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Gamma-ray emission from the SNR W44: confirmations and challenges for cosmic-ray acceleration

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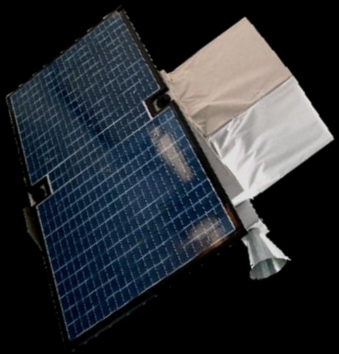
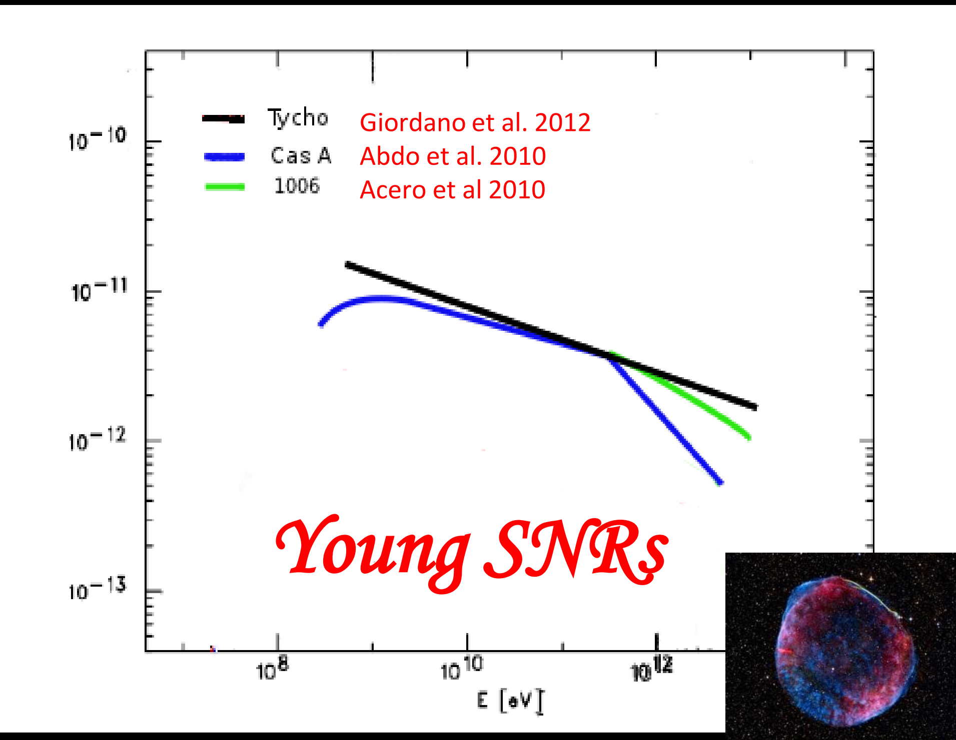
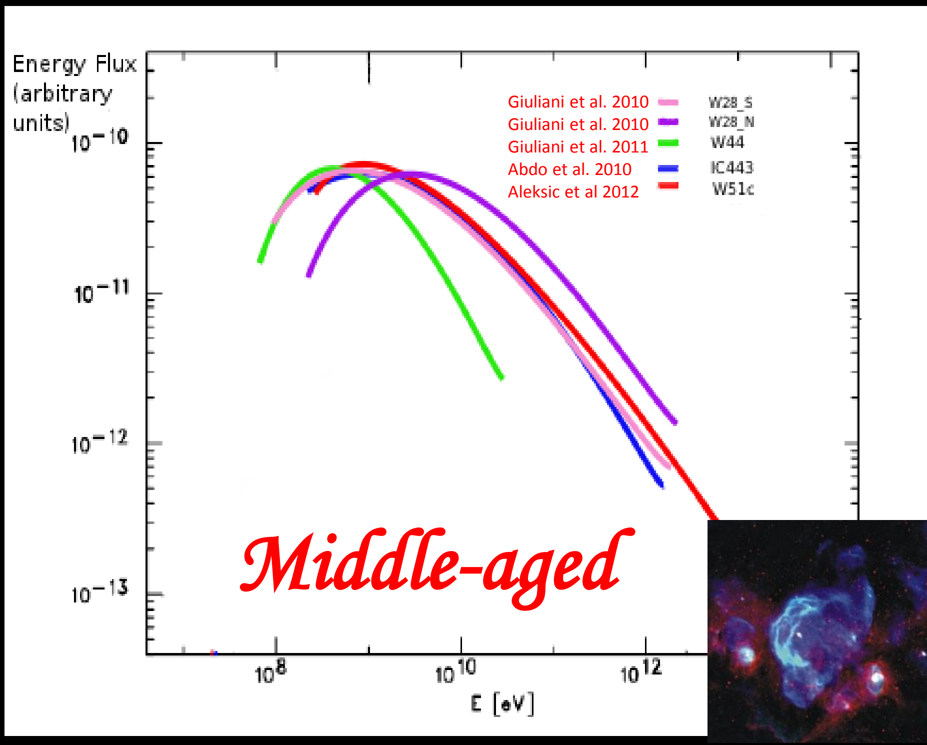


- Overview
- New AGILE data
- Modelling
- Theoretical discussion and open issues
- Conclusions

Context





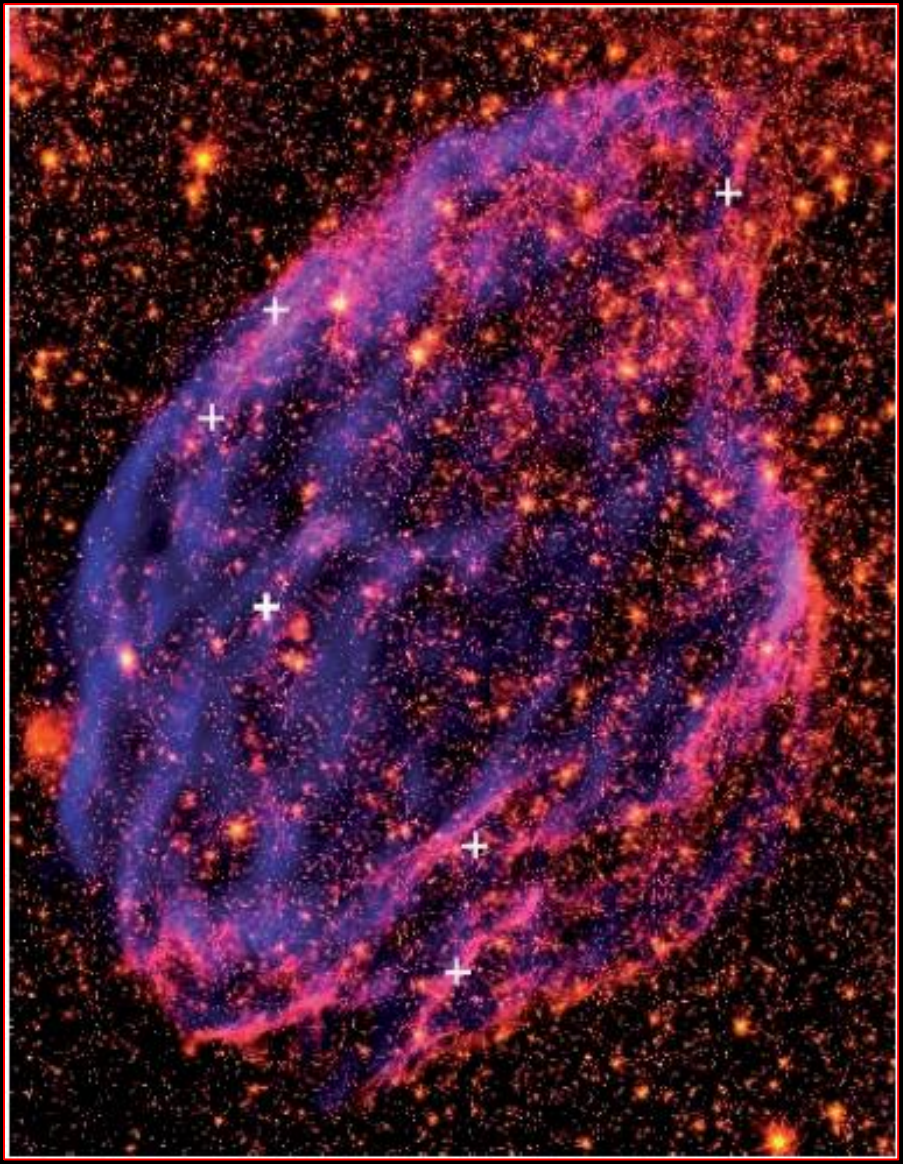
Theory:

