Discovery of a Pulsar Candidate Associated with TEV Source HESS J1813-178

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Introduction

- HESS Galactic sources - SNe connection?
- Multi-wavelength Study of HESS J1813-178,
- Chandra pulsar/PWN detection,
- Origin of the TEV Gamma-rays?
- Future Work: Pulsar Search.

HESS Detection of SN products

From Funk (2006;astro-ph/ 0609586)

HESS Galactic survey source statistics (Classification)

Of 21 Galactic HESS source detected over the past 2 yrs :

- 6 are known PWNe, 2 non-thermal SNR ("A" Class*)
- 2 are probable PWNe/SNRs associations ("B" Class)
- 3 have uncertain identifications ("C" Class)
- 9 have no known counterpart ("D" Class)
- 1 (2?) are X-ray binaries

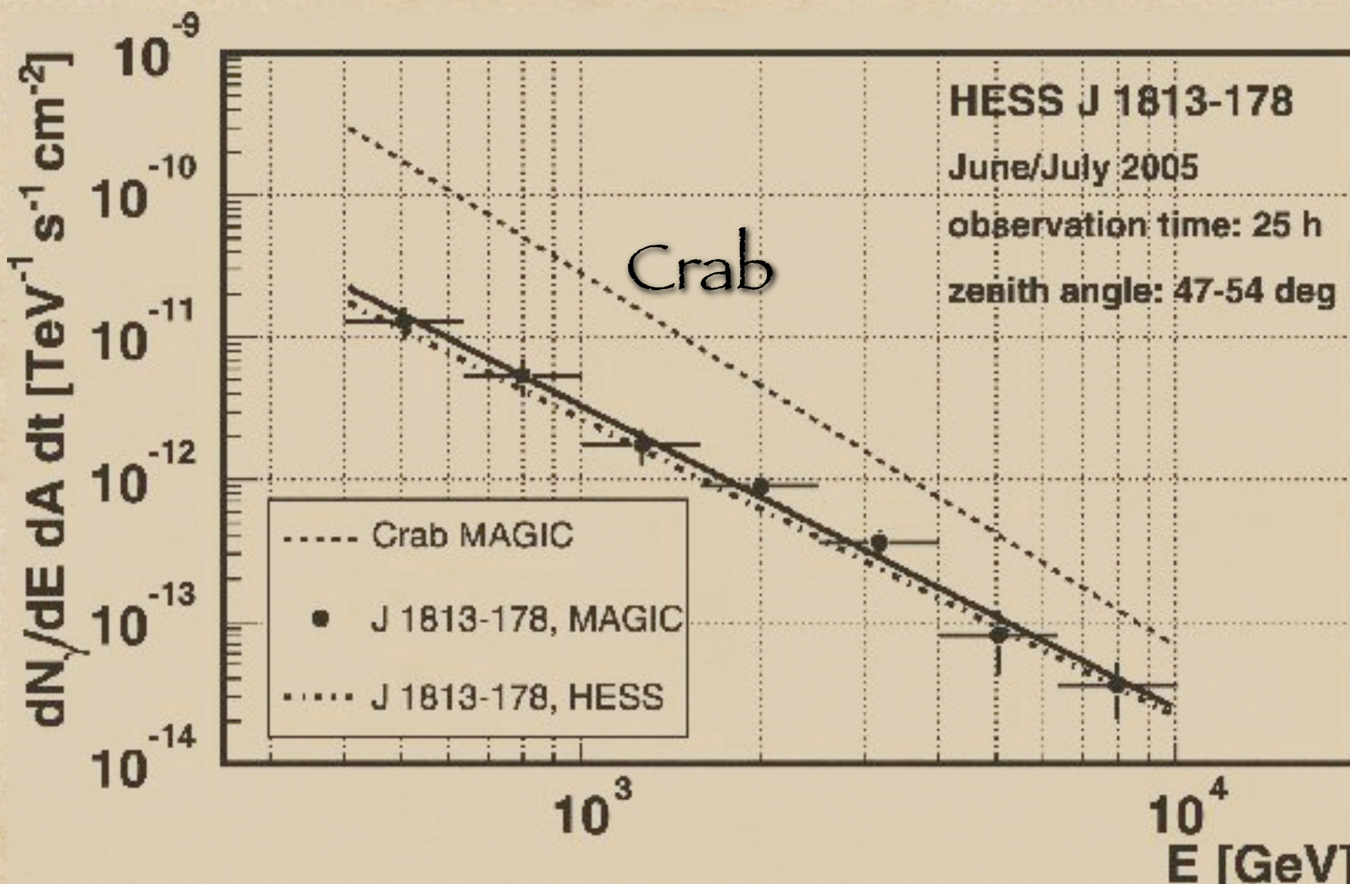
* Funk classification by: position match/plausible emission mechanism/ consistent MW picture

Discovery of a unidentified compact TEV source HESS J1813-178

- First Source Detected in the Galactic Plane Survey (Aharonian et al. 2005, 2006),
- Re-observed 9.7 hrs; 340 cts; 14σ detection significance (Funk et al. 2006),
- Compact γ-ray source, Gaussian $\sigma = 2.2' \pm 0.4'$; evidence for a faint extended diffuse tail,
- Power-law Spectrum (0.2 -20 TeV) with $\Gamma = 2.09 \pm 0.08$; $L_\gamma = 1.4 \times 10^{34}$ erg s^{-1} @ d = 4 kpc.

