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FEEDBACK IN GALAXY FORMATION WITH TWO-PHASE ISM

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RESUMEN

Presento un modelo para la formación de galaxias basado en la física de un medio interestelar de dos fases en equilibrio de presión. En el modelo, el gas se enfría o cae desde un halo externo, fragmentándose en pequeñas nubes. Estas nubes coalescen para formar complejos gigantes de nubes moleculares, los que colapsan y forman estrellas. Las supernovas impulsan a las superburbujas a la fase caliente. El efecto de retroalimentación depende de si las superburbujas están confinadas o si se expanden fuera del sistema antes de enfriarse. Según los valores de la densidad y la geometría del sistema, obtengo sistemas auto-regulados, brotes estelares rápidos o sistemas críticos, en los cuales la fase caliente se colapsa.

ABSTRACT

I present a model for galaxy formation based on the physics of two-phase ISM in pressure equilibrium. In this model gas cools or infalls from an external halo, fragmenting into small clouds. These coagulate to form giant molecular complexes, which collapse and form stars. Supernovae drive superbubbles into the hot phase. The effect of feedback depends on whether superbubbles are confined or blow out of the system before cooling. Depending on the density and geometry of the system, I obtain self-regulated systems, rapid starbursts or critical systems where the hot phase suddenly collapses.

Key Words: **GALAXIES: FORMATION — GALAXIES: ISM — ISM: EVOLUTION**

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1. INTRODUCTION

The problem of galaxy formation couples several physical processes that are important on different scales. Here we present results from a (work-in-progress) analytical model for the dominant processes in the range of scales from ∼10 pc to ∼1 kpc.

This "sub-grid physics" (with respect to hydro simulations of galaxy formation) has often been treated with the aid of "simple" heuristic recipes which connect the efficiency of feedback to some fundamental parameters of the dark matter halo, especially to the circular velocity (see, e.g., Kauffmann et al. 1999; Somerville & Primack 1999; Cole et al. 2000). On the other hand, the physics of the ISM is fare more complex than these simple parametrizations allow (see, e.g., the contributions by Avila-Reese, Franco and Ballestreros-Paredes to these proceedings; see also Efstathiou 2000; Silk 2001). Here we present a dynamical model which is based on the hypothesis of two-phase ISM in pressure equilibrium. Some preliminary results were presented in Monaco (2002).

2. THE MODEL

A patch of ISM (much smaller than the galaxy but much larger than a typical cloud or bubble) is separated into three phases, namely hot gas (with $T \sim 10^6 K$), cold gas (with $T \sim 10^2 K$) and stars. Cold gas infalls continually from an external halo. Figure 1 shows the mass fluxes between the four components.

(i) Gas cools from the hot phase and from the cold halo, and fragments into clouds with a given mass function, which is a power-law with exponent $-\alpha_{\rm cl}$ ($\simeq 2$). (ii) The mass function is truncated both at small masses (small clouds are easily evaporated by the hot gas) and at large masses (large clouds can collapse). (iii) Clouds coagulate according to the Smoluchowski equation of kinetic aggregations (see, e.g., Cavaliere, Colafrancesco & Menci 1992). (iv) Clouds that are larger than the Jeans mass collapse. (v) They thus cool to $10K$ and become sites of active star formation. (vi) These molecular clouds are destroyed by HII regions after having formed stars by a fraction $f_\star$ ($\simeq 0.1$) in mass. (vii) SNe explode (one for each $\sim 120\ M_\odot$ of stars formed), and their remnants soon percolate to form a superbubble. Most energy is lost by radiation, only a fraction $f_{\rm evap}$ (tentatively set to $\simeq 0.1 - 0.3$) of the collapsed cloud is evaporated. (viii) The superbubbles sweep the hot medium or collapse it into a shell (following the model of Weaver et al. 1977), according to whether they remain into the adiabatic phase or cool and get into the snowplow regime. (ix) Cold clouds inside active bubbles are evaporated as in McKee & Ostriker (1977); we find this process rather inefficient. (x) The superbubble stops either by blowing out of the structure (in which case only a fraction $f_{\rm bo} \simeq 0.1$ of internal gas is retained) or by pressure confinement.