- Linear DSA: p=2 & δ=0,7
- Non linear DSA: high energy hardening
- Pevatrons

Data:

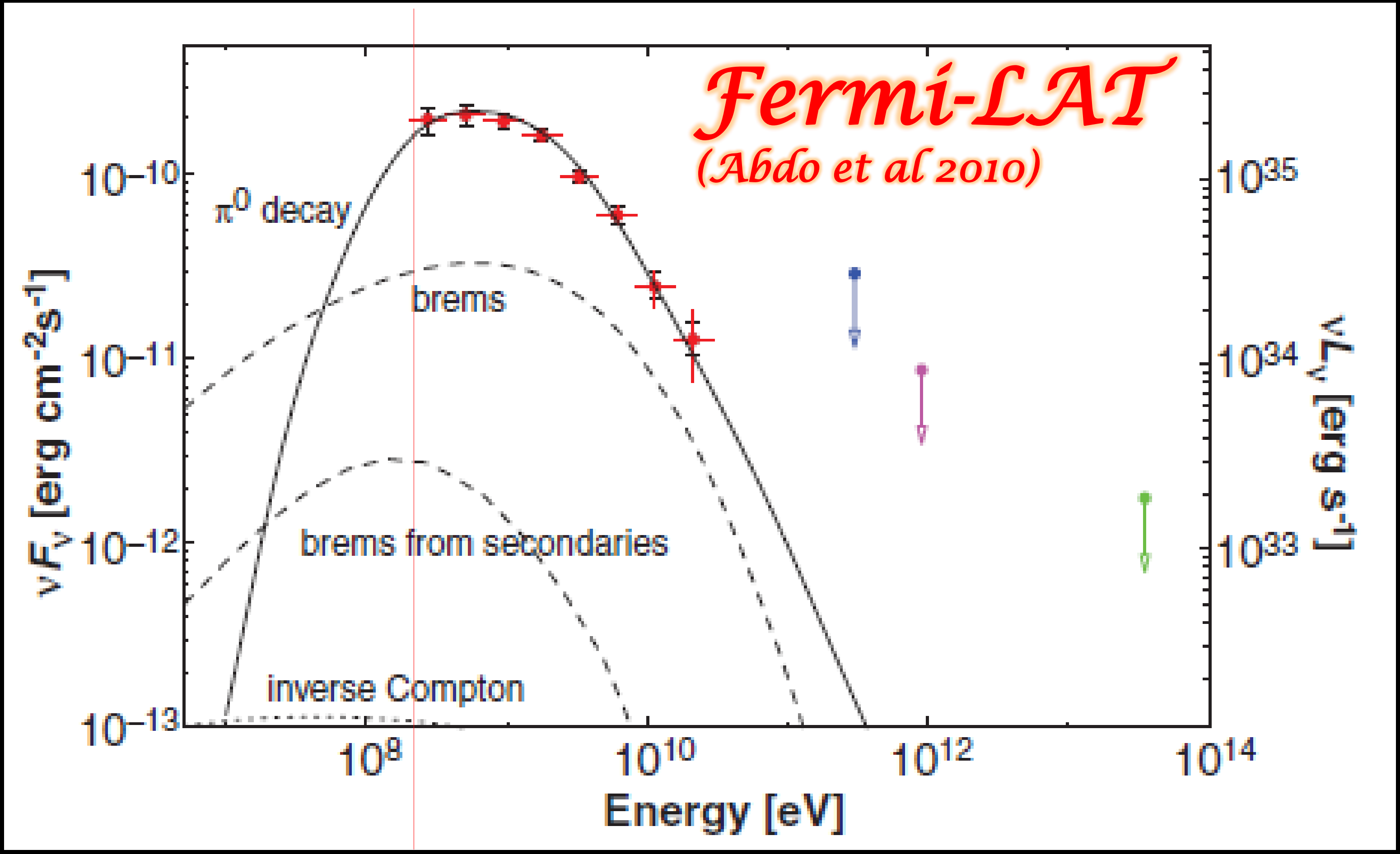
- Young: p= 2,3-2,4
- Middle-aged: 2,6 < α < 3
- No evidence of Pevatrons

The SNR W44: what we do know until now



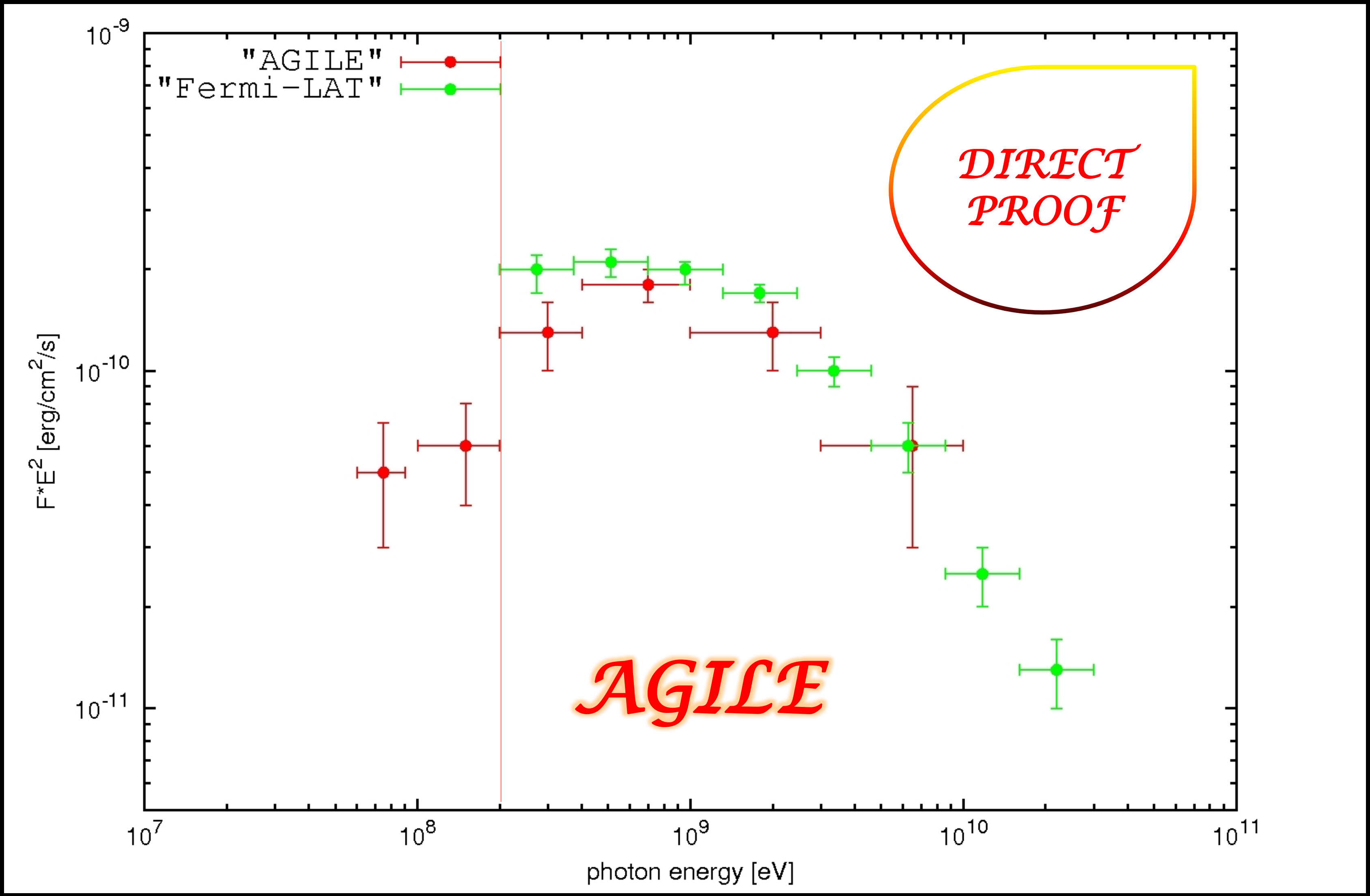
- 20000 yrs old
- d= 3,1 kpc
- Radio spectral index $\alpha = 0{,}37$
- No thermal emission
- Weak at TeV energies
- Interaction with MCs

