GeV Survey of Radio SNRs

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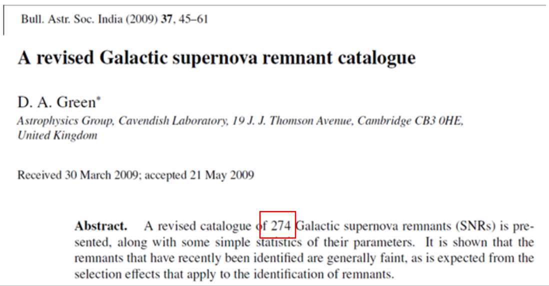
Summary: After two years of data taking, the Fermi-LAT has collected firm evidence of GeV emission from many radio SNRs, and some others are under investigation. A possible correlation between radio luminosity and GeV flux is presented, with the focus on possible explanations behind the emission mechanisms. For some cases, a closer look at possible interactions of the SNRs with dense environment has been carried out and results are presented.

RADIO SNRs

Starting from a sample of 274 radio sources (The Green's Catalog), a GeV survey with the Fermi-LAT has been conducted. 11 firmly detections have been obtained as SNRs and 6 as PWNe. The survey is still continuing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A revised Galactic supernova remnant catalogue

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Abstract. A revised catalogue of 274 Galactic supernova remnants (SNRs) is presented, along with some simple statistics of their parameters. It is shown that the remnants that have recently been identified are generally faint, as is expected from the selection effects that apply to the identification of remnants.

Assuming that the acceleration process takes place at the same moment and in the same place, a strong correlation between radio Map and gamma counts is expected [1].
Superimposing radio contours on GeV count maps (Fig.1), good indications about possible correlation between the two emission mechanisms can be obtained.
Radio data are explained by synchrotron emission from accelerated electrons interacting with amplified magnetic field.

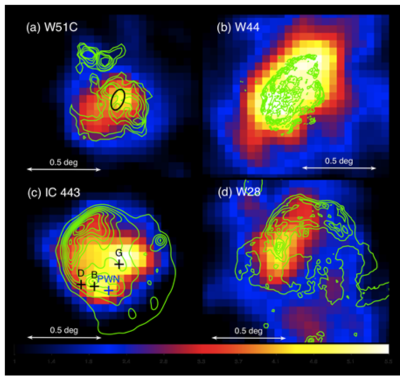


Fig.1 VLA contours superimposed on Fermi GeV count Maps

HE SNRs

With the goal of solving the puzzle of CR acceleration and injection, we have analyzed in detail some of the radio SNRs detected as GeV-TeV emitters. For almost all of them, the observed spectrum can be interpreted as the result of neutral pion decay produced in hadronic interactions between accelerated particles and the surrounding environment.

	Fermi -SNRs	Index [1]	Index [2]	γ_{Break} (GeV)	Age (yrs)	Proton break	Ref.
Young	Cassiopeia A	-2.1 ±0.1	-2.4**	>100GeV	330	80TeV	[2]
	Tycho	-2.3 ± 0.1	--	--	438	350TeV	[3]
	Vela Jr.	-1.87±0.2	-2.1**		680	50TeV	[4]
	RX J1713	-1.5±0.1	-2.2**		1600	Leptonic dominated	[5]
Middle aged	CTB 37A	-2.28±0.1	--	--	1500?	>10TeV	[6]
	W49B	-2.18 ± 0.04	-2.9 ± 0.2	4.8 ± 1.6	1k-4k	4GeV	[7]
	Cygnus loop	-1.83 ± 0.06	3.23±0.19	2.39±0.26	20k	2GeV	[11]
	IC 443	-1.93 ± 0.03	-2.56 ± 0.11	3.25 ± 0.6	3-4k 20-30k	70GeV	[8]
	W44	-2.06 ± 0.1	-3.02 ± 0.20	1.9 ± 0.5	~20k	9GeV	[9]
	W28 (N) (and G6.5-0.4)	-2.09 ± 0.3	-2.74 ± 0.1	1.0 ± 0.2	35-150k (40k)	1-2GeV	[10]
	W51C	-1.97 ± 0.08	-2.44 ± 0.09	1.9 ± 0.2	~30k	15GeV (5-20)	[12]

** the index is taken from VHE measurements

Though extension studies with GeV data indicate the same acceleration region, it is the analysis of the photon spectrum that allows us to get into more details on the mechanisms behind the HE emission. For all Fermi-LAT detected SNRs, only one single population of accelerated electrons hardly explains the GeV flux and the observed shape.
For the Molecular Cloud Interacting SNRs, the interaction with dense environments enhances the GeV flux, but may hide the natural acceleration process by cosmic rays.

