EARLY EVOLUTION OF GALAXIES
Preliminary results

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I. INTRODUCTION

This paper is a progress report on studies of coupled dynamical and chemical evolution of galaxies. We have focused our attention on the occurence of galactic hot winds. Such hot winds have been studied by Mathews and Baker (1971) for elliptical galