X-ray Identifications HESS Galactic TeV Sources with Pulsars

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Introduction

Three examples of Galactic TeV sources identified with pulsars:

1. HESS J1837-069*: Discovery of 70 ms energetic pulsar,*

2. HESS J1813-178*: A PSR/PWN inside a young radio SNR,*

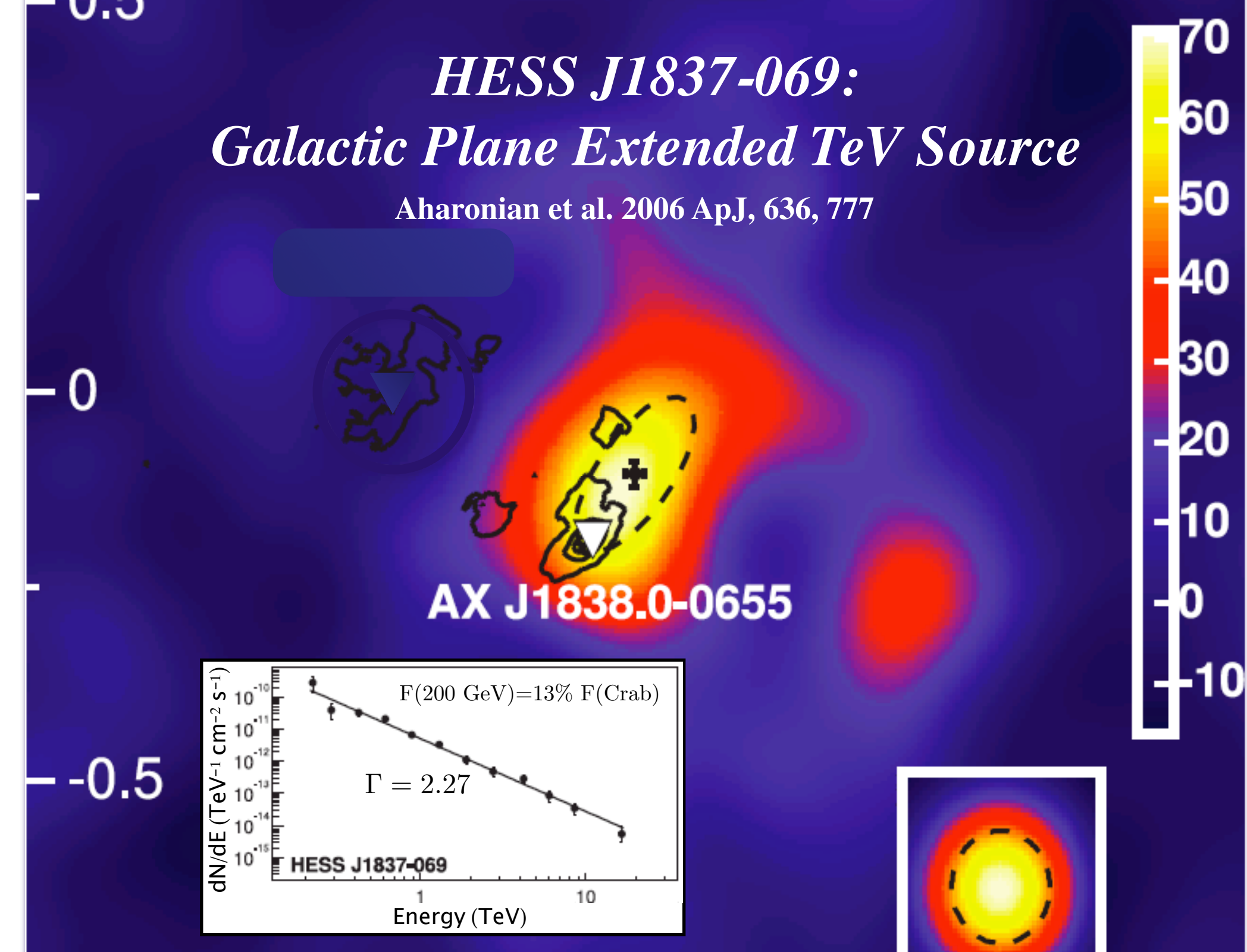
3. HESS J1834-087*: Likely faint PSR/PWN inside a known SNR W41*.

Part of a comprehensive campaign:

- *to study all Galactic TeV sources in X-rays,*
- *to search for PSR/PWN associated with TeV sources,*
- *to resolve the origin TeV emission from Galactic Sources*.

HESS J1837-069: Galactic Plane Extended TeV Source

Aharonian et al. 2006 ApJ, 636, 777



AX J1838.0-0655

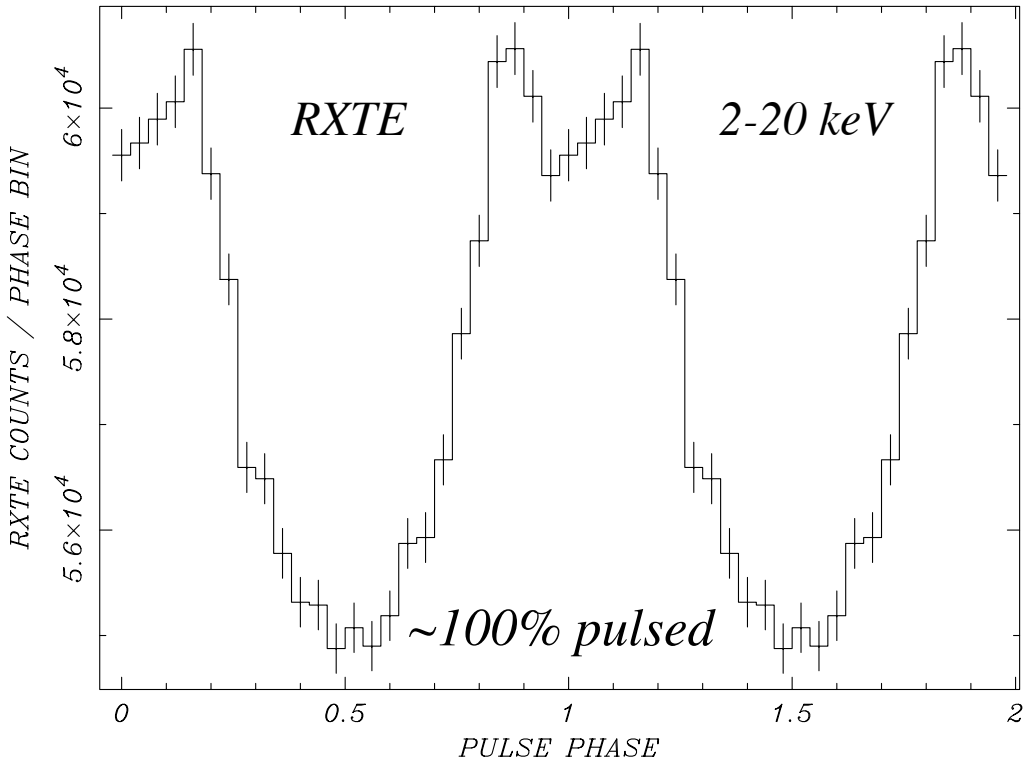
- *Steady 2-10 keV X-ray source based on decades of archival data (1980-),*
- *Hard source, INTEGRAL detection up to 300 keV (Malizia et al. 2005),*
- *Detected 0.2-20 TeV gamma-rays, if associated with the HESS emission.*
- *Not an EGRET source,*

Chandra:

- *Decomposed into a pt. source embedded in diffuse emission - PSR/PWN,*
- *R.A. = $18^h\ 38^m\ 03^s.13$, Dec. = $-06^o\ 55'\ 55''.33$ (J2000); Uncert. $0''.3$,*
- *Lies near a massive star cluster RSGC1, possible birthplace.*

Detection of PSR J1838-0655

(ATel #1392, Gotthelf et al. 2008; Gotthelf & Halpern 2008, astro-ph:0803.1361)



$$P = 70.498243969(54) \text{ ms}$$
$$\dot{P} = 4.925(29) \times 10^{-14} ss^{-1}$$

$$\tau \equiv P/2\dot{P} = 22.7 \text{ kyr}$$
$$\dot{E} \equiv I\omega\dot{\omega} = 5.5 \times 10^{36} \text{ erg s}^{-1}$$
$$B \equiv 3.2 \times 10^{19} \sqrt{P\dot{P}} = 1.9 \times 10^{12} \text{ G}$$