The SNR W44: what we do know until now



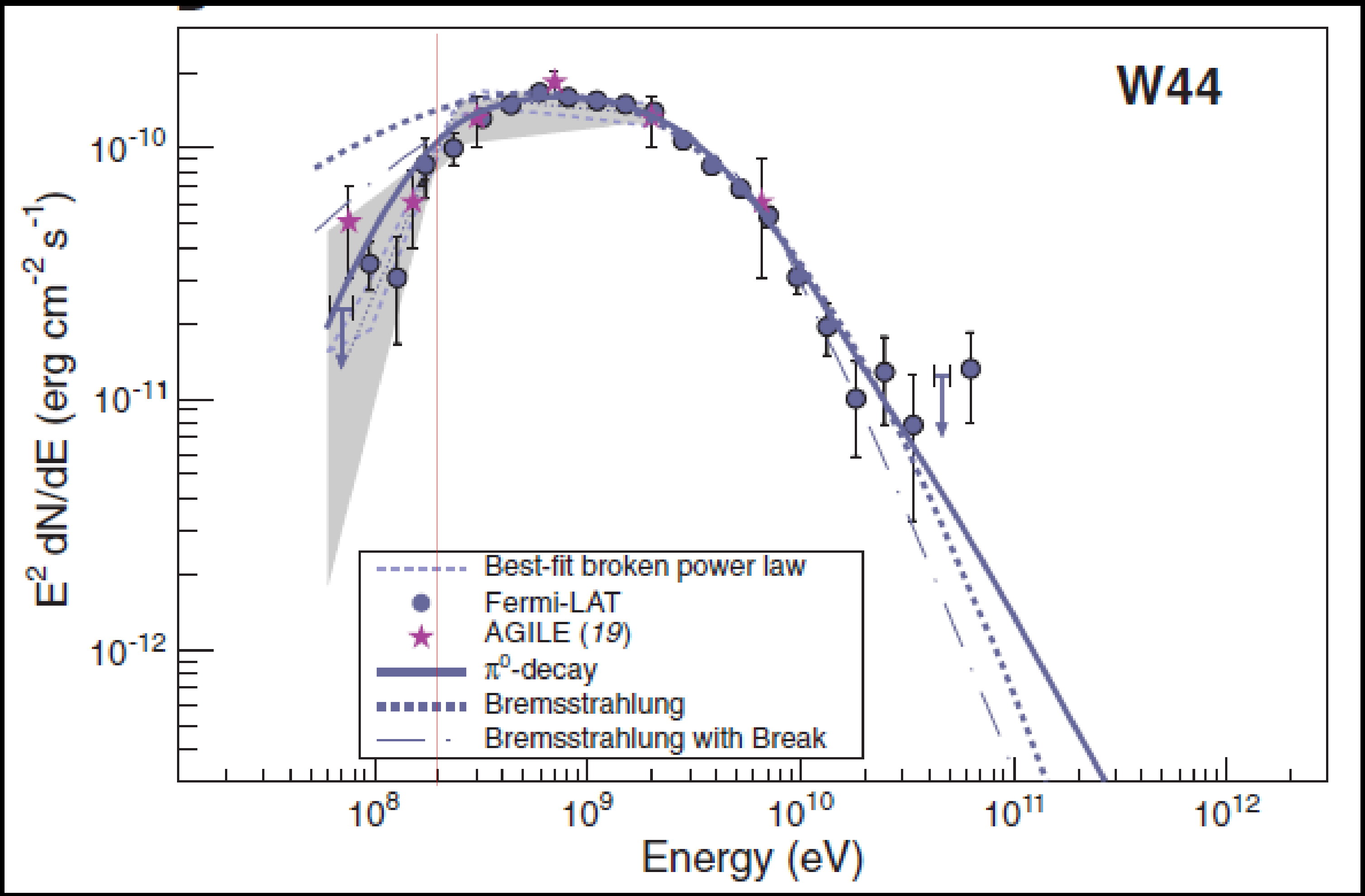
Bremsstrahlung is excluded as dominant contribution assuming n= 10^2 and $K_{ep}\sim10^{-2}$→ B~$70\mu G$

The SNR W44: what we do know until now



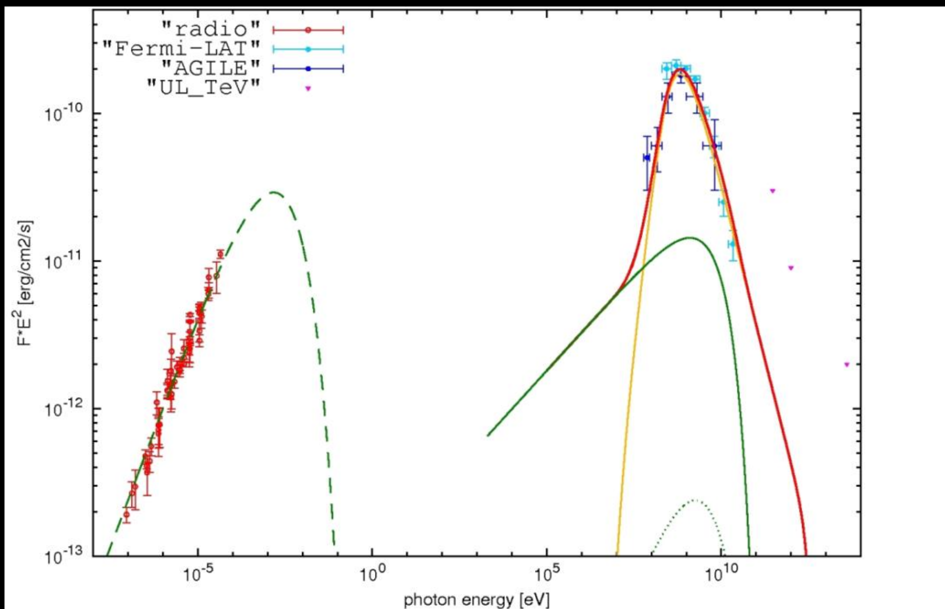
Giuliani, Cardillo, Tavani et al .(2011)