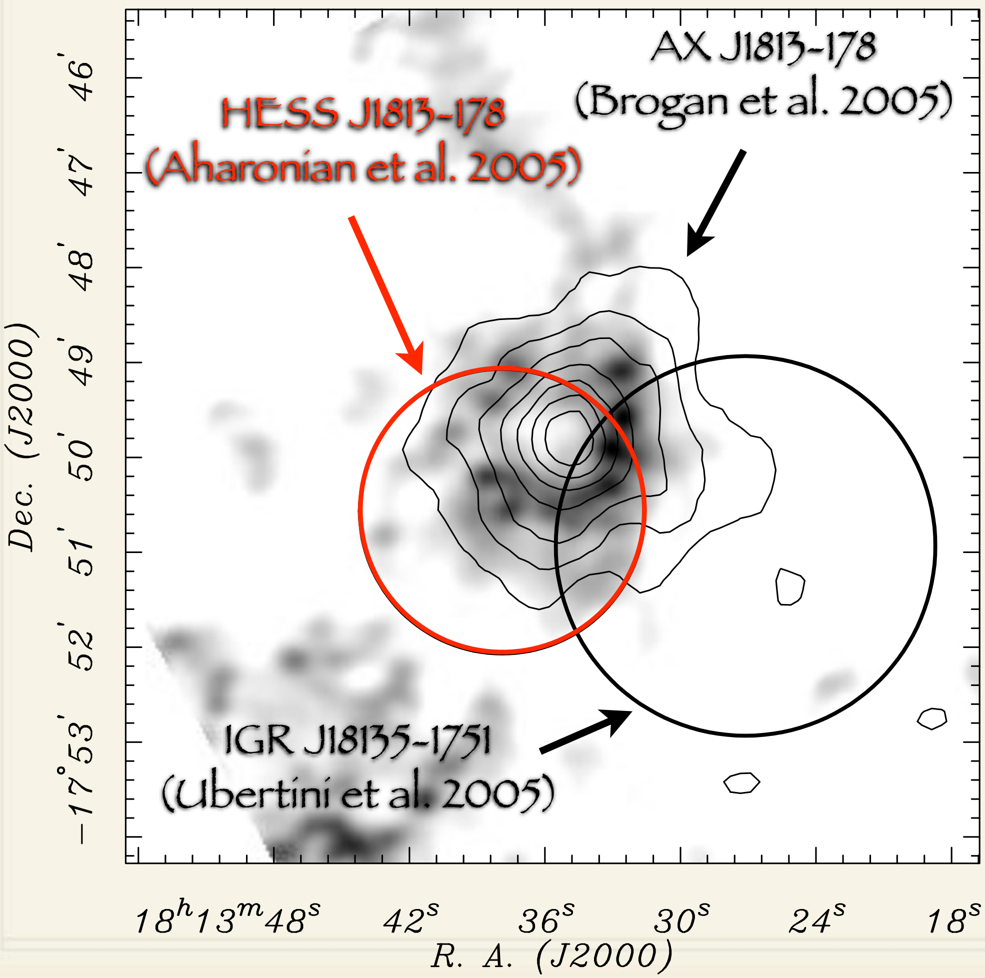
MAGIC Spectrum of HESS J1813-178

(From Albert et al. 2006)



