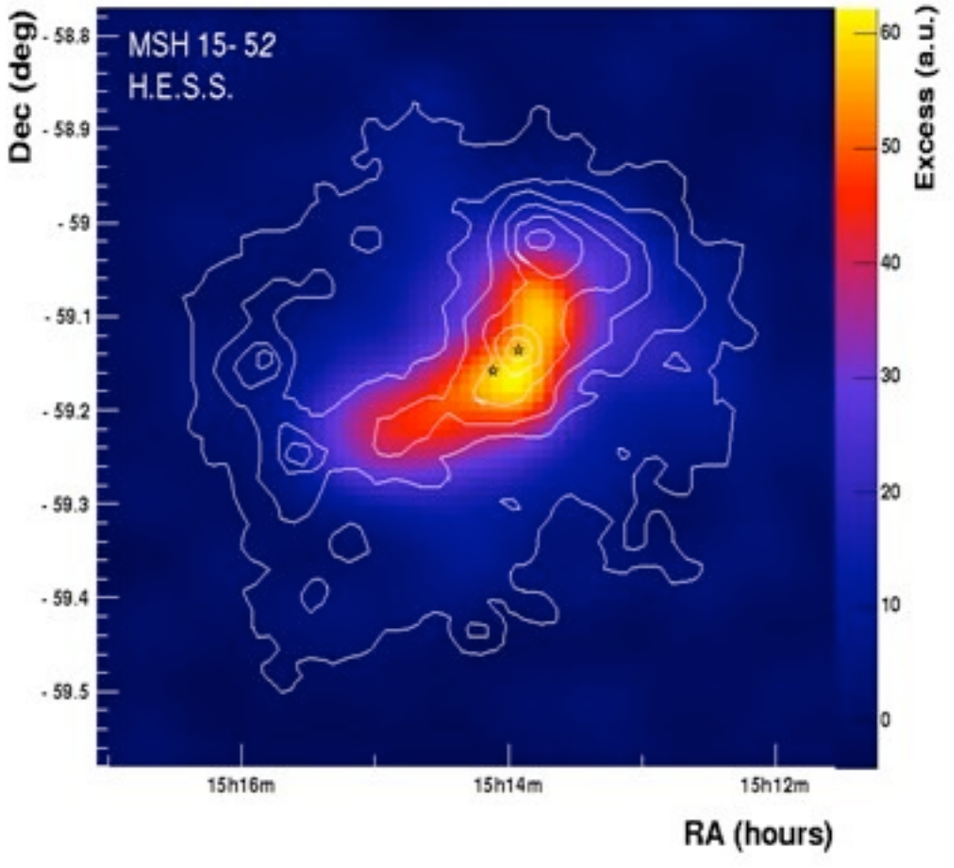
HESS J1356-645
HESS J1303-631
HESS J1023-575
HESS J1302-638
b [deg]
l [deg]

Chaves (HESS Collaboration) ICRC 2009

Galactic plane at TeV energies

Identified PWNe

Matching morphology with radio or X-ray PWN

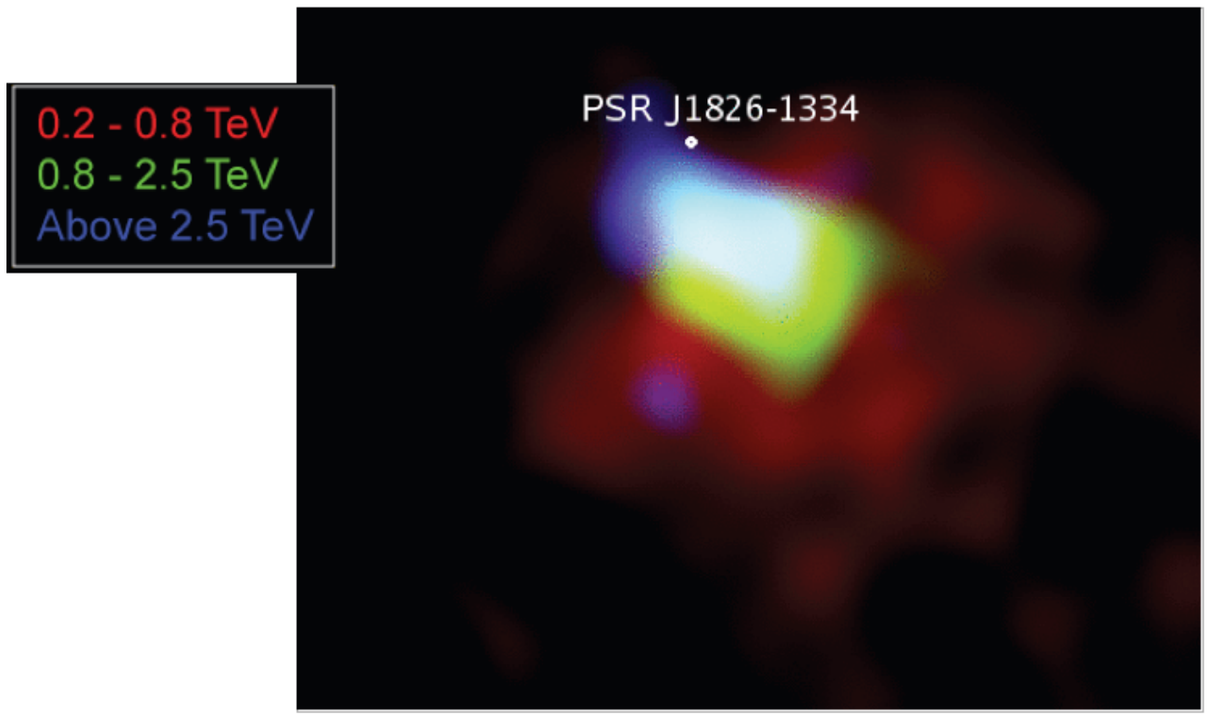


MSH 15-52
Vela X
Rabbit
K3 in Kookaburra
HESS J1356-645

Identified PWNe

Spectral steepening away from the pulsar

HESS J1825-137

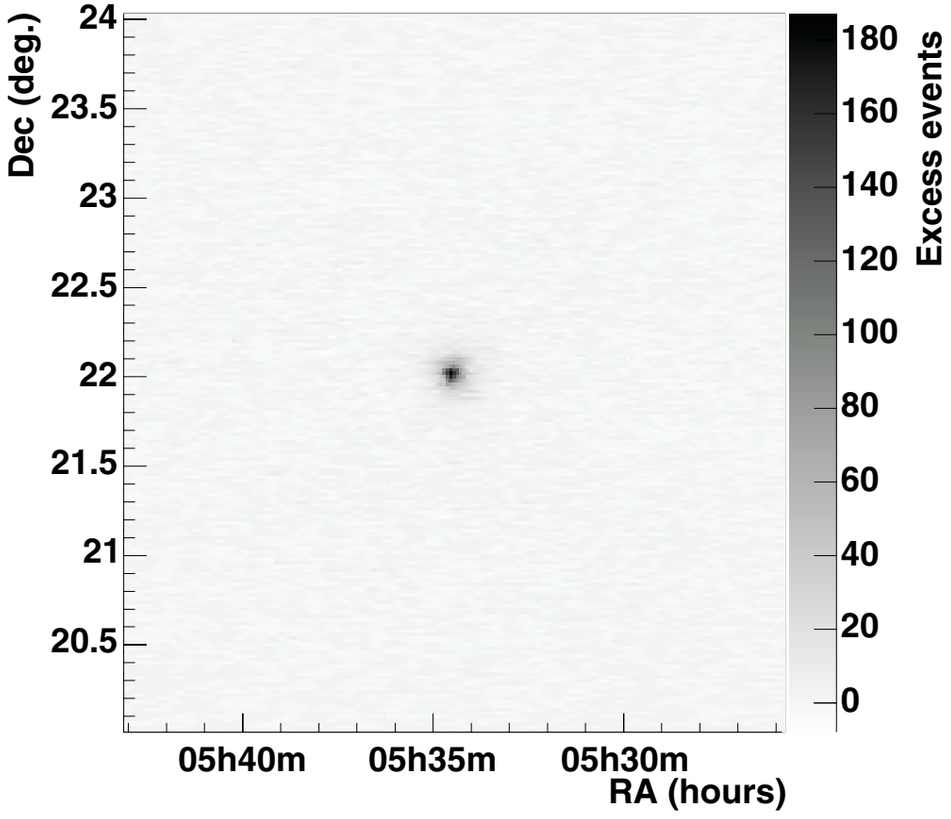


HESS J1303-631

Dalton et al. (HESS Collaboration)
ICRC 2009 (Preliminary)

