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Development of a simple modeling for SNR

- **Fit of the spectrum** of some SNR published by Fermi-LAT collaboration
- **Systematic study** of the SED of SNRs

PROCESSES INVOLVED

Synchrotron Radiation

$$Q_\gamma(\omega) = \frac{\sqrt{3}Be^3}{2\pi m_e c^2}\frac{4\pi}{\beta c}\int \frac{dN_e}{dE_e} R\left(\frac{\omega}{\omega_c}\right) dE_e$$

[Zirakashvili, V.N. Aharonian, F., 2007, AA, 465, 695]

Inverse Compton Radiation

$$Q_\gamma(E_\gamma) = \int \frac{dN_e}{dE_e} dE_e \int n(E_s)\sigma_{K-N}(E_s, E_e, E_\gamma) dE_s$$

[Sturner, S.J., Skibo, J.G., Dermer C.D., Mattox J.R., 1997, ApJ, 490, 619]

Bremsstrahlung

$$Q_\gamma(\varepsilon) = 4\pi n_H \int \frac{dN_e}{dE_e}\frac{d\sigma_{B-H}}{d\varepsilon} dE_e$$

[Baring, M.G., Ellison, D.C., Reynold, S.P., Grenier, I.A., Goret, P., 1999, ApJ, 513, 311]

Hadronic production

$$Q_\gamma(E_\gamma) = \frac{4\pi}{\beta c} n_H \int \frac{dN_p}{dE_p}\frac{d\sigma(E_p / E_\gamma)}{dE_\gamma} dE_p$$

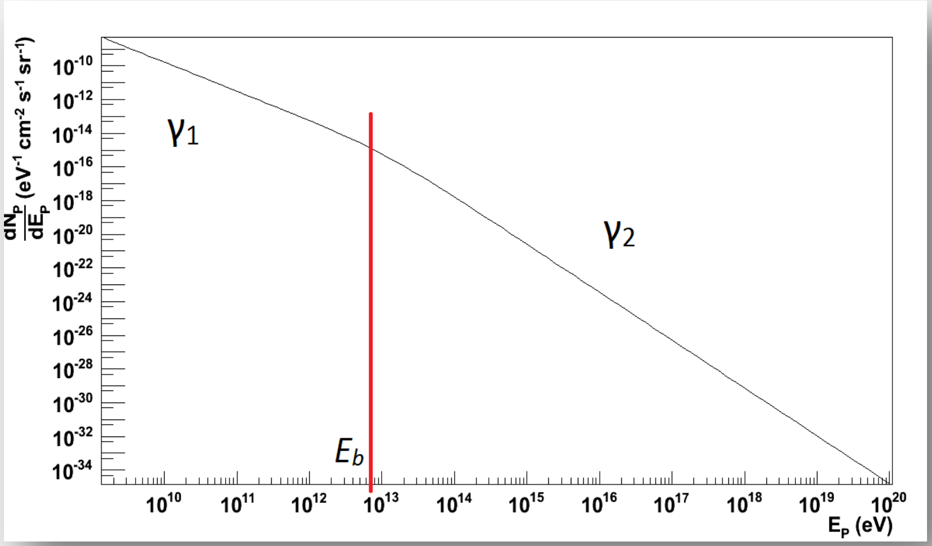
[Kamae, T., et al. 2006, ApJ, 647, 692]

Injection of Particles

We assumed the same broken power law to describe the population of protons and electrons accelerated:

$$\frac{dN}{dE} = A\left(\frac{E}{E_0}\right)^{-\gamma_1}\left[1+\left(\frac{E}{E_b}\right)^{\frac{(\gamma_2-\gamma_1)}{\gamma_3}}\right]^{-\gamma_3}$$