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

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



Archival Data

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

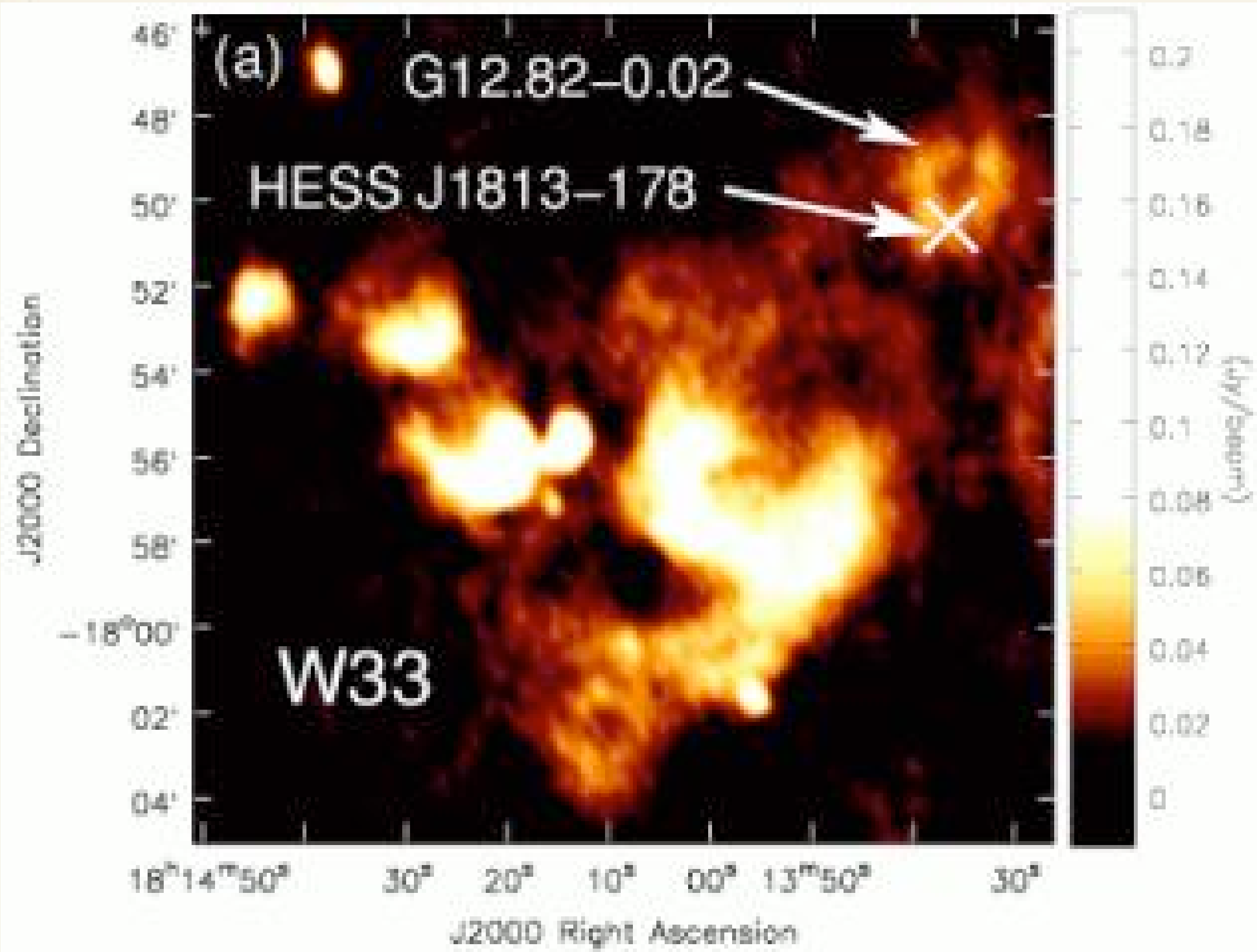
ASCA-SIS
X-ray: 2-10 keV

INTEGRAL-IBIS
γ-ray: 20-100 keV

Not an EGRET source
γ-ray: 0.3-30 GeV

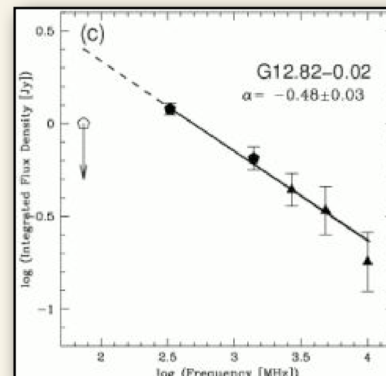
HESS 4-Tels mode
γ-ray: 0.2-20 TeV

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



From Brogan et al. 2005

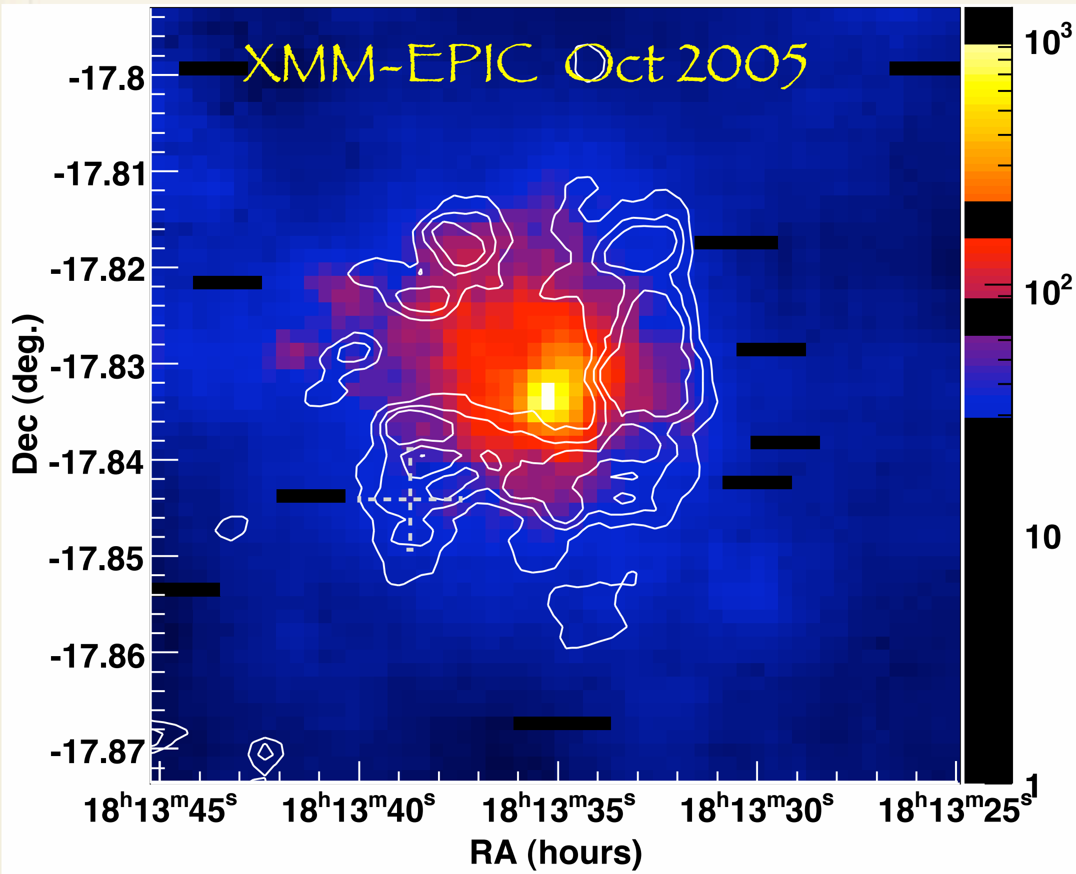
- Shell shaped
- 2.'5 diameter
- No distinct dust emission