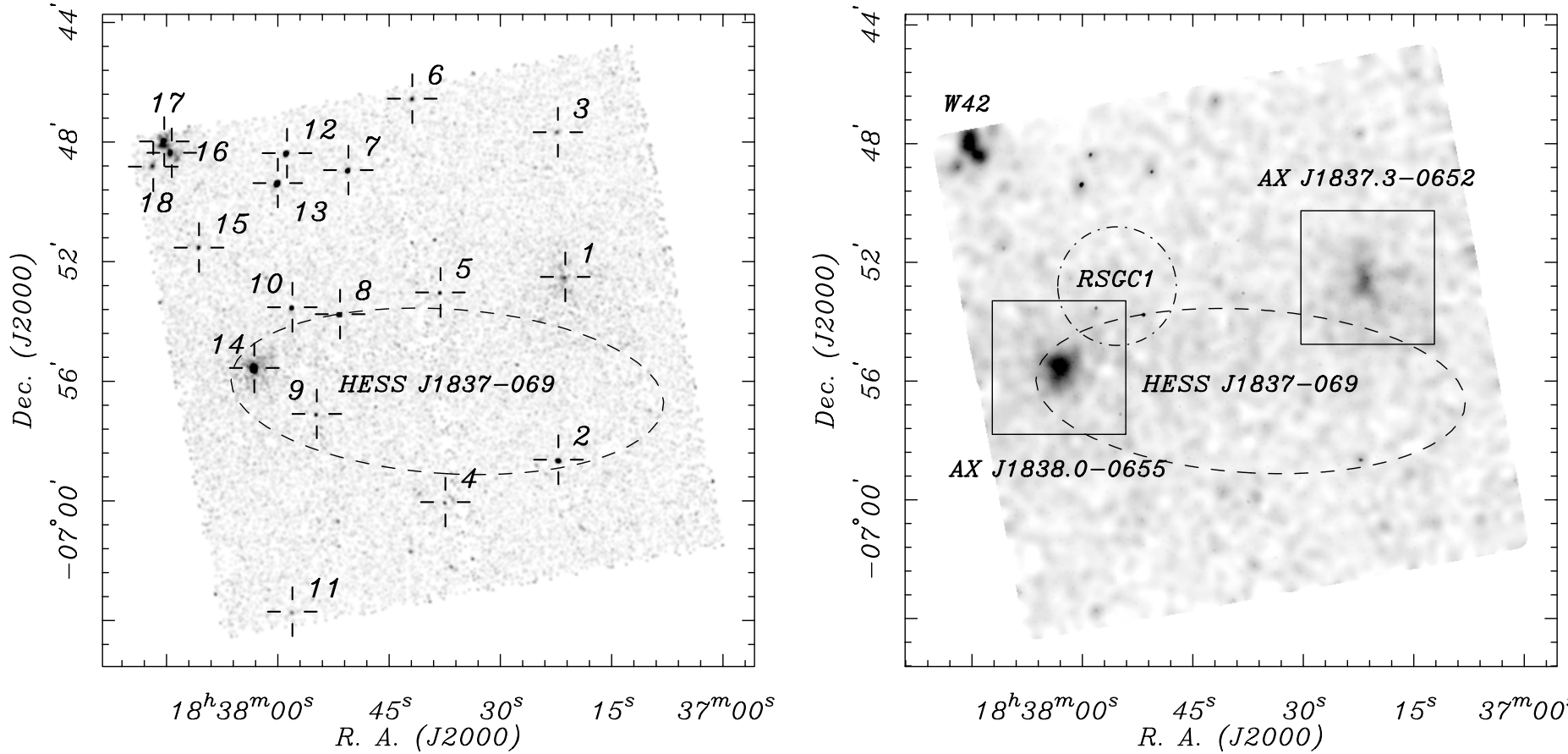
PSR J1838-0655: a rotation-powered pulsar of sufficient energy to power the TeV emission.

First pulsar identified from its TeV emission?!?

Excellent GLAST source candidate - we are currently monitor PSR J1838-0655 with XTE to allow a search for gamma-ray pulsations with GLAST.

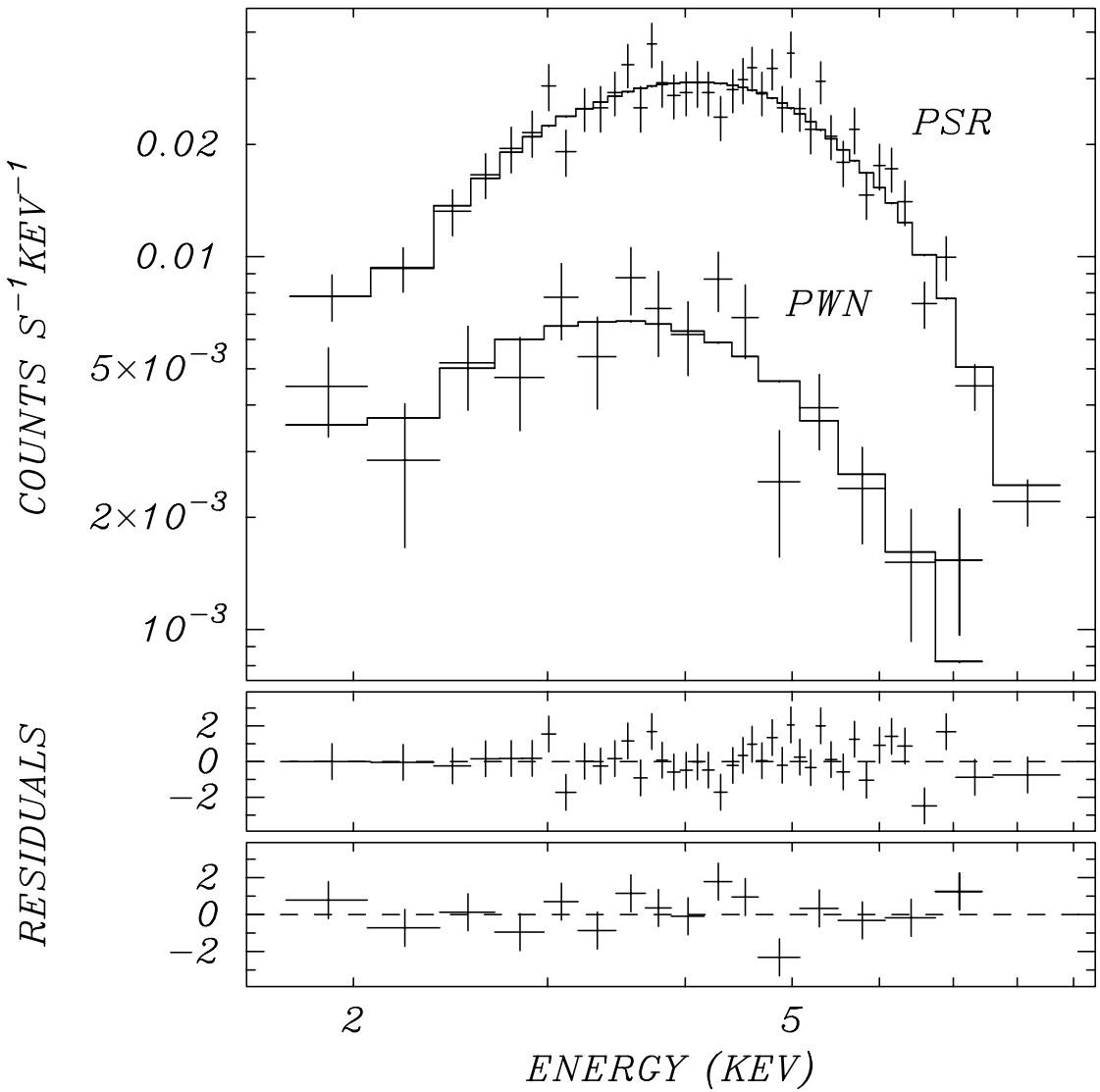
Chandra Observation of HESS J1837-069

19 August 2006, PI: G. Puehlhofer



Point Sources #1 and #14 are embedded in diffuse emission, nearby projected massive star cluster RSGC1, possible birthplace, source of seed photons for TeV emission by inverse Compton scattering?

Chandra Spectrum of PSR J1838-0655 and its Wind Nebula



Power-law Model (2-10 keV):
$N_H = 4.5 \times 10^{22}$ cm^{-2}

PSR: $\Gamma = 0.5(0.3\text{-}0.7)$
$F_{PL} = 8.8 \times 10^{-12}$ cgs

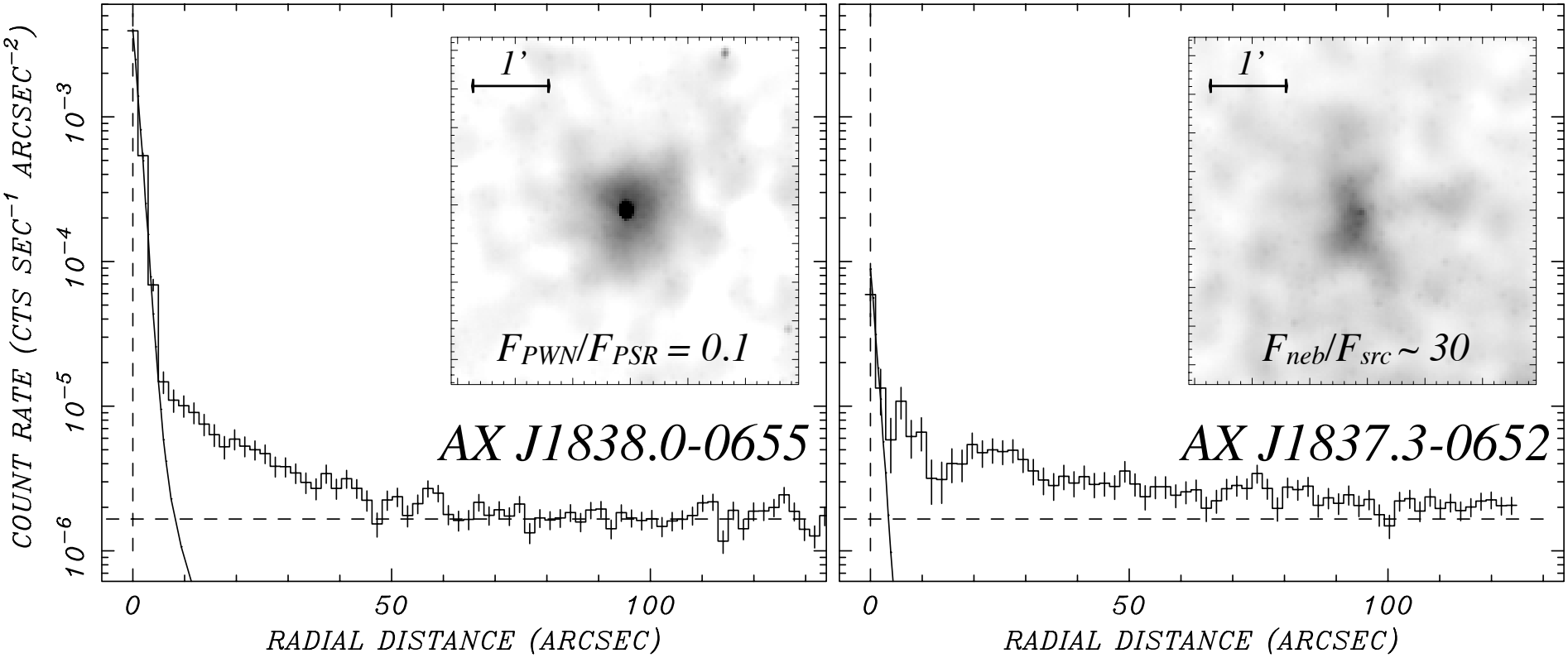
PWN: $\Gamma = 1.6(1.1\text{-}2.0)$
$F_{PL} = 1.0 \times 10^{-12}$ cgs

ASCA Composite:

