Altro che LHC !
SNRs i veri acceleratori Galattici

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Summary of the Presentation

- **SNR, CR and γ-rays**
- **AGILE SNRs**
  - **IC 443**
  - **W 28**

3 phases in SNR's life

1) Free expansion (less than 200-300 years)

2) Adiabatic or "Taylor-Sedov" phase

(about 20 000 - 40 000 years)

3) Radiative or Snow-plow phase

(up to 500 000 years)

4) ... and then, merge with the ISM

Sedov-Taylor phase

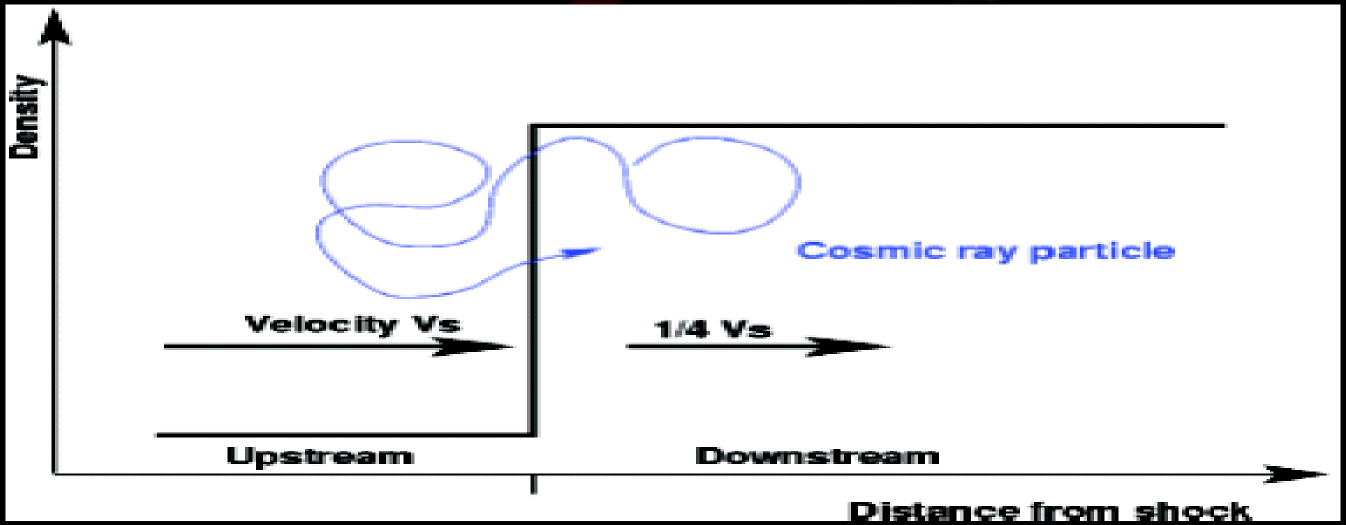
In Sedov-Taylor model one expects thermal emission coming from a thin shell behind the blast wave.

As the shock expands the pressure drops between the shock wave and the material ejected.

R_s=12.4 pc $(KE_{51}/n_1)^{1/5}\ t_4^{\ 2/5}$

At one point, "reverse" shock starts propagating ===> will eventually heat the ejecta (also thermal emission).

Shocks



- Conservation laws: mass, momentum and energy conservation: Use system in which shock is at rest

$$\rho_1 v_1 = \rho_2 v_2$$
$$(\rho_1 v_1)v_1 + p = (\rho_2 v_2)v_2 + p$$
$$(1/2\rho_1 v_1^2 + u)v_1 = (1/2\rho_2 v_2^2 + u)v_2$$

internal energy $u=p/(\gamma-1)$, $\gamma=5/3$ for monatomic gas

- Simplification: heat sinks (cosmic ray acceleration!), magnetic fields, and radiation losses not taken into account.

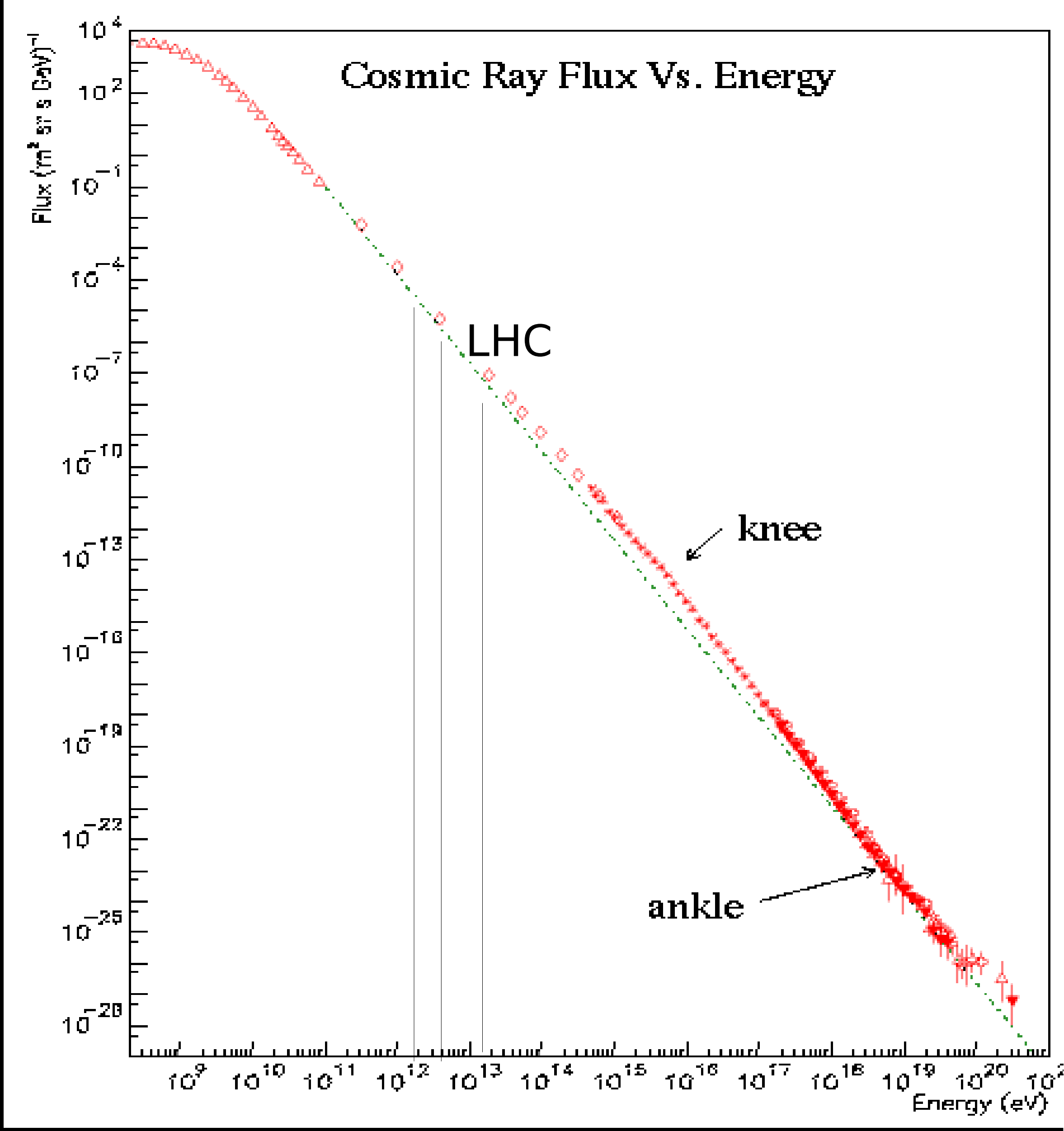
- For strong shocks ($M\rightarrow\infty$) one finds:

$\rho_2/\rho_1 = (\gamma+1)/(\gamma-1) = 4$, implying $v_2 = 1/4 v_s$

$kT_2 = 2(\gamma-1)(\gamma+1)^{-2}\, m\, v_s^2 = 3/16 m\, v_s^2$, with m particle mass

SNRs as accelerators

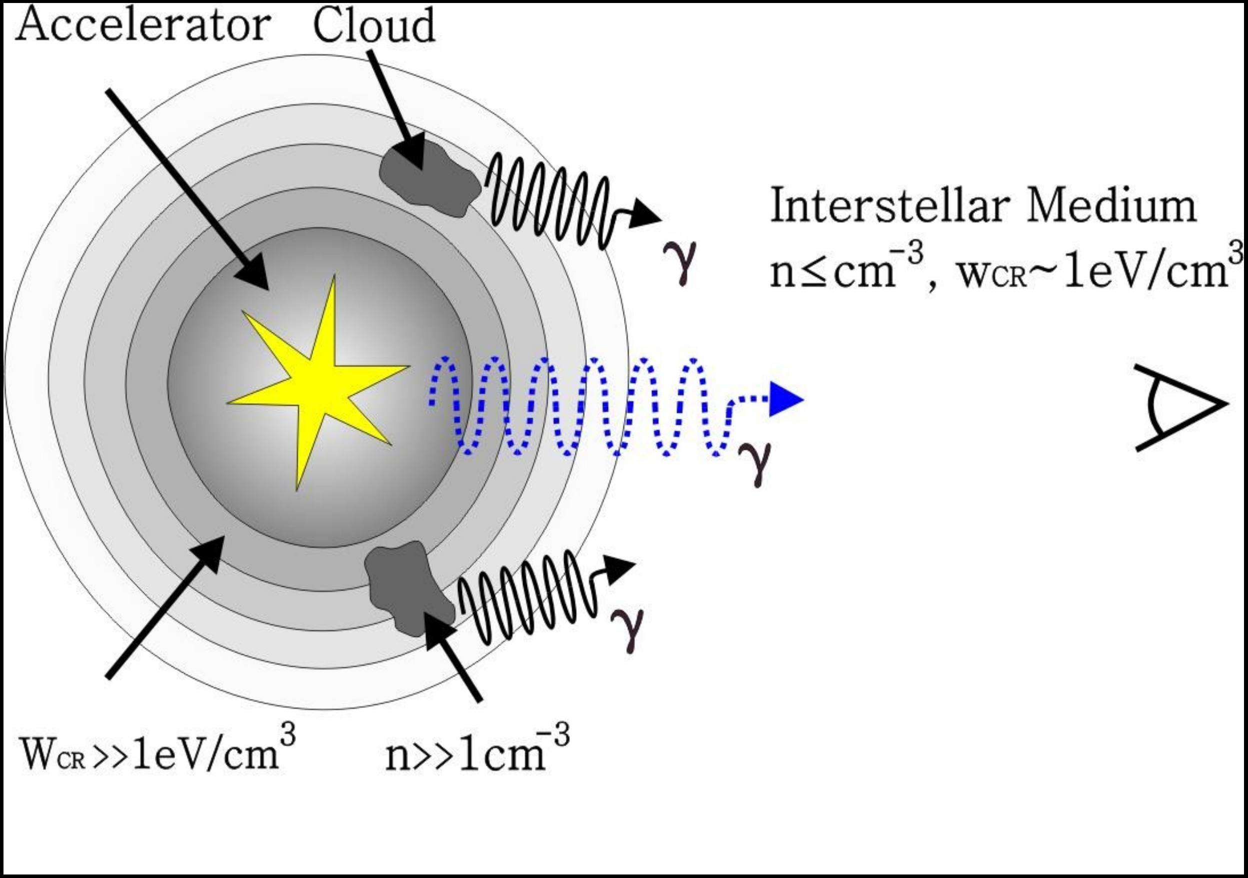
- Shocks
- SNRs accelerate electrons (Radio, X)
- Escape time ~ E $^{0.5 - 0.6}$
- p and e spectrum at Earth



- Protons are also accelerated ?
- Injection spectrum ?

diffusion coeff D(E) ?