(Identified) PWNe

Unresolved HESS source coincident with a resolved radio or X-ray PWN

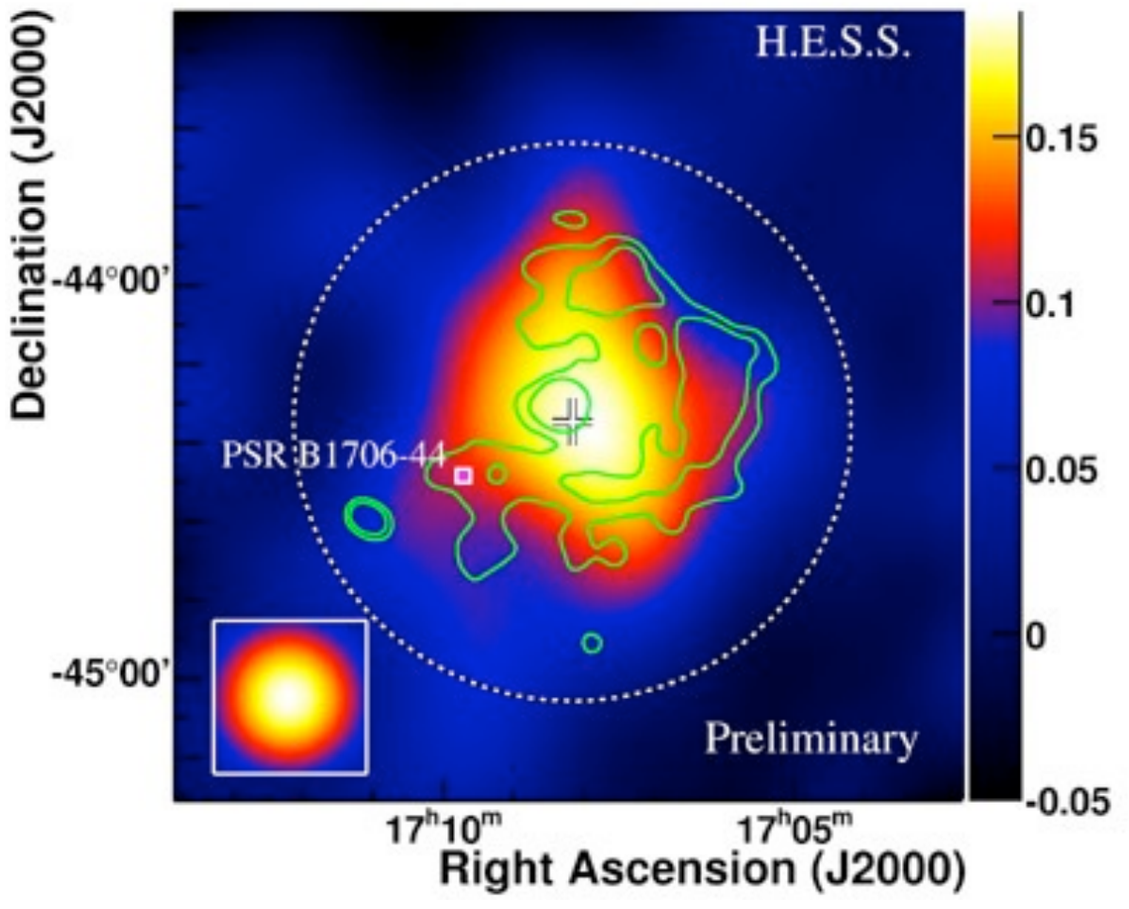


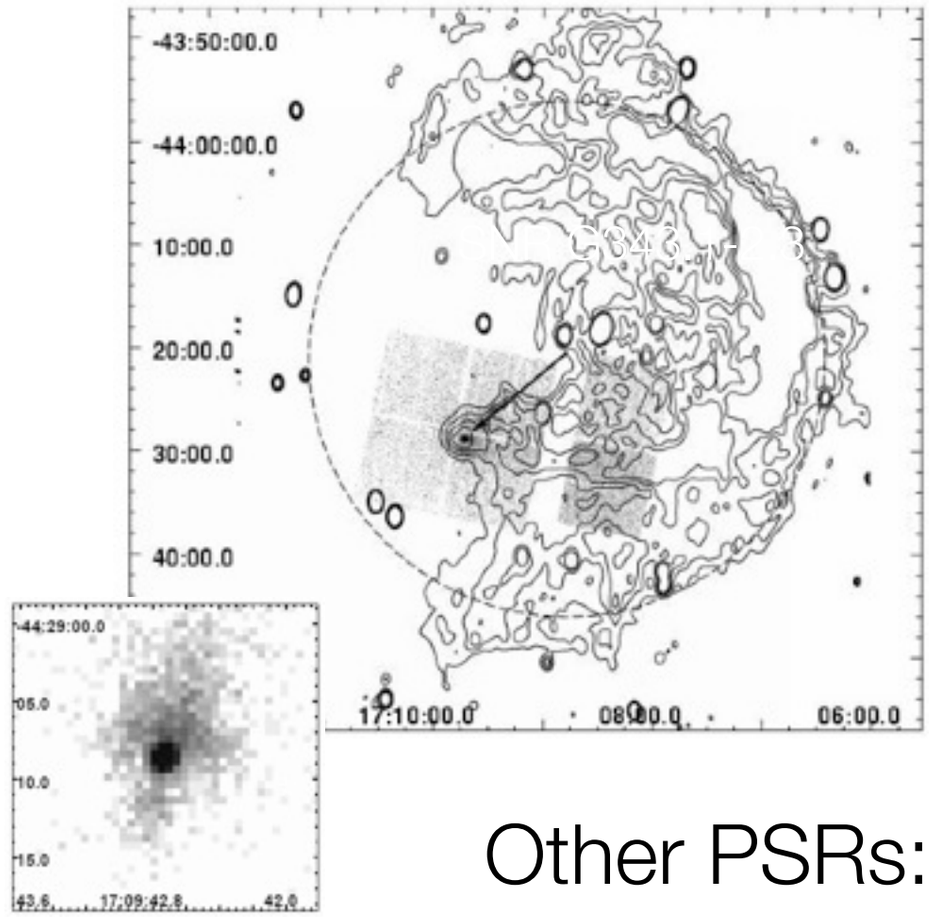
Crab
G0.9+0.1
G21.5-0.9
Kes 75
N157B in LMC