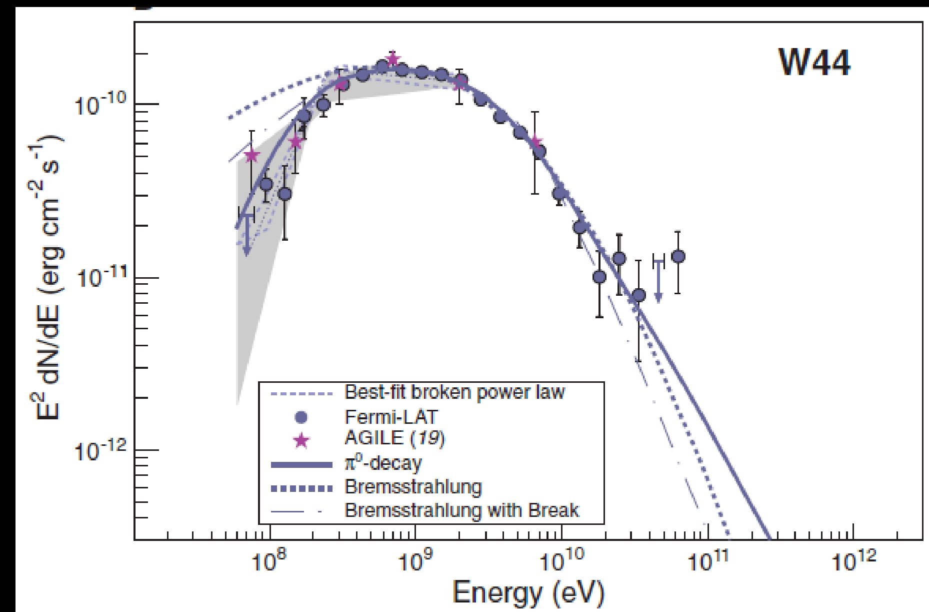
The SNR W44: new Fermi-LAT data



Ackermann et al. 2013

The SNR W44: what we do know until now



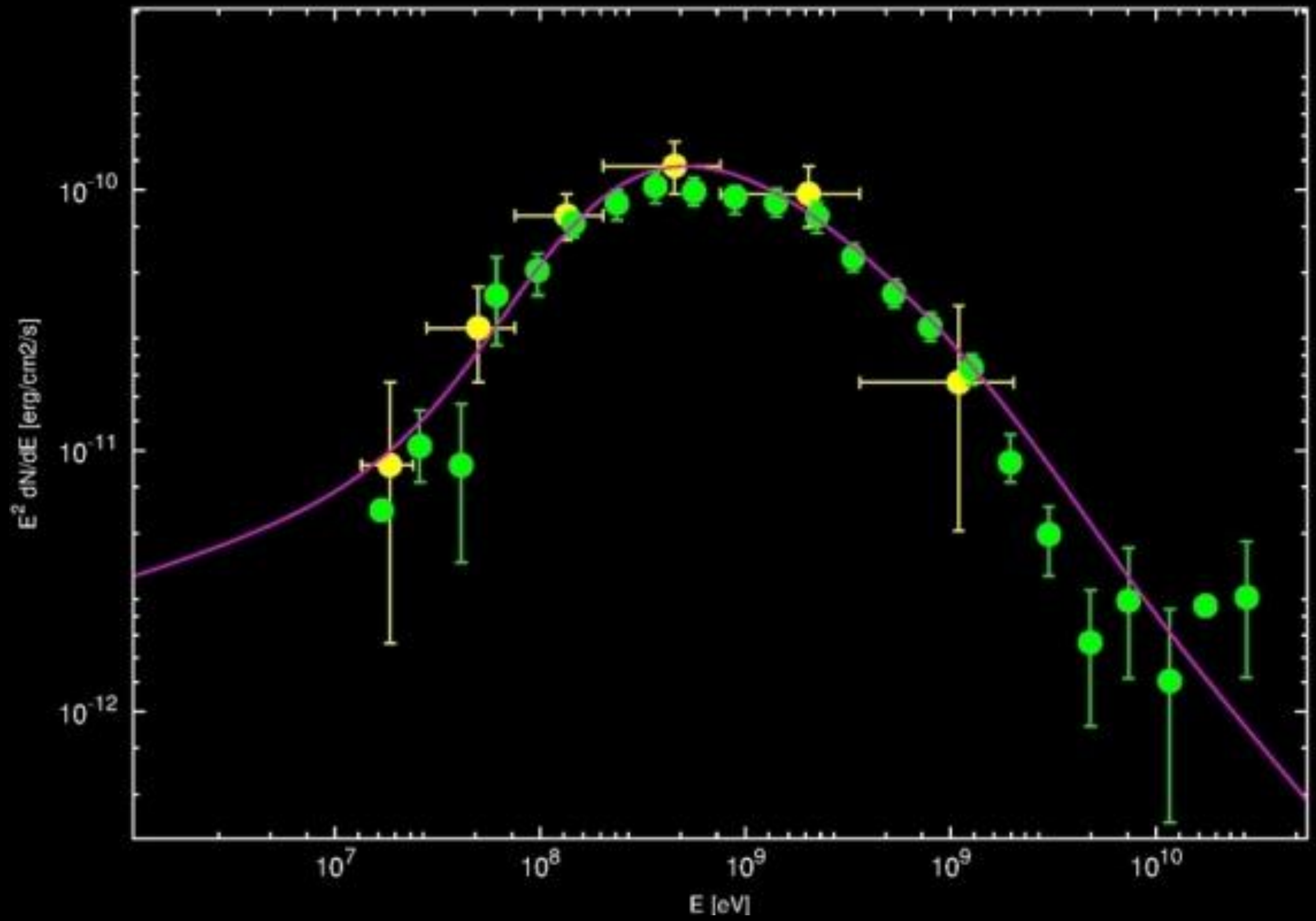


Models	B [μG]	n [cm^{-3}]	E^p_{br} [GeV]	E^p_c [GeV]	E^e_{br} [GeV]	E^e_c [GeV]	p_1	p_2	p'_1	p'_2	W_p [erg]	W_e [erg]
AGILE paper	70	100	-	5.5	-	15	3	-	1.74	-	3.3×10^{49}	2.8×10^{48}
Fermi paper	50	100	22	-	-		2.36	3.5	1.74	-	4×10^{49}	-