SNRs in gamma-rays



Bright gamma-ray sources:

Inverse Compton : **electrons + ISRF photons → γ rays**

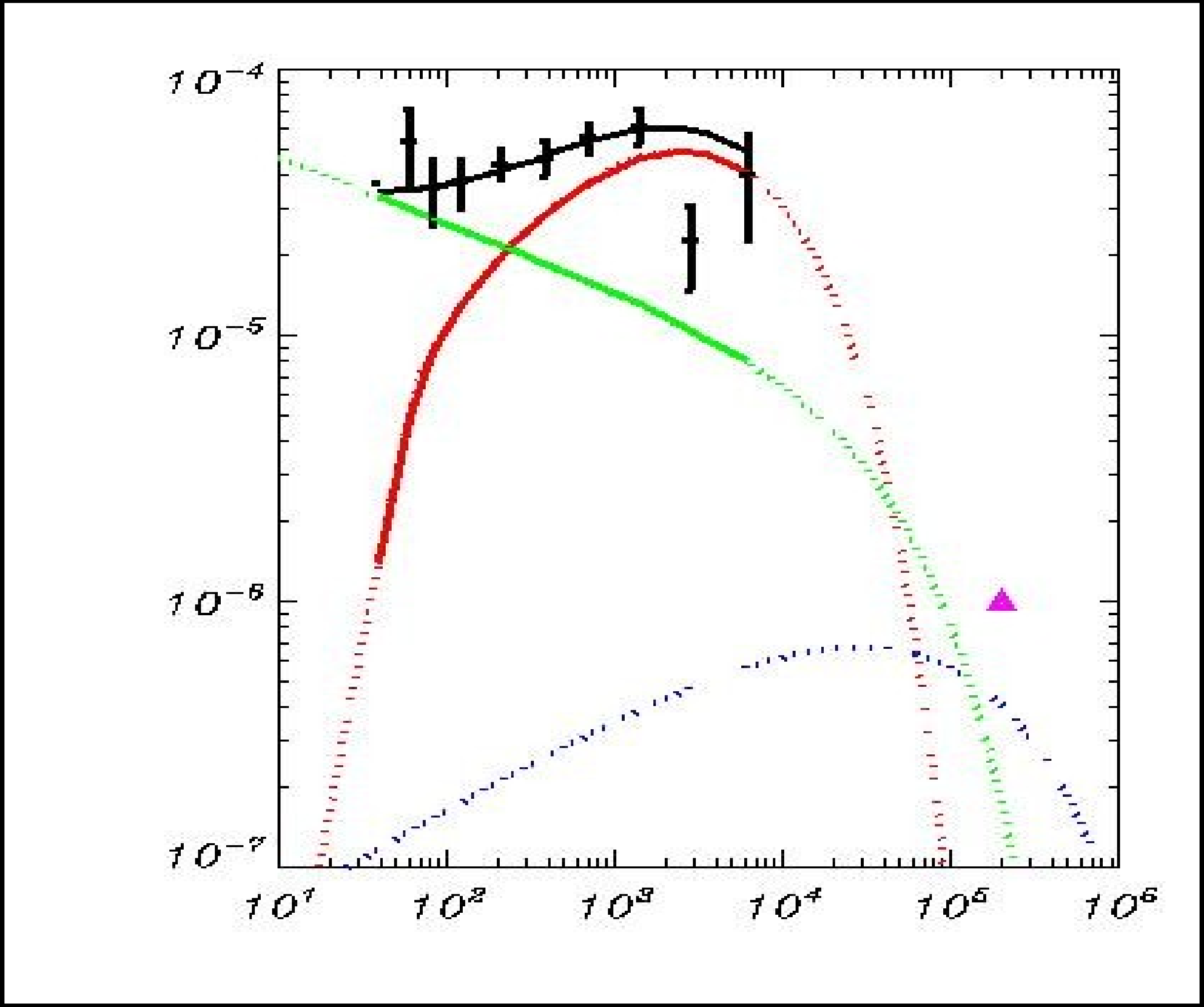
Electron Bremsstrahlung: **electrons + ISM nuclei → γ rays**

Neutral π decay **: protons + ISM nuclei → π^0 → γ rays**

SNRs in gamma-rays

3 component in the gamma-ray spectrum

The hadronic component peaks @ GeV energies

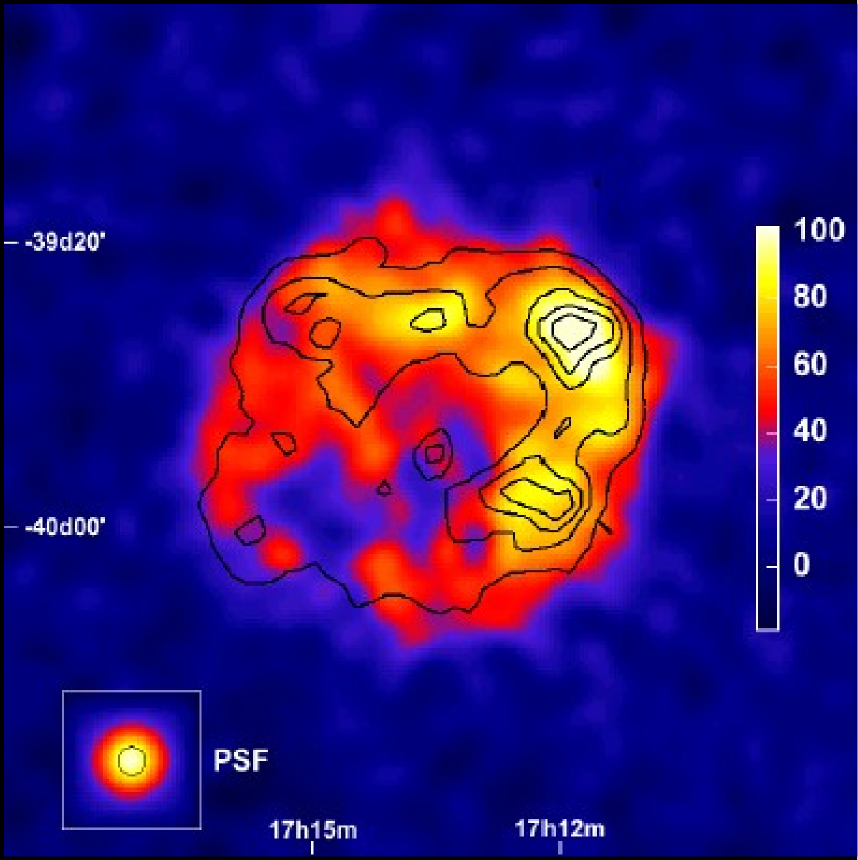


SNRs in gamma-rays

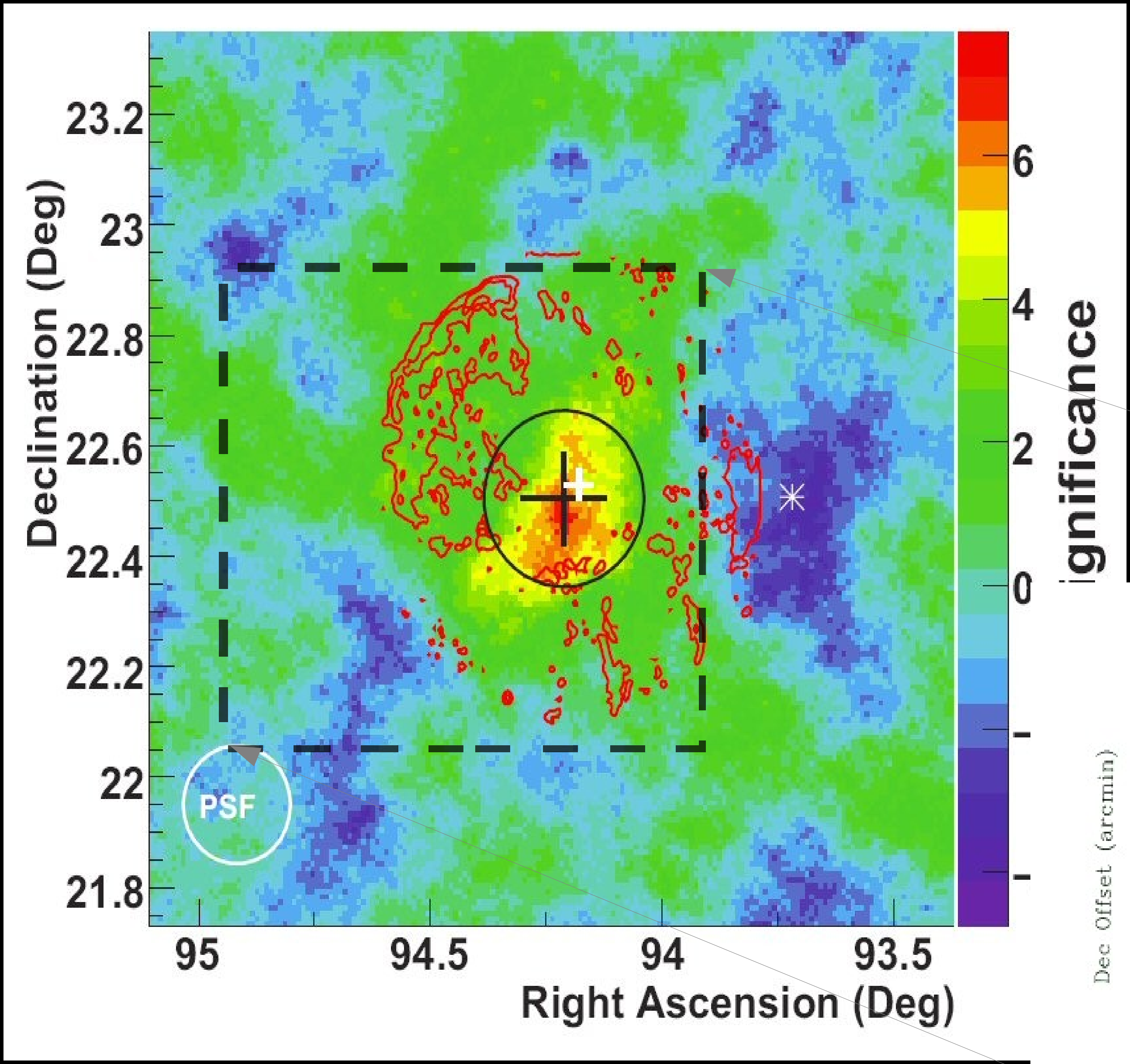
Gamma Luminosity ~ 10^{36-37} erg/s

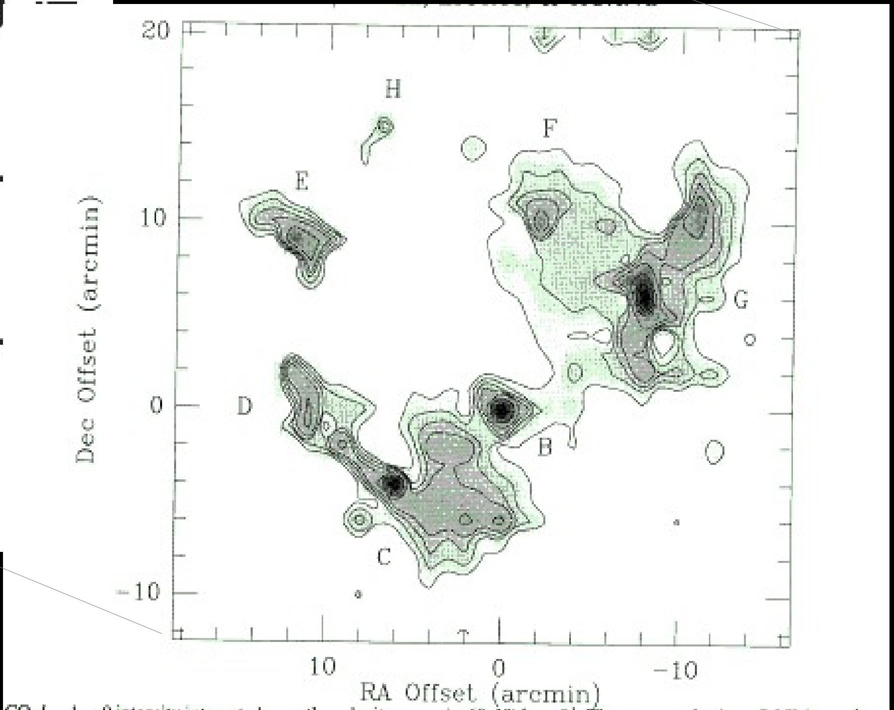
No time signature (No variability)

--> Easy to detect, hard to identify !



