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MASS AND METAL EJECTION EFFICIENCY IN DISK GALAXIES DRIVEN BY YOUNG STELLAR CLUSTERS OF NUCLEAR STARBURST

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RESUMEN

Presentamos las eficiencias de pérdida de masa obtenidas de modelos numéricos de vientos galácticos empujados por la energía depositada en brotes de formación estelar nucleares. Los brotes de formación estelar contienen cúmulos estelares jóvenes los cuales inyectan la energía suficiente para empujar parte del medio interestelar fuera de las galaxias. En algunos casos los vientos galácticos contienen una importante parte de los metales producidos por las nuevas generaciones estelares. Para estudiar las eficiencias de pérdida de masa hemos desarrollado simulaciones numéricas 3D "N-Body/Smooth Particle Hydrodynamics" de vientos galácticos para el caso con pérdidas radiativas. Los modelos numéricos cubren una amplio intervalo de masas en los brotes de formación estelar (de $\sim 10^2$ a $\sim 10^7$ $M_\odot$) y de masas en las galaxias anfitrionas (de $\sim 6\times 10^6$ a $\sim 10^{11}$ $M_\odot$). Las regiones de formación estelar concentradas en el centro del potencial, son una maquinaria importante para la pérdida y redistribución de masa y metales en este tipo de galaxias.

ABSTRACT

We present results from models of galactic winds driven by energy injected by nuclear starbursts. The total energy of the starburst is provided by young central stellar clusters and parts of the galactic interstellar medium are pushed out as part of the galactic wind (in some cases the galactic wind contains an important part of the metals produced in the new generation of stars). We have performed radiative 3D N-Body/Smooth Particle Hydrodynamics simulations of galactic winds using the GADGET-2 code. The numerical models cover a wide range of starburst (from $\sim 10^2$ to $\sim 10^7$ $M_\odot$) and galactic gas masses (from $\sim 6\times 10^6$ to $\sim 10^{11}$ $M_\odot$). The concentrated central starburst regions are an efficient engine for producing of the mass and metal loss in galaxies, and also for driving the metal redistribution in the galaxies.

Key Words: galaxies: starburst — galaxies: star clusters — ISM: general — stars: winds, outflows

1. INTRODUCTION

A great amount of evidence both, observational and theoretical, indicates that Galactic Winds (GWs) are a necessary and very important ingredient of the evolution of galaxies and the inter-galactic medium. Their presence can explain, among other things, the very low metallicities found in dwarf galaxies or the abundance of metals observed in the intra-cluster medium. Many authors have shown that in the nearest starburst galaxies GWs could form through the collective effect of many individual stellar cluster winds, which in turn are formed by the collective effect of many individual stellar winds. In the starburst galaxies many authors are founded a super stellar cluster (SSC) with Hα luminosities in the range of $(0.01\text{–}23)\times 10^{38}$ erg s^{-1} (Melo et al 2005). Such an exceptional density of massive clusters (i.e $\sim$620 kpc^{-2}, for M82, Melo et al. 2005) is the best scenario to study powerful GWs driven by SSC winds originated in nuclear starburst regions. In the present paper we study the effects of young stellar clusters in the nuclear starburst (SB) region on the ISM of dwarf disk-galaxies. In particular, we calculate the amount of enhanced metallicity material that will end up in the intergalactic medium (IGM) and/or in the outer regions of the galactic disk.

2. GALACTIC MODEL INGREDIENTS AND THE MASS EJECTION EFFICIENCY

Each galaxy in our study consist of a dark matter halo, and a rotationally supported disk of gas and stars. The models are constructed in a similar manner to the approach described in Springel et al. (2005, see also Hernquist 1990; Springel 2005). A near-equilibrium galaxy model is constructed, with a dark matter halo that follows a Hernquist (1990) profile, and a disk with exponential surface gas density. Then, using an iterative procedure, the vertical gas profile is determined self-consistently for a particular effective equation of state. We adopt the cooling

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funtions computed in collisional ionization equilibrium (CIE) by Sutherland & Dopita (1993) for solar abundances.