- $E_0 = 1$ GeV
- $\gamma_3 = 1$



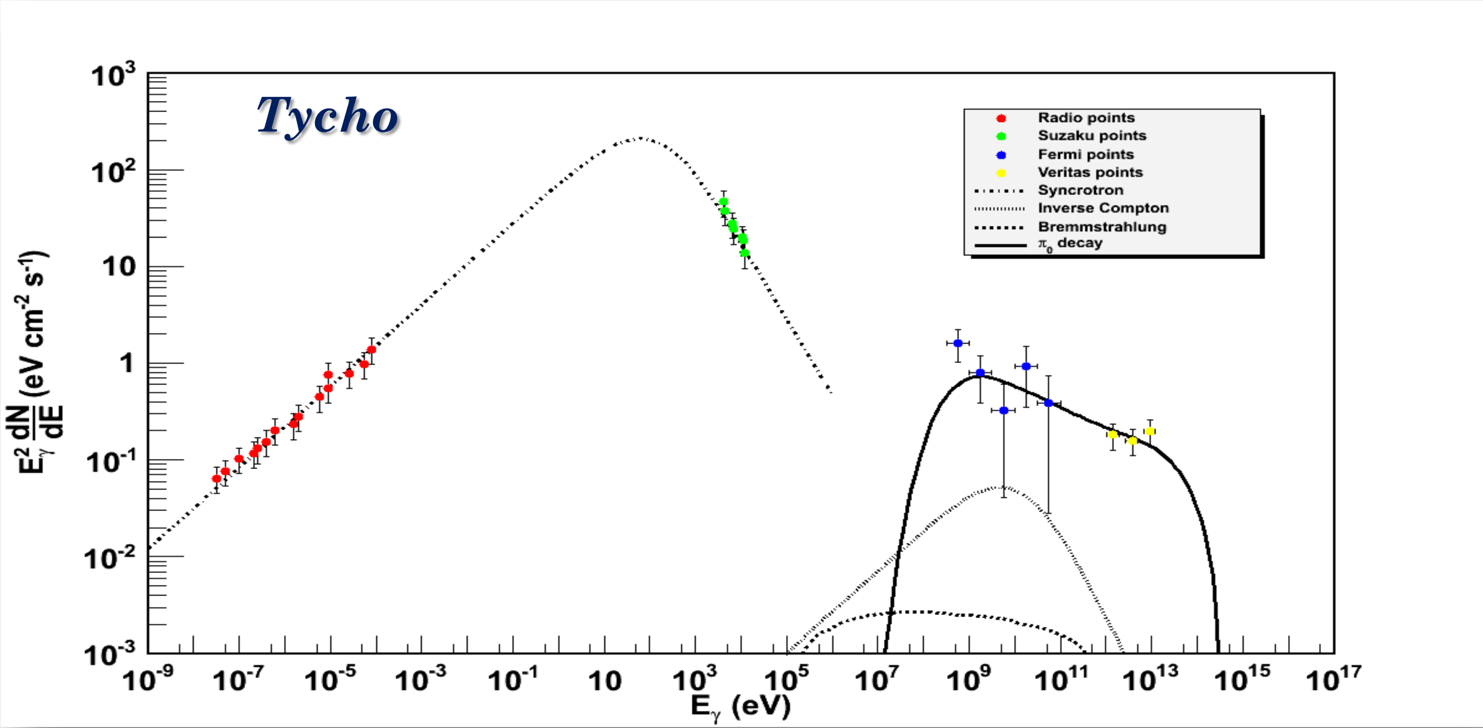
The parameters to be determined thanks to fit are the <u>normalization constant</u>, the <u>two indices</u> and the <u>energy break</u>.

SED OF SNR

$$F_{\gamma,SNR}(E_\gamma) = \frac{Q_\gamma(E_\gamma)V_{SNR}}{4\pi d^2}$$

- ***d*** is the distance of the SNR from the Earth,

- $\boldsymbol{V_{SNR}}$ is the volume of the sphere that approximate the expanding SNR.



IMPROVEMENTS

✓ use of the Monte Carlo code <u>Fluka</u> for the determination of the proton- proton cross section;

✓ development of a code for the <u>temporal evolution</u> of SNR.