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

Follow-up X-ray and CO observations

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



20 ks XMM observation

X-rays localized within radio shell

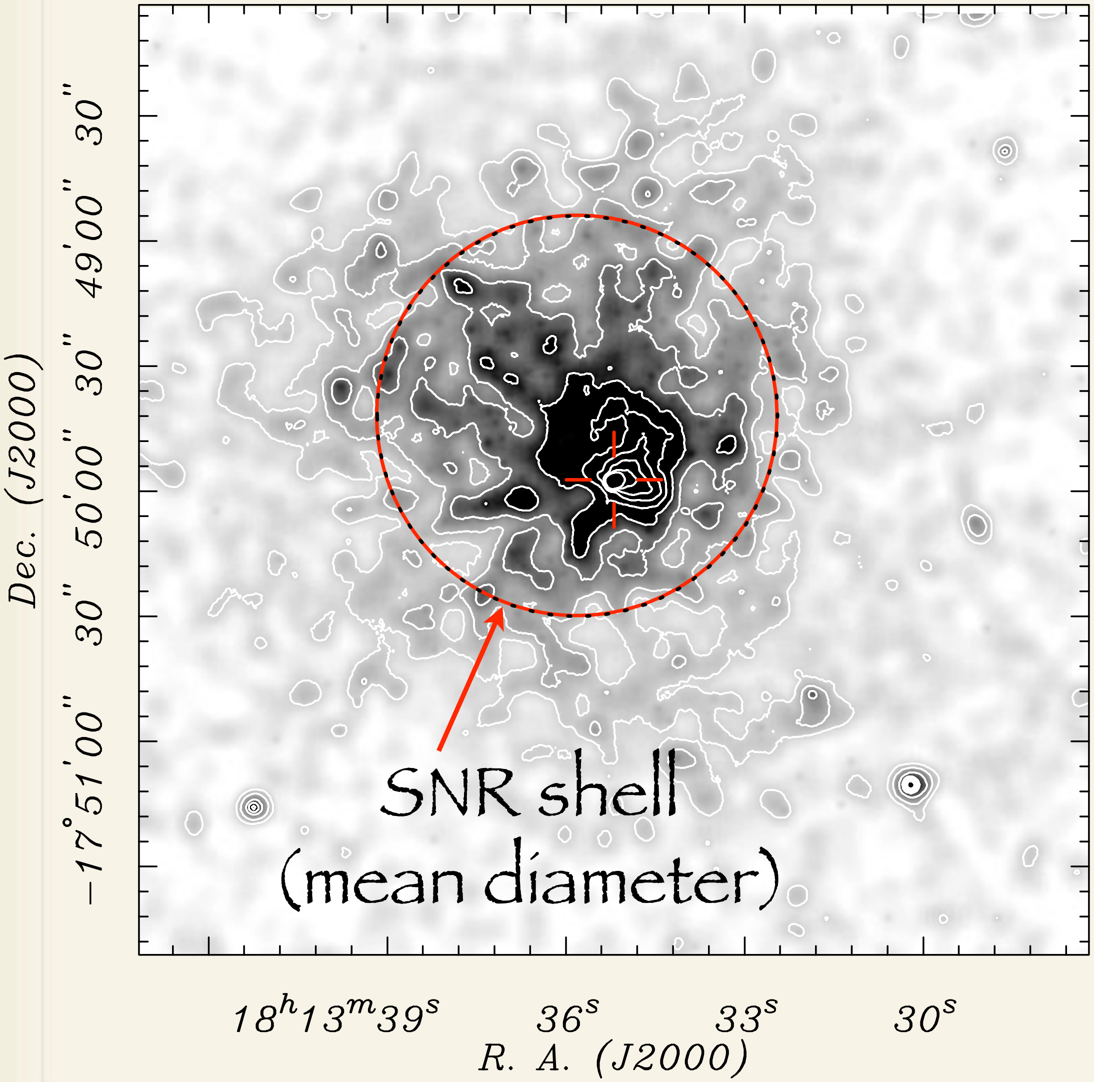
Diffuse emission fills radio shell

Unresolved central source + nebula?

No SNR lines in spectrum!

$N_H \approx 9 \times 10^{22}$ cm^{-2} derived from NANTEN ^{12}CO(J=1-0), consistent with X-ray spectrum results

Chandra Observation of HESS J1813-178

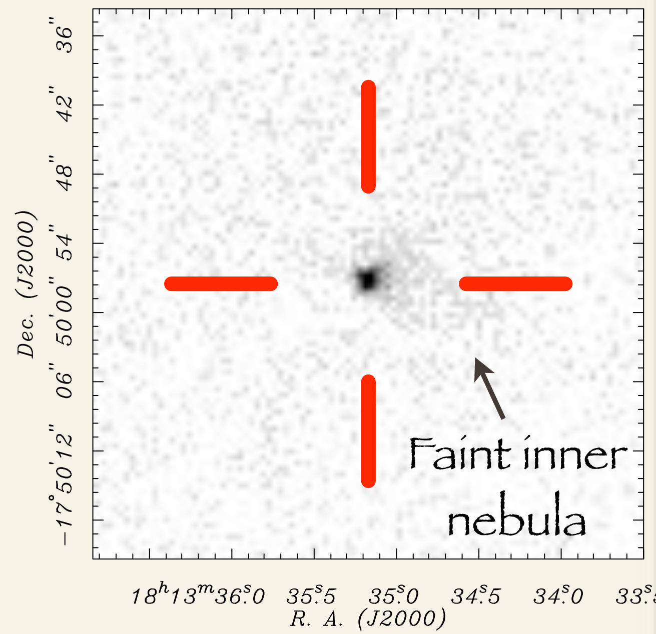


Resolved ACIS point source:

