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GALAXY FORMATION AND SUPERNOVA FEEDBACK

P. B. Tissera,[1,2] C. Scannapieco,[1,2] S. D. M. White,[3] and V. Springel[3]

RESUMEN

Presentamos un modelo de retroalimentación de supernovas (SN) para describir los efectos químicos y energéticos de explosiones de SN en simulaciones de formación de galaxias. Este nuevo modelo de SN ha sido acoplado a GADGET-2 dentro de un nuevo esquema de multifases que permite la descripción de una mezcla co-espacial de fases frías y calientes del medio interestelar. Estas SN y los modelos de multifases no tienen asociados ningunos parámetros ad hoc dependientes de escala lo cual los hace particularmente convenientes para estudios de formación de galaxias dentro de un marco cosmológico. Nuestro modelo de SN no sólo logra establecer la actividad autorregulada de formación estelar en galaxias, sino también provocar los vientos galácticos colimados, enriquecidos químicamente. Los efectos de los vientos varían con la masa virial de los sistemas, de manera que cuanto más pequeña sea la galaxia, mayor será la fracción de masa del gas barrido y más pronunciada la disminución en su actividad de formación estelar. El hecho de que la fracción de los metales expulsados excede 60% sin tomar en cuenta la masa sugiere que la retroalimentación de SN pudiera ser el mecanismo responsable del enriquecimiento del medio intergaláctico a los niveles observados.

ABSTRACT

We present a Supernova (SN) feedback model that succeeds at describing the chemical and energetic effects of SN explosions in galaxy formation simulations. This new SN model has been coupled to GADGET-2 and works within a new multiphase scheme which allows the description of a co-spatial mixture of cold and hot interstellar medium phases. No ad hoc scale-dependent parameters are associated to these SN and multiphase models making them particularly suited to studies of galaxy formation in a cosmological framework. Our SN model succeeds not only in setting a self-regulated star formation activity in galaxies but in triggering collimated chemical-enriched galactic winds. The effects of winds vary with the virial mass of the systems so that the smaller the galaxy, the larger the fraction of swept away gas and the stronger the decrease in its star formation activity. The fact that the fraction of ejected metals exceeds 60 per cent regardless of mass, suggests that SN feedback can be the responsible mechanism of the enrichment of the intergalactic medium to the observed levels.

Key Words: **COSMOLOGY — GALAXY: FORMATION — SUPERNOVAE**

1. INTRODUCTION

The understanding of galaxy formation in hierarchical clustering scenarios remains a primary goal for cosmology. Whereas gravitation governs matter evolution in large scales, more complex physical processes appear as principal actors at galaxy scales. Lagrangian-based models, such as Smoothed Particle Hydrodynamical (SPH) codes, have been widely used in the last two decades to study galaxy formation. Several models have been developed to describe gas cooling and star formation. However, problems arise owing to the fact that SPH tends to overestimate the densities of the hot gas, resulting in an overestimation of the cooling rates and an excessive condensation of cold gas (e.g. Springel & Hernquist 2003). This excess of dense-cold gas translates into high star formation rates. Because new stars tend to form in these dense-cold clumps with very short cooling times, if the energy released by SN explosions is directly thermalized within these regions, no effects on the dynamical evolution of the systems are achieved. Several strategies have been developed to overcome these problems (e.g Marri & White 2003 and references therein). In this work, we use previous ideas discussed by Marri & White (2003) and develop a new numerical implementation for SN feedback. We include a numerical treatment for both chemical and energy release. No ad hoc numerical or scale-dependent parameters are needed in our SN model which makes it specially suited for cosmological studies.

[1]Instituto de Astronomía y Física del Espacio, Argentina (patricia@iafe.uba.ar).
[2]Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina.
[3]Max-Planck Institute for Astrophysics, Germany.

