1 The Leaky Box Approach

Starburst galaxies are generally extremely bright at infrared wavelengths showing a distinct FIR-radio correlation that enables to estimate the star formation rate (SFR) in these galaxies. The high SFR suggests a high density of target particles $N_{i} \gg 1 \text{ cm}^{-3}$ as well as a magnetic field strength $B$ in the order of a few $\mu \text{G}$ up to a few mG.

Do recent observations in the $\gamma$-ray band enable to draw further conclusions on the physics of starburst galaxies?

Shock acceleration by supernovae (SNe) commonly represent the source of the relativistic particles in starburst galaxies. In the case of relativistic electrons, the spectral index $\alpha$ of the resulting energy spectrum is supposed to steepen to $\alpha \approx -1.5$ at $\gamma \approx \gamma_{B}$ due to the competing inverse Compton (IC) losses. Subsequently, the relativistic particles propagate through the galaxy and emit synchrotron and gamma radiation, so that we account for:

- SN rate determines proton source rate $q_{\text{p}}(\gamma) \rightarrow q_{\text{p}}(\gamma)$ due to quasi-neutrality (see Fig. 1a);
- Diffusive particle transport with escape timescale $\tau_{\text{esc}}(\gamma) \propto \gamma^{-\alpha} \Gamma_{e,p}$ vs. advection losses with $\tau_{\text{adv}} \approx R/\nu_{\text{adv}}$ by the galactic wind;
- Continuous energy losses $\gamma_{B} \propto \tau_{\text{adv}}$ due to synchrotron (e), IC (e), Bremsstrahlung (e), ionization (e,p) and hadronic pion production (p).

Hence, the relativistic particle density of electrons and protons $n_{e,p}(\gamma)$ in the innermost region of a spherical symmetric starburst galaxy is described by

$$\partial \rho_{e,p}(\gamma, \nu_{\text{adv}}) = \frac{\partial}{\partial \gamma} n_{e,p}(\gamma) - \frac{\partial}{\partial \nu_{\text{adv}}} n_{e,p}(\gamma),$$

and a corresponding solution is shown in Fig. 1b.

2 Radio & Gamma Spectrum & Secondary Particles

- The synchrotron radiation $F_{\nu}(\nu, p)$ from the primary and secondary relativistic electrons are supposed to describe the steep part of the observed radio spectrum between $1 \text{ GHz} \lesssim \nu \lesssim 10 \text{ GHz}$ (see Fig. 1c).

- The gamma radiation $\Phi_{\gamma}(E_{\gamma})$ from non-thermal Bremsstrahlung, IC collisions and hadronic pion production ($\pi^{\pm}$ decay) is considered to describe the observed spectrum above $100 \text{ keV}$ (see Fig. 1d).

- Secondary particles like electrons and neutrinos result from hadronic pion production ($\pi^{\pm}$ decay).

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For further information please look at the publication (Eichmann & Tjus, 2016, ApJ, 821) or contact: eiche@tp4.rub.de