Komin et al. (HESS Collaboration), ICRC 2009

PWN candidates:
TeV source with nearby energetic pulsar

HESS J1708-443

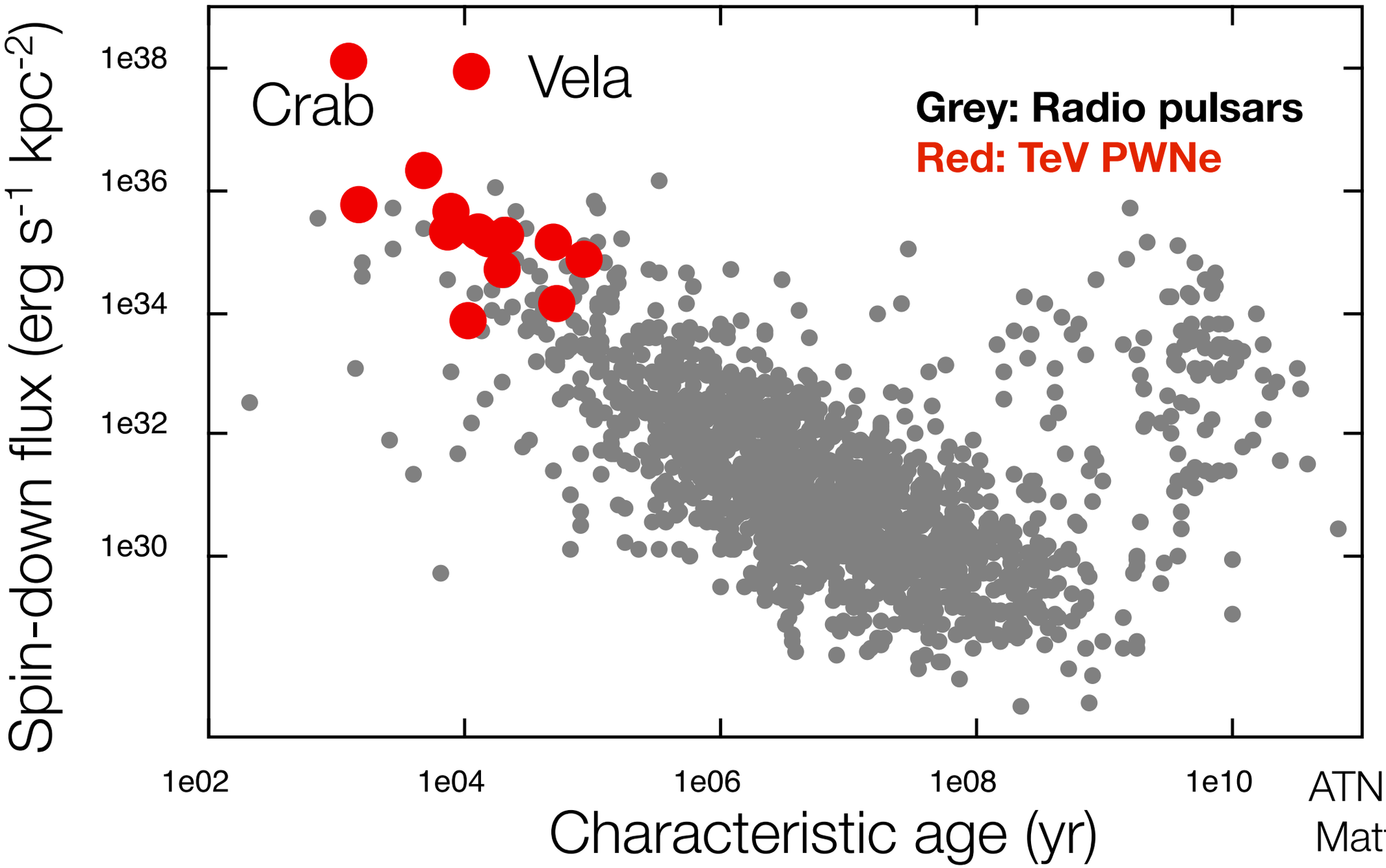




Other PSRs:
J1617-5055
J1718-3825
B1800-21
J1809-1917
J1119-6127

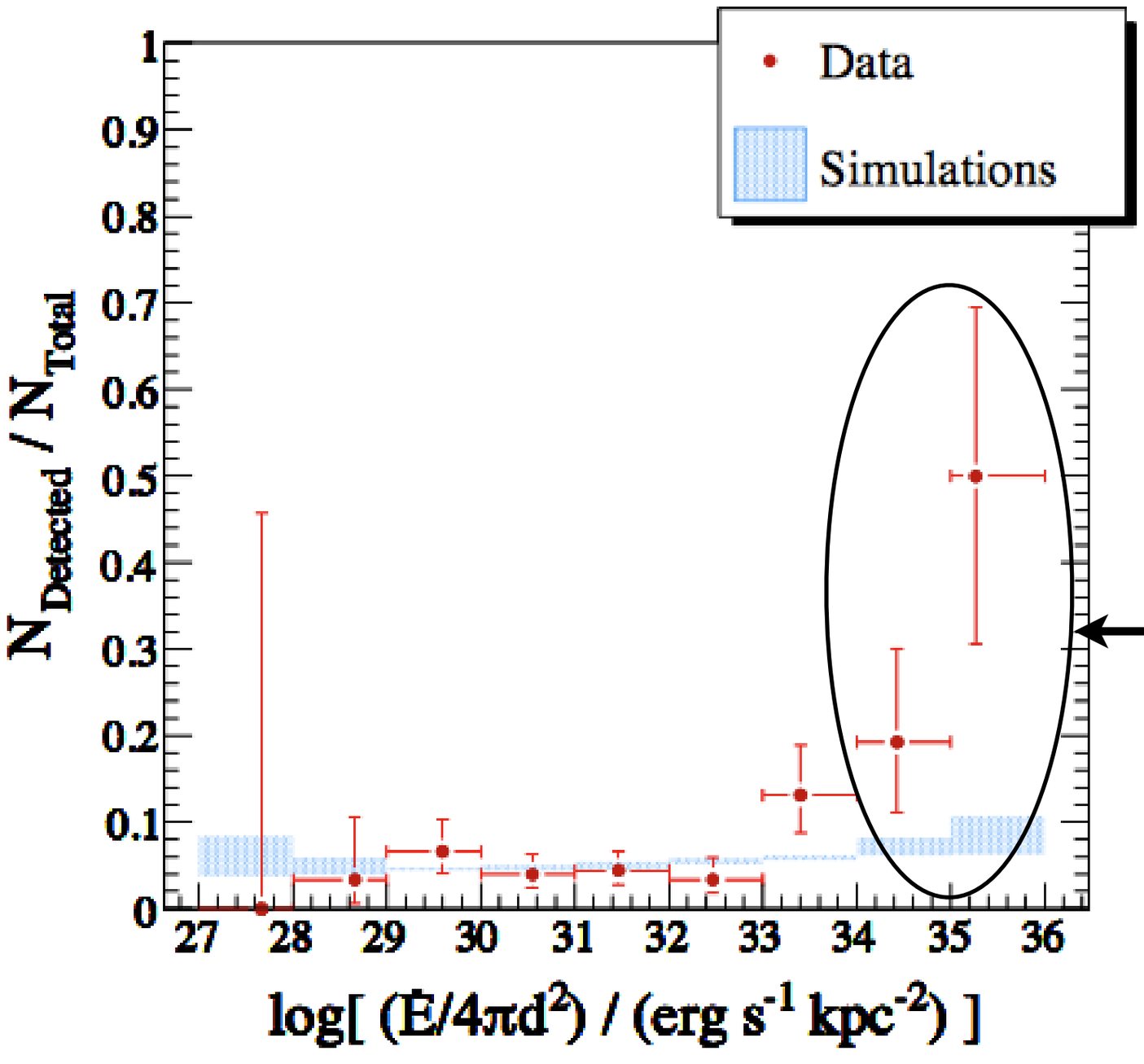
Djannati-Atai et al. (HESS Collaboration),
2009 Boston SNR/PWN Workshop

Which Pulsars create TeV PWNe?