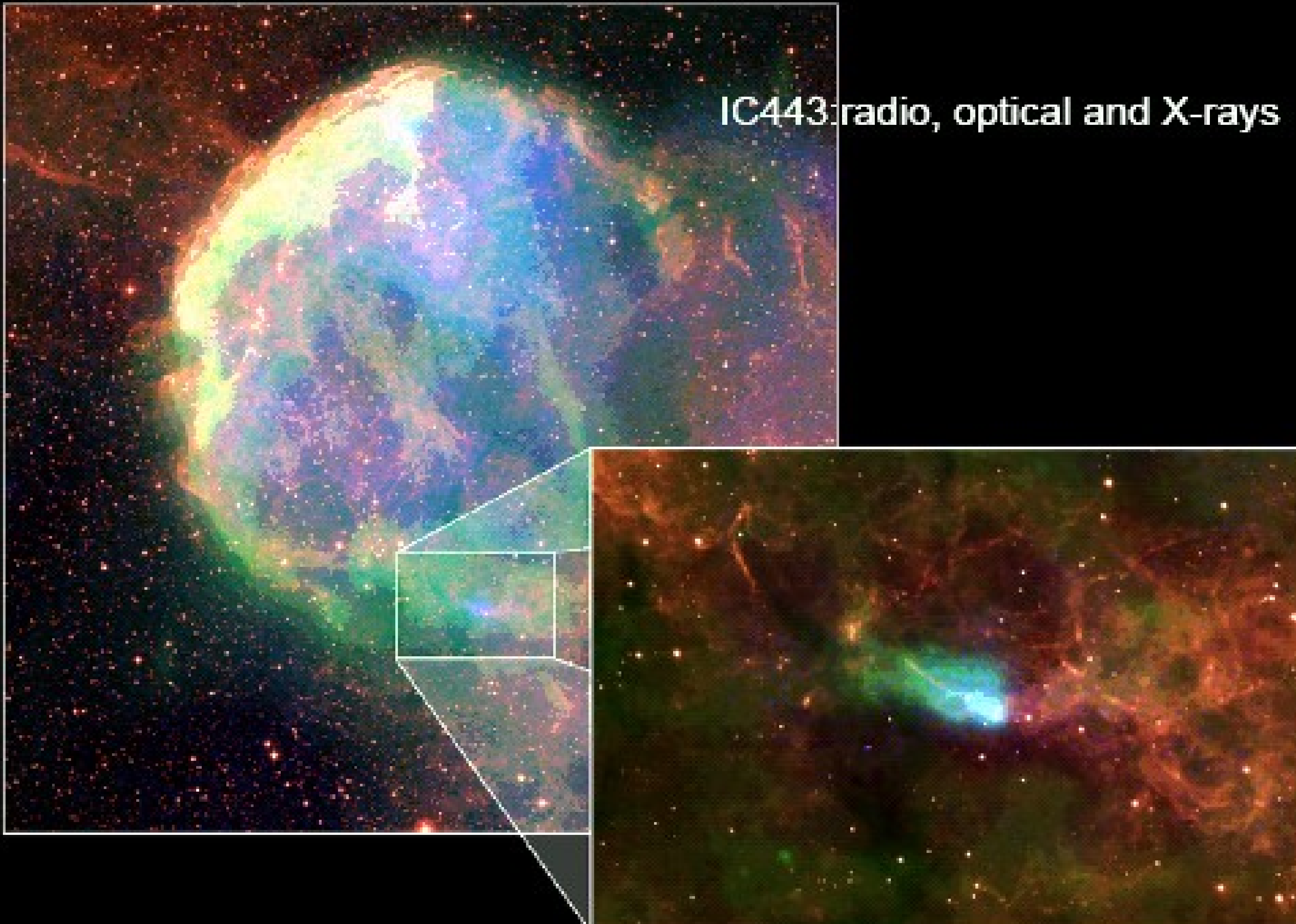
IC 443 – TeV detection by VERITAS



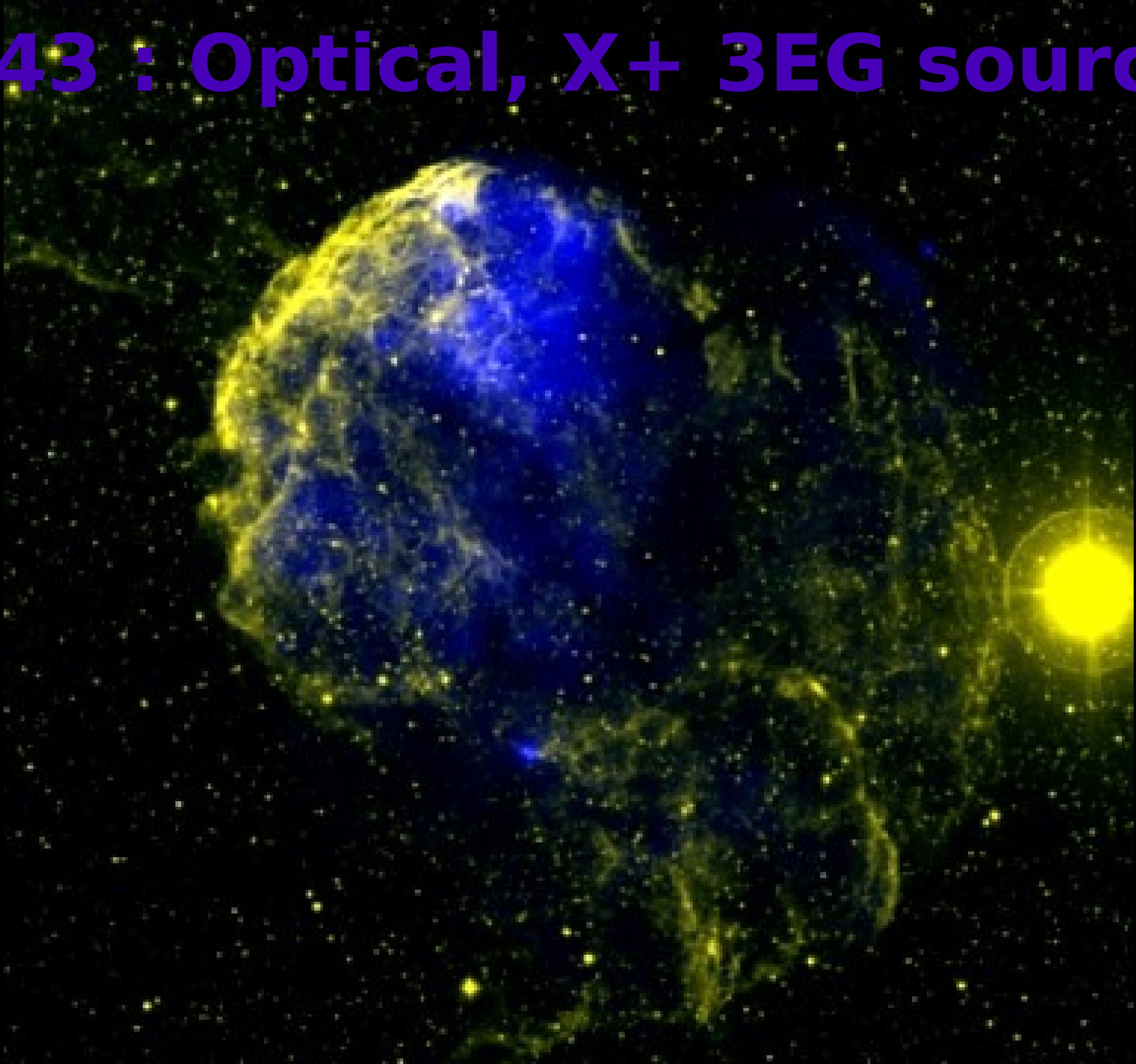


Acciari et al. 2009

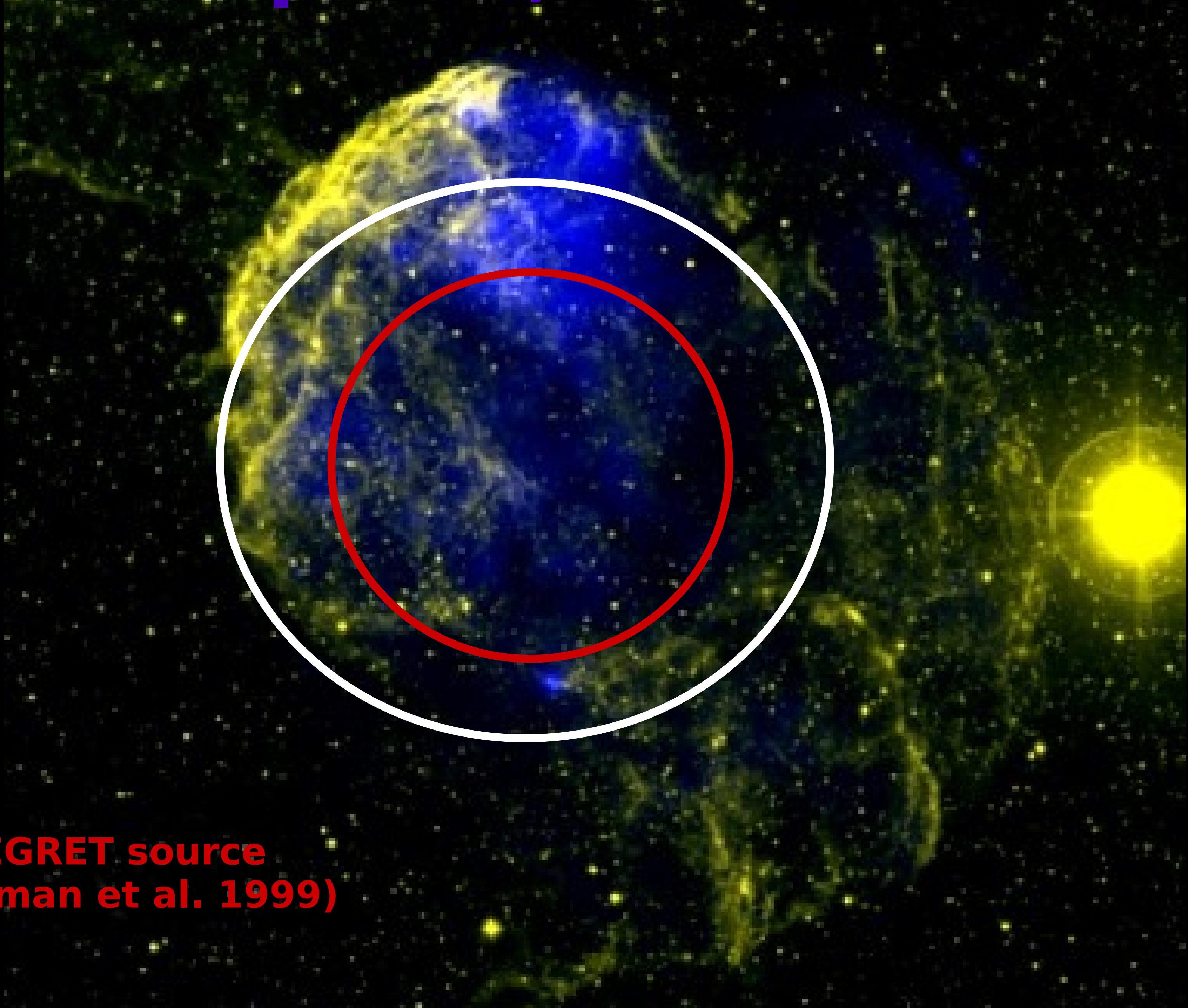
IC443:radio, optical and X-rays



IC 443 : Optical, X+ 3EG source

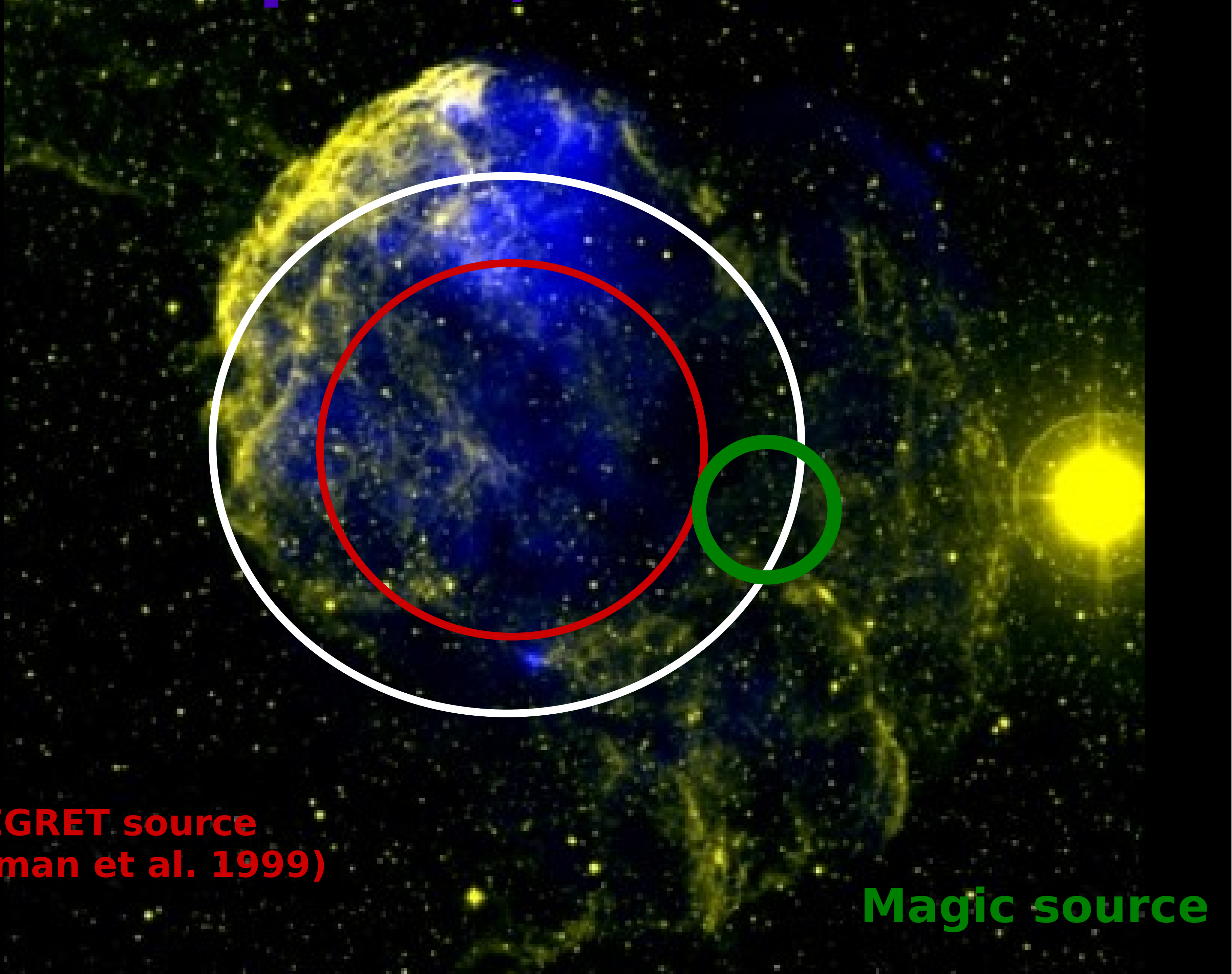


IC 443 : Optical, X+ 3EG source

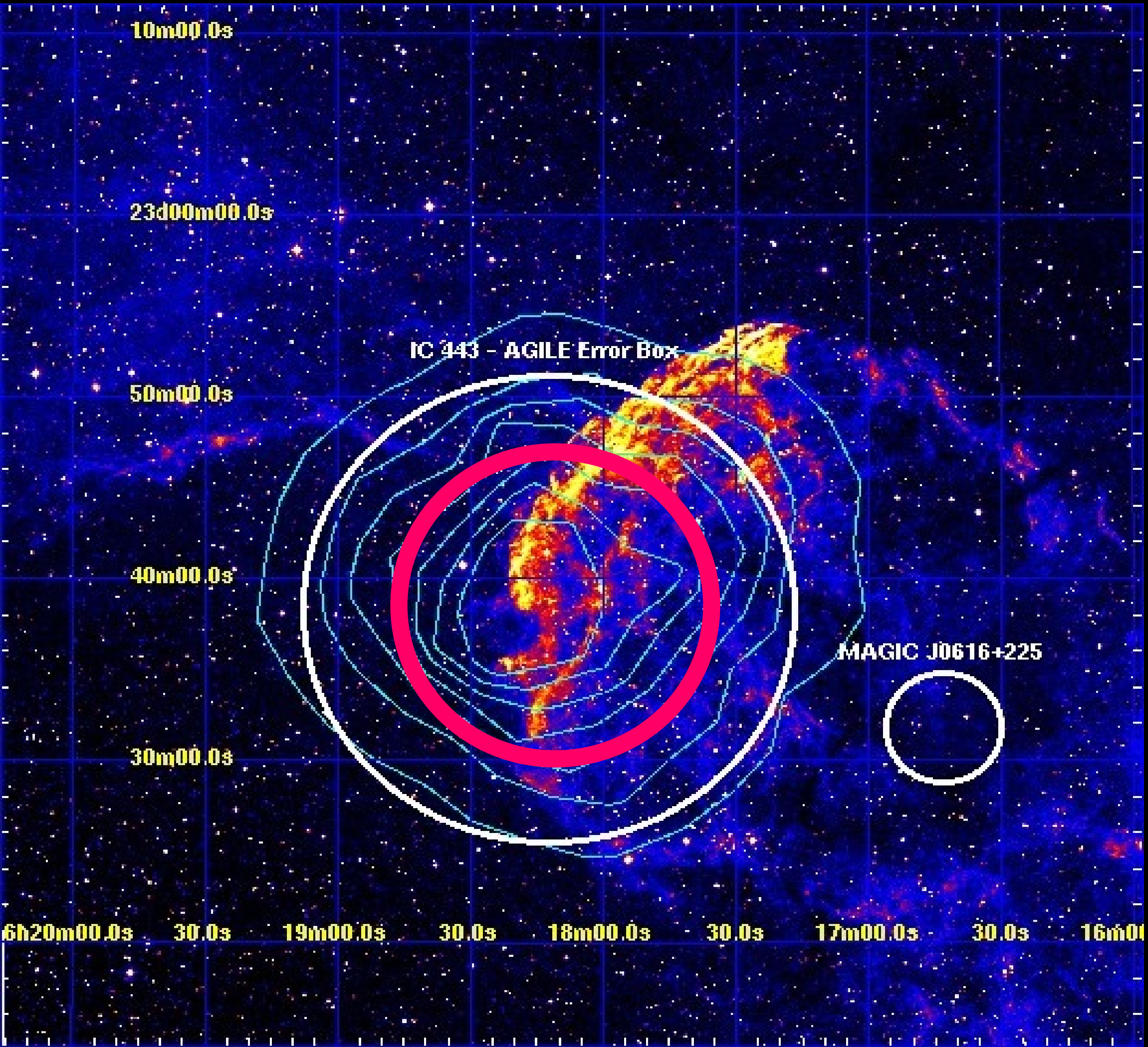


3EG EGRET source
(Hartman et al. 1999)