$N_H = 4.0 \times 10^{22}$ cm^{-2}
$\Gamma = 0.8$, $F_{PL} = 1.3 \times 10^{-11}$ cgs

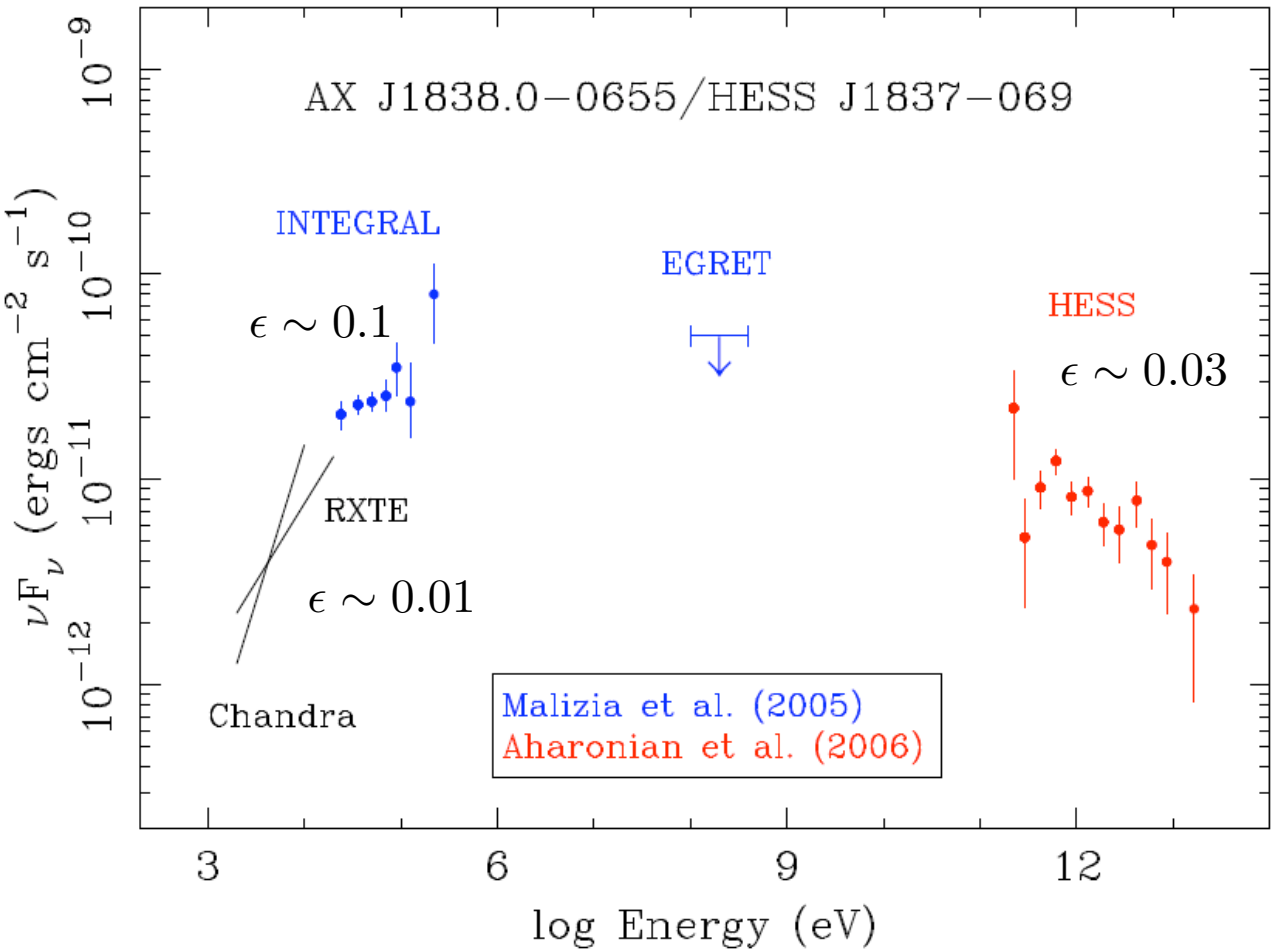
cgs = erg s^{-1} cm^{-2}

Radial Profile of Two Candidate PWN: Both Associated with HESS J1837-069?



If both born in RSGC1 cluster (d = 6.6 kpc): $L_{neb/PWN}$ (2-10 keV) ~ 5 x 10^{33} erg/s. This implies a spin down luminosity of ~ 5 x 10^{36} (Possenti et al. 2002), as measured, however the ratios F_{PWN}/F_{PSR} of AX J1838.0-0655 is low for an energetic pulsar. On the other hand, if AX J1837.3-0652 contains a pulsar, flux ratio implies very high $\dot{E}$.

Combined spectrum of PSR J1838-0655/HESS J1837-069



The proximity of PSR J1838-0655 to the massive star cluster RSGC1 and an X-ray luminosity consistent with spin down luminosity for the distance to the cluster allows an association.

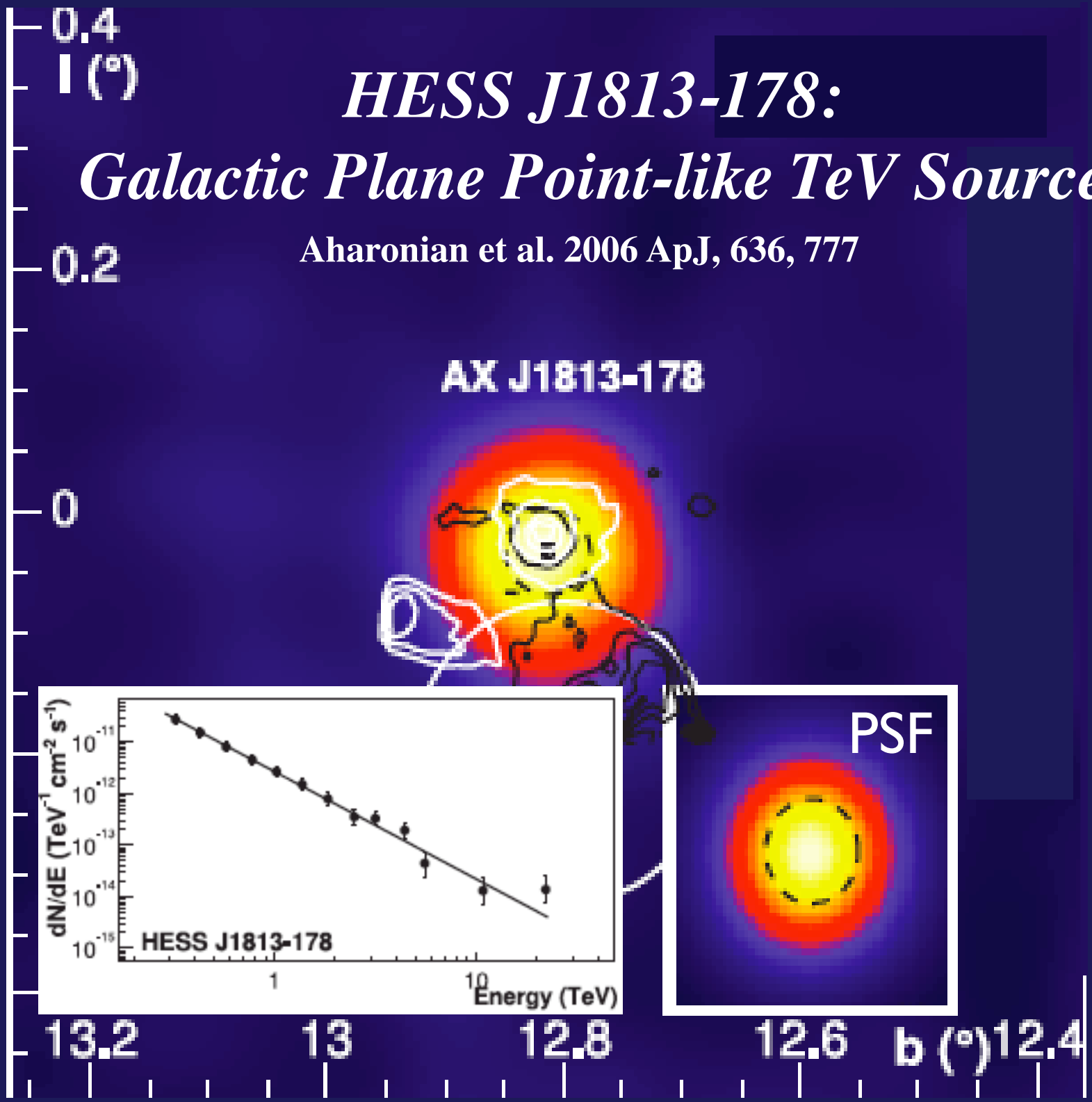
1. The star cluster may have given birth to the pulsar,

2. Cluster may fuel TeV emission with target photons for inverse Compton scattering of PWN particles.

Next ...