ATNF pulsar catalog
Mattana et al. 2009

Pulsar — TeV Source Coincidences

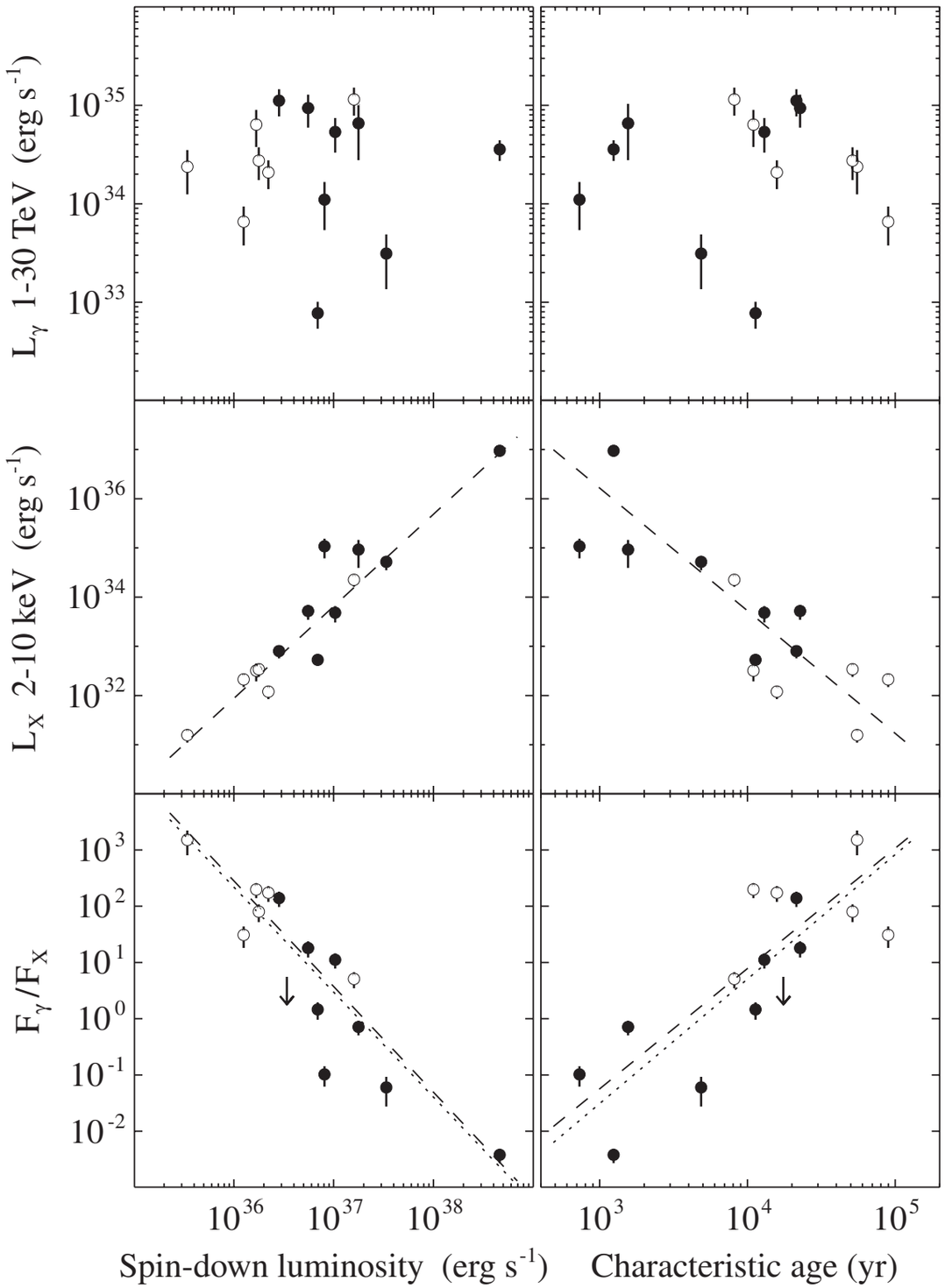


Some energetic pulsars have TeV-bright nebulae.

Chance Probability = 0.1%

Wenig et al. 2008

What determines the TeV luminosity?



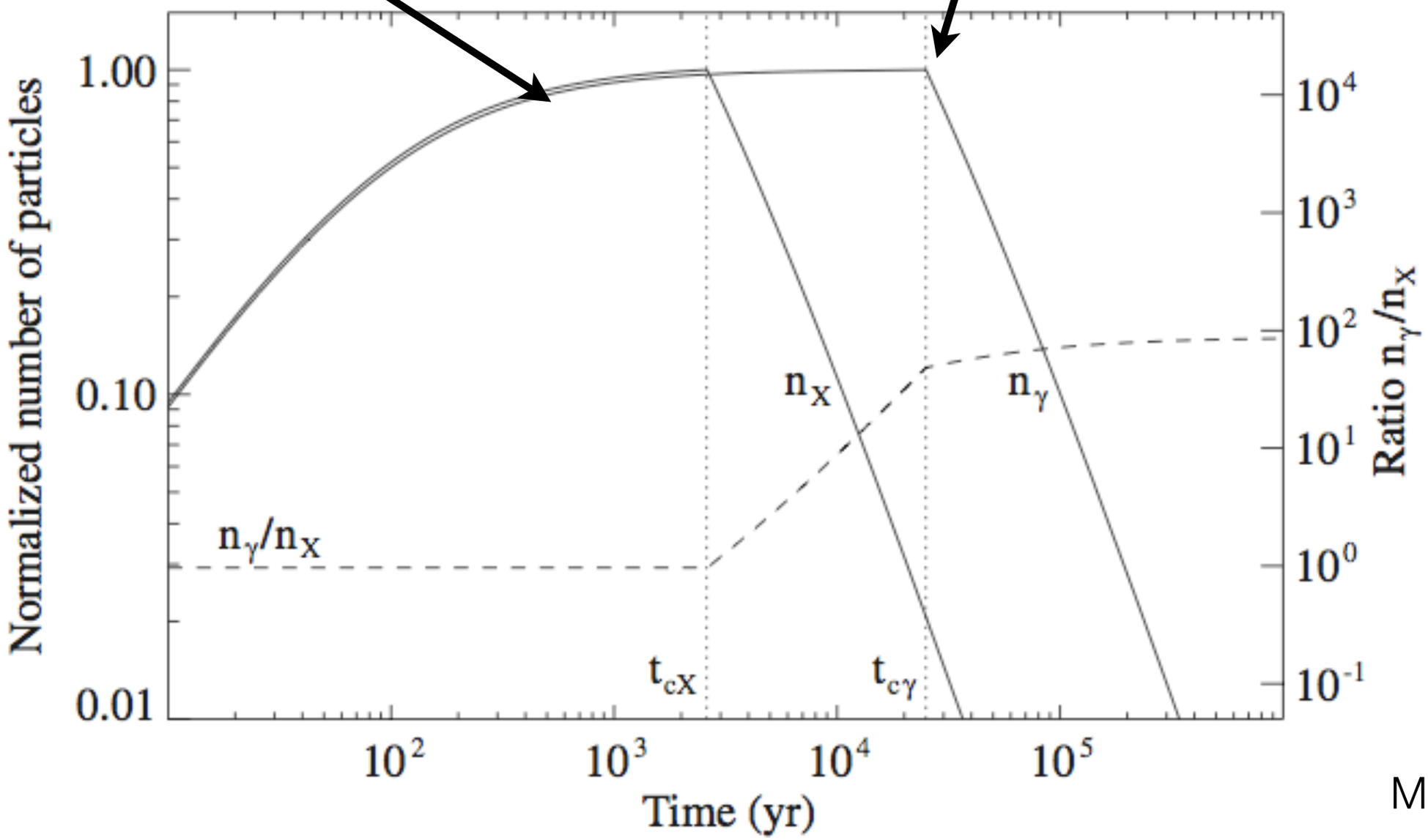
Mattana et al. 2009

Pulsar — PWN Evolution Timescales

Pulsar spin-down timescale
$t_{SD} \sim 10^2 - 10^3$ years

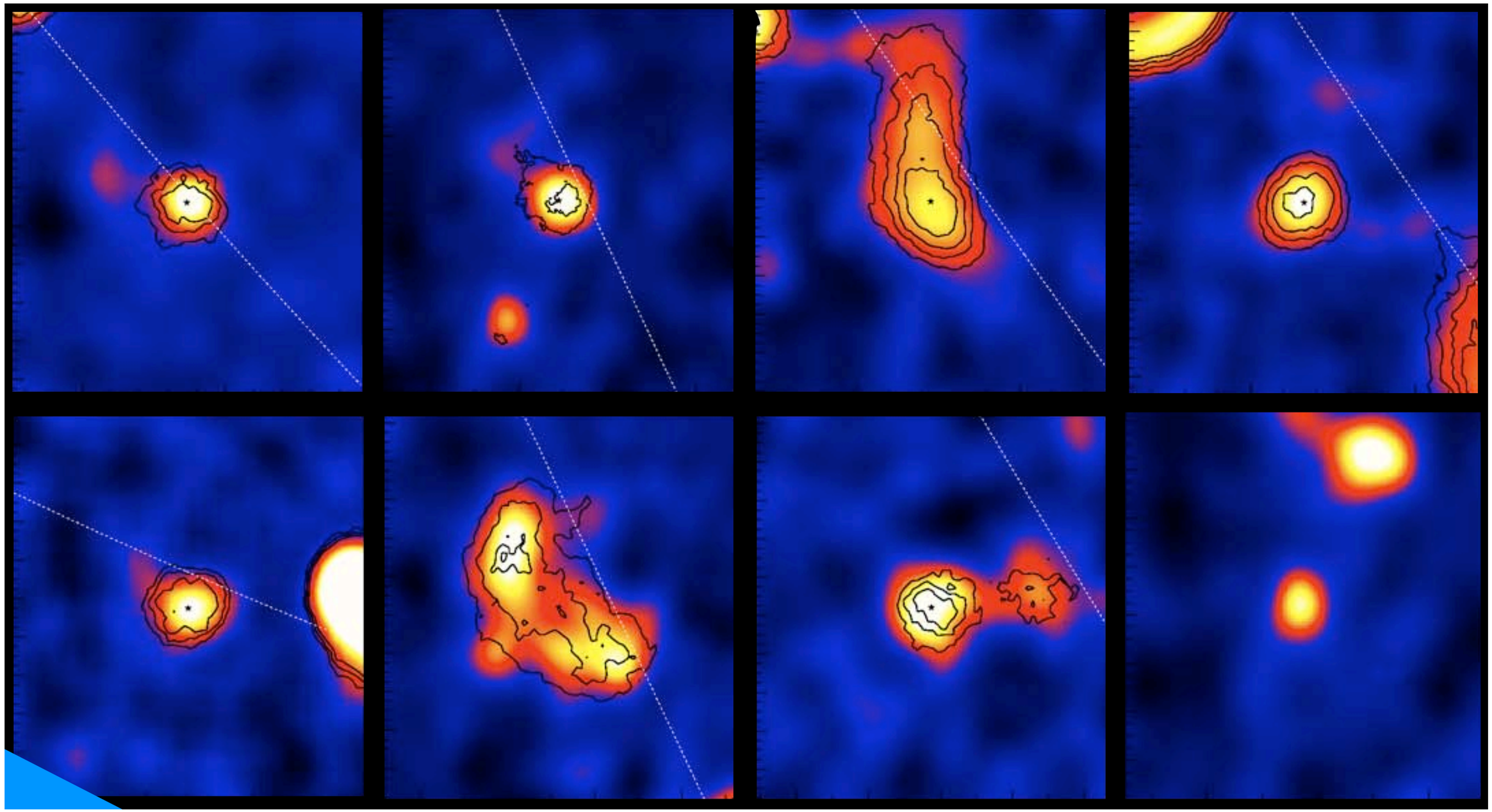
TeV electron synchrotron cooling timescale $t_{cool} \sim 10^4 - 10^6$ years

$$t_{\rm cool} \approx 130\ {\rm kyr} \left(\frac{B}{10\,\mu{\rm G}}\right)^{-2} \left(\frac{E_e}{1\,{\rm TeV}}\right)^{-1}$$