No Bremsstrahlung

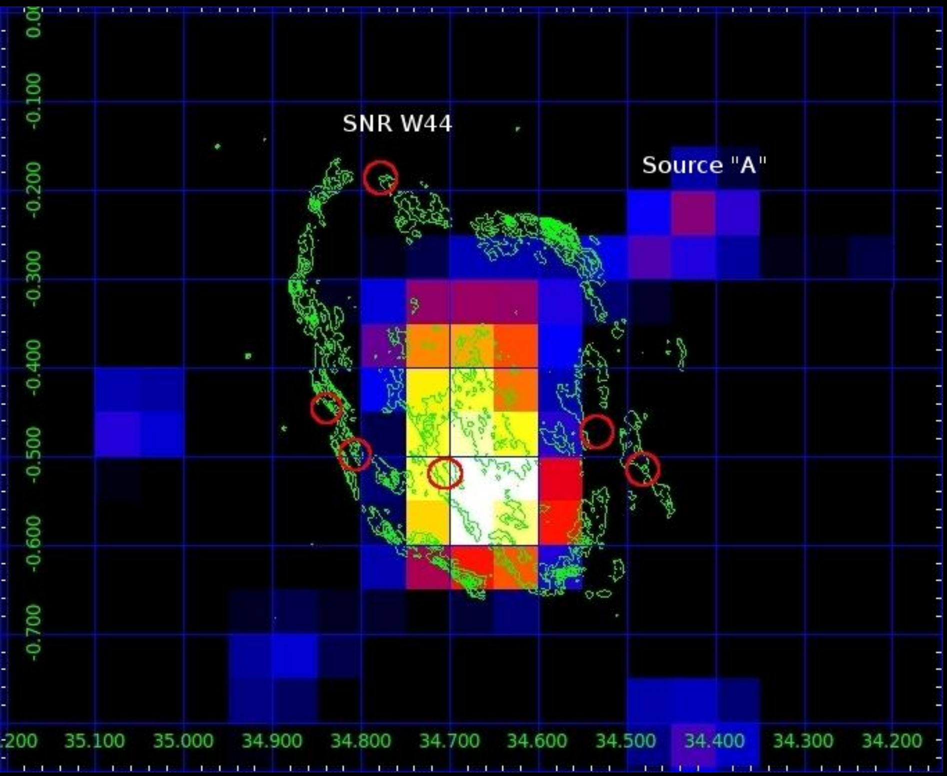
The SNR W44: new AGILE data

Cardillo et al., in preparation

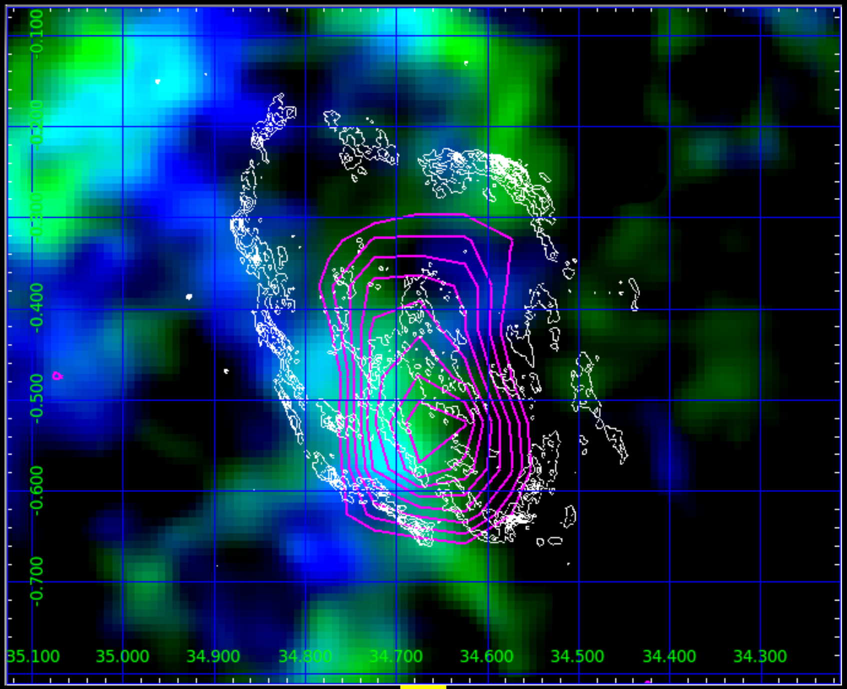


The SNR W44: morphology

AGILE 400-10000 MeV
VLA contours and masers



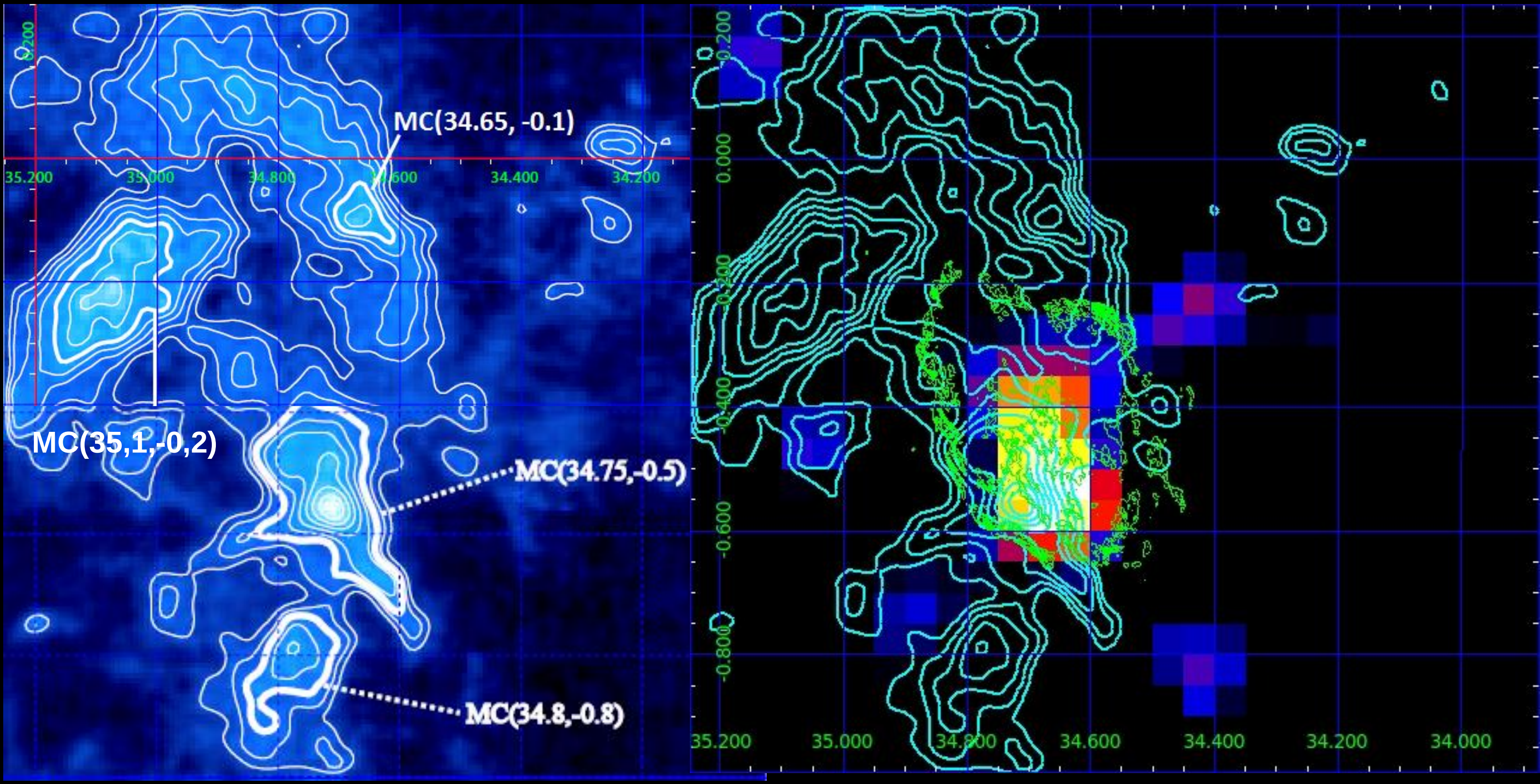
NANTEN2 CO 40-43 km/s
(Yoshiike et al. 2013)
VLA and AGILE contours