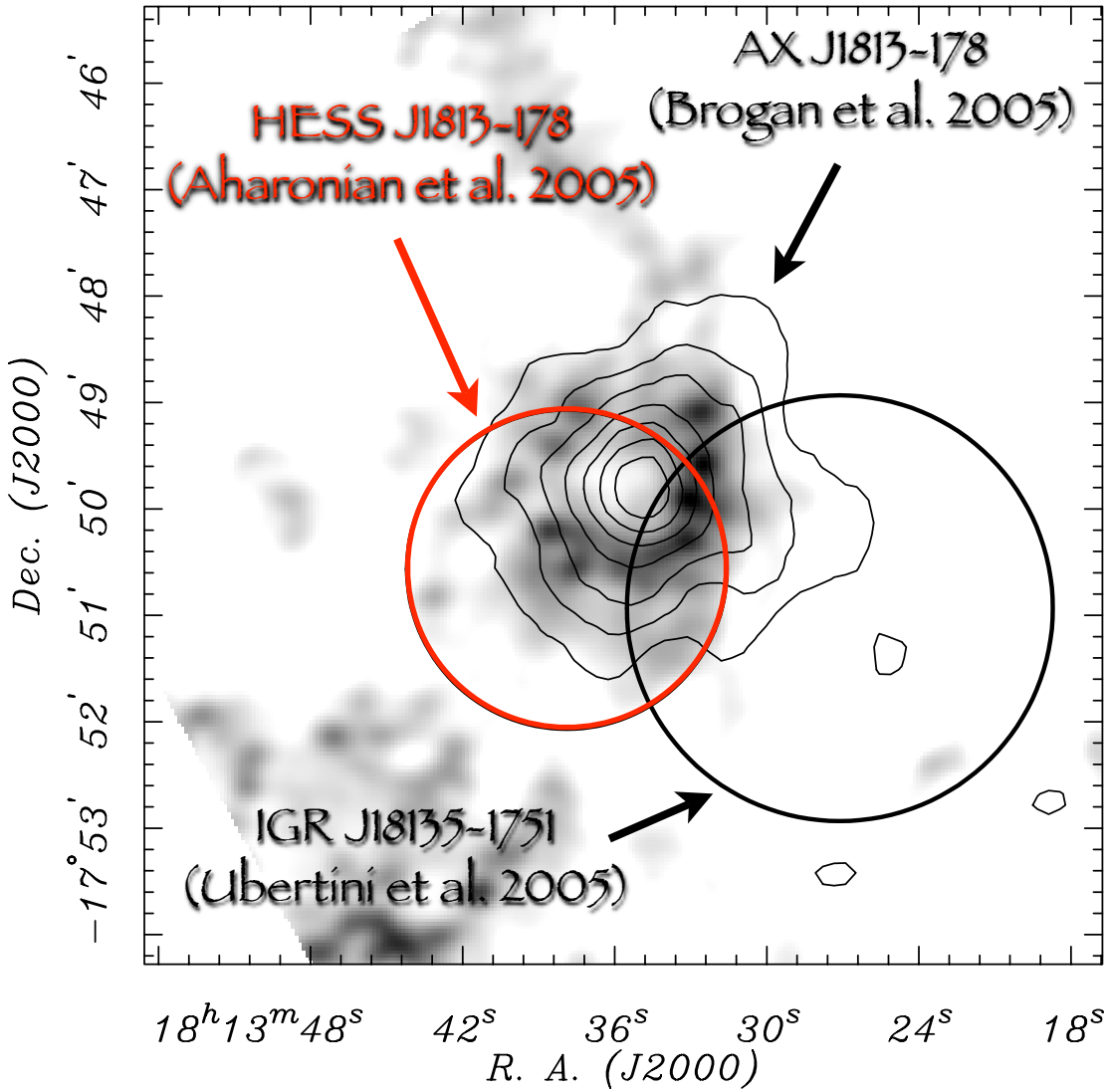
HESS J1813-178: Galactic Plane Point-like TeV Source

Aharonian et al. 2006 ApJ, 636, 777



HESS J1813-178 is Coincident with a Faint Shell-type Radio SNR: G12.82-178

VLA G12.08-0.02 (Helfand et al. 2005)



