



High Energy Supernova Remnants and Pulsar Wind Nebulae

F. Giordano

Dipartimento Interateneo di Fisica and INFN Sez. Bari

For the Fermi-LAT Collaboration

Scineghe 2010



The Afterlife of a star

Depending on the its mass a star mass may evolve into a white dwarf or a neutron star.

The neutron star may radiate energy in pulses (PSR).

The PSR may also interact with the surrounding medium originating a PWN



and/or

IC443

The shock waves of the explosion interacting with the surrounding medium may produce radiation at different wavelenghts

Crab

SN1006







Cocoon

-5

0

HESS

15

ASCA

5

log Energy (eV)

10

(n 10)

10-11

10-18

 E^2 dN/dE (erg cm⁻²

- •Spectral index = 2.41 (soft spectrum) •Flux E>100 MeV = 4.73 x10⁻⁷ cm⁻² s⁻¹
- the SED strongly favors a <u>two</u> component leptonic model
- Hadronic model is disfavoured





Declination (J2000)

-46:30:00.0

35:00.0

40:00.0

42:00.0

41:00.0

Right Ascension (J2000)

16:40:00.0

The latest HESS J1640-465

(Slane et al., 2010, ApJ, 726)



Modifying low-energy electron spectrum by adding Maxwellian produces GeV emission through inverse Compton scattering:

 primary contribution is from IR from dust (similar to Vela X)

- mean energy (γ =10⁵) and fraction in power law (~4%) consistent w/ particle acceleration model



Is it time for a HE PWNe Catalog?



low gamma-ray efficiency in the Fermi-LAT energy range
Lack of detection of several Velalike Pulsars (e.g. J1418-6058)
suggest that these spectra have a low energy turn-over as expected from IC scattering off an electron spectrum of index ~2.3



Van Etten, Romani arxiv.org/abs/1001.4807v1





Fermi-detected SNRs (1yr)

Object	Diameter	Age	Cloud Interaction	Lγ 1-100 GeV
Cas A	5 pc	330 yr	No	4x10 ³⁴ erg/s
W49B	10 pc	~3000 yr	Yes	9x10 ³⁵ erg/s
3C 391	15 pc	~6000 yr	Yes	6x10 ³⁴ erg/s
G349.7+0.2	17 pc	~6000 yr	Yes	9x10 ³⁴ erg/s
IC 443	20 pc	~10000 yr	Yes	8x10 ³⁴ erg/s
W44	25 pc	~10000 yr	Yes	3x10 ³⁵ erg/s
W28	28 pc	~10000 yr	Yes	9x10 ³⁴ erg/s
CTB 37A	50 pc	~20000 yr	Yes	9x10 ³⁴ erg/s
G8.7-0.1	63 pc	~30000 yr	Yes	8x10 ³⁴ erg/s
W51C	76 pc	~30000 yr	Yes	8x10 ³⁵ erg/s





W51C* & W44**: Morpholgy and...

• Ages: $3\ 000 \div 50\ 000\ years$ • Interaction with molecular clouds can act as target material for π^0 production • Typically rather steep (compared to young remnants) • Rollover or break in proton spectrum at ~10GeV/c • Extremely luminous (W51C: 10³⁶ erg/s at 6 kpc) • Detection of remnants interaction with clouds favours p+



*Abdo et al., 2009, ApJ, 706, L1

**_Abdo et al. Science 26 Febrary 2010 pp. 1103 - 1106



Leptonic models need large electron/proton ratios; piondecay is favoured

Brems: hard to reproduce the radio synchrotron spectrum => less likely but not fully excluded

IC: very large energy content in electrons and very low density => very unlikely







•Electron bremsstrahlung can hardly explain the observed IC 443 gamma-ray emissivity

•In a hadronic scenario, pion-producing proton population with a broken powerlaw spectrum well fit the data

•The bremsstrahlung likely makes a non-negligible contribution below E = 200 MeV where the EGRET data points exceed the best-fit pionic spectrum





Conclusions

PWNe and SNRs are HE gamma-ray sources More informations is being added in the comprehension of acceleration mechanisms and sites Some PWNe and SNRs have been and many others are being detected in different evolutionary stages and in different environments

Stay tuned!!!





Thanks for your attention!



Cosmic ray content in SNRs

	Cas A	RX J1713.7 -3946	IC443	W44	W51C
Age (kyears)	0.3	2	10	20	30
N _{average} (cm-3)	10	0.1	10	100	10
CR _{fraction}	2%	50%	25%	5%	10%

- Can now start to determine the CR content in SNRs
- Significant fraction of the explosion energy (uncertainty by factor of a few)



Before results... a bit of Analysis

• Gamma-ray Pulsars are <u>everywhere</u> !!! One can use only the unpulsed signal to analyse most of these sources => we keep only ~1/3 of the signal for analyses such as Crab, Vela-X...

 SNR & PWN are steady sources: we don't have the variability as an identification tool (as for AGNs) and no timing information (as for Pulsars)

 SNR & PWN are predominantly located in the Galactic Plane => contamination from the Galactic diffuse background

• SNR & PWN can be extended sources (W44, Vela-X...): gamma-ray photons are spread over larger regions which render the analysis and identification with a potential counterpart very hard (and even more in the Galactic plane !)

It is not an easy job... but there's a lot of fun!!!