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3. RESULTS

The efficiency of feedback $\epsilon_{\rm E}$ in heating the ISM mostly depends on the density and vertical scale-height of the system. In particular, at densities lower than a few $M_\odot pc^{-3}$ the superbubbles do not go into the snowplow phase. Then, if the vertical scale-length is such that it does not allow blow-out, the efficiency of feedback is maximum and is of order one. For higher densities the superbubbles go into the snowplow phase, so that the feedback acts cooling the hot gas and star formation is self-stimulated and very fast. When blow-out occurs in the adiabatic phase, the ISM is very stable and self-regulating, with values of the density ($n_H \sim 10^{-3}\ cm^{-3}$, $n_c \sim 10\ cm^{-3}$) very similar to those found in the Milky Way, while the star formation (for a system of $\sim 10^{11}\ M_\odot$) is limited to a few $M_\odot yr^{-1}$, slowly decreasing with time.

In some cases the hot phase is so heavily depleted by feedback (for instance by blow-out) that the filling factor of the cold phase becomes close to one. In this critical case the pressure of the hot phase drops and the cold phase percolates the whole volume, forming a giant cloud. All the accumulated gas is thus consumed into stars very quickly. This mechanism could help in understanding big starbursts. However, the presence of this mechanism depends on many uncertain details, and could be quenched by magnetic fields, if these can keep the clouds confined even in absence of a hot medium.

4. CONCLUSIONS

(i) Feedback acts in different ways, depending mostly on the density and geometry of the gas. These quantities are expected to be only loosely connected to the properties of the dark-matter halo. (ii) In a spiral-like case, the typical properties of the ISM in the Galaxy are recovered. (iii) The two-phase ISM may be unstable; critical phenomena may generate starbursts without need for merging. (iv) The free parameters of the model can be constrained both by reproducing the Milky Way (work in progress) or by careful N-body simulations of patches of ISM.

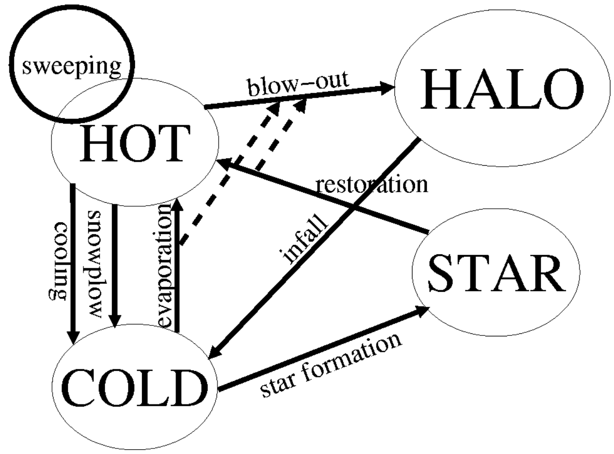

Fig. 1. Mass fluxes in the model.

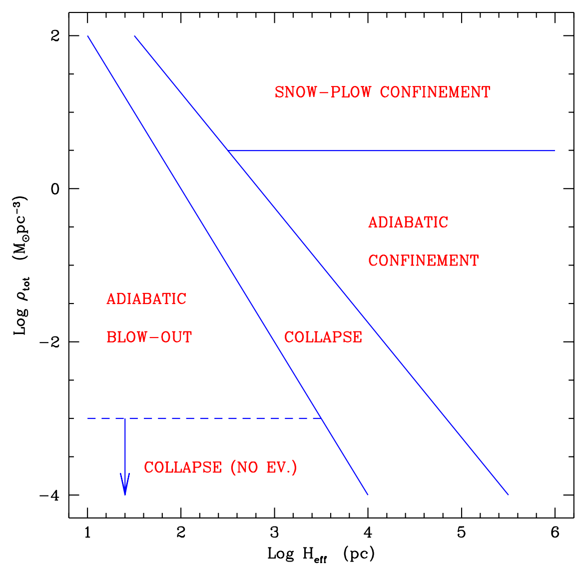

Fig. 2. Different kind of regimes for feedback as a function of density and vertical scale-height.

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