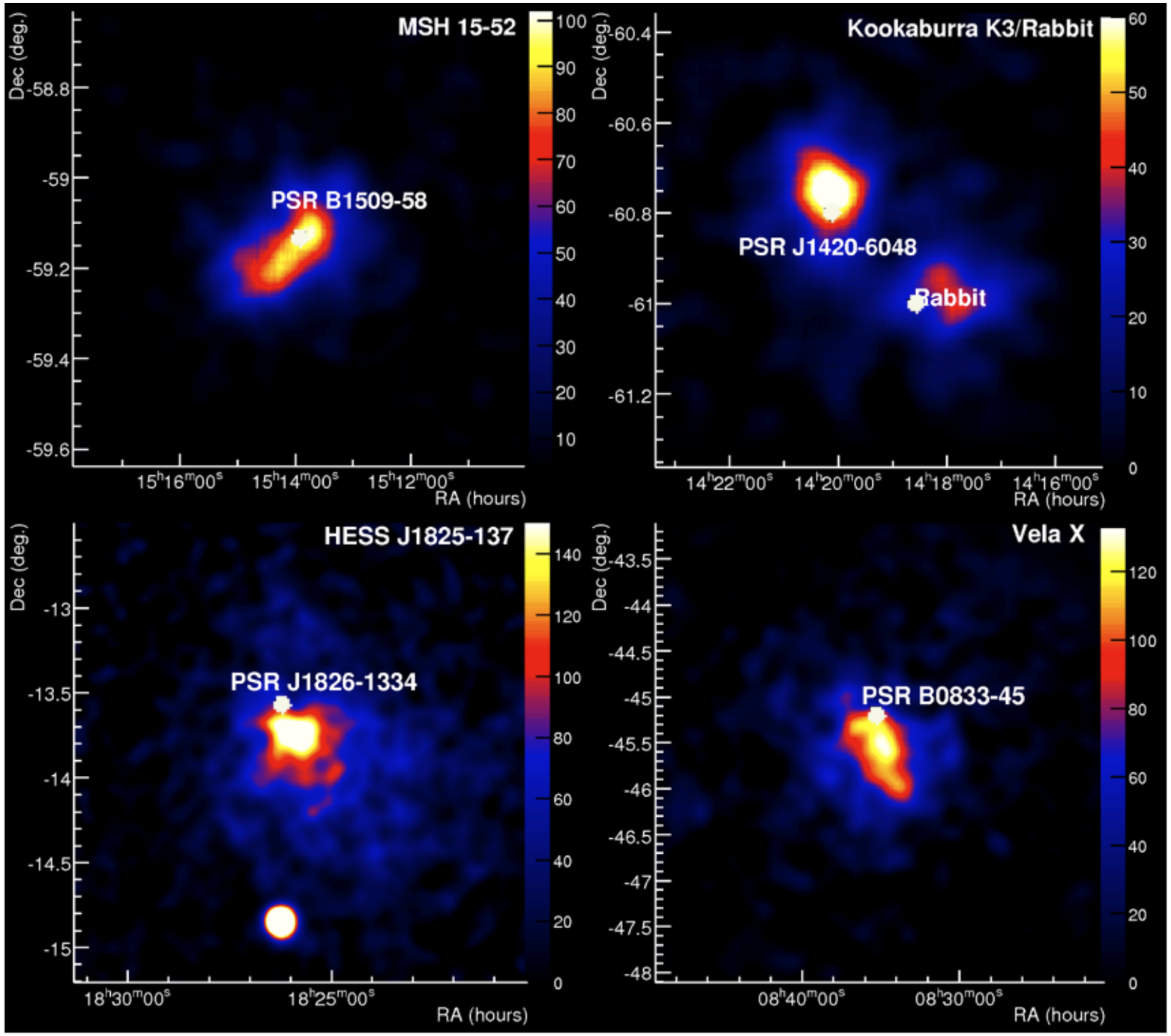
Mattana et al. 2009

Unidentified TeV sources → Old PWNe?

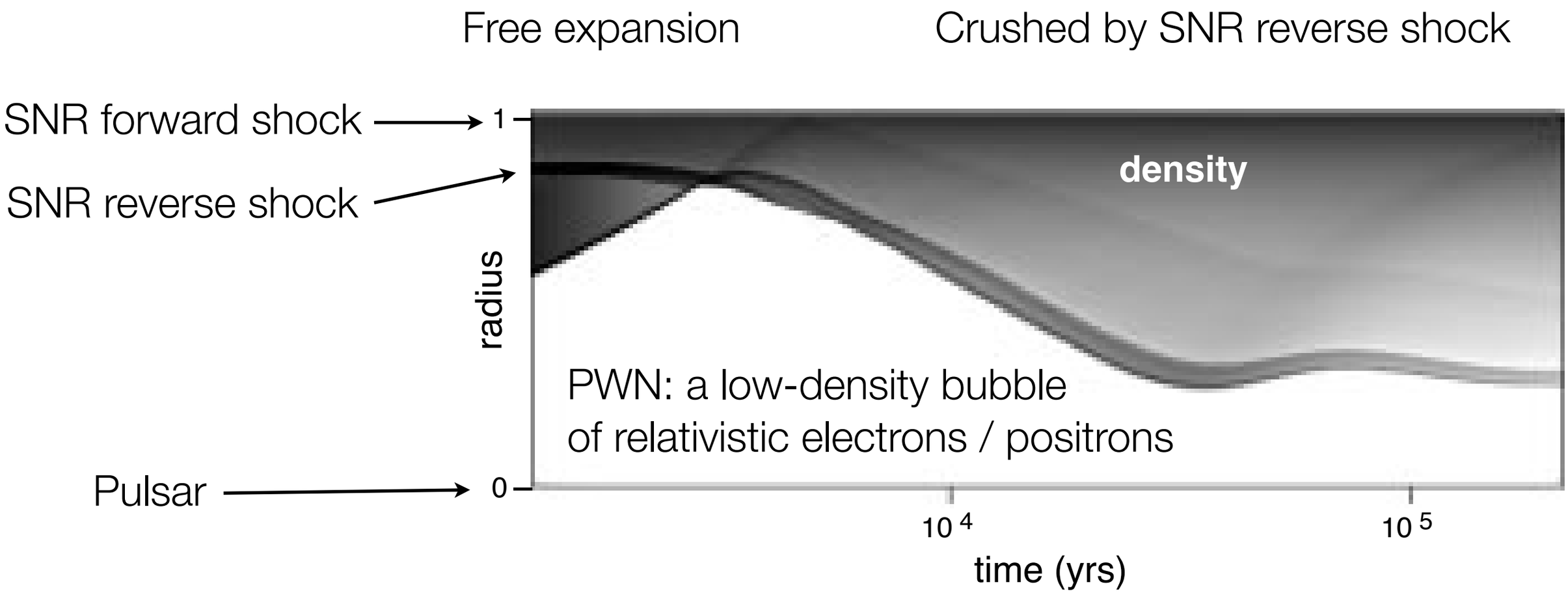


Aharonian et al. (HESS Collaboration) 2008

Why are PWNe offset from their pulsar?

