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Supernova Feedback in SPH Simulations of Galaxies

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Abstract. We report on the development of a N-body/SPH code for galaxy interactions, with particular emphasis on SN feedback implementations. We show that current methods of SN feedback probably need simulations with $> 10^5 - 10^6$ gas particles per galactic disk to be able to realistically describe galactic fountains and superwinds.

1. Introduction

The study of starbursting systems, such as Ultra Luminous Infrared Galaxy (ULIRG) type mergers, would benefit from an effective prescription of Supernova (SN) feedback to include in N-body/SPH simulations. The relevant physical processes for SN feedback operate on scales much smaller than those accessible even in simulations of single galaxies, so the various methods for including SN feedback have been phenomenological (see eg. Thacker & Couchman 2000). These methods have been employed successfully to model the heating of the ISM and formation of superbubbles by SN. Ideally one would like to be able to model galactic fountains and superwinds, since these processes radically alter the evolution of starbursting systems. This is not trivial because the galactic gas layer is underresolved unless very high numbers of particles are used. We will elaborate this by considering feedback for different particle numbers.

2. Method and Results

We employ a TreeSPH(Hernquist & Katz 1989) code we are developing to evolve a $10^{11} M_\odot$ galaxy consisting of a dark halo, a stellar disc and a gas disc. Gravitational interactions are calculated through a tree code, SPH is used for the gas dynamics. Star formation, heating by the local FUV flux and cooling are included. The feedback method used is the so called *pressure particle* (Gerritsen 1997). This method consists of putting all SN energy of a young star particle($= f_{SN} E_{SN} M_{star}$, with f_{SN} the number of SN per $M_\odot$, E_{SN} the effective supernova energy) into *one* SPH particle for the duration t_{SN} of the SN phase during which the particle is not allowed to cool radiatively (the rationale for this being the fact that the SPH estimate for the density is a very poor estimate for the actual low density inside a SN bubble). We take: $f_{SN} = 0.0086$, $E_{SN} = 5 * 10^{50}$ and $t_{SN} = 3 * 10^7$ yrs. In these simulations a hot gas halo forms, which consists of particles that have escaped the disc after being heated up through SN action. The forces that drive the particles out of the disc have a physical origin and

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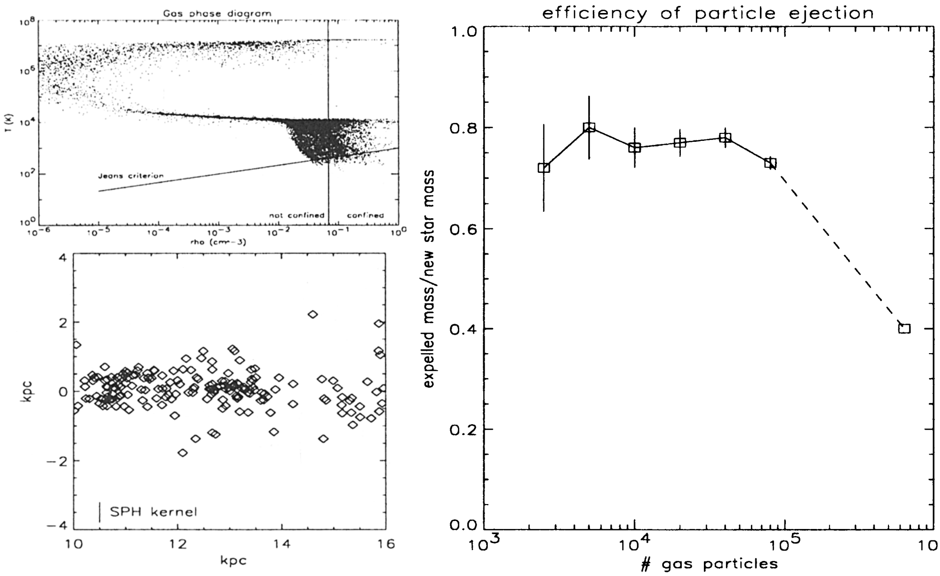

Figure 1. Right panel: The ratio of ejected particle mass over the new star mass after 1 Gyr for different number of gas particles. Upper left panel: gas phase diagram of the $N = 80k$ simulation, gas to the right of the vertical is confined by a resolved gas layer. Lower left panel: x-z projection of a 1 kpc slice of the gas disk in the N=80k run.

particle ejection is a general feature of SN feedback prescriptions. However particle ejection may be too readily allowed as the gas disc is not well resolved in scale height (the SPH kernel size is of the order of the scale height, see Fig. 1). To test this hypothesis we vary the resolution(Fig 1). The particle ejection efficiency is surprisingly constant for $N < 10^5$. This does not mean that all simulations are well resolved, but probably that all simulations are so far from being resolved as to perform equally poorly. The $N = 640k$ point is extrapolated from a simulation with a small region of gas at high resolution and it seems to indicate qualitatively different behaviour for $N > 10^5$. Fig. 1 also shows a gas phase diagram for the highest resolution run and a rough estimate of the limiting density ($\rho_{conf} \approx m_{particle}/z^3$, z being the disc scale height of the gas) below which particles in the disc are no longer confined in a resolved gas layer (hot SN particles move to the left). It is possible to suppress particle ejection by cooling down the gas particle artificially after the supernova period (Bottema, priv. com.), but this will also suppress the formation of a galactic wind.

References

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