<u>*Archival Data*</u>

VLA-A/B/C/D
3/6/11/20/90 cm

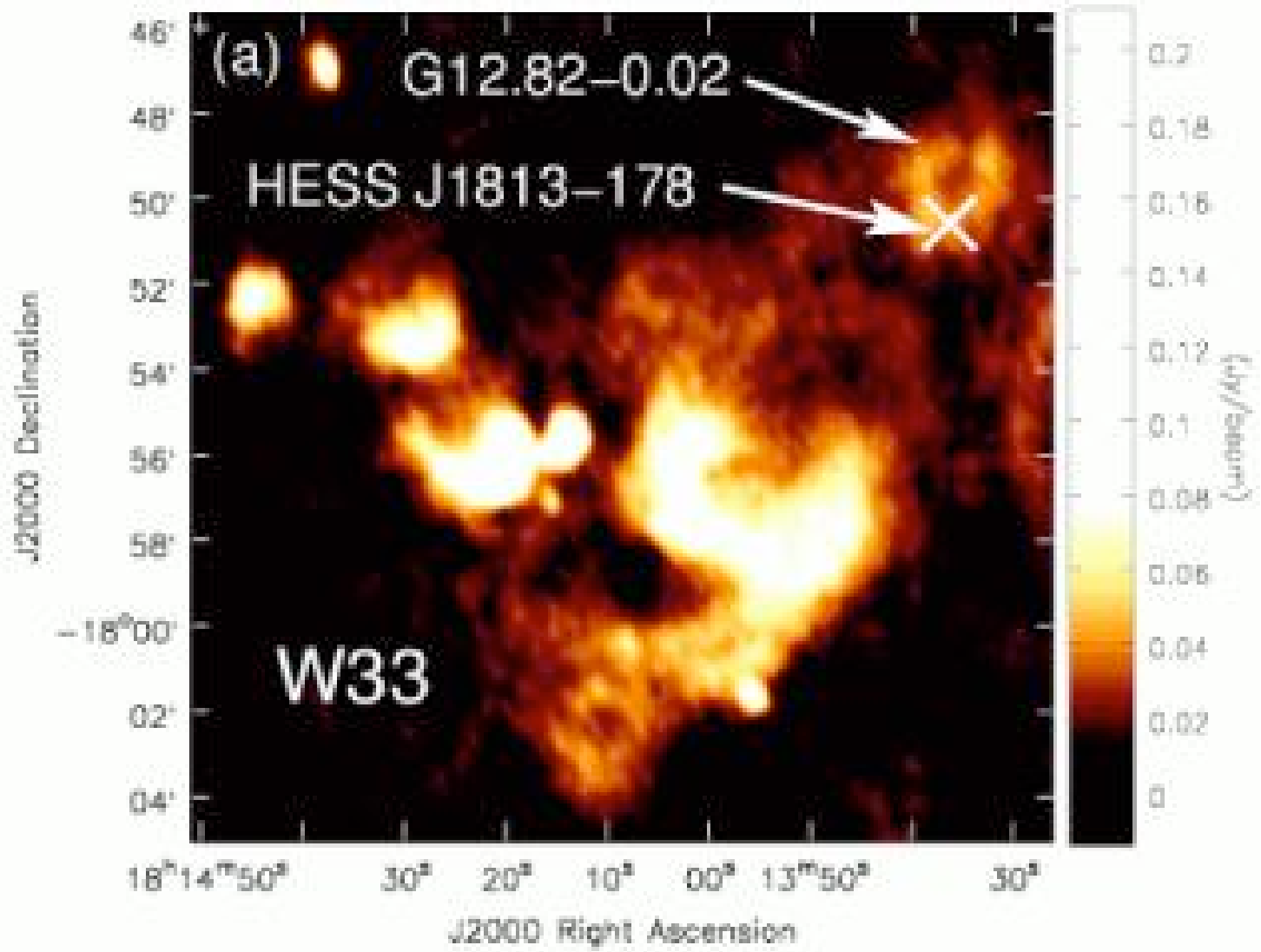
ASCA-SIS
X-ray: 2-10 keV

INTEGRAL-IBIS
γ-ray: 20-100 keV

Not an EGRET source
γ-ray: 0.3-30 GeV

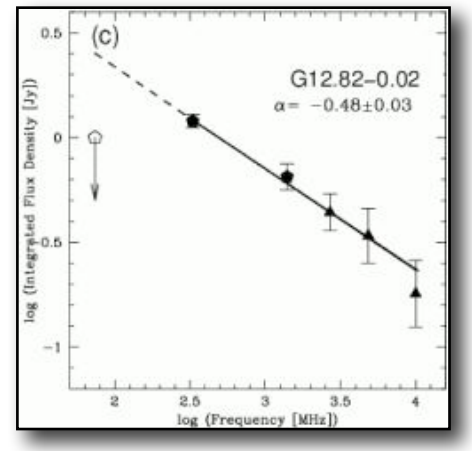
HESS 4-Tels mode
γ-ray: 0.2-20 TeV

G12.82-0.02: a Faint Shell-type Radio SNR Near the Star-formation Region W33



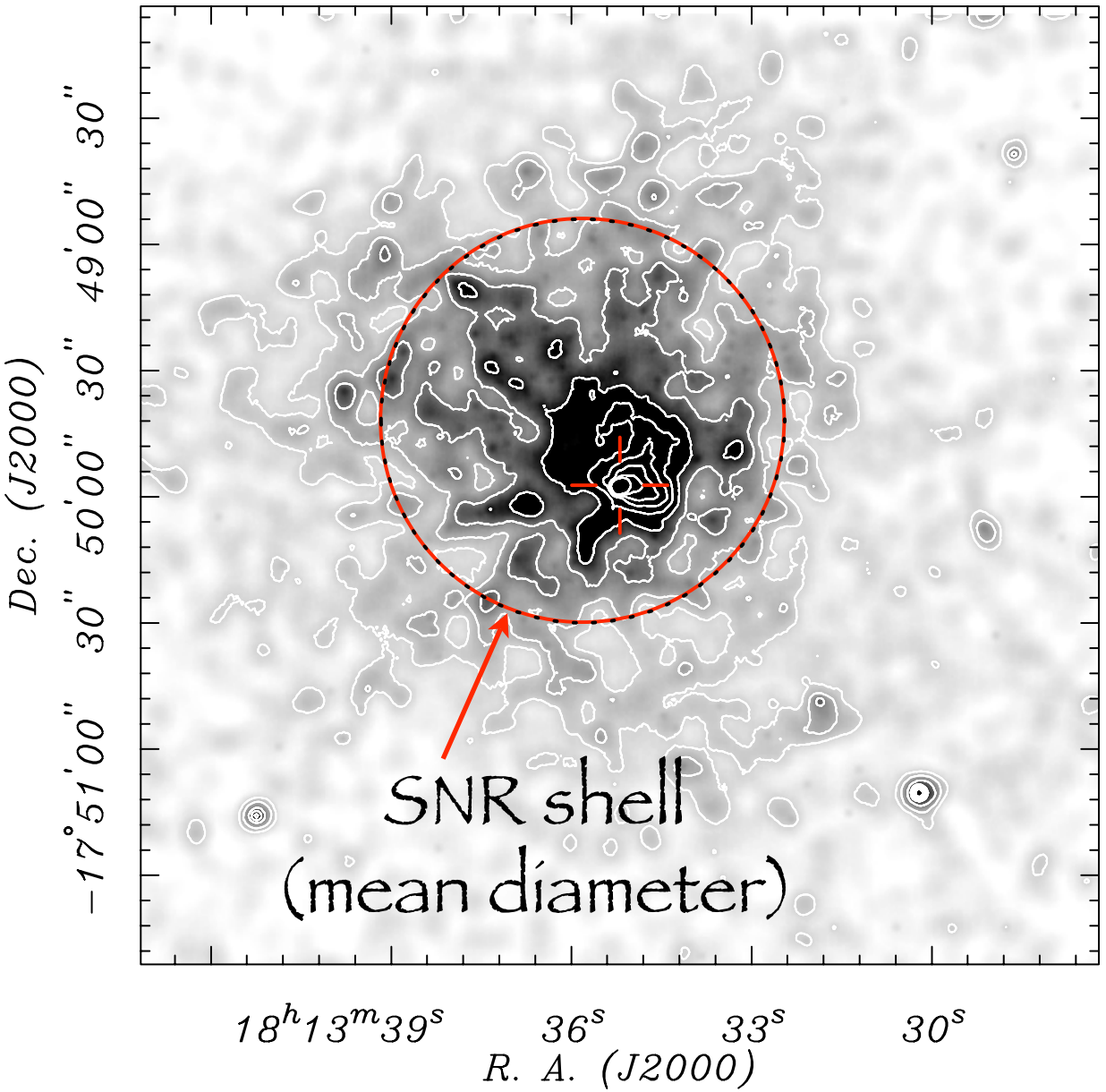
From Brogan et al. 2005

- *Shell shaped*
- *2'.5 diameter*
- *No distinct dust emission*

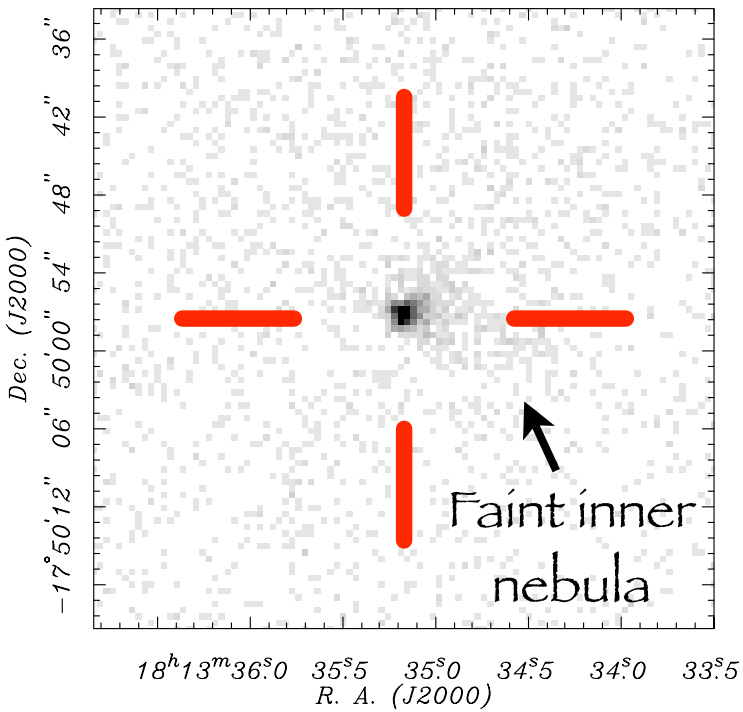


- *Non-thermal*
- $L_r = 4 \times 10^{32}$ *erg/s*
- *d ~4 pc*

Chandra Observation of HESS J1813-178

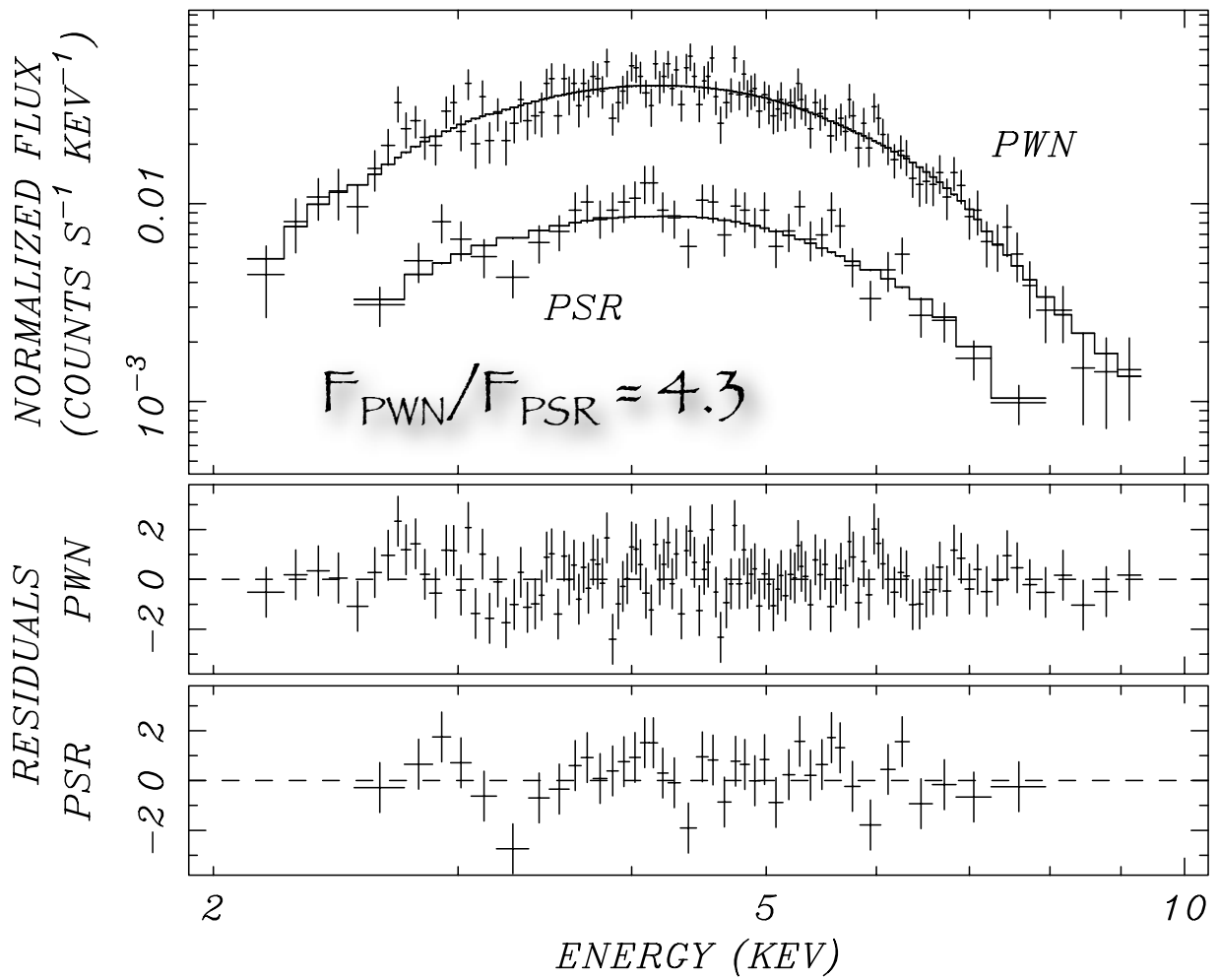


- *Resolved ACIS source:*
  R.A. = 18h 13m 35s.17,
  Dec. = -17o 49′ 57″.48
  (J2000); Uncert. 0″.2
- *Diffuse emission,*
- *Faint nebula:*



Putative Pulsar and Nebula Spectrum 2-10 keV ACIS: Power-law Model

(Helfand et al. 2007)



$N_H = 9.8 \times 10^{21}$ cm^{-2}

PSR:

$\Gamma = 1.3(1.0\text{-}1.6)$

$F_{PL} = 1.3 \times 10^{-12}$ cgs

PWN:

$\Gamma = 1.3(1.1\text{-}1.6)$

$F_{PL} = 5.6 \times 10^{-12}$ cgs

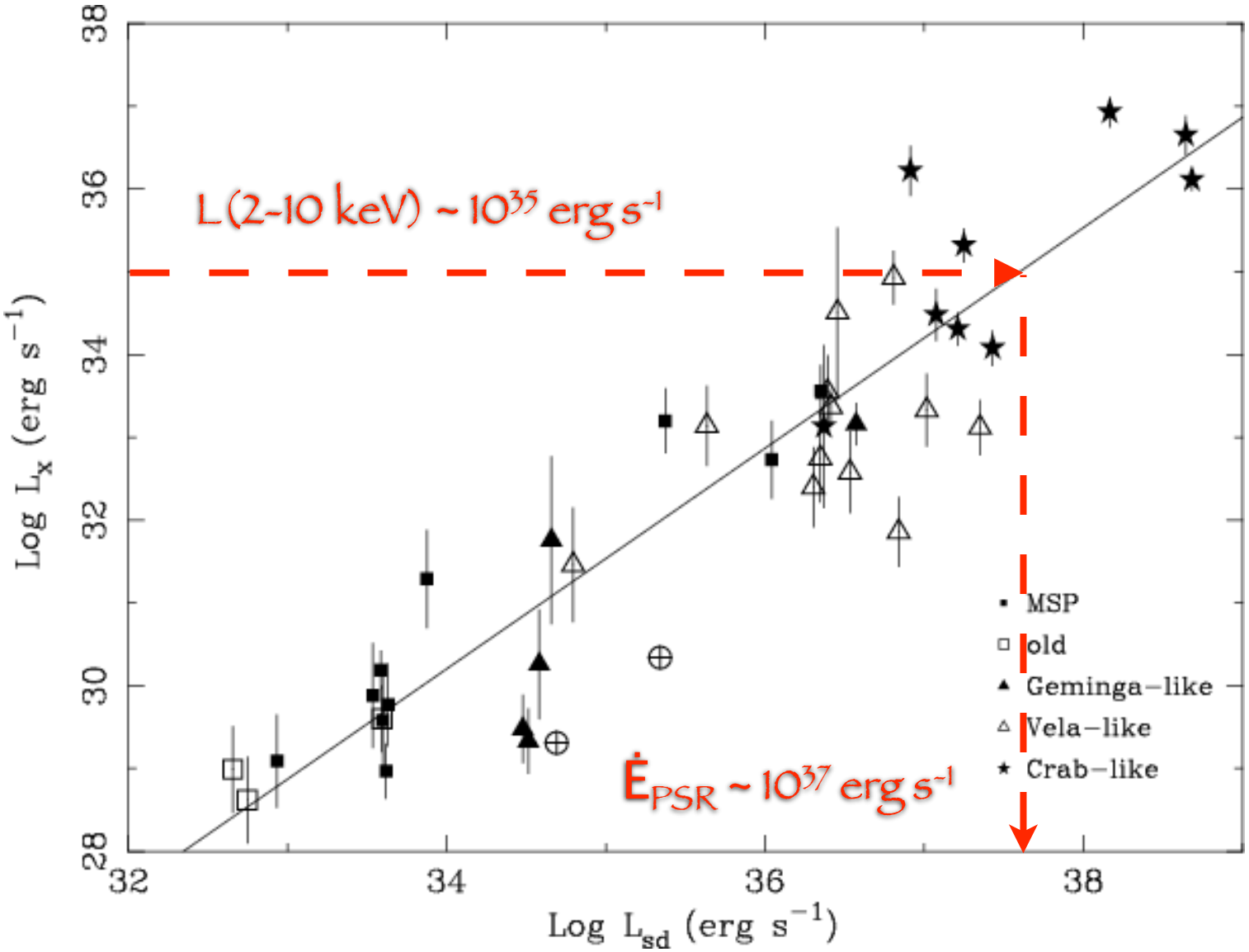
FAINT NEB(not shown):

$\Gamma = 0.4(-0.3\text{-}0.8)$

$F_{PL} = 4 \times 10^{-13}$ cgs

cgs = erg s^{-1} cm^{-2}

L(2-10 keV) vs. $\dot{E}_{PSR}$ from Possenti et al. 2002



Origin of the X-rays/ϒ-rays?

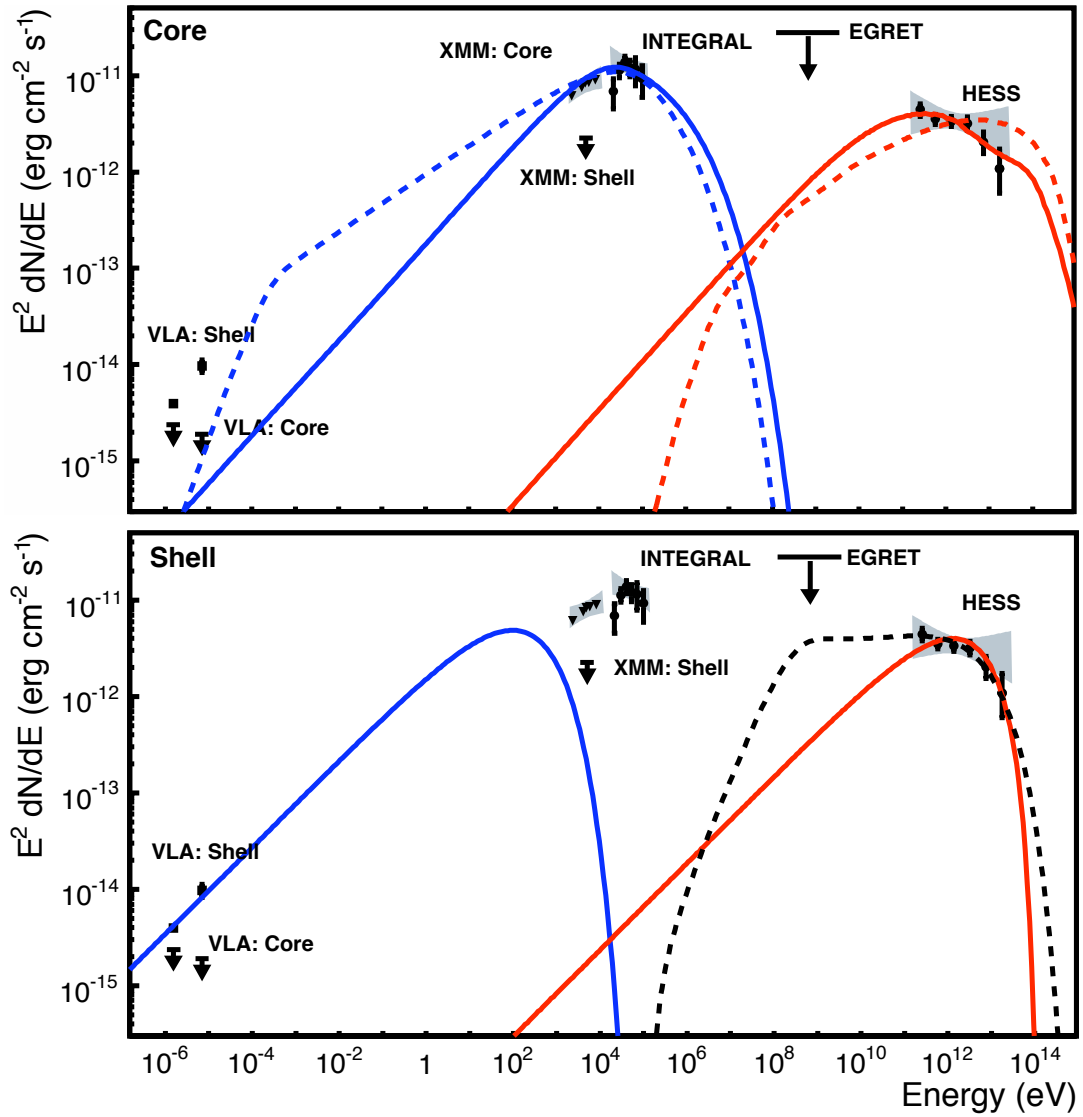
The ultimate source of energy for the TEV emission from HESS J1813-178 is likely spin-down losses for a rotation-powered pulsar.

Some interesting questions to resolve:

- *Is the SNR shell or the PWN responsible for the TEVs?*
- *Is the same seed population of particles responsible for both the X-rays and ϒ-rays?*
- *What background photons participate in the IC?*
- *Why is there no X-ray emission from the SNR shell?*
- *Is the SNR another example of a non-thermal remnant*
- *Does the ϒ-ray emission imply CR accelerations?*

Spectral models for HESS J1813-178

(Funk et al. 2006; astro-ph/0611646)



<u>γ-rays from core:</u>

Relativistic e⁻ synchrotron/ inverse Compton model

γ/X-rays same population (Aharonian & Atoyan 1999)

[Revise using Chandra flux]

<u>γ-rays from shell:</u>

Leptonic model (solid line)

Hadronic model (dash line)

Pulsar Search of AX J1813-178

Detecting and timing the putative pulsar is crucial to estimating the magnetic field, age, and input energy in order to constrain spectral models:

- *Radio search negative (Helfand et al. 2007; Camilo 2008),*
- *XTE X-ray timing search underway,*
- *Chandra pulsar search proposal.*

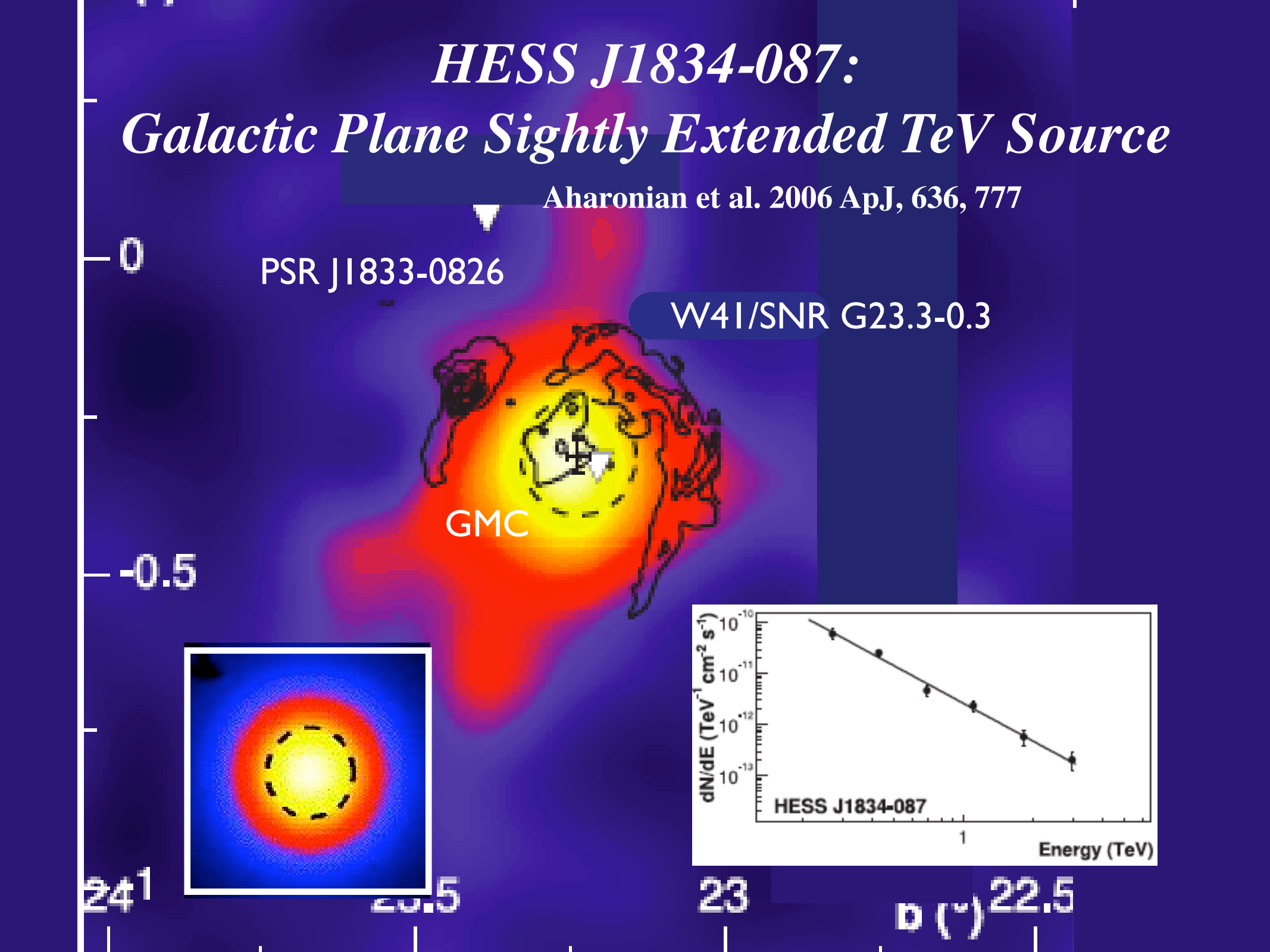
HESS J1813-187 is an excellent GLAST pulsar target:
$\dot{E}/d^2 \gtrsim 6 \times 10^{35}$ *erg* s^{-1} kpc^{-2} *(top* 14^{th} *or higher).*

Critical to find the pulsed signal soon in order to trigger our XTE ToO monitoring program during its last AO, to obtain a phase-coherent timing solution to search for Υ*-ray pulsations with GLAST.*

Next ...