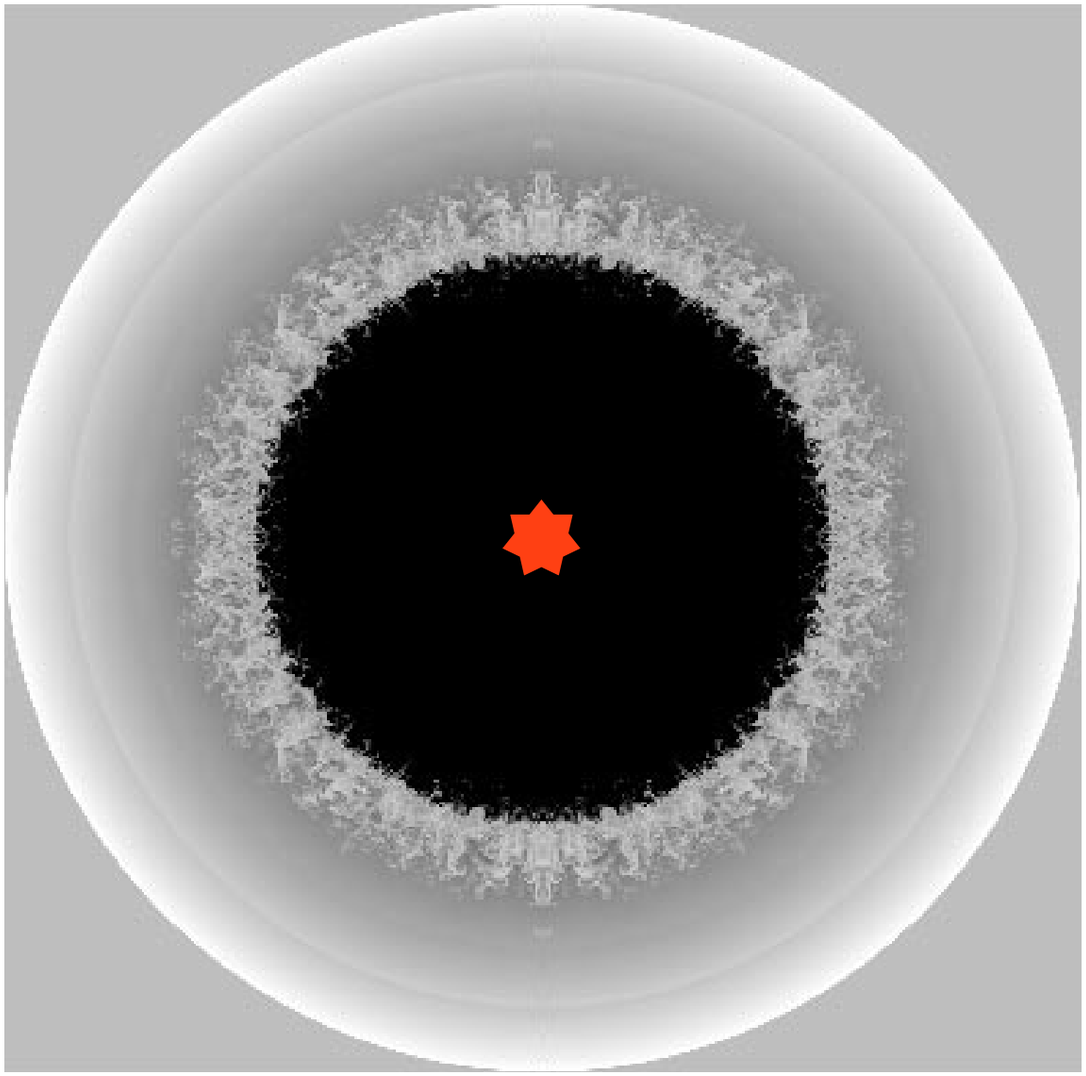


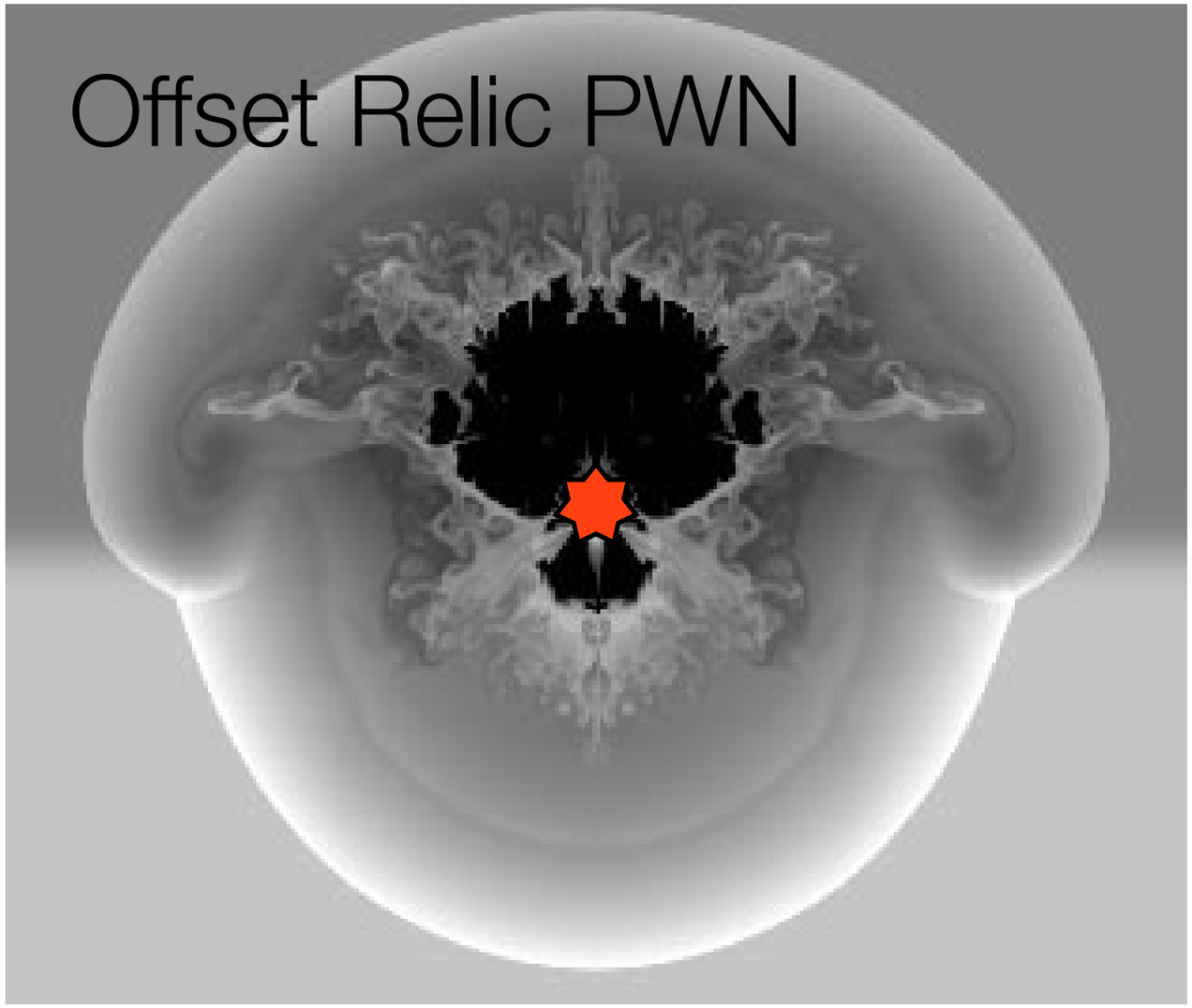
PWN Evolution Phases



Simulations by Blondin et al. 2001

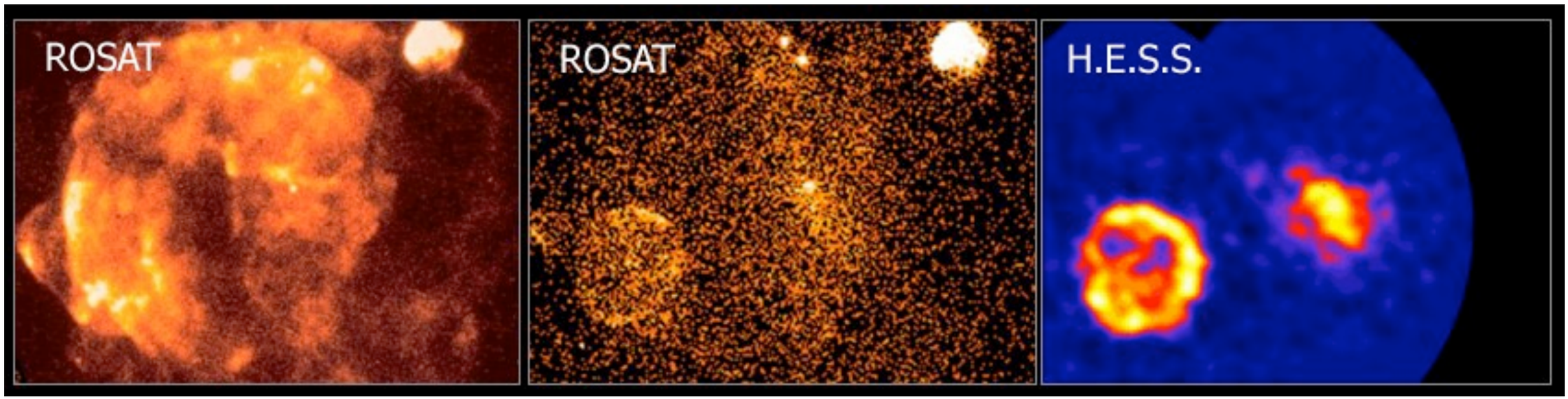
Inhomogeneous ISM → Asymmetric Crushing





Simulations by Blondin et al. 2001

Vela SNR and PWN “Vela X”