IC 443 : Optical, X+ 3EG source



IC 443 seen by AGILE (2008)



Gev Source

≠

TeV Source

Diffusion of CR in the ISM

$$\frac{\partial f(E,r)}{\partial t} = D(E)\frac{1}{r^2}\frac{\partial}{\partial r}r^2\frac{\partial f(E,r)}{\partial r} + \frac{\partial}{\partial E}P(E)f(E,r) + Q(E,r)$$

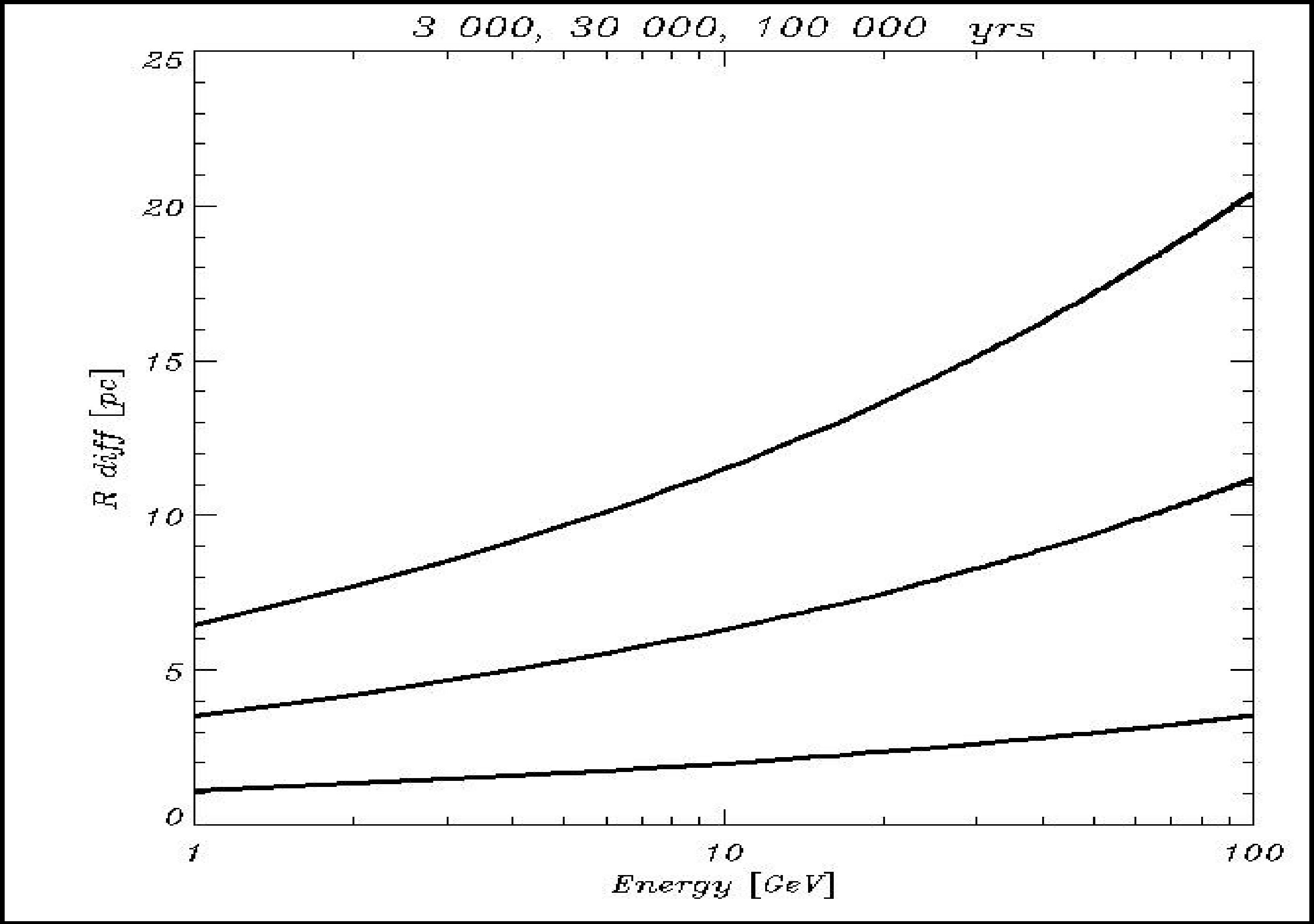
$$R_{diff} = 2\sqrt{Dt}$$

Aharonian & Atoyan, A&A, 309, 1996

Diffusion Coef :