$$n_{av} \sim 200 \ cm^{-3}$$

Cardillo et al., in preparation

The SNR W44: new Fermi-LAT data



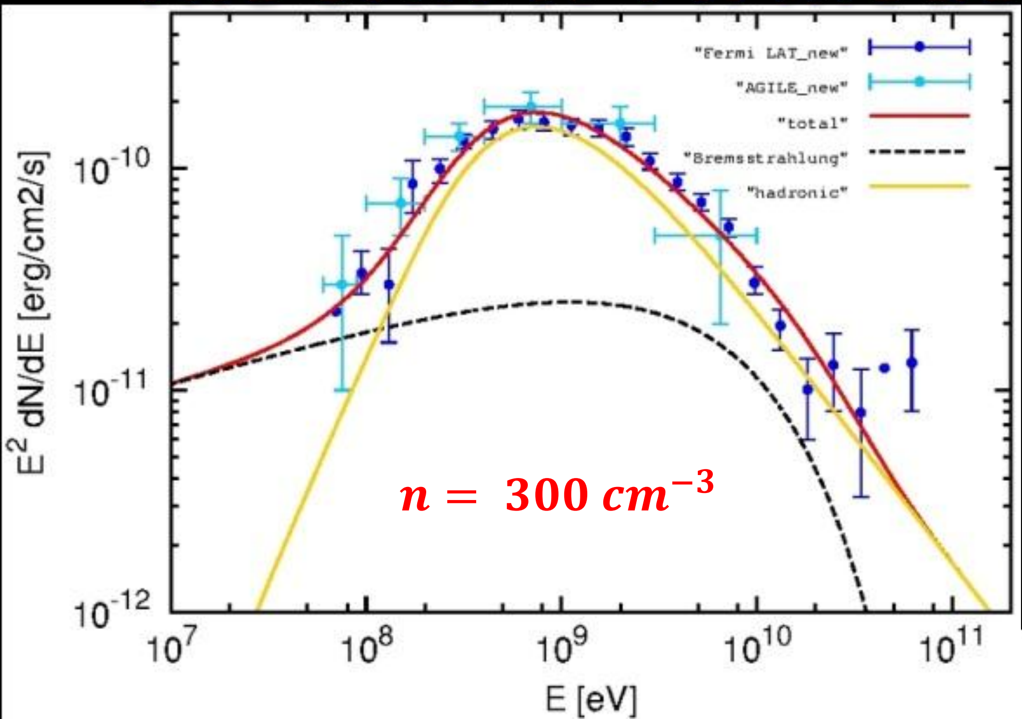
$$\mathcal{M} = 2 \times 10^4 \, Ms$$

$$n_p \sim 1000 \, cm^{-3}$$

$$R \sim 5 \cdot 5 \, pc$$

Cardillo et al., in preparation

The SNR W44: modelling → hadronic

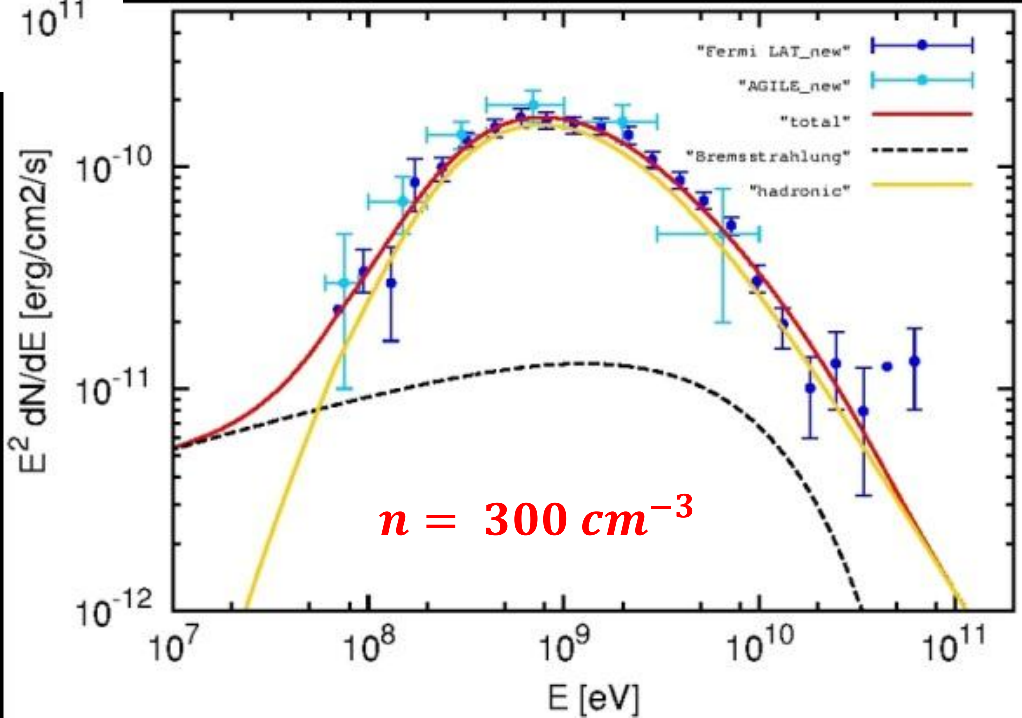


$$F_p(E) = K_p E^{-p} e^{-\frac{E_c^p}{E}}$$

$p = 3.2$
$E_c = 7.5\ GeV$

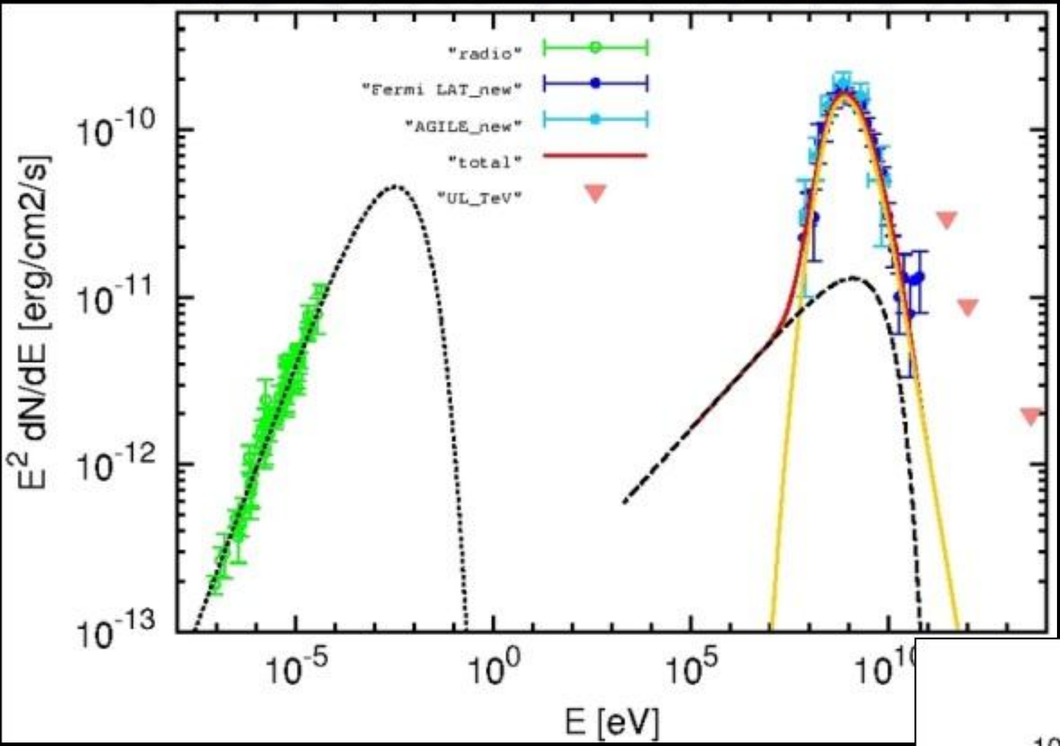
$$F_p(E) = K_p \left(\frac{E}{E_{br}^p}\right)^{p_1} \left(\frac{1}{2}\left(1 + \frac{E}{E_{br}^p}\right)\right)^{p_1 - p_2} e^{-\frac{E_c^p}{E}}$$