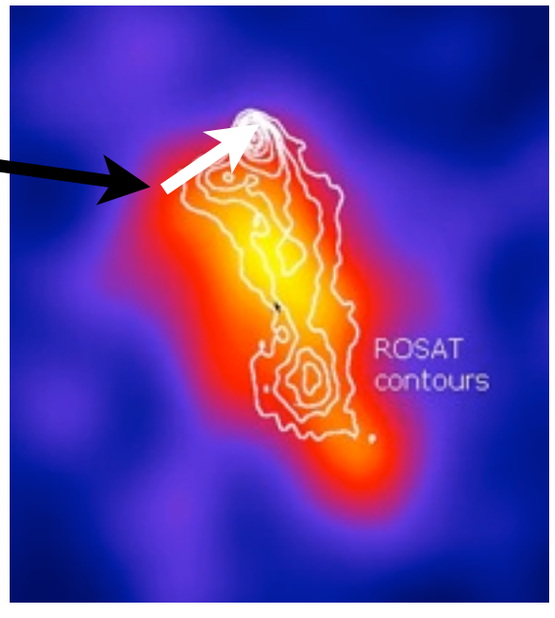
0.1 — 2.4 keV

1.3 — 2.4 keV

TeV

Vela PSR B0833-45
Distance 0.3 kpc
Characteristic age 11 kyr
Vela SNR diameter 8 deg

Note: offset not caused by pulsar motion!