$D(E)=10^{26}$ (E/10 GeV)$^{0.5}$ --> t~sqrt(E)

Diffusion of CR in the ISM

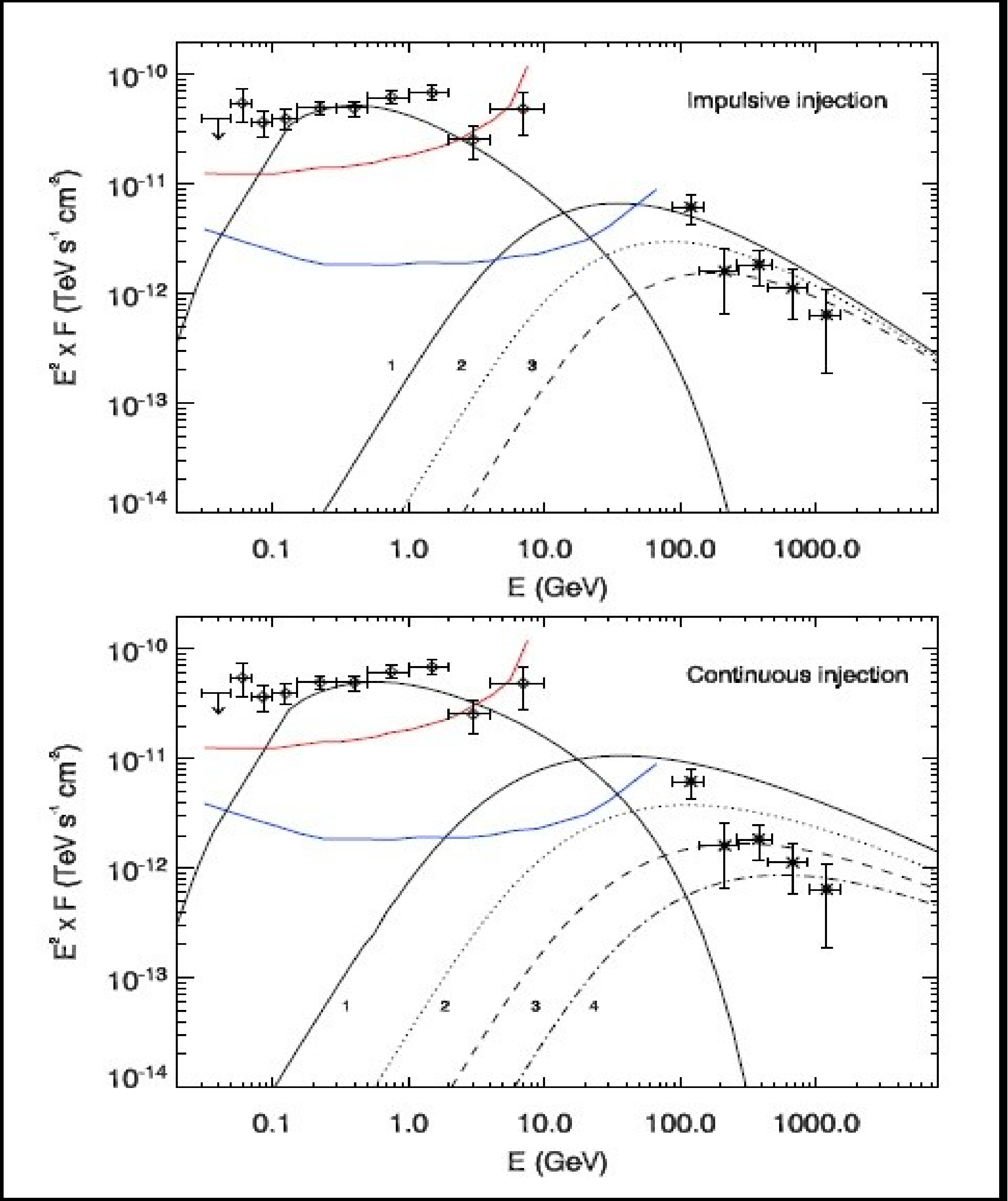


Diffusion Coef :

$D(E)=10^{26}$ $(E/10\ GeV)^{0.5}$ --> t~sqrt(E)

IC 443: EGRET vs. MAGIC data

Impulsive vs. continuous injection



Torres et al., MNRAS, 08

Conclusion for IC 443

EGRET detected SNRs (and AGILE can identify them)

GeV and TeV emissions can be displaced

Diffusion in the ISM have to be taken into account

Hadronic scenario is favoured

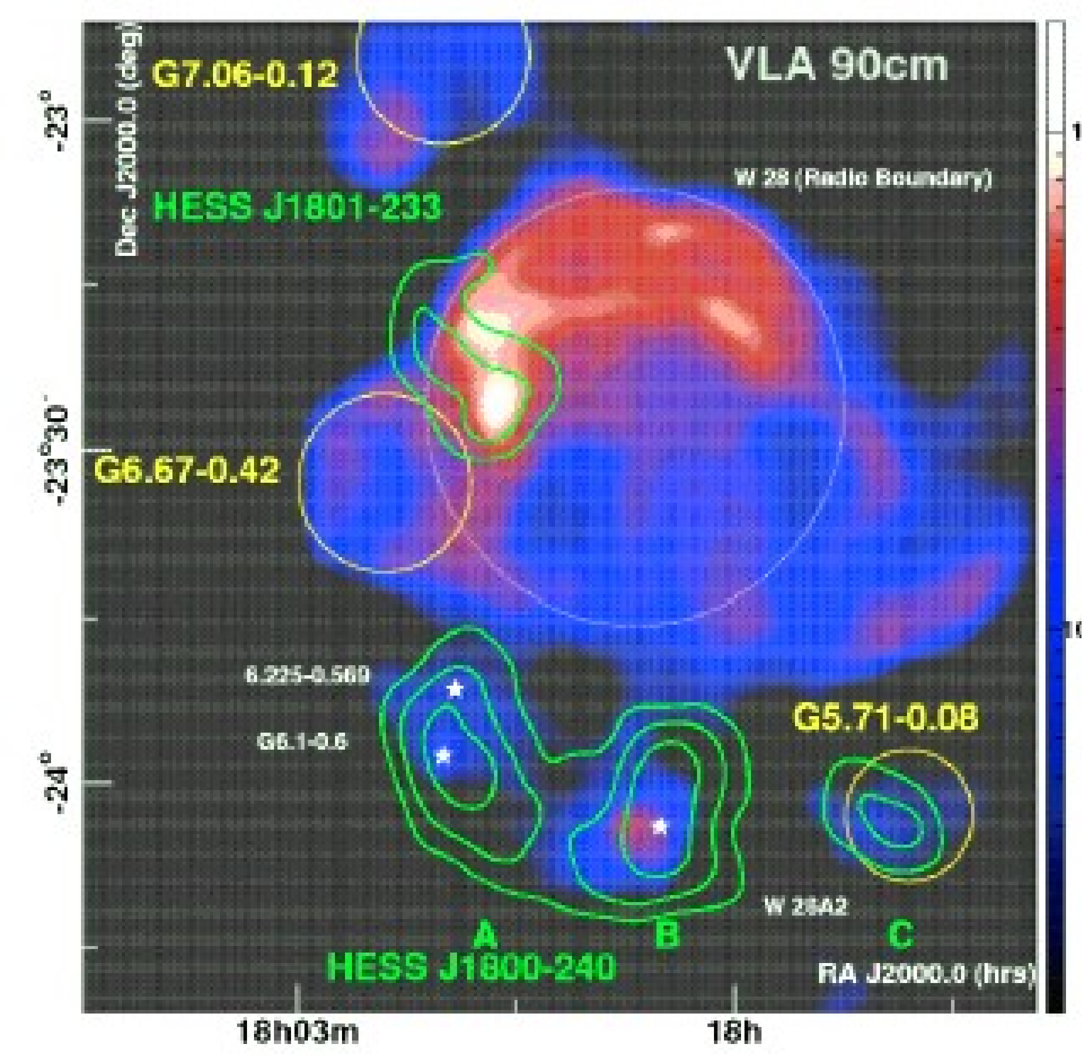
SNR W 28

Distance : 2 – 3 kpc

Age : > 35 yrs

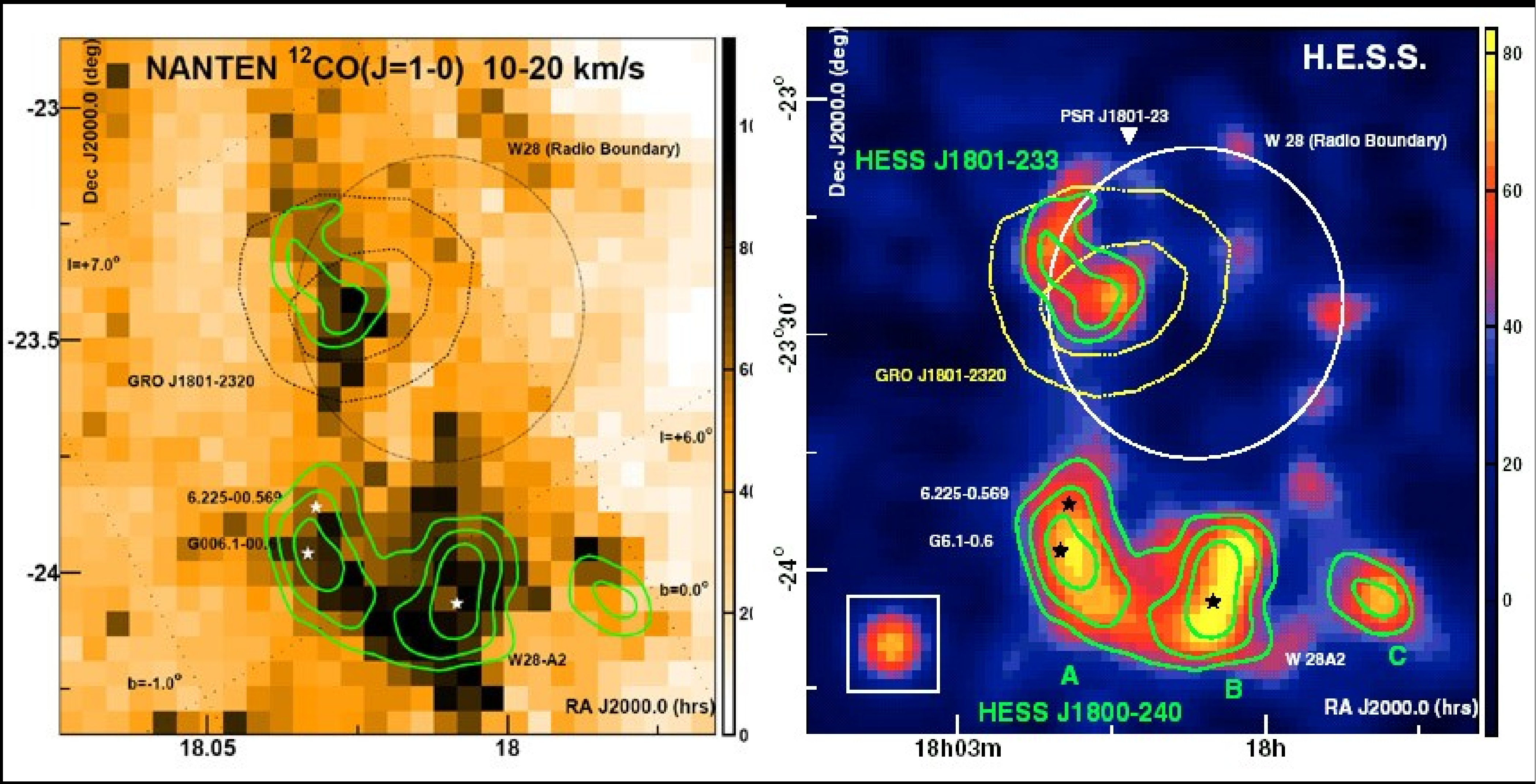
Size : 20-35 pc (50')