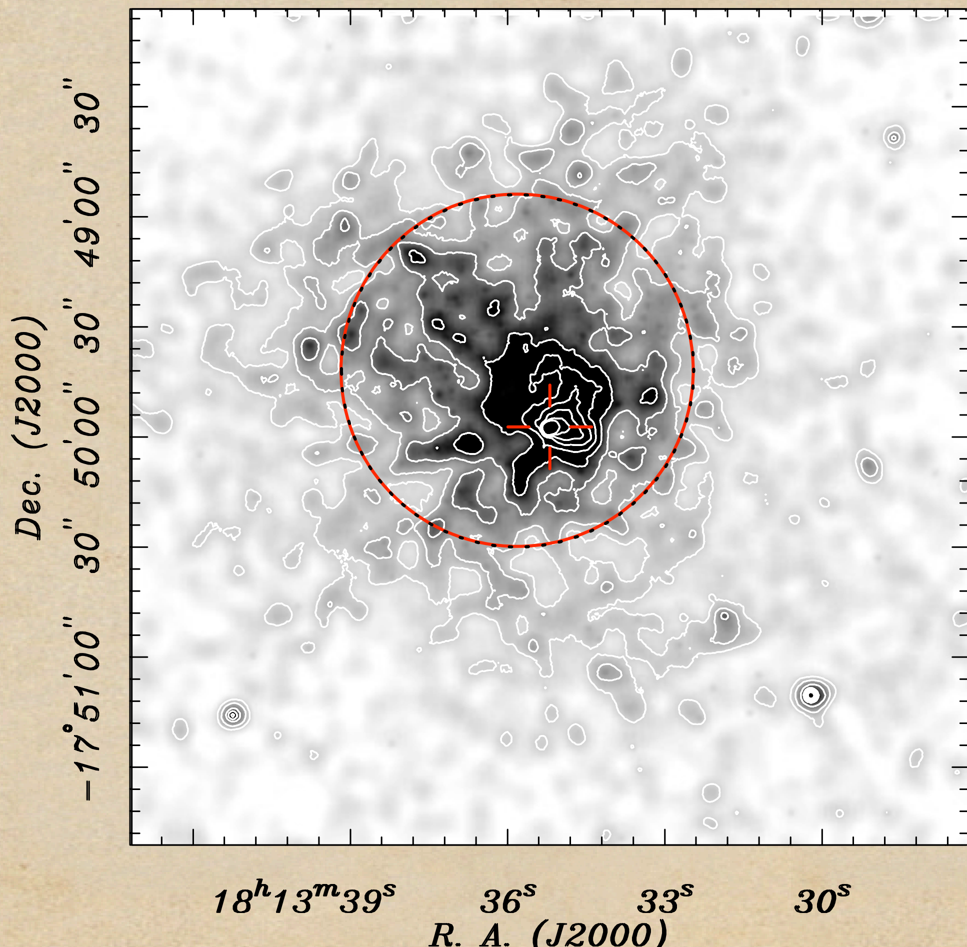
R.A. = $18^h 13^m 35^s.17$,

Dec. = $-17° 49' 57''.48$

(J2000); Uncert. 0″.2



X-ray morphology of HESS J1813-178

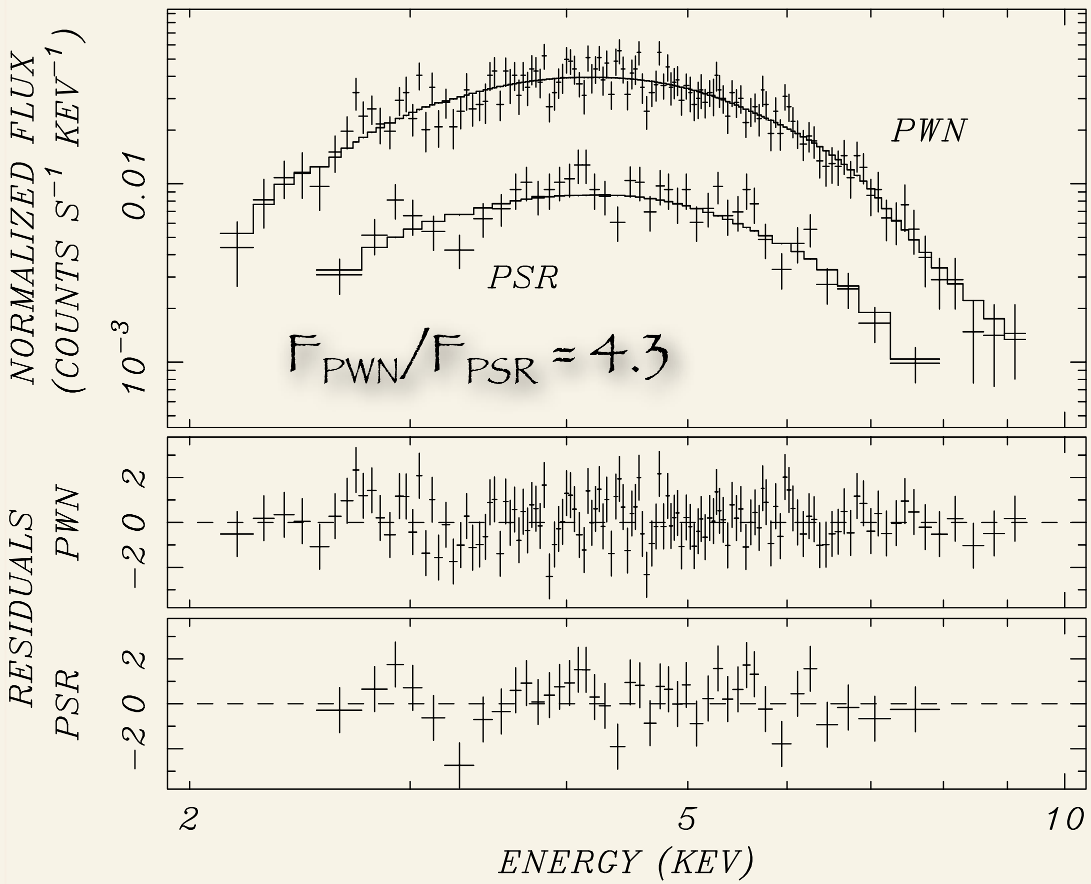


Diffuse X-ray flux
fills
the radio shell

X-ray
point source
offset
in radio shell

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):