HESS J1834-087: Galactic Plane Sightly Extended TeV Source

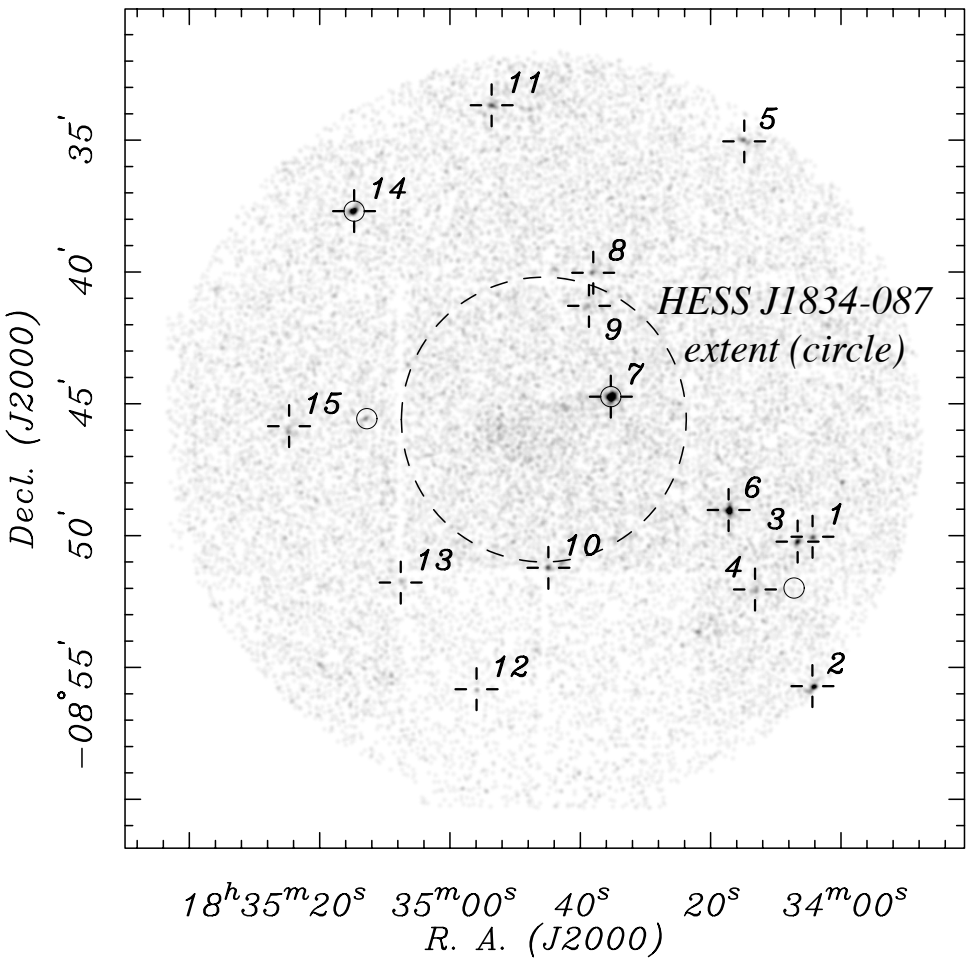
Aharonian et al. 2006 ApJ, 636, 777

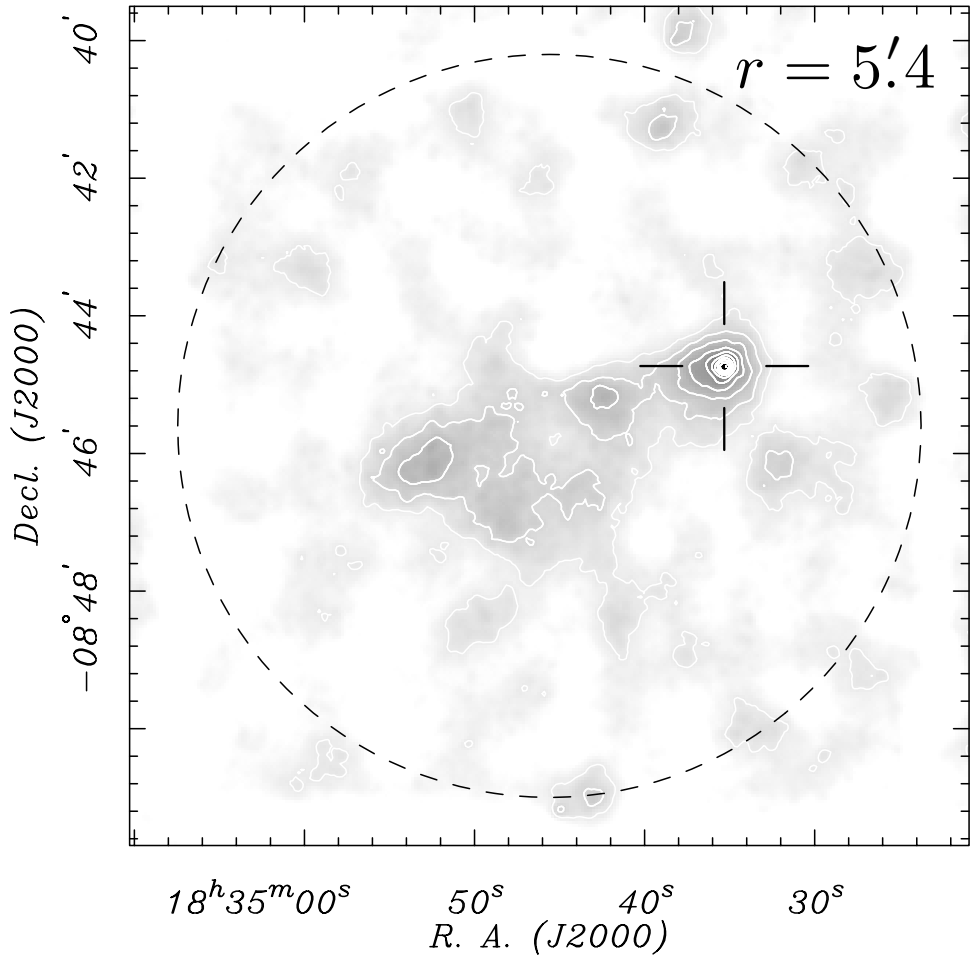


What is generating the TeV Emission from HESS J1834-087 and How?

- *Giant Molecular Cloud (GMC) interacting with Old SNR a la' Yamazaki et al (2006), resulting in p-p collisions that generate TeV photon via pion decay (Tian et al. 2007),*
- *Wind from the nearby (24') pulsar PSR J1833-0827 interacting with ambient photons from the W41 SNR shell or from the GMC (e.g., Bartko & Bednarek 2008),*
- *Central pulsar in SNR W41 feeding a PWN as the origin of electrons inverse Compton scattered off of ambient photons (this work).*