Depending on the kinetic energy of the gas injected by the young stellar objects one has two possible outcomes: if the kinetic energy is larger than the gravitational potential of the galaxy, the material is not bounded and will integrate with the IGM; otherwise, the gas is bound to the galaxy and it will return to reintegrate with the ISM. If the material from the SSCs returns and reincorporates to the galaxy ISM two things can happen: it can fall back close to the galactic centre or far from it. Considering that the GW are ejected more or less confined into a cone, material that does not reach a high altitude will fall close to the galactic centre, while gas that reaches a high altitude can fall back at large galactocentric radii.

In order to quantify the mass loss in numerical models one has to determine which material will be considered lost to the IGM. Here, we calculate the mass ejection efficiency as as the ratio of the mass ejected (unbound) to the total gas mass,

$$\xi_m \equiv \frac{M_{\rm ej}}{M_g}. \quad (1)$$

One can also define a "metal ejection efficiency" as

$$\xi_z \equiv \frac{M_{c,\rm ej}}{M_c}, \quad (2)$$

where M_c is the total mass injected by the SSCs, and $M_{c,\rm ej}$ the mass, also originated in the SSCs that is unbound.

3. NUMERICAL SIMULATIONS

We have performed radiative 3D N-Body/SPH simulations that model the effect of a central compact starburst, in which mechanical energy is injected by stellar cluster winds, using GADGET-2. All simulations were done with 3 types of particles: disk, halo, and gas particles, and, unless otherwise stated, each consist of 30000, 40000, and 30000 particles, respectively.

3.1. *The host galaxies and the starburst regions*

We constructed ten isolated galaxies as described in Springel (2005) and in Rodríguez-González et al. (2011). The galaxies are named from G1 to G10, they have ISM masses in the range of $\sim 5\times10^6 - 10^{10}\ M_\odot$, with the total masses are in the $\sim 4\times10^8 - 1\times10^{12}\ M_\odot$ range. The disk masses of the galaxies are given by $M_d = 0.041\ M_{\rm tot}$, and the total mass of the gas is of 35% of the galactic visible mass in

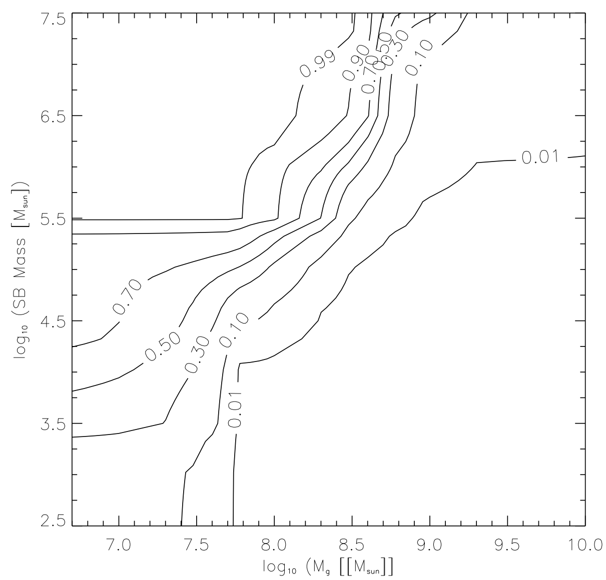

Fig. 1. Mass ejection efficiency (equation 1) countours as a function of total mass of the gas and total starburst masses.

all of the models. On the other hand, 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 $R_c = 200$ pc at the center of the disk galaxy as thermal energy.

Our results of mass ejection efficiencies is presented in Figure 1. In Rodríguez-González et al. (2011) we present a mass and metal ejection efficiencies for adiabatic and radiative cases, in the same range of ISM galaxy and starburst masses.

4. CONCLUSION

We show that for compact starburst regions (e.g. inside the SSC) with masses larger than $2\times10^6\ M_\odot$ in the adiabatic case, the metal injected by the nuclear starburst is expelled to the IGM (at least 90% of this gas). We show that in galaxies with gas masses between 10^7 to $10^{10}\ M_\odot$ and with a massive nuclear starbursts the available metals are freed from the gravitational potential of the galaxy.

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