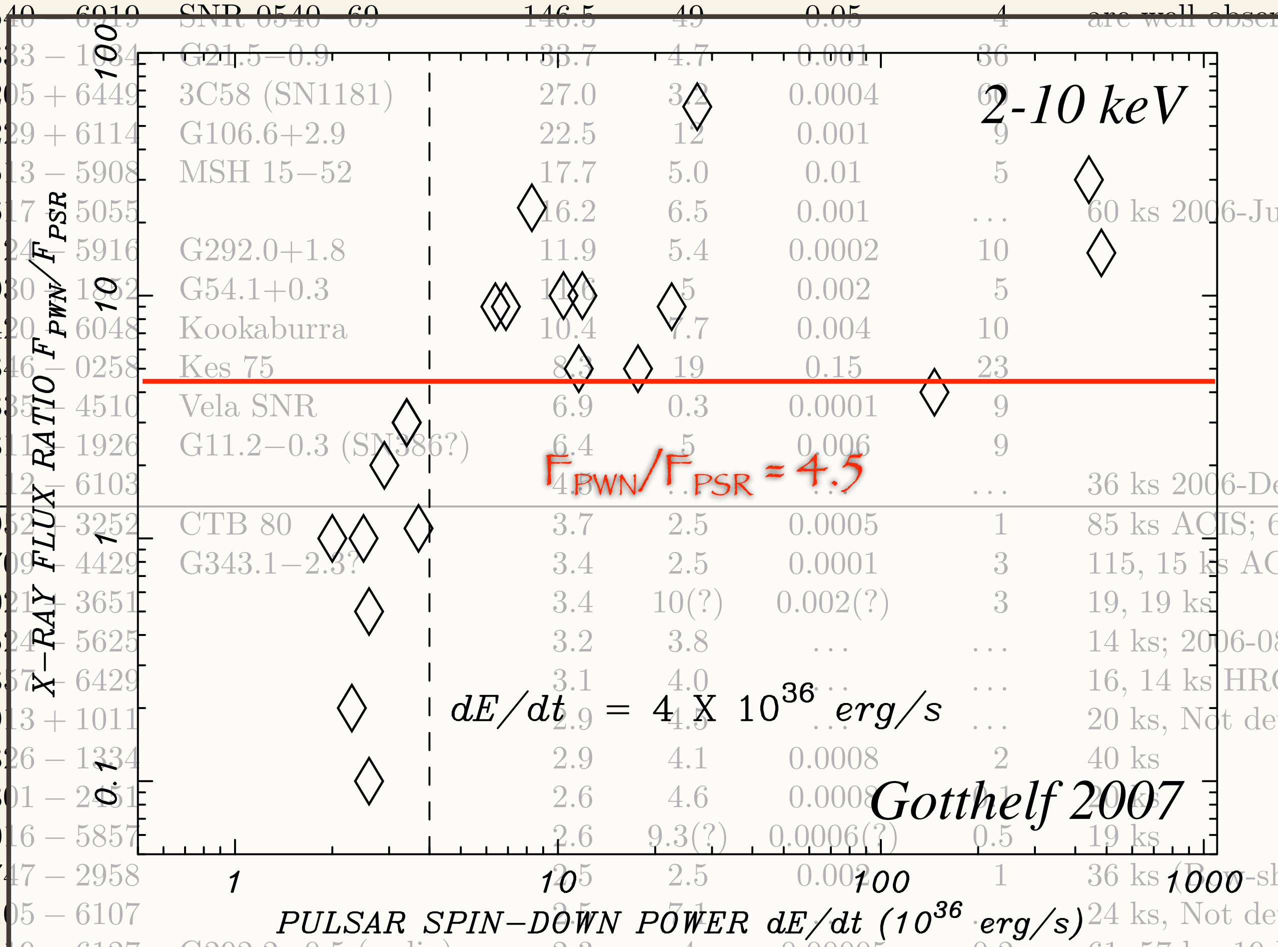
$\Gamma = 0.4(-0.3\text{-}0.8)$

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

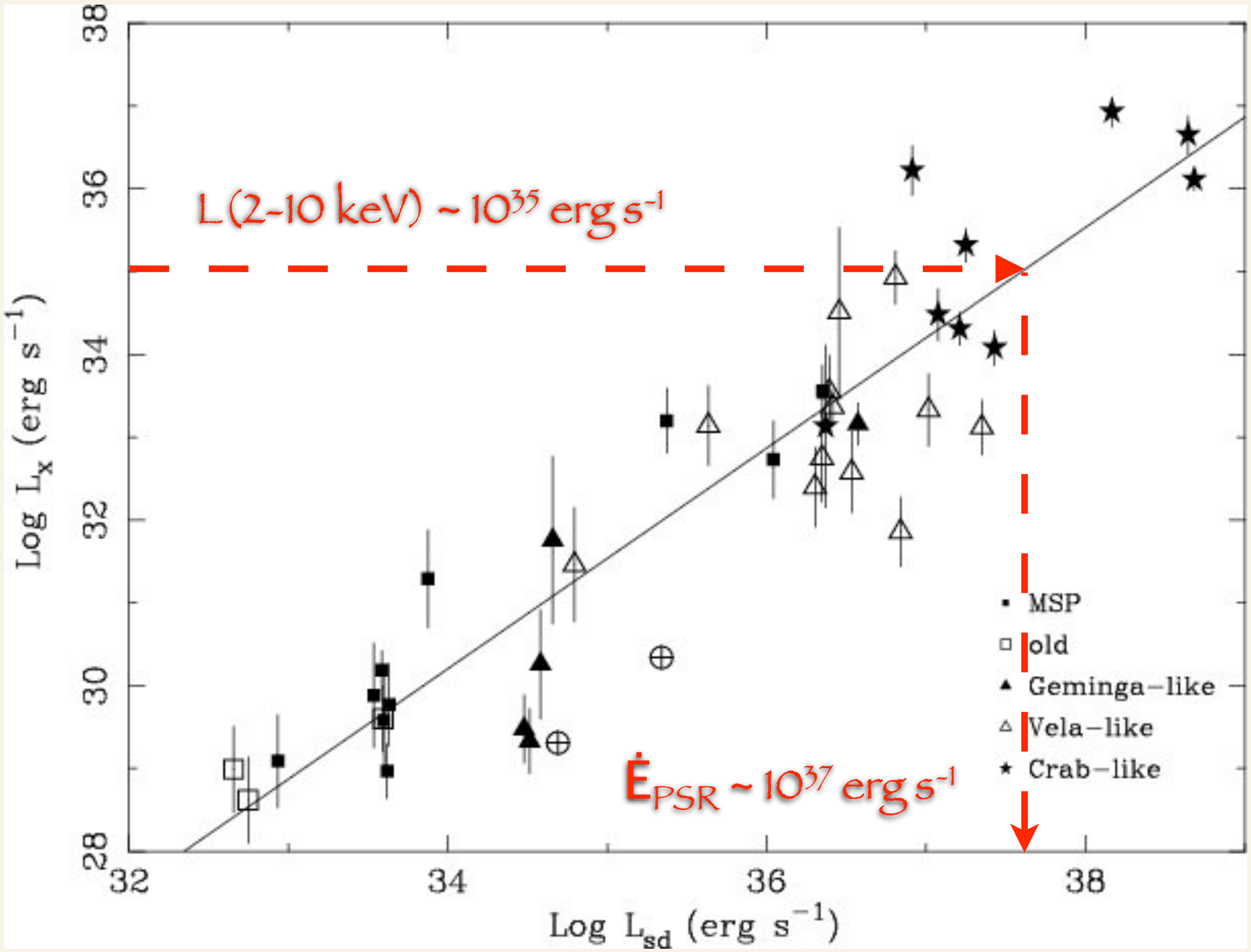
cgs = erg $s^{-1}\ cm^{-2}$

Table 1: Pulsars Ordered by Spin-down Power[a] (Gotthelf 2004)

#	Pulsar	Remnant	$\dot{E}^a$ $\times 10^{36}$ (erg/s)	Dist[b] (kpc)	$\epsilon^c = L_X/\dot{E}$	F_{PWN}/F_{PSR} (2-10 keV)	Chandra Observations (Exposure; dates for new data)
1	J0537 − 6910	N157B	481.6	49	0.003	15	Except where noted all pulsars
2	J0534 + 2200	Crab (SN1054)	440.6	2.0	0.03	30	above the following line
3	J0540 − 6919	SNR 0540−69	146.5	49	0.05	4	are well observed with ACIS.
4	J1833 − 1034	G21.5−0.9	33.7	4.7	0.001	36	
5	J0205 + 6449	3C58 (SN1181)	27.0	3.2	0.0004	[illegible]	
6	J2229 + 6114	G106.6+2.9	22.5	12	0.001	9	
7	J1513 − 5908	MSH 15−52	17.7	5.0	0.01	5	
8	J1617 − 5055		16.2	6.5	0.001	. . .	60 ks 2006-Jun-21
9	J1124 − 5916	G292.0+1.8	11.9	5.4	0.0002	10	
10	J1930 + 1852	G54.1+0.3	[illegible]	5	0.002	5	
