TABLE 2

THE STARBURST MODELS

Starburst Model	E_c (erg)	$M_{\rm SB}$ ($M_\odot$)
S1	1×10^{52}	$\sim 5.5 \times 10^2$
S2	5×10^{52}	$\sim 2.75 \times 10^3$
S3	1×10^{53}	$\sim 5.5 \times 10^3$
S4	5×10^{53}	$\sim 2.75 \times 10^4$
S5	1×10^{54}	$\sim 5.5 \times 10^4$
S6	5×10^{54}	$\sim 2.75 \times 10^5$
S7	1×10^{55}	$\sim 5.5 \times 10^5$
S8	5×10^{55}	$\sim 2.75 \times 10^6$
S9	1×10^{56}	$\sim 5.5 \times 10^6$
S10	5×10^{56}	$\sim 2.75 \times 10^7$
S11	1×10^{57}	$\sim 5.5 \times 10^7$

for M82 see Melo et al. 2005; for NGC 1569 see Westmoquette et al. 2008). Since there is a high level of obscuration in the nuclear regions of M82, NGC 1569, and NGC 253, the real number of clusters would be larger. Melo et al. (2005) and Smith et al. (2007) have shown that in the nuclear SBs region of M82 the SSCs are confined to the central ∼200 pc of the galaxy.

We estimated the mass of the starburst using Starburst 99 models (Leitherer & Heckman 1995 and Leitherer et al. 1999[4]) with the appropriate mechanical energy and a Salpeter initial mass function (IMF) that includes stars between 1 and 100 $M_\odot$. In order to obtain a better estimation of the total starburst masses, we have calculated the mass of the stars between 0.1 and 1 $M_\odot$ using the Kroupa, Tout, & Gilmore (1993) IMF. We assumed that all of the energy produced in the SB lifetime is injected instantaneously, at a given time t_c, inside a spherical region of radius R_c at the center of the disk galaxy as thermal energy. At this time (corresponding to ∼10 orbital periods of the galactic disk at a radius of 150 pc), the gas in the central regions of the galaxy has already developed a clumpy structure. Actually, in the present version of the code we cannot consider the case of an injection that extends over a finite time period.

The total injected energy is obtained from

$$E_c = \int_0^{t_f} L_m(t) dt \,, \qquad (15)$$

where t_f is the typical SBs lifetime, and $L_m(t)$ the mechanical luminosity as a function of time. The most important contribution to the mechanical luminosity happens at ∼40 Myr (see also Leitherer et al. 1999) and after that time the mechanical luminosity decreases drastically, due to the fact that the most massive stars have died by then. Table 2 shows the total energy and the respective mass of all the starburst models (S1–S11).

[4]http://www.stsci.edu/science/starburst99/.

4.3. *The grid of models*

We computed a total of 220 numerical simulations of GWs produced by the nuclear starburst events, with different total masses of the galaxies G1–G10 (see Table 1), combined with different starburst energies S1–S11 (see Table 2), all adiabatic as well radiative (110 models each). The total energy injected by the starburst of the models S1–S11 was distributed in the gas particles inside a sphere of $R_c = 150$ pc at the center of each of the galactic models G1–G10.

We choose this size for the region in which the energy of the starburst is injected, because it is representative of the sizes of observed starbursts. For example, in M82 the starburst region has a $R_c \sim 175$ pc radius (Moorwood 1996), and in NGC 1569A the starburst hole has a $R_c \sim 100$ pc radius (Fujita et al. 2009). An exploration of the effects on our results of varying R_c is shown in § 6.

The number of energetic particles ($N^a_{\rm ep}$ and $N^r_{\rm ep}$, for the adiabatic and radiative cases, respectively) is related to the total number of particles of gas in the initial conditions. The energy per particle in the starburst region is $E_i = E_c/N_{\rm ep}$, the number of energetic points used in the galactic models, is shown in Table 1. All the cluster particles (the energetic particles) are tagged in order to estimate the fate of the metals produced during the starburst lifetime.

5. RESULTS

We have let the galaxy models evolve on their own for $t_c = 1.5 \times 10^7$ yr. At the time t_c, the total energy of the SB is injected in the center of the galaxy. MacLow & Ferrara (1999) injected the energy from the cluster in a continuous way over a period of 40 Myr. Given the fact that the flow induced by the cluster takes ∼0.5 Gyr to travel a distance of ∼10 kpc (i.e., the size of the galaxy), the differences that might result from releasing the cluster energy over ∼40 Myr=0.04 Gyr (rather than instantaneously) cannot be very important.

The ejection efficiencies were computed at $t =$ 1 Gyr in all our models. The values of the efficiencies reach a constant value of integration times of ∼0.2–0.5 Gyr and ∼0.4–0.7 Gyr for the adiabatic and radiative models (respectively).