HADRONIC SCENARIO

The process we are interested is described by the following:

$$pp \rightarrow \pi^0 + X$$
$$\quad\quad\quad\;\, \hookrightarrow \gamma\gamma$$

We used **Kamae et al. (2006)** for parametrizing the p-p cross section, thanks to which we have determined the emissivity of the photons and thus the SED of the SNRs studied.

$$Q_{\pi^0}(E_\gamma) = \frac{4\pi}{\beta c} n_H \int \frac{dN_p}{dE_p} \frac{1}{E_\gamma} \frac{d\sigma(E_p / E_\gamma)}{d\log(E_\gamma)} dE_p \quad \Rightarrow \quad F_{\gamma,SNR}(E_\gamma) = \frac{Q_\gamma(E_\gamma)V_{SNR}}{4\pi d^2}$$

where **d** is the distance of the SNR from the Earth and $\mathbf{V_{SNR}}$ is the volume of the sphere that approximate the expanding SNR.

Fit of Experimental Data

We fit the public GeV-TeV experimental data of several SNRs. We choose **young SNRs** (e.g. Tycho and Vela jr.) that show different spectral shapes in GeV band, and **molecular cloud SNRs** (e. g. IC 443) that instead interacts with the dense environment.

In our model we fixed the values of SNR *radius, the density of the environment and the distance of the SNR from the Earth.*

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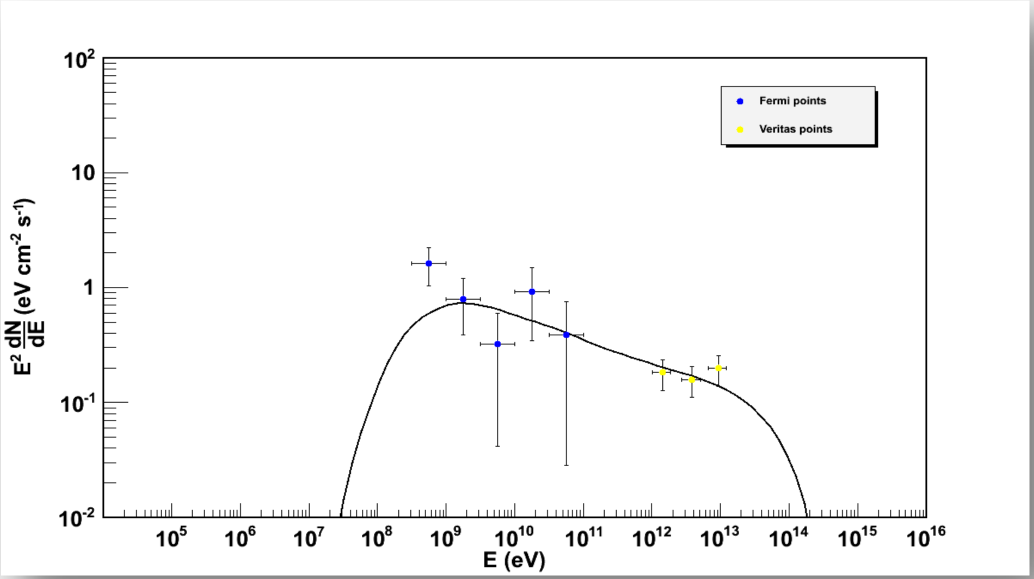
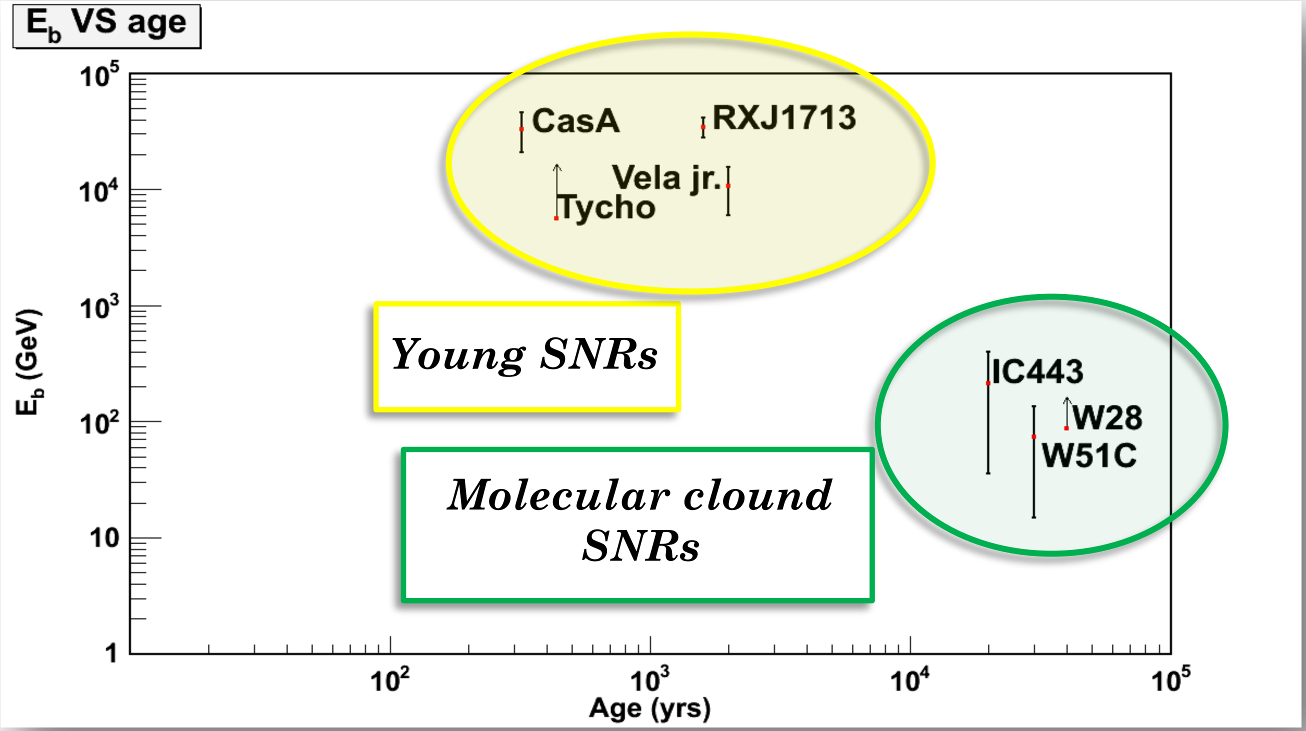