11	J1420 − 6048	Kookaburra	10.4	7.7	0.004	10	
12	J1846 − 0258	Kes 75	8.3	19	0.15	23	
13	J0835 − 4510	Vela SNR	6.9	0.3	0.0001	9	
14	J1811 − 1926	G11.2−0.3 (SN386?)	6.4	5	0.006	9	
15	J1112 − 6103		4.5	. . .	. . .	. . .	36 ks 2006-Dec-28
16	J1952 + 3252	CTB 80	3.7	2.5	0.0005	1	85 ks ACIS; 65 ks HRC
17	J1709 − 4429	G343.1−2.3?	3.4	2.5	0.0001	3	115, 15 ks ACIS; 50 ks HRC
18	J2021 + 3651		3.4	10(?)	0.002(?)	3	19, 19 ks
19	J1524 − 5625		3.2	3.8	. . .	. . .	14 ks; 2006-08-26
20	J1357 − 6429		3.1	4.0	. . .	. . .	16, 14 ks HRC 2005-Nov-18
21	J1913 + 1011		2.9	4.5	. . .	. . .	20 ks, Not detected
22	J1826 − 1334		2.9	4.1	0.0008	2	40 ks
23	J1801 − 2451		2.6	4.6	0.0008	1	[illegible]
24	J1016 − 5857		2.6	9.3(?)	0.0006(?)	0.5	19 ks
25	J1747 − 2958		2.5	2.5	0.002	1	36 ks (Bow-shock Nebula)
26	J1105 − 6107		2.5	7.1	. . .	. . .	24 ks, Not detected
27	J1119 − 6127	G292.2−0.5 (radio)	2.3	4	0.00005	0.2	61, 57 ks, 19 ks
28	J1824 − 2452	ms pulsar	2.2	4.9	. . .	. . .	40 ks; 50 ks, HRC
29	J1803 − 2137		2.2	4.0	. . .	. . .	30 ks 2005-May-04