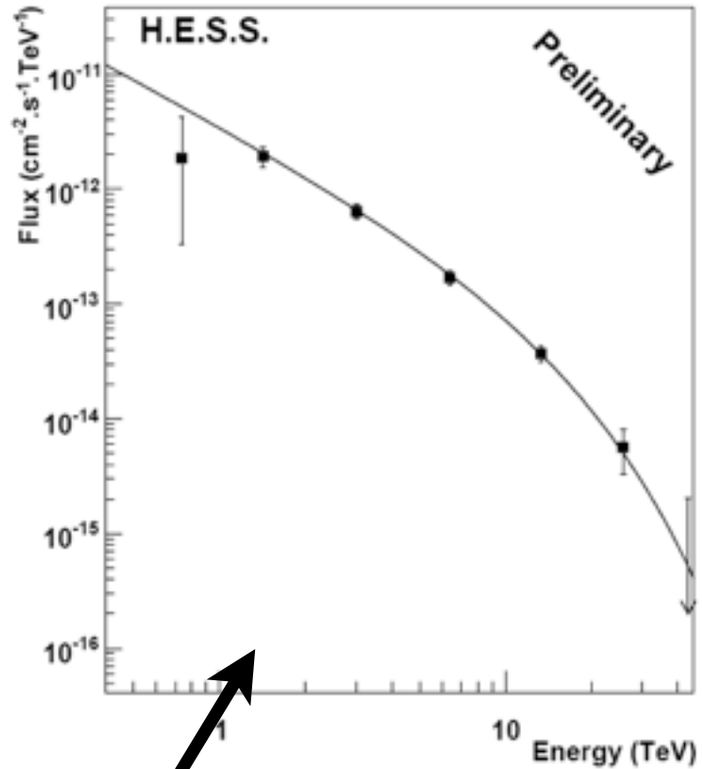


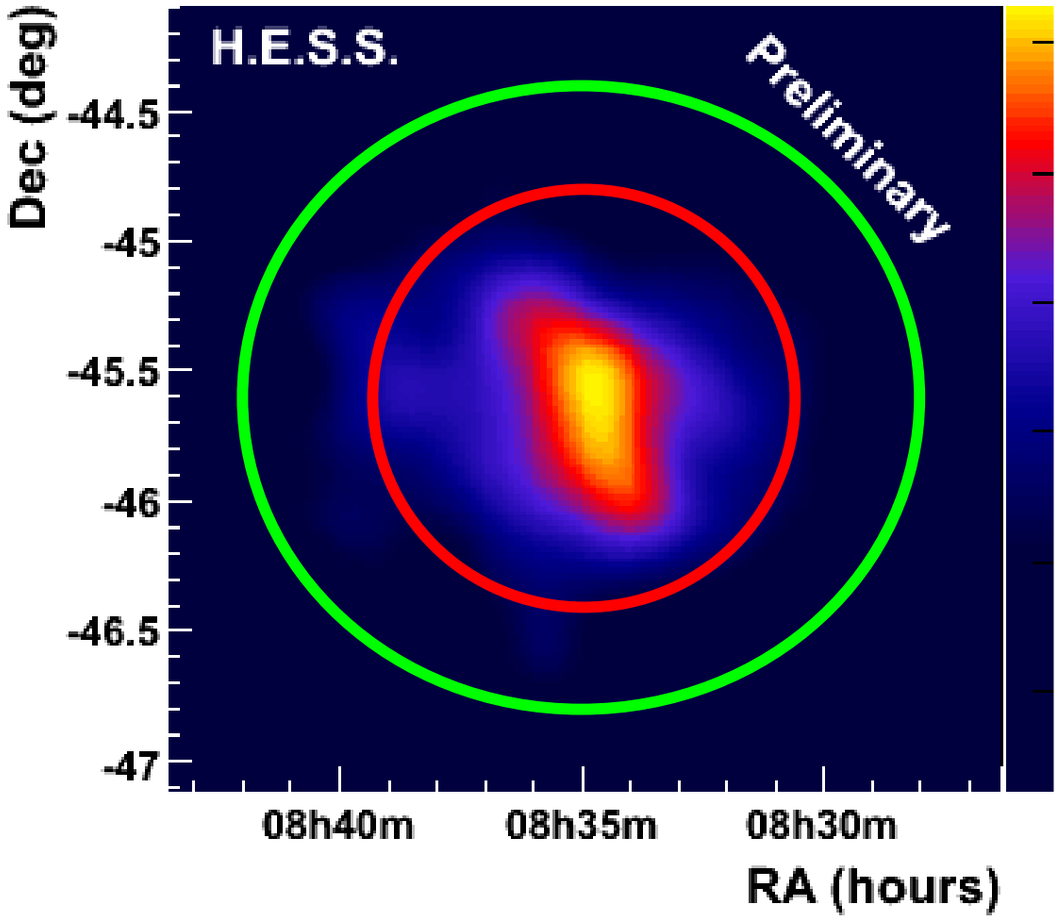
HESS 2006

HESS 2009 Measurement of Vela X

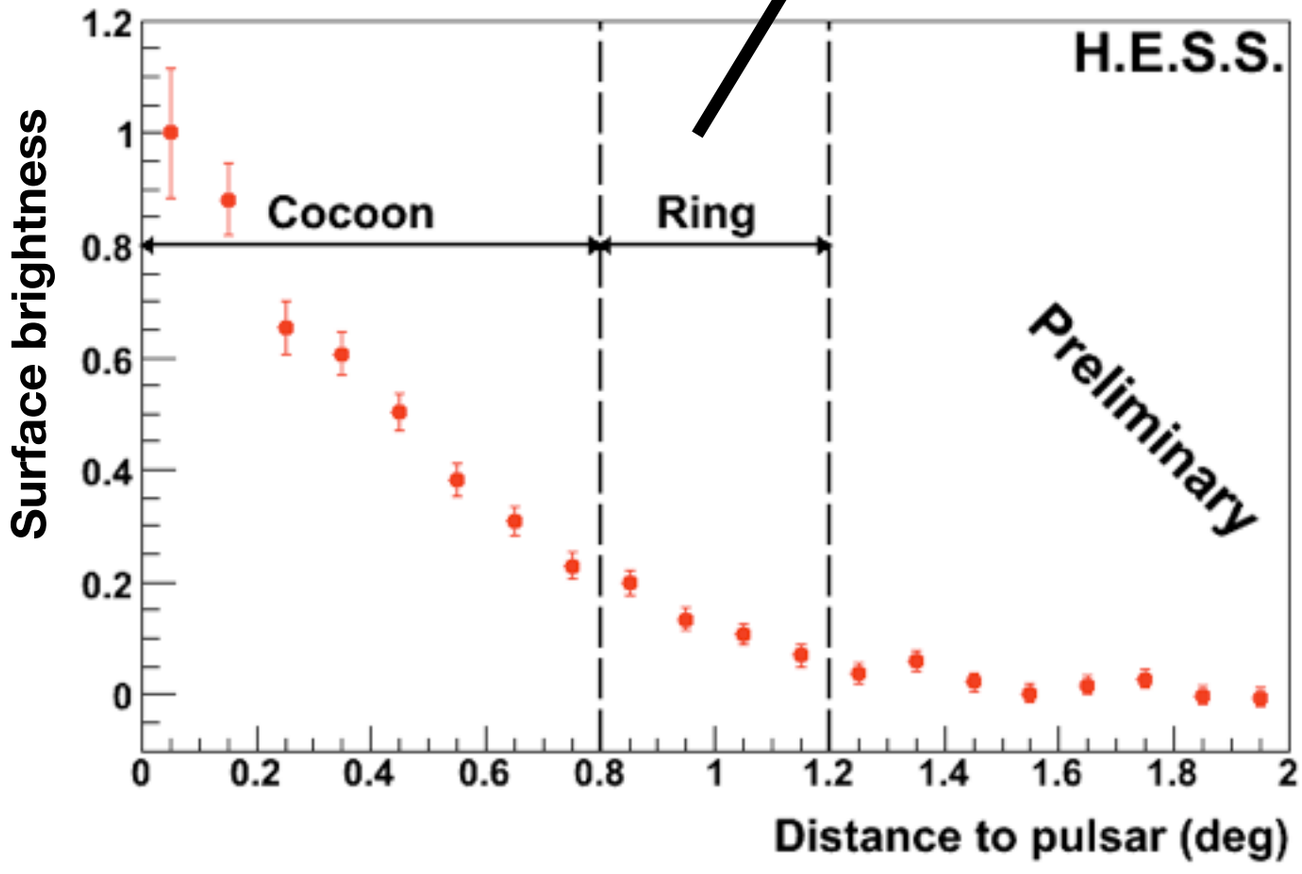
TeV nebula as extended as radio nebula

Ring spectrum is indistinguishable from cocoon spectrum



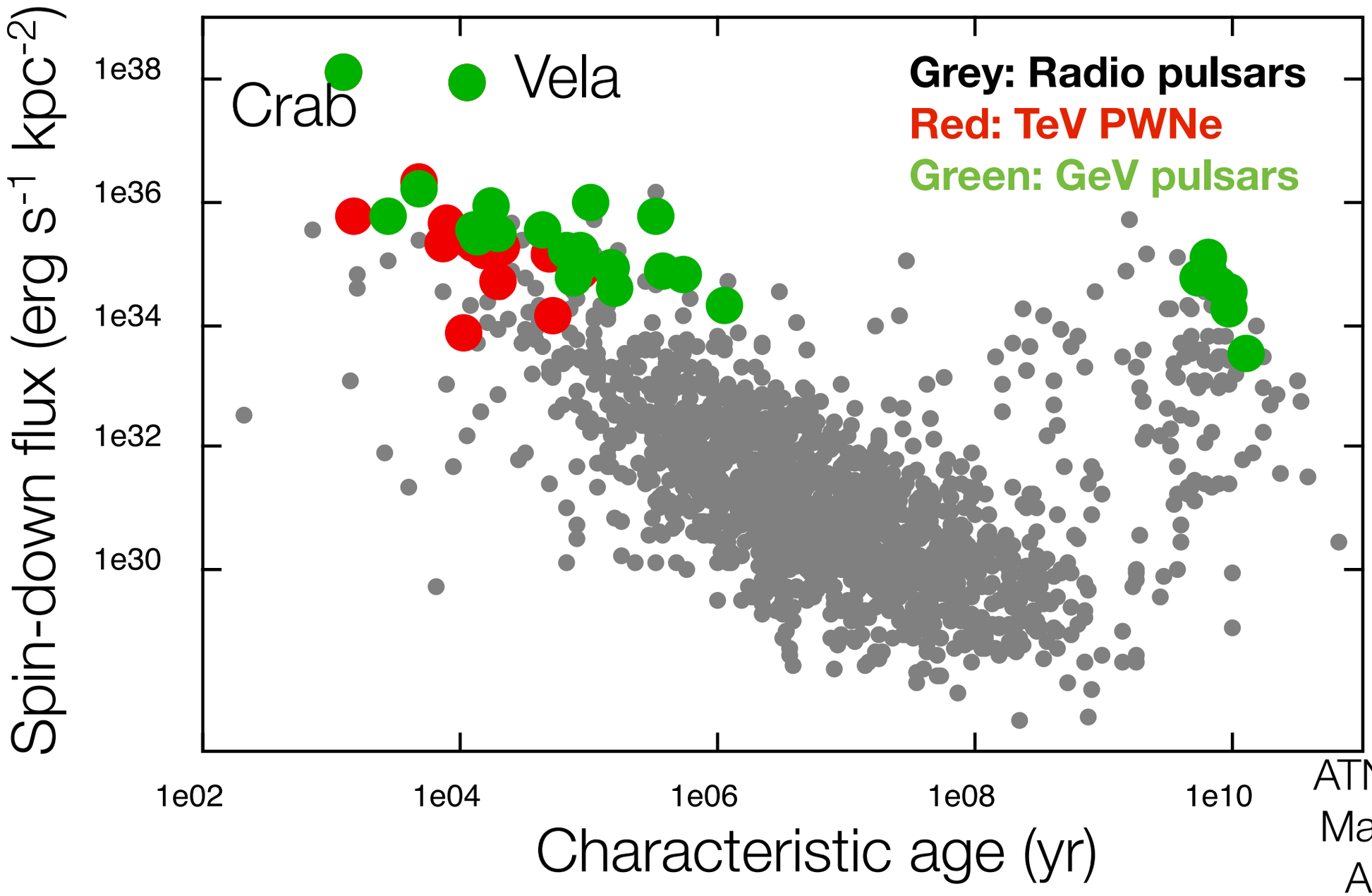


Circles centered on TeV emission center
at RA = 08h35m00, Dec = -45°36' (J2000)



Dubois et al. ICRC 2009,
Glück et al., 2009 Boston SNR/PWN Workshop

Fermi gives a more complete overview of the energetic pulsars in our Galaxy!



ATNF pulsar catalog
Mattana et al. 2009
Abdo et al. 2009

Thank you for your attention!

Summary

- PWNe are possibly the largest population of Galactic TeV sources
    - All identified PWNe associate with a young and energetic pulsar, but no correlation of TeV luminosity with pulsar characteristic age or spin-down flux
    - Many of the unidentified TeV sources might be old PWNe
- Two evolutionary stages are observed:
    - Younger: Freely expanding into unshocked SNR ejecta
    - Older: crushed by SNR reverse shock and often offset
- Fermi gives a more complete overview of energetic pulsars in our Galaxy, improving TeV source identification and population studies in the future

References

- Abdo et al. (Fermi Collaboration) 2009, arXiv0910.1608A
  “The First Fermi Large Area Telescope Catalog of Gamma-ray Pulsars”
- Aharonian et al. (HESS Collaboration) 2008, A&A, 477, 353A
  “HESS very-high-energy gamma-ray sources without identified counterparts”
- Blondin et al. 2001, ApJ, 563, 806B
  “Pulsar Wind Nebulae in Evolved Supernova Remnants”
- Chaves (HESS Collaboration) 2009 arXiv0907.0768C
  “Extending the H.E.S.S. Galactic Plane Survey”
- Manchester et al. 2005, arXiv:astro-ph/0412641
  ATNF Pulsar Catalog v1.37 @ http://www.atnf.csiro.au/research/pulsar/psrcat/
- Mattana et al. 2009, ApJ, 694, 12M
  “The evolution of the gamma- and X-ray luminosities of pulsar wind nebulae”
- Wenig et al. (HESS Collaboration) 2008, AIPC, 1085, 698W
  “Statistical Search for Counterparts of Galactic VHE Gamma-Ray Sources”