Evolution of the ISM in starbursting dwarf galaxies

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Abstract. We present a 2D-hydrodynamical simulation of the gas flow generated by a starburst in a dwarf galaxy. We focus in particular on the ejection efficiency both of the ISM and of the metals produced during the burst. It turns out that while the galaxy is able to retain most of the ISM, a significant fraction of the metals is lost, supporting the differential wind scenario. A new burst may occur after ~ 0.5–1 Gyr, when the central gas surface density approaches the critical value, during the post starburst gas replenishment.

We performed a 2D-hydrodynamical simulation of the ISM in a starburst dwarf galaxy. We assume that the energy production lasts 30 Myr, and we follow the gas evolution up to 500 Myr. We aimed at understanding the gas flow in general, and the circulation of the metal rich stellar ejecta in particular, in order to test the differential galactic winds scenario often used in chemical evolution studies (Tosi 1998).

We started with a rotating isothermal ISM in equilibrium in a potential well generated by an infinitesimally thin stellar disk and by a spherical quasi-isothermal dark halo. Details can be found in D'Ercole & Brighenti (1999). As the starburst wind starts, a typical superbubble develops. While the inner shock remains spherical because of the high sound speed of the hot rarefied shocked wind gas, the outer shock runs quicker along the polar direction, where the ISM density profile is steeper. Thus the superbubble assumes a hourglass shape (Fig. 1). As the polar expansion accelerates, the outer dense cold shell of swept up ISM fragments because of Rayleigh-Taylor instabilities. The shock in the polar region moves through a less and less dense gas, becoming unobservable. On the equatorial plane, instead, the inner edge of the cold shell starts to recede toward the center ~ 20 Myr after the starburst energy injection ceases. 150 Myr after the starburst the central region of the galaxy is filled again by cold ISM. The replenishment, however, proceeds rather slowly. After 200 Myr the gas mass inside the galactic region is 0.025 % of the initial ISM mass, and increases linearly up to 20 % at the end of the simulation, after 500 Myr. The gas surface-density increases in pace with the mass, and we obtain $\Sigma \simeq 6 \times 10^{20}$ cm^{-3} at 500 Myr. Since the gas is still accreting at this time, we can reasonably assume that, after a time of the order of 1 Gyr, Σ reaches the critical value $\Sigma_{\rm cr} \simeq 5$–10×10^{20} cm^{-3} for efficient star formation (*e.g.*, Gallagher & Hunter 1984). This time-interval between bursts is broadly consistent with many studies of star formation history in BCD galaxies, indicating that stars are formed through a sequel of short bursts of star formation separated by long quiescent periods (*cf.* Tosi 1999).

We define the ISM ejection efficiency $f_{\rm ISM} \equiv M_{\rm lost}/M_0$, where M_0 is the ISM mass initially present and $M_{\rm lost}$ the mass of gas whose velocity or sound
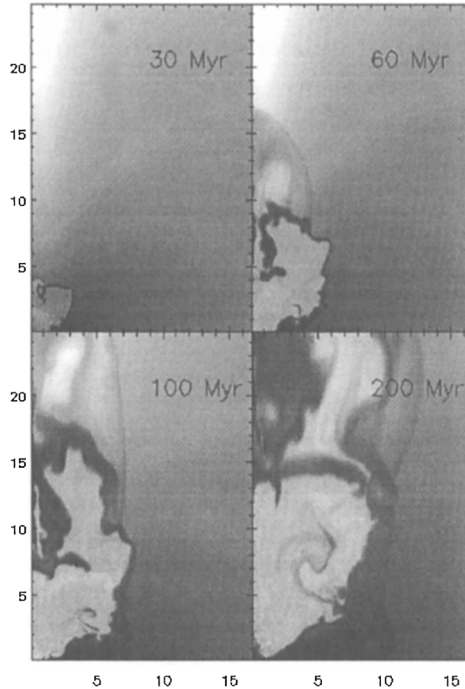
Figure 1.   Map of the gas density distribution at four different times. Axis labels are in kpc. High density regions are darker.

speed is higher than the escape velocity. Analogously, the ejection efficency of the gas expelled by massive stars and SNII is $f_{\mathrm{metals}} \equiv M_{\mathrm{bur,lost}}/M_{\mathrm{bur}}$, where M_{bur} is the total gas mass returned by the burst. After $200\,\mathrm{Myr}$ we obtain $f_{\mathrm{ISM}} = 0.058$ and $f_{\mathrm{metals}} = 0.46$. Thus, the metal rich gas is lost by the galaxy much more easily than the pristine ISM (De Young & Gallagher 1990). In fact, when a 'funnel' is formed through the galaxy, the wind leaves the galaxy through it without mixing efficiently with the ISM. Such dynamical behaviour supports the differential wind scenario required by most chemical models in order to explain the low α-element abundances found in the irregulars.

References

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