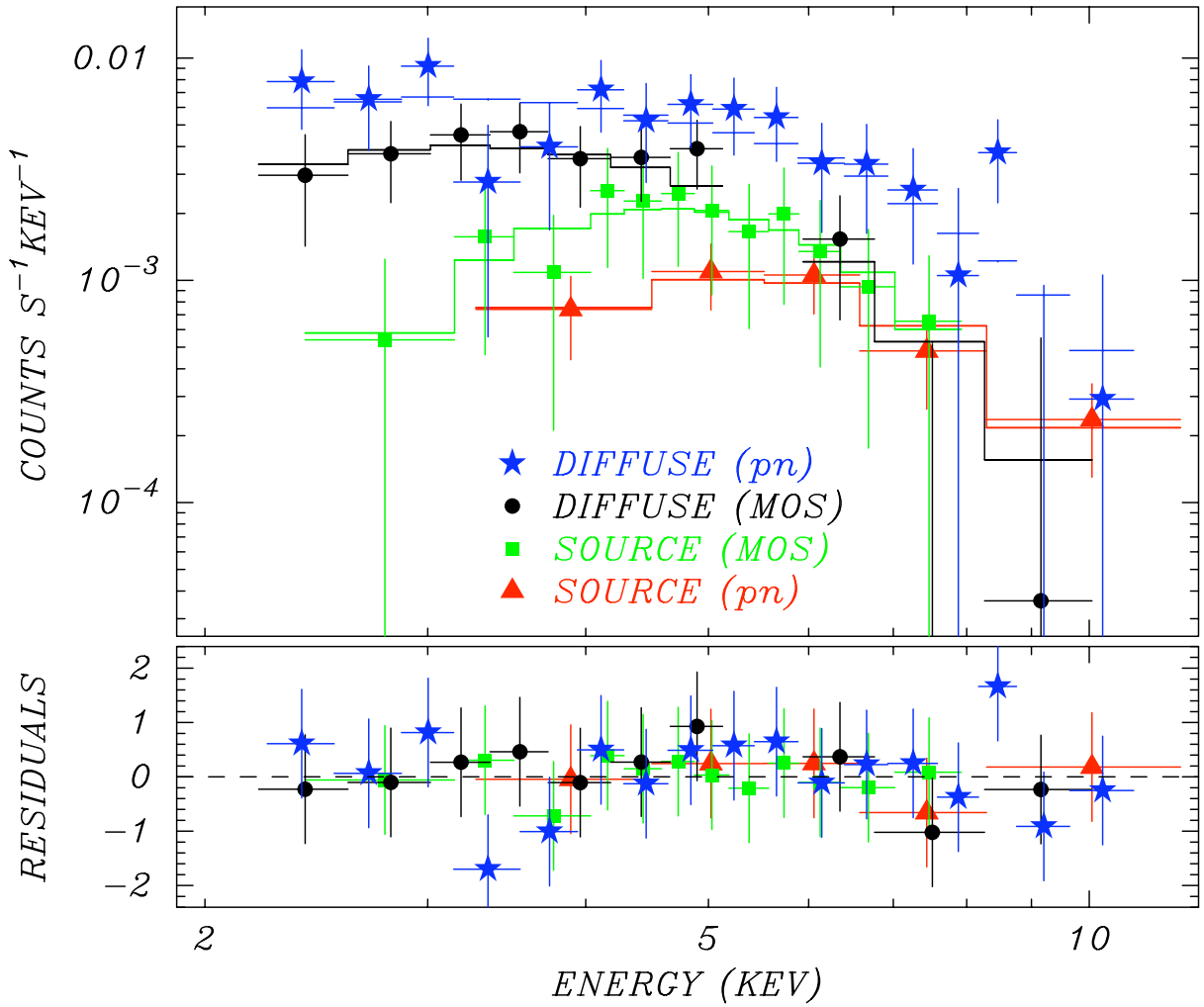
XMM Observation of HESS J1834-087





Src #7: XMMU J183435.32-084443.8 is a hard, steady non-thermal source lacking an optical/IR counterpart (R>21) and lies at the vertex of non-thermal diffuse emission, at the center of W41, 3′ from HESS centroid.

XMM Spectrum of Putative PSR and PWN in HESS J1834-087



Power-law Model
(2-10 keV)

$N_H \sim 6 \times 10^{22}$ cm^{-2}

PSR: $\Gamma = 0.2$
$F_{PL} = 4.9 \times 10^{-13}$ erg/cm^2/s

PWN: $\Gamma = 1.9$
$F_{PL} = 4.0 \times 10^{-13}$ erg/cm^2/s

L_x(PSR) = 9.1×10^{32} erg/s
at D = 4 kpc (W41)

Is a Central PSR Energetically Favorable?

At the distance of SNR W41:

- *X-rays: Pulsar luminosity implies a spin-down energy loss rate of* $\dot{E} \sim 10^{36}\mathrm{erg\ s^{-1}}$
- *Gamma-rays: Estimated 0.3-30 TeV efficiency is*
  $\epsilon = L_{TeV}/\dot{E} \sim 2.7 \times 10^{34}\mathrm{erg\ s^{-1}}/1.0 \times 10^{34}\mathrm{erg\ s^{-1}} \sim 3\%.$

Conclusions:

Spin-down luminosity is sufficient to power the TeV emission.

γ-ray efficiency consistent with range for HESS PWN sources.

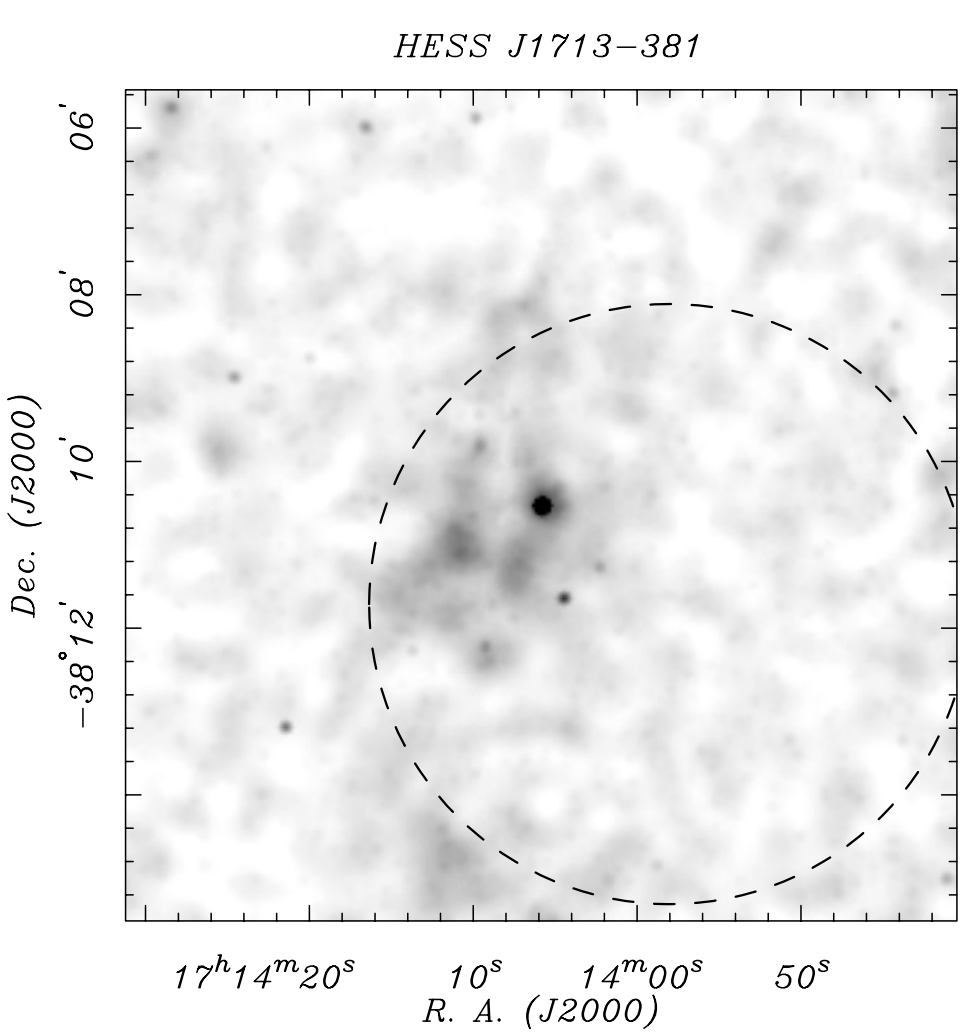
$L_\gamma/L_x \sim 29$ is the highest of all current HESS PWN sources.

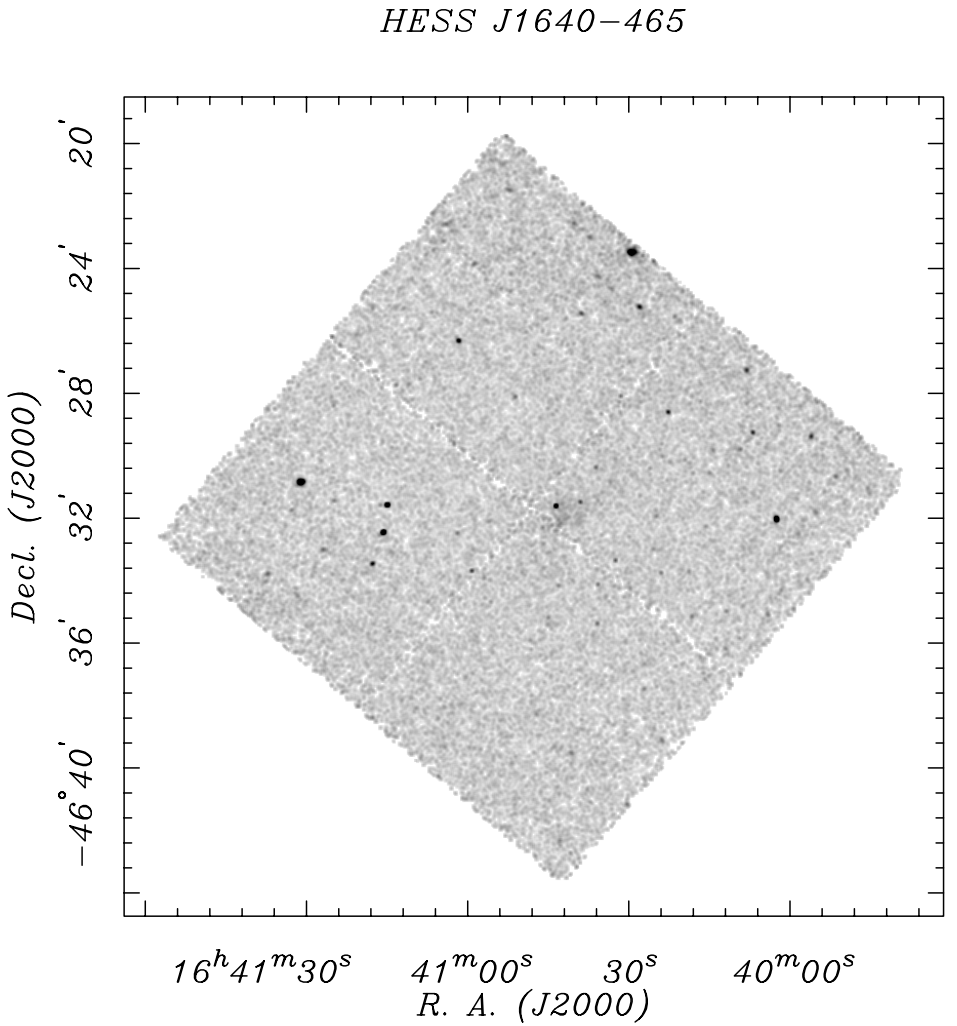
OTHER HESS/PWN ASSOCIATIONS...

Stay tuned!

We are studying all available X-ray data on all the TeV sources and have many other interesting results to be reported on in the near future...

Examples...


HESS J1713−381
Dec. (J2000)
−38°12′
10′
08′
06′
17h14m20s
10s
14m00s
50s
R. A. (J2000)


HESS J1640−465
Decl. (J2000)
−46°40′
36′
32′
28′
24′
20′
16h41m30s
41m00s
30s
40m00s
R. A. (J2000)