2. ANALISIS AND DISCUSSION

Our new SN feedback has been coupled to GADGET-2 (Springel & Hernquist 2002) and is described in detail by Scannapieco et al. (2005, 2006a in preparation). A new multiphase model which allows a better overlapping between gas clumps of different densities and temperature has been developed. This multiphase model prevents particles of very different entropy to be selected as neighbours. Hence, diffuse, hot gas clumps can co-exist with cold and dense ones because they are adequately decoupled within the SPH calculations. Both chemical elements and energy released by SNII and SNIa are distributed within the gas neighbours of stellar particles hosting the SN events. However, these neighbours are segregated into cold and hot phases so that each of these phases receives a given fraction of metals and energy. Whereas the hot gaseous phase stores the metals and thermalizes instantaneously the energy, the cold phase gets chemically enriched but the received energy is stored in a reservoir. Cold gas particles accumulate energy by successive nearby SN events until the reservoir energy is enough to change the thermodynamical properties of the cold particle to match those of its hot environment. The properties of the hot environment of each cold gas particle are estimated from those particles that do not consider it as a neighbour during SPH calculation. This new SN model is capable of regulating the star formation activity in systems of different virial masses in a self-consistent way. The success of this new SN model is owing to the fact that it works within a multiphase scheme which defines the properties of each gas clump and its hot and cold environments on individual basis. It is a particle-particle criterium and there is no global definition involved. Within this new SN scheme, collimated metal-enriched winds are consistently triggered. In Figure 1 we show the metallicity distribution for an edge-on isolated disc galaxy test. Velocities along the outflows can be up to 1000 kms^{-1} depending on how the SN energy is distributed among the hot and cold environments, and on the potential well of the systems. Discs with less than $10^{10} M_{\odot} h^{-1}$ are gas-depletted more efficiently. Part of this gas is not unbound and can be accreted later again producing new starburst episodes.

We used this SN model in high resolution cosmological simulations of Local group-type regions in a Λ-CDM scenario. We found that this new SN model assures the conservation of the specific angular momentum of the disc component, being able to produce extended exponential discs with scale-lengths of ≈ 3 kpc h^{-1} ($h = 0.7$). The stars in the bulge and halo components have age and mean metallicity distributions which resembled those of the Milky-Way (see Scannapieco et al. 2006b, in preparation).

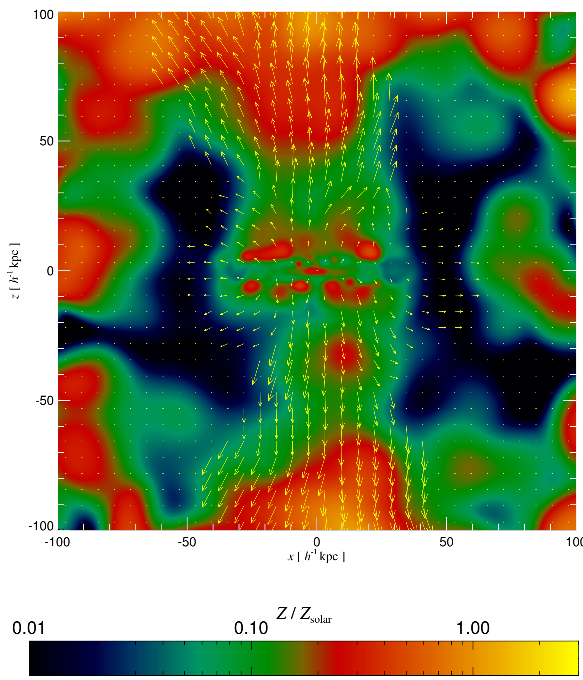

Fig. 1. Mean metallicity distribution of an edge-on disc of $10^{12} M_{\odot} h^{-1}$ virial mass resolved initially with 10^4 gas particles and 10^4 dark matter particles. The arrows point out toward the flow direction and their lengths represent the mean velocity at the corresponding point. The metallicity scale is also shown.

In summary, this new SN feedback model probes to be able to regulate the star formation activity and to trigger enriched galactic winds, self-consistently. This new SN feedback model opens a new stage in the study of galaxy formation and the history of chemical enrichment of the Universe.

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