As a common behavior, the photon spectrum observed in Middle Aged SNRs (i.e. the IC443 Fig.2) typically shows a steeper slope than young SNRs (i.e. VelaJr Fig.3)

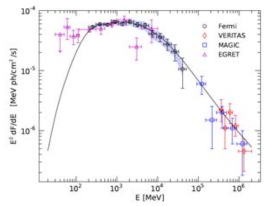


Fig.2 IC443 SED

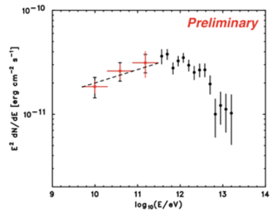


Fig.3 VelaJr SED

To highlight cosmic rays acceleration, the background has to be well studied and known. More straightforward objects may be those where the contribution from possible interaction with nearby molecular clouds is not dominant. When the SNR is evolving in a cloud-free region, the GeV emission is not enhanced by the dense target, and the age evolution may be more easily studied.

Cygnus Loop

For the Cygnus Loop case, an interaction with clouds is not favored, while from the very good match with X- rays and Hα (Fig.4) it can be inferred that acceleration processes for protons and electrons are taking place at the shocks of the SNR with interstellar matter.

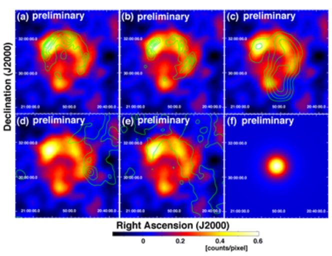


Fig.4 Smoothed BKG subtracted CountMap with a) ROSAT, b)Ha DSS; c) 1420 MHz; d) CO; e) 100um IRAS

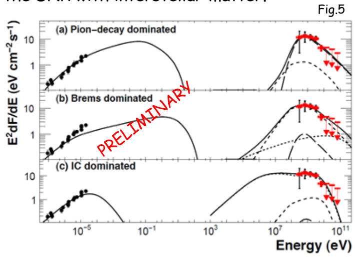
Fig.5


Fig.5 Pure leptonic model is not excluded, but hadronic acceleration process are favored [7]

Tycho

Tycho is a historical SNR, observed for the first time by the astronomer Tycho Brahe in 1572. Due to its age and its expansion in mostly free environment, it is an ideal case where cosmic rays acceleration processes may be studied «easily».
Looking at the SED, a pure leptonic model is unable to fit the GeV-TeV data for the following reasons:
1. the CMB is the minimal target for IC emission 2. the ambient density is <0.3cm^{-3}; 3. the resulting spectrum (in which the IC has to be a significant component) would be much harder than the GeV-TeV data.

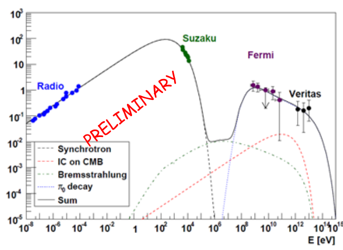


Fig.6 The MW Spectral energy Distribution of Tycho SNR [3]

Then the expected gamma-ray spectrum is mainly of hadronic origin and can be calculated on the assumption that efficient proton acceleration is taking place at the forward shock in Tycho's SNR.

Analysis details

The detection of GeV emitting SNRs is very complex. SNRs are expected to be extended sources, often hidden by very bright PSRs and embedded in very crowded region within the galactic plane. The detection analysis is based on:

- A likelihood method for extended sources [13]
  - PuppisA
- Off-Pulse analysis [14]
  - VelaX
- A selection of high energy photons [15]
  - GammaCygni

Extended SNR

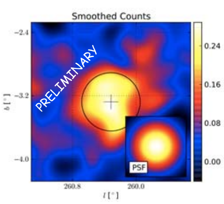


Fig.7 PuppisA: Fermi-LAT smoothed Count map (BKG subtracted)

«Hidden» SNRs:

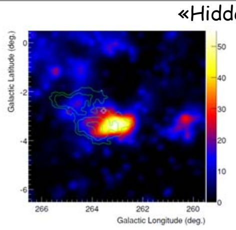


Fig.8 VelaX: [16] Fermi-LAT TS map (E > 800 MeV)WMAP @ 61 GHz (green)

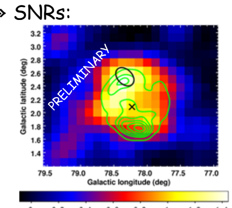


Fig.9 GammaCygni : Residuals E>10 GeV, 408 MHz from CGPS (green), PSR J2021+4026 (X) VER 2019+407 (black) .

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