$p_1 = 2,\ p_2 = 3.5$
$E_{br} = 16\ GeV$
$E_c = 3\ GeV$



Cardillo et al., in preparation

The SNR W44: modelling → hadronic

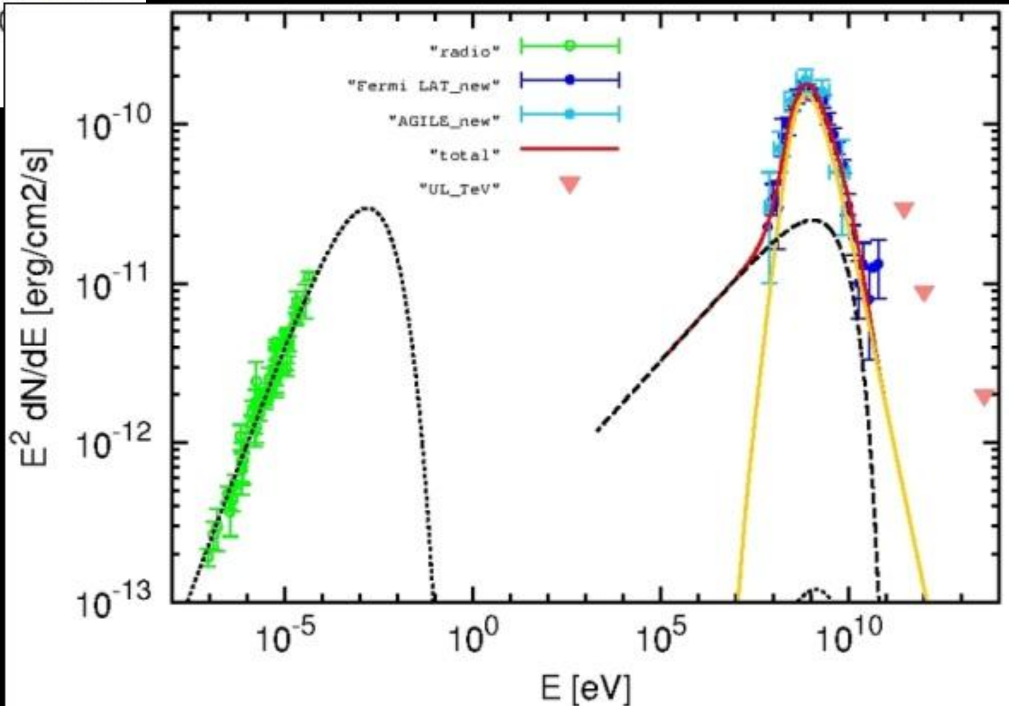


$$F_p(E) = K_p E^{-p} e^{-\frac{E_c^p}{E}}$$

$$F_e(E) = K_e E^{-p'} e^{-\frac{E}{E_c^e}}$$

$$F_p(E) = K_p \left(\frac{E}{E_{br}^p}\right)^{p_1} \left(\frac{1}{2}\left(1 + \frac{E}{E_{br}^p}\right)\right)^{p_1 - p_2} e^{-\frac{E_c^p}{E}}$$

$$F_e(E) = K_e E^{-p'} e^{-\frac{E}{E_c^e}}$$



Cardillo et al., in preparation

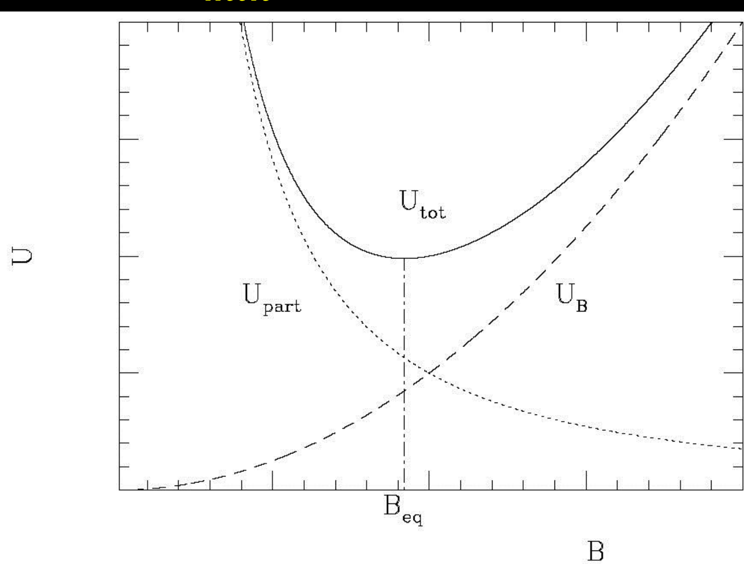
The SNR W44: modelling

Models	B [μG]	n [cm^{-3}]	E^p_{br} [GeV]	E^p_c [GeV]	E^e_{br} [GeV]	E^e_c [GeV]	p_1	p_2	p'_1	p'_2	W_p [erg]	W_e [erg]
Hadronic	100	300	-	7.5	-	13	3.2	-	1.74	-	8×10^{48}	1.6×10^{48}
	160	300	16	3	-	15	2.	3.5	1.74	-	6×10^{50}	9.6×10^{47}

Equipartition
(Castelletti et al. 2007)

$U_{min} = 5,8 \times 10^{49}$ erg

B_{min} = 13 μG



$B \sim 10^2 \mu G >> B_{min}$

$W_p < U_{min}$

$W_p > U_{min}$

Simple power-law

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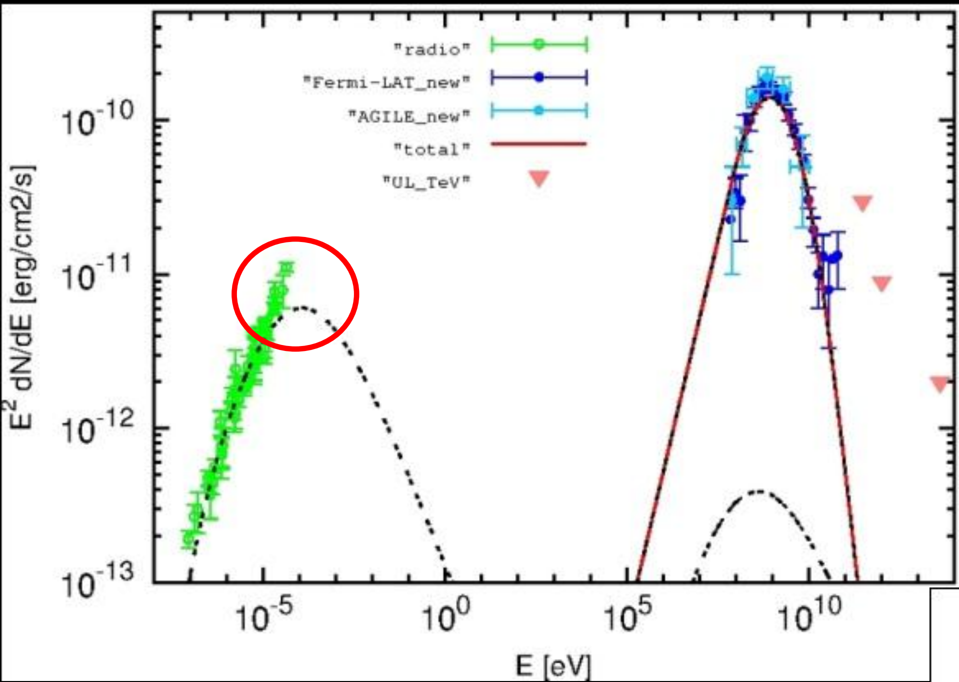
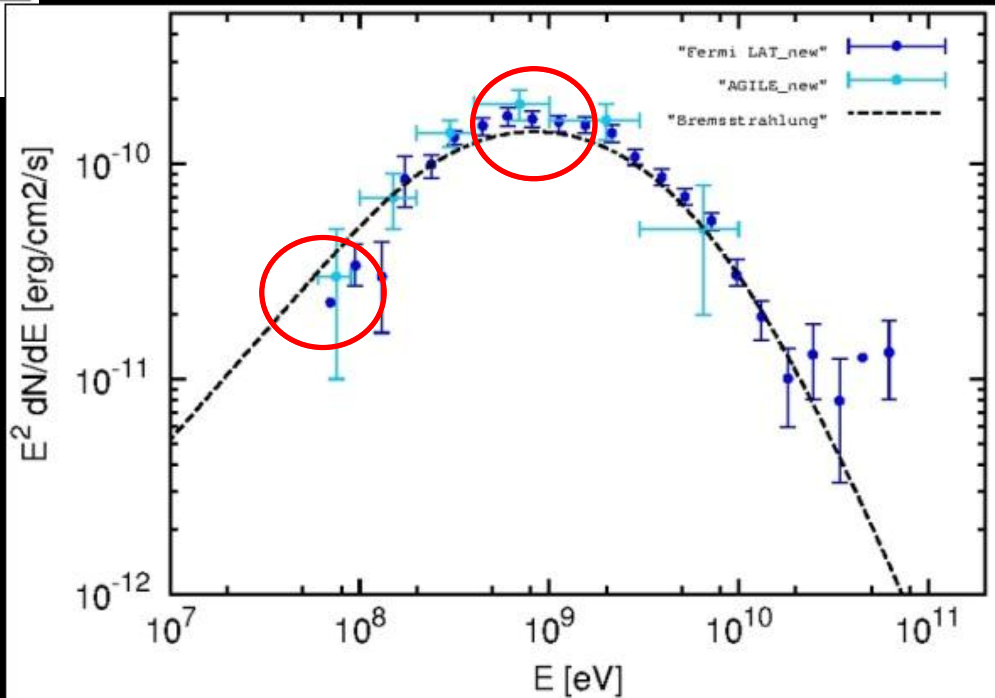
The SNR W44: modelling → leptonic