TYCHO SNR

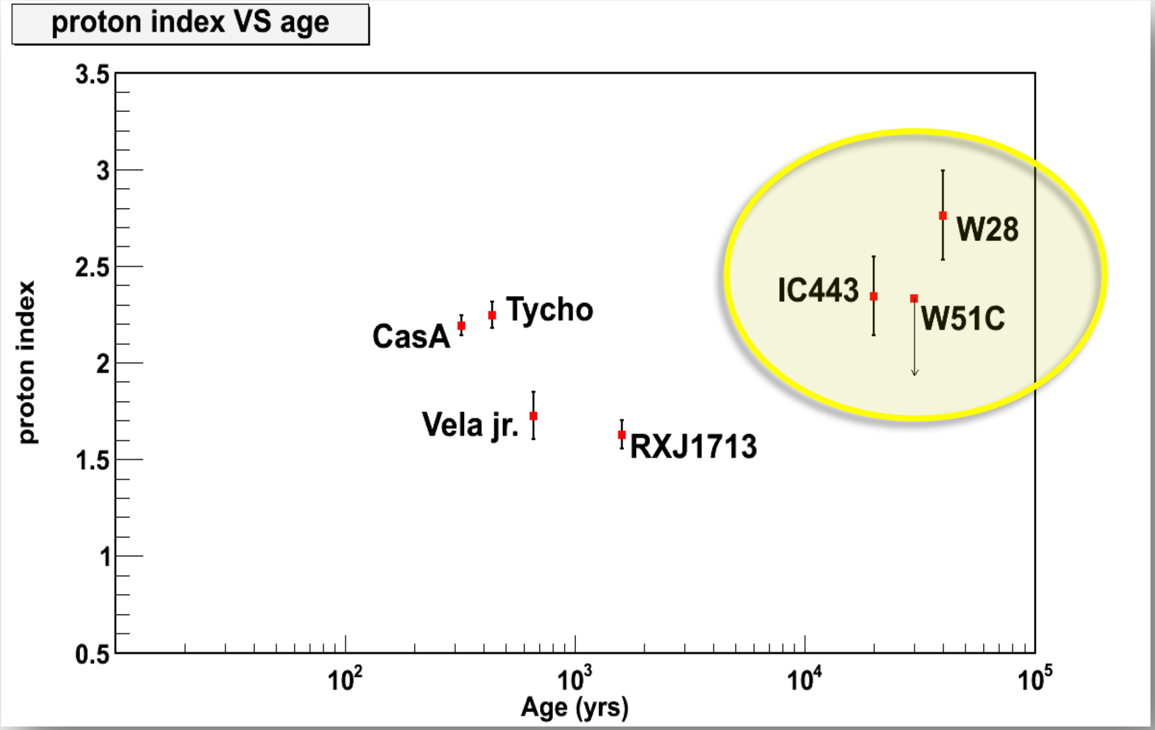
- ***SN 1572***
- ***SN type:*** Ia
- ***Age:*** 349 anni
- ***Distance:*** ~ 3.5 kpc
- ***Radius:*** ~ 3.7 pc
- $n_H = 0.24$ cm^{-3}