Mixedmorphology SNR



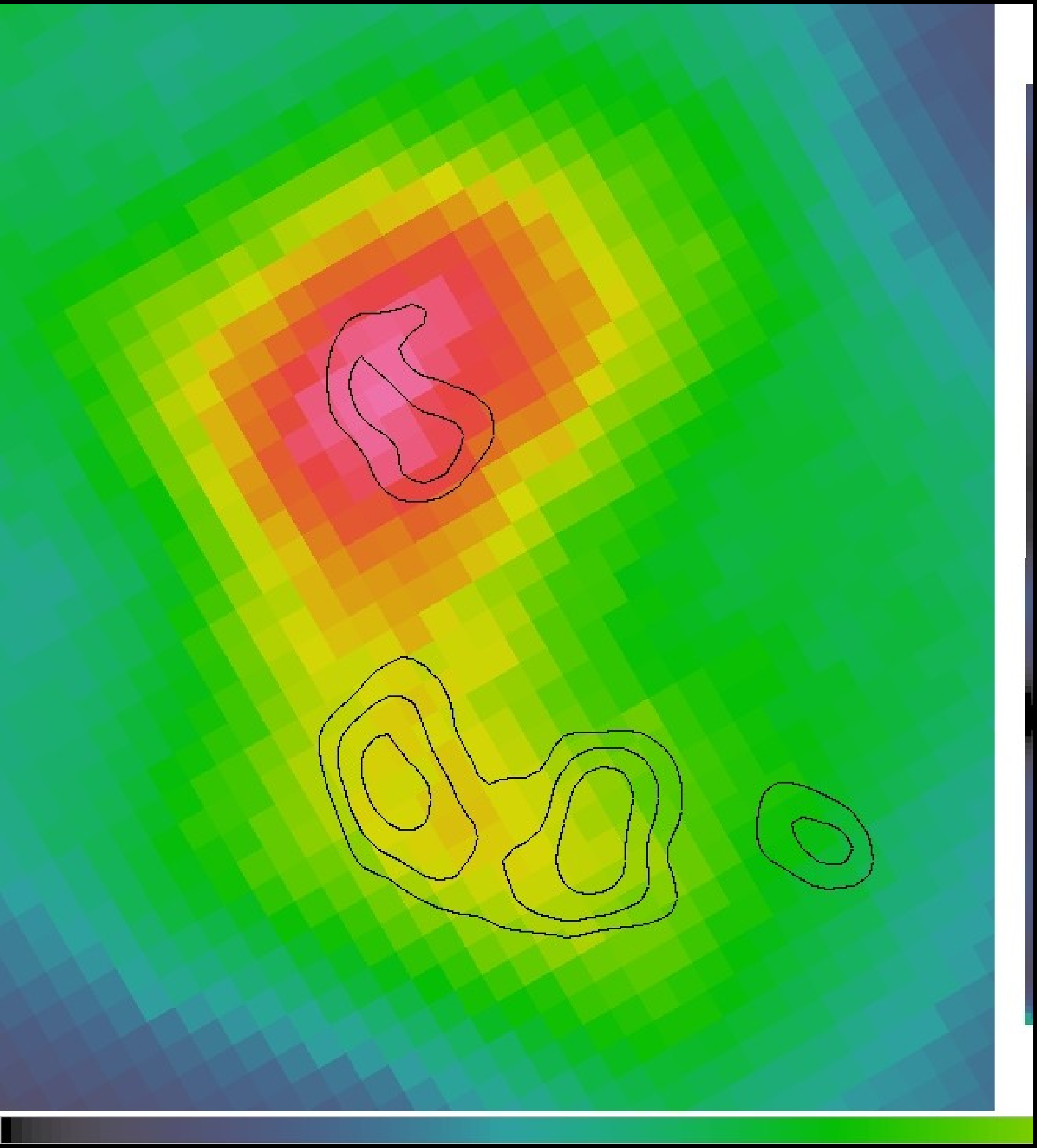
from **Aharonian et al. 2008**

SNR W 28 : M.Clouds and TeV



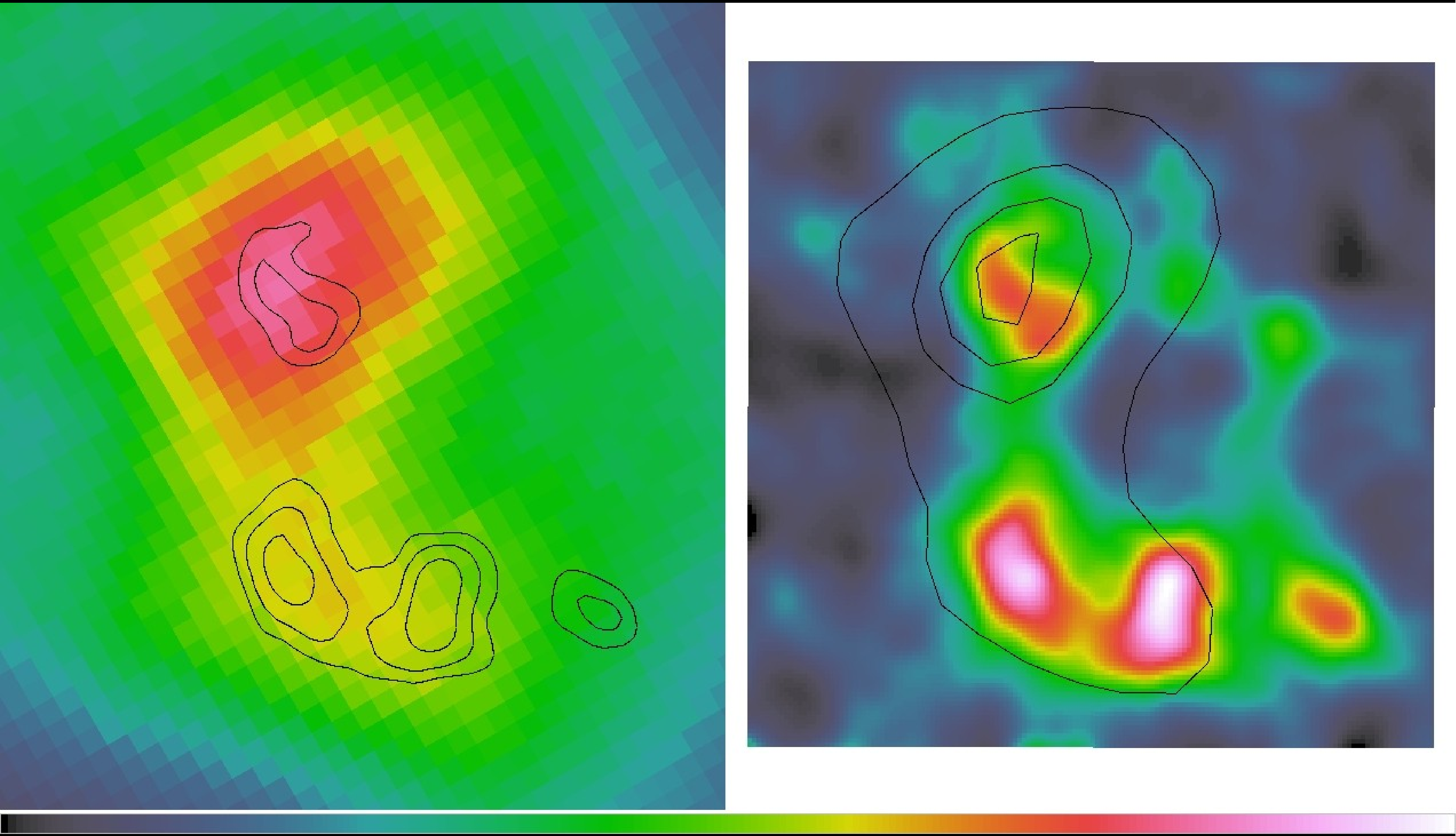
from **Aharonian et al. 2008**

AGILE/GRID Observations E>400 MeV (+HESS contours)



AGILE/GRID Observations
E>400 MeV (+HESS contours)

HESS signif. map
(+ AGILE contours)