$$F_e(E) = K_e \left(\frac{E}{E^e_{br}}\right)^{p'_1} \left(\frac{1}{2}\left(1 + \frac{E}{E^e_{br}}\right)\right)^{p'_1 - p'_2} e^{-\frac{E^e_c}{E}}$$

$$p'_1 = 1.74, p_2 = 4.2$$
$$E_{br} = 8.3\ GeV$$
$$E_c = 3.5\ GeV$$



Planck data are very important

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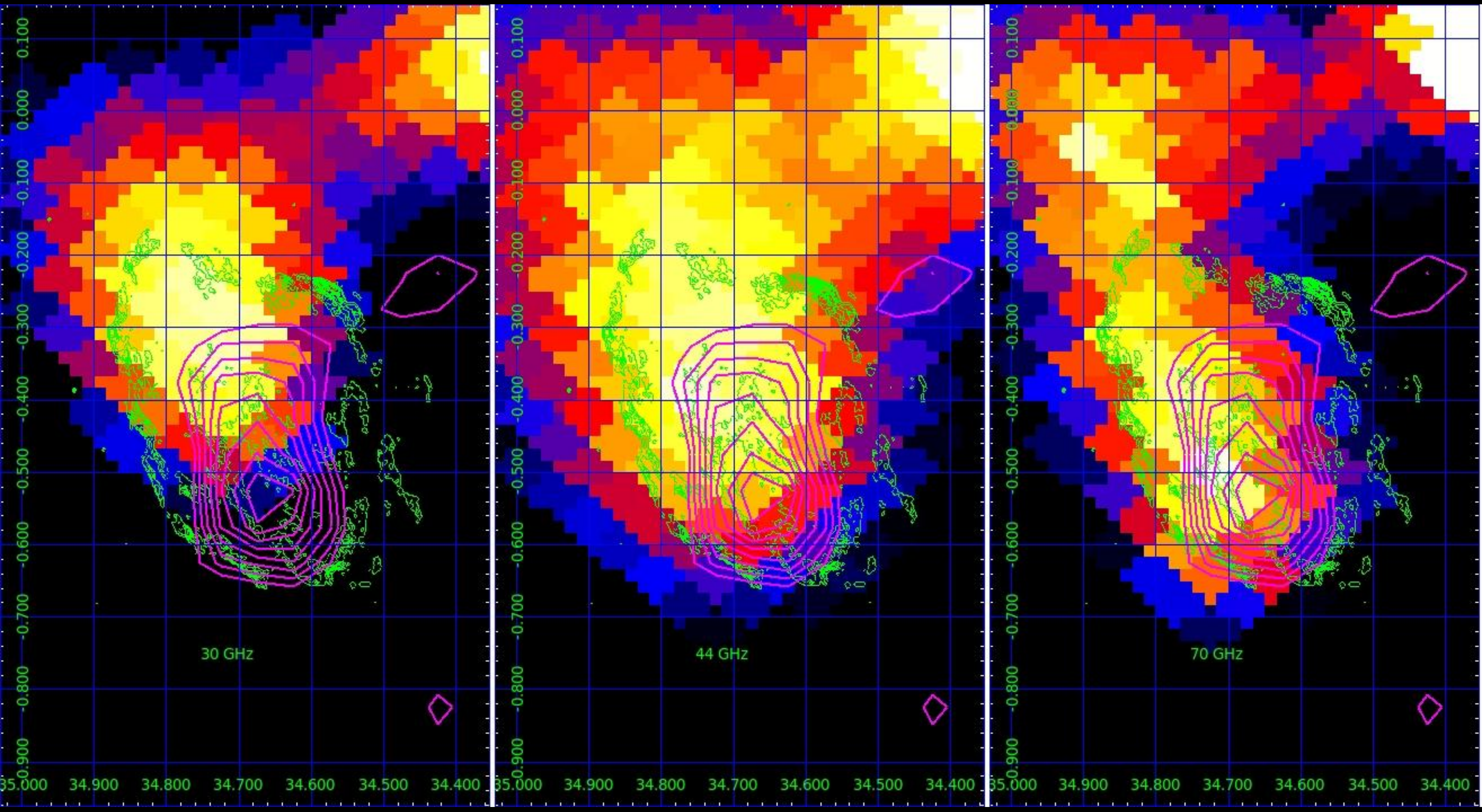
The SNR W44: Planck

30 GHz 44 GHz 70 GHz



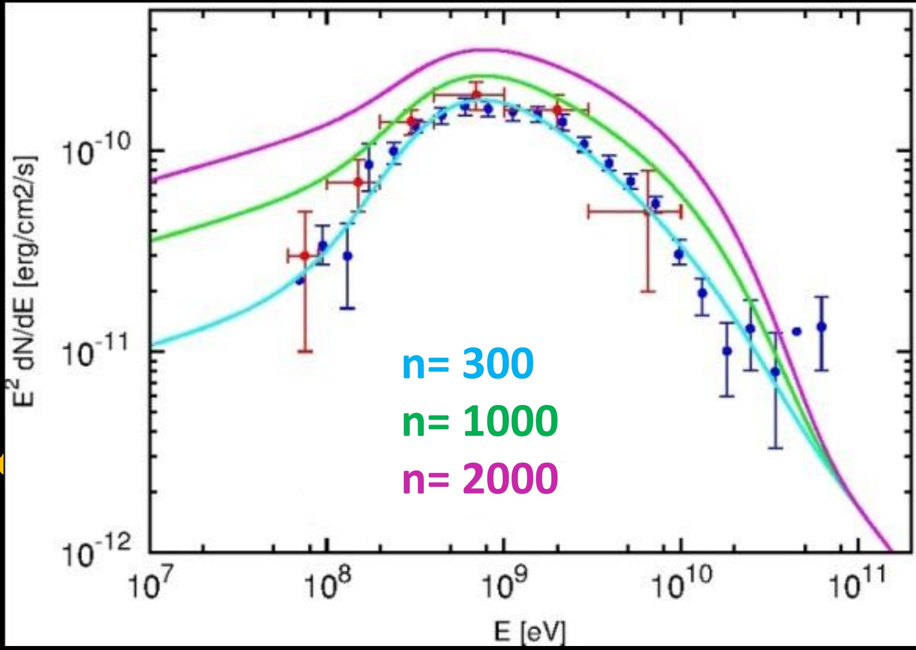
The SNR W44: opening issues

- Low energy cut off:

  * diffusion coefficient suppression (Gabici 2007)

- High density:

  * In all the middle-aged
  SNRs → related to th
  high magnetic field



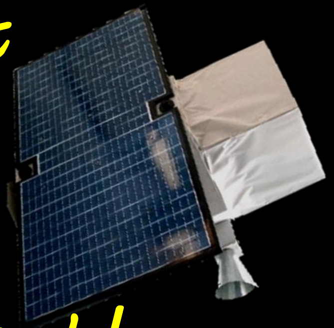
Cardillo et al., in preparation

The SNR W44: opening issues

- High magnetic field:
  - * in the most of the SNRs → compression
  - * differences between young and old
- Steepness:
  - * Alfvèn damping (Malkov 2011) ?

Cardillo et al., in preparation

Conclusions



- W44 is one of the most important sources
- New Fermi and AGILE data confirm the pion signature
- NANTEN2 → high density!
- Modelling: high magnetic field and steepness
- Confirmations and open issues..


Thank you!!