Fit of Experimental Data

This plot show the behavior of the energy break as a function of the SNRs age. We can distinguish the young SNRs from the molecular cloud ones.



Fit of Experimental Data

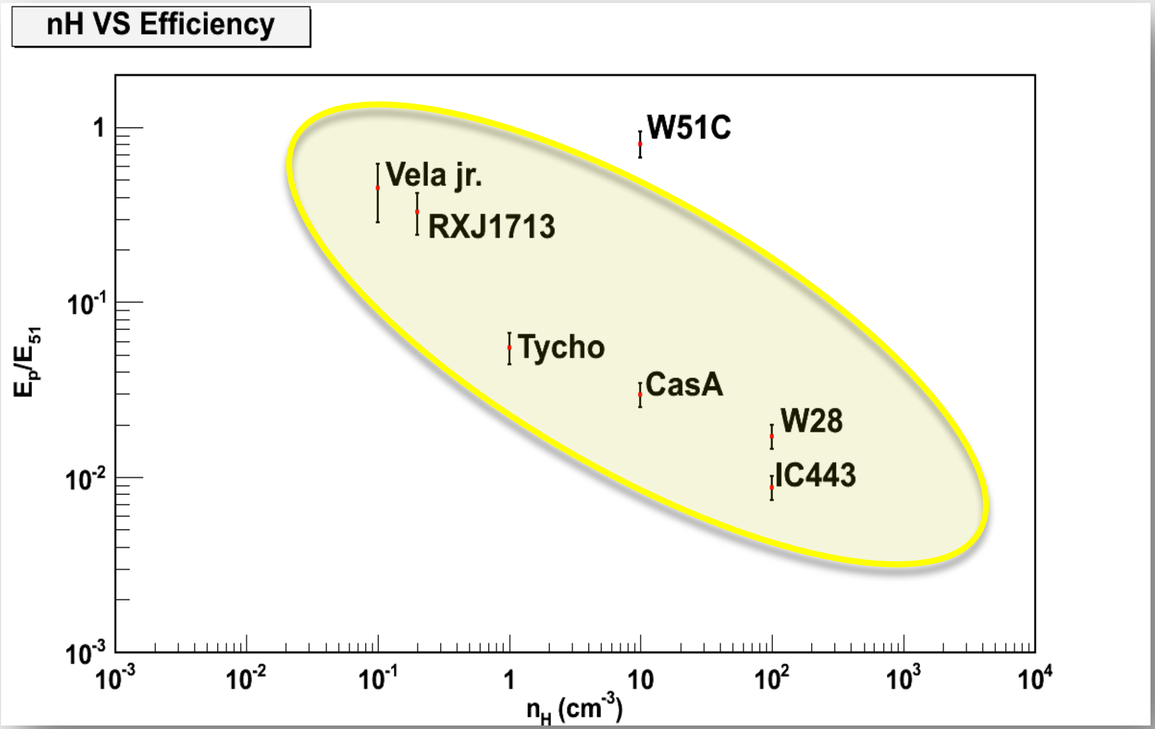


We relate the first index of the broken-power law and the environment density.

The greater the density softer is the index, indicating a possible different propagation of CRs in different envronments.

Fit of Experimental Data

In this plot we show the behavior of the efficiency (normalized to total kinetic energy of 10^{51} *erg*.) as a function of the density of the environment.



The role of the density is to enhance the GeV brightness even keeping at a lower level the acceleration efficiency.