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



G12.82-0.02 Chandra Results

Evidence for a young, energetic pulsar/PWN system:

1) Pulsar candidate at coordinates (J2000):
   R.A.= $18^h\,13^m\,35^s.17$, Dec. $-17^\circ\,49'\,57''.48$, uncert. $\approx 0''.2$,
   18″ from HESS J1813-178 centroid, within error circle,

2) Young system by virtue of SNR association,

3) Non-thermal X-rays detected from point source and nebula,

4) Complex PWN Morphology with $F_{PWN}/F_{PSR} \approx 4.3$, this suggests $\dot{E}_{PSR} \gtrsim 4 \times 10^{36}$ erg s^{-1} (Gotthelf 2004),

5) L(2-10 keV) ~ 10^{35} erg s^{-1} @ 4 kpc implies an spin-down power of $\dot{E}_{PSR} \gtrsim 10^{37}$ erg s^{-1} (Possenti et al. 2002).

6) No X-rays detected specifically from SNR,

Near twin to PSR J2229+6114, a 51.6 ms pulsar with similar X-ray and radio morphology and energetics (Halpern et al. 2004).

Origin of the X-rays/γ-rays

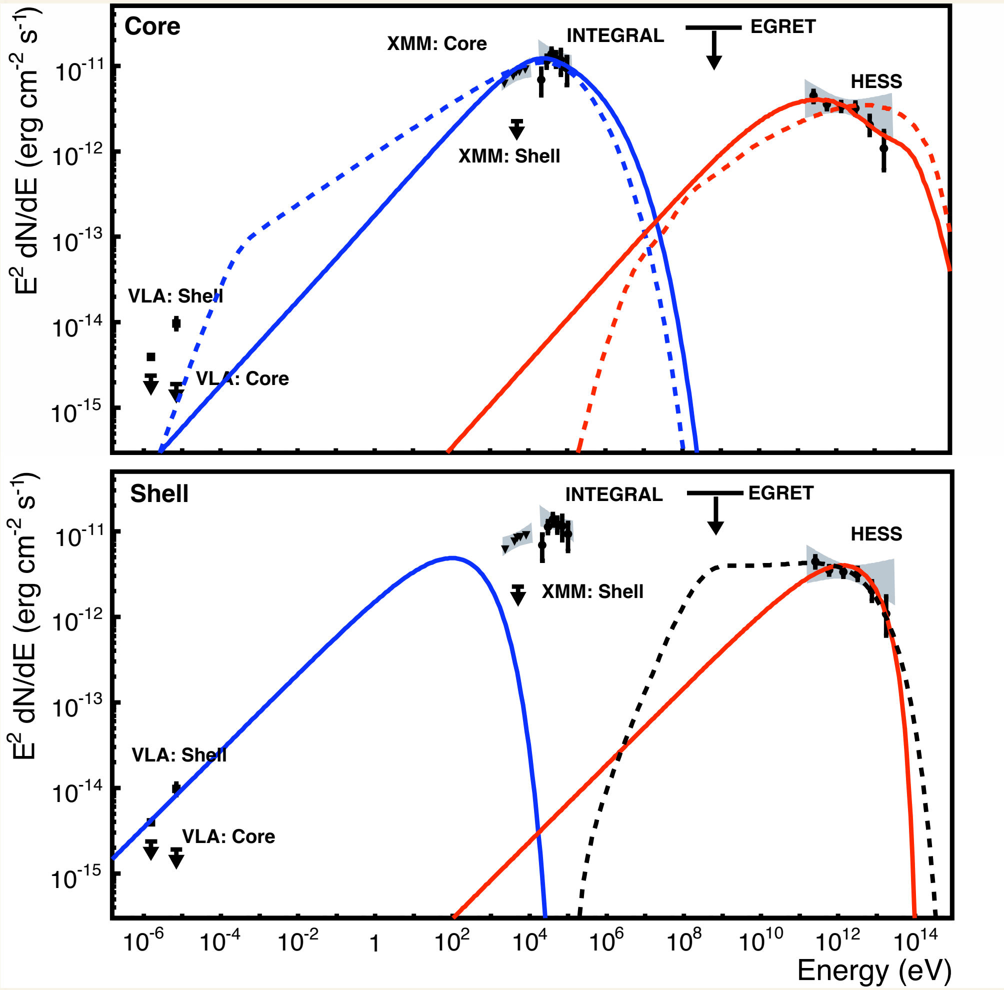
The ultimate source of energy for the TEV emission is likely spin-down losses for a rotation-powered pulsar.

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 γ-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 γ-ray emission imply CR accelerations?

Broad-band Spectrum of HESS J1812-178

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



Theoretical Models

γ-rays from core:

Relativistic e$^-$ synchrotron/ inverse Compton model

γ/X-rays same population

(Aharonian & Atoyan 1999)

[Revise using Chandra flux]

γ-rays from shell:

Leptonic model (solid line)

Hadronic model (dash line)

Future Work: Pulsar Search

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

- Radio pulsar search negative (Helfand et al. 2007),
- Proposed XTE X-ray timing search and ToO monitoring,
- Proposing Chandra deep imaging observation,
- Deeper radio pulse search planned.

HESS J1813-187 is an excellent GLAST pulsar target:

$\dot{E}/d^2 \gtrsim 6 \times 10^{35}$ erg s^{-1} kpc^{-2} (top 14th or higher).