AGILE/GRID Observations
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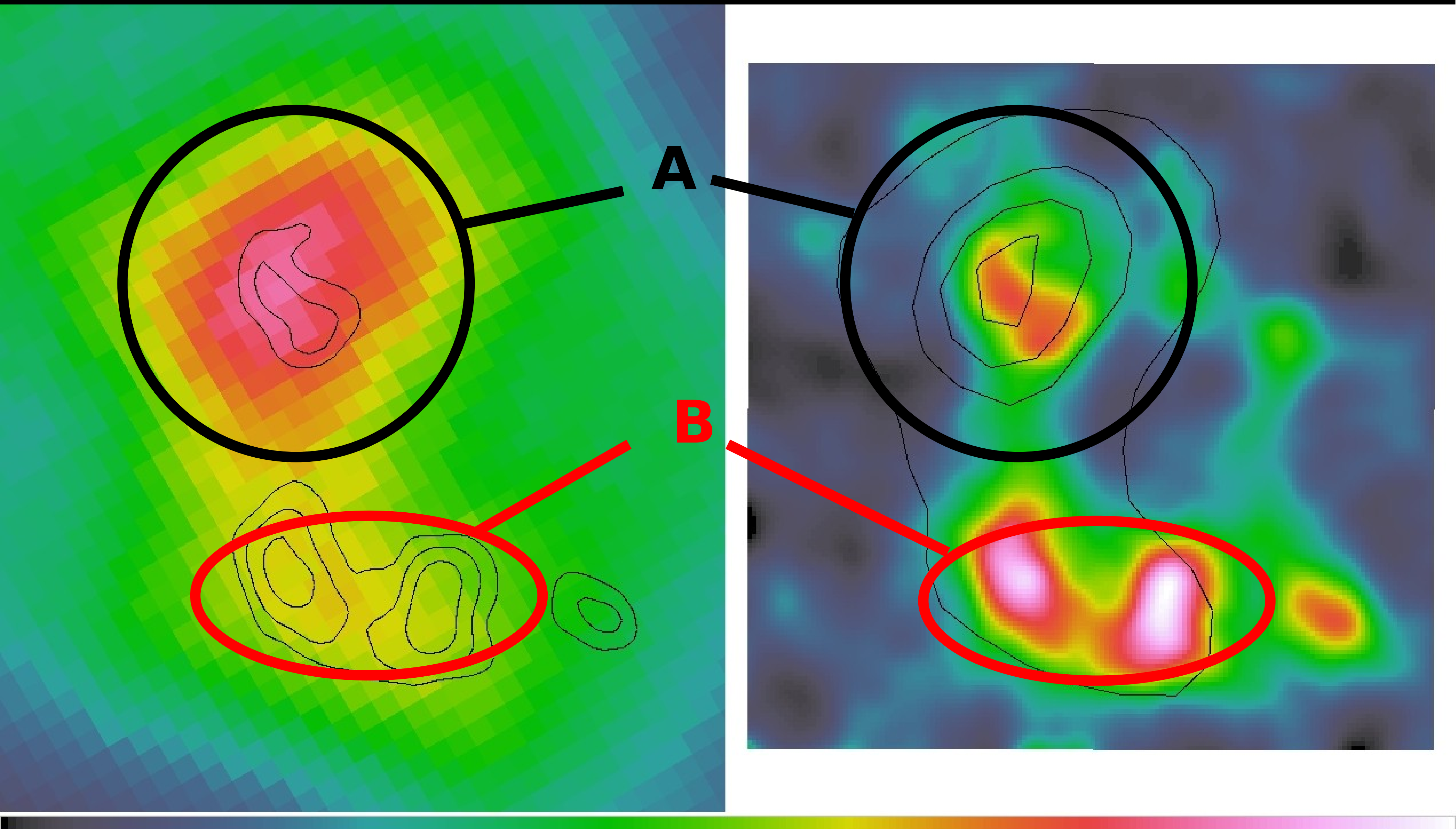
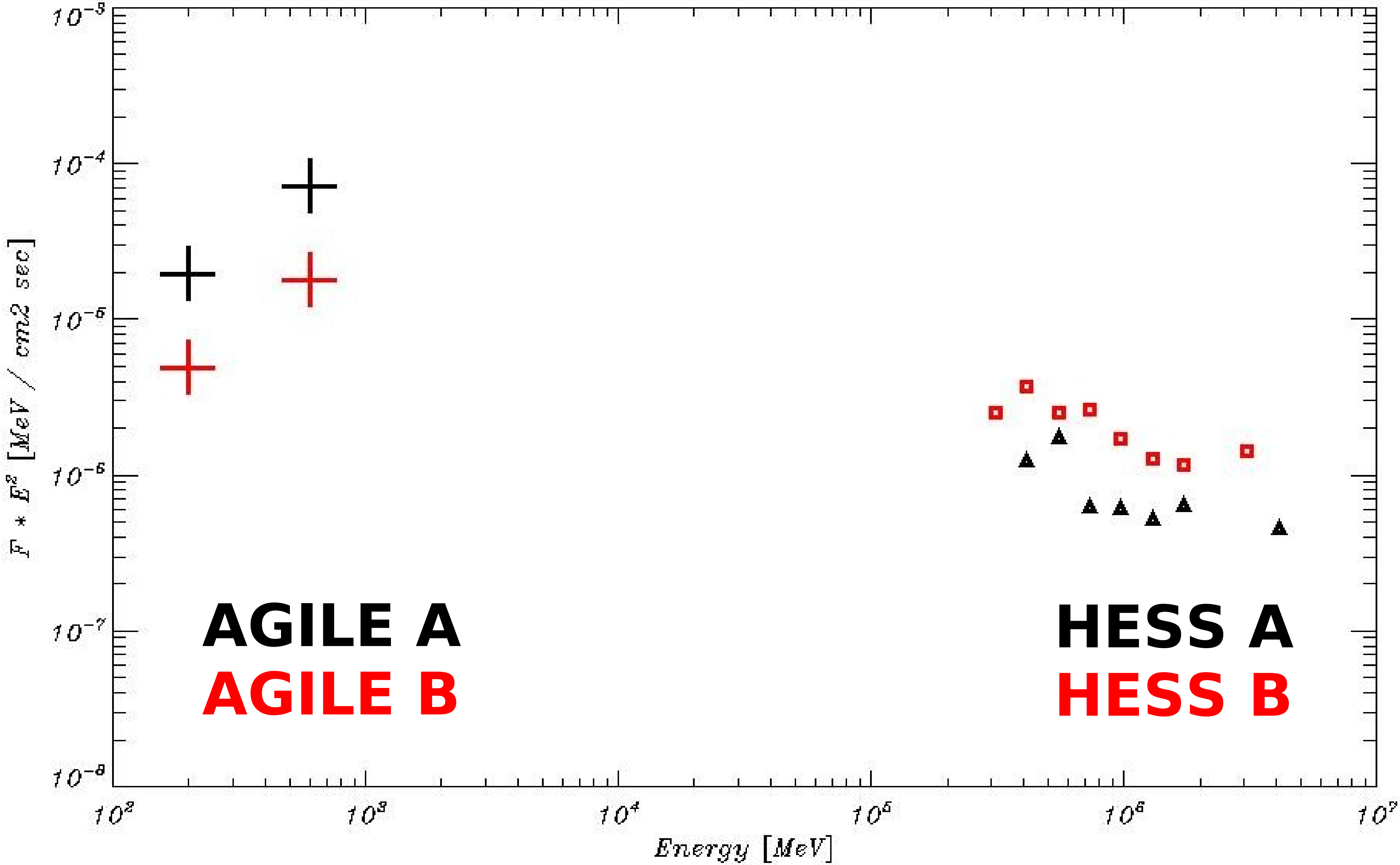




10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
$F * E^2$ [MeV / cm2 sec]
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
Energy [MeV]
AGILE A
AGILE B
HESS A
HESS B

Model for W 28

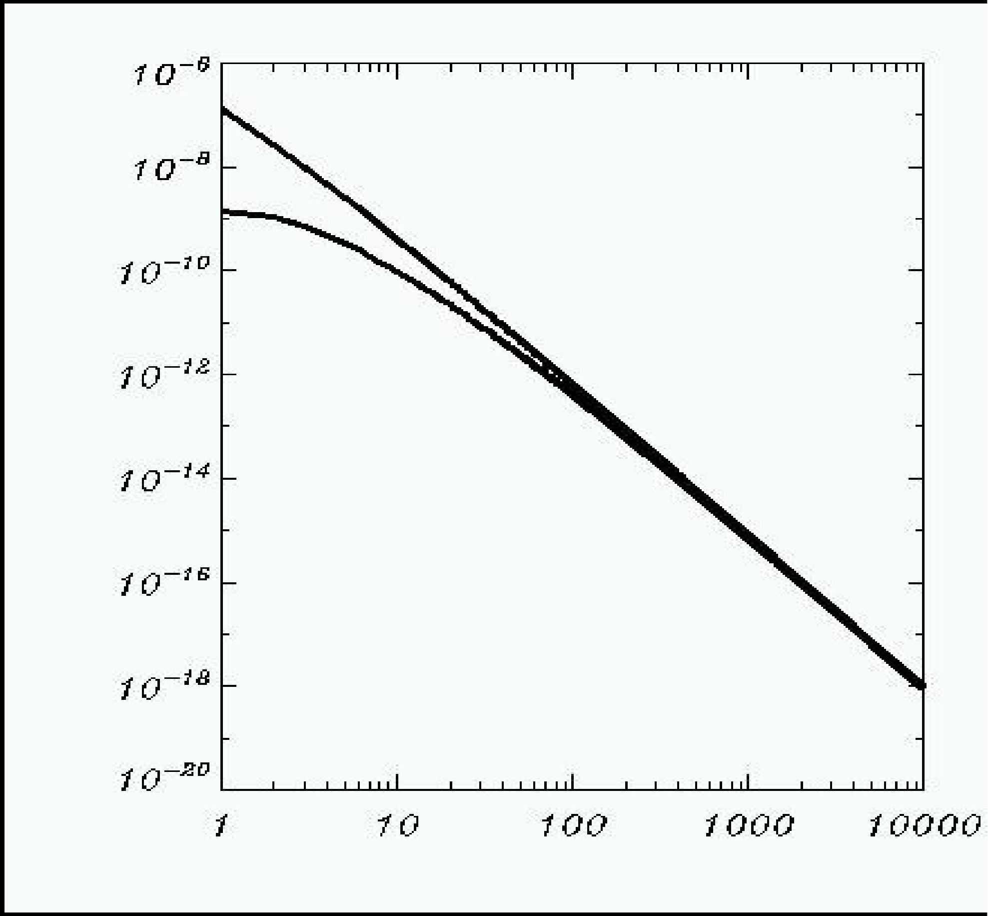
Gamma ray by
π^0 decay

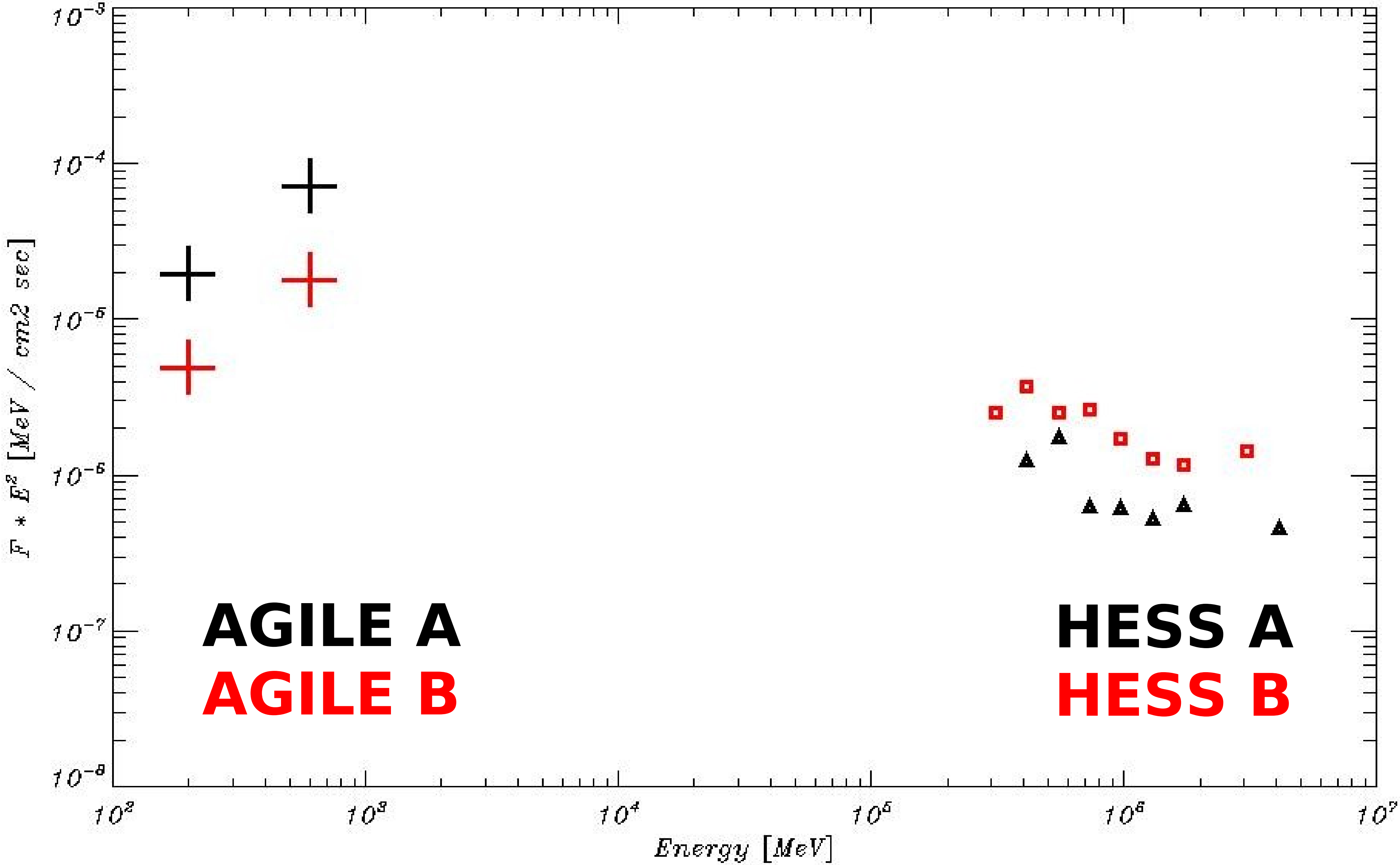
Proton spectrum @ SNR :
$F \sim E^{-2.2}$

