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SN Heating Efficiency of the ISM of Starburst Galaxies

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Abstract. The interstellar medium heated by supernova explosions (SN) may acquire an expansion velocity larger than the escape velocity and leave the galaxy through a supersonic wind. Galactic winds are effectively observed in many local starburst galaxies (Lehnert & Heckman 1996). The SN ejecta are transported out of the galaxies by such winds which must affect the chemical evolution of the galaxies. The effectiveness of the processes mentioned above depends on the heating efficiency (HE) of the SNs, i.e., the ratio between the kinetic plus internal energy density of the ambient gas and the SN energy density. In a starburst region, several SN explosions occur at a large rate inside a relatively small volume. If the successive generations of SN remnants (SNRs) interact with each other very fast, then a superbubble of high temperature and low density will rapidly develop, before a significant increase of the ambient gas density that could lead to substantial losses of energy by radiation. In this case, it is common to assume a value for HE of the order of unity, since most of the available energy of the SNs will be transferred to the ambient gas in the form of kinetic and internal energy, instead of being radiated away. However this assumption fails to reproduce both the chemical and dynamical characteristics of most starburst (SB) galaxies. In order to solve this paradigm, we have constructed a simple semi-analytical model, considering the essential ingredients of a SB environment, i.e., a three-phase medium composed by hot diffuse gas, SNRs and clouds, which is able to qualitatively trace the thermalisation history of the ISM in a SB region and determine the HE evolution (Melioli, de Gouveia Dal Pino, & D'Ercole, A&A, 2003, submitted). Our study has also been accompanied by fully 3-D radiative cooling, hydrodynamical simulations of SNR-SNR and SNR-clouds interactions (see Melioli, de Gouveia Dal Pino, & Raga 2003, in preparation).

We have found that as long as the mass loss timescales of the clouds through photoevaporation, Kelvin-Helmholtz drag, and thermal evaporation remain smaller than the timescale for a superbubble formation, the SN heating

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efficiency remains very small, since the radiative cooling of the gas dominates in this case. This occurs during the first ~ 16 Myrs of the SB lifetime (of ~ 30 Myrs, see Figure 1), after which the efficiency rapidly increases to one, leading to gas expansion and possible galactic wind formation. This result is found to be quite insensitive to the initial conditions of the hot diffuse ambient gas of the SB, but is affected by the assumed initial value of the total gas mass in the clouds. The result above was obtained for a total gas mass in the clouds of $8 \times 10^6 M_\odot$. Larger values cause a longer delay in the increase of HE to unity. We conclude that the HE value has a time-dependent trend that is sensitive to the initial conditions of the system and cannot be simply assumed to be ~ 1, as it is commonly done in most SB galaxy evolution models. Our model also provides a natural explaination for the low HE values often required to justify the chemical compositions, e.g., in dwarf galaxies.

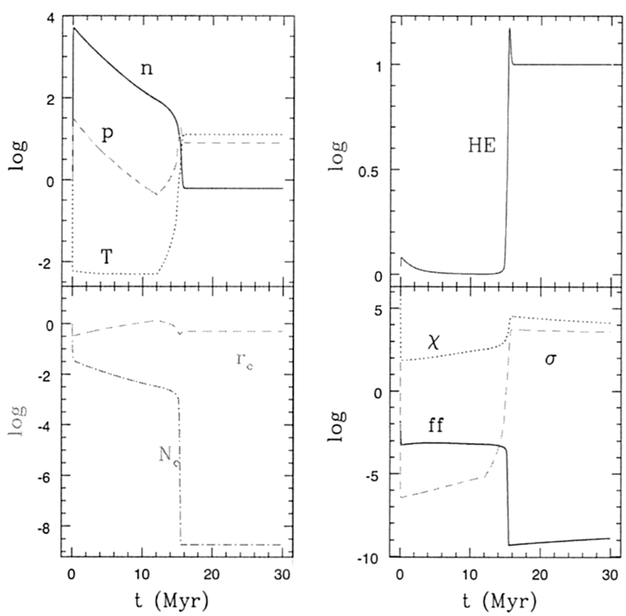

Figure 1. Model: Ambient density (n), temperature (T) and pressure (p) evolution in the top-left panel for a spherical SB with initial R_{SB}=100 pc, $n = 0.01$ cm^{-3}, $T = 2 \times 10^6$ K, and total gas mass $M_g = 8 \times 10^6 M_\odot$. In the bottom-left panel: evolution of the number of clouds (N_c) and the radius of clouds (r_c) evolution; in the top-right panel: the SN heating efficiency (HE); and in the bottom-right panel: the cloud filling factor (ff), the saturation parameter for the thermal evaporation of the clouds (σ; for $\sigma < 0.03$ the clouds condense rather than evaporate), and the cloud to ambient gas density ratio ($\chi = \rho_c/\rho$).

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