Diffussion :
$D = 10^{26}$ (E/10 GeV)$^{0.5}$

Distances of targets:
A region : 5 pc
B region : 10 pc

Age of the SNR : 45 kyrs





10^{-3}
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$F * E^2$ [MeV / cm2 sec]
10^2
10^3
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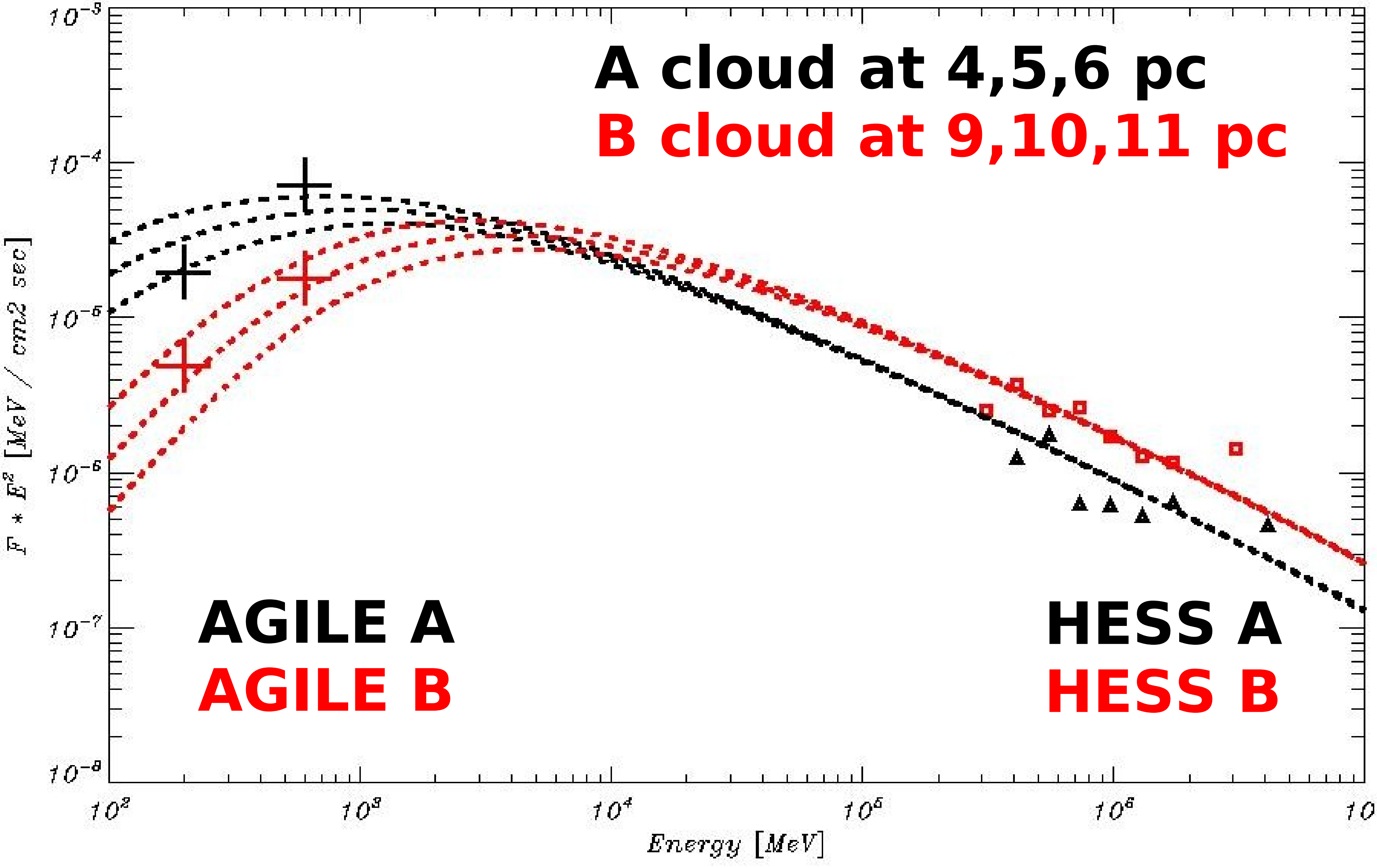
10^7
Energy [MeV]
AGILE A
AGILE B
HESS A
HESS B

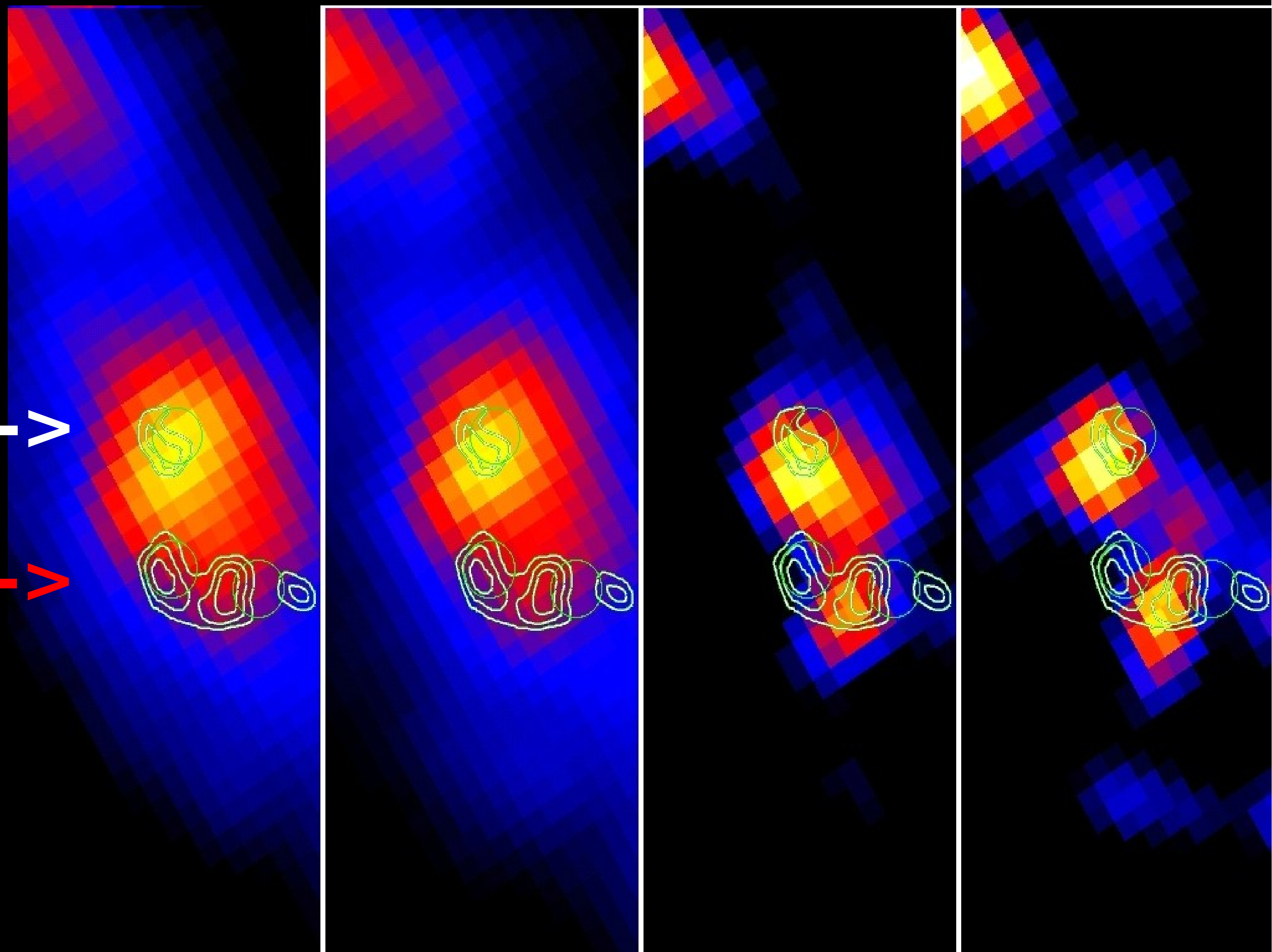


Giuliani et al. 2009 in prep.

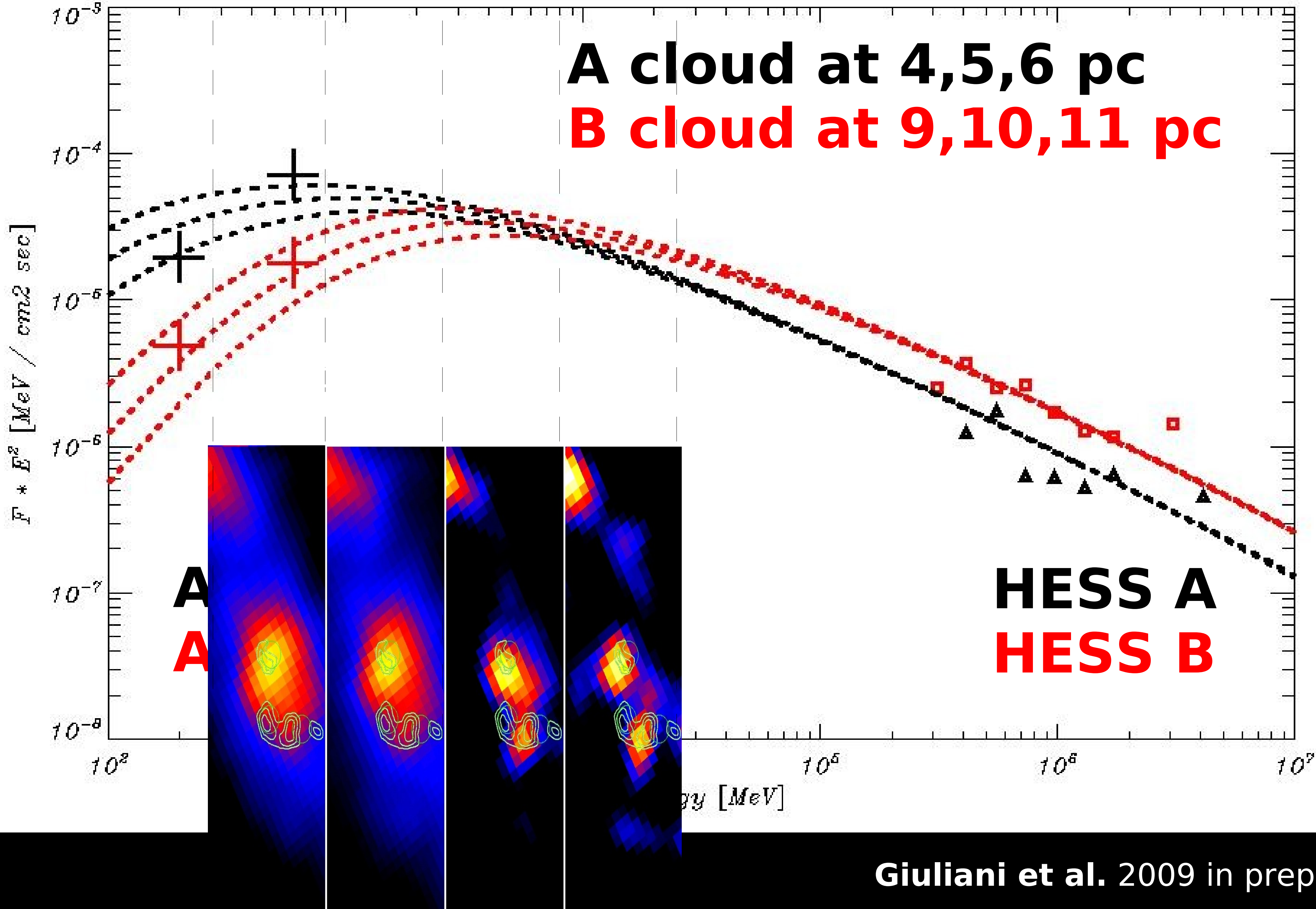
Fermi Observations (preliminar)

Region A ->

Region B ->



E = 500 MeV E=1.5 GeV E=5 GeV E=15 GeV



Giuliani et al. 2009 in prep.

Conclusion for SNR W 28

SNRs appear diferent in GeV and TeV band

It seems to be a common feature (at least for midle age SNRs)

Gamma observations (GeV+TeV) can give constrains on the CR diffusion coeficient

Strong indication of an hadronic scenario

Conclusions

- SNRs are finally resolved in the MeV-GeV energy range
- Clear correlation between 100 MeV-GeV emission and shocked Molecular Clouds (IC 443, W 28, RX J1713)
- Apparent flux anticorrelation between 100 MeV -Gev and TeV bands
- GeV and TeV connection is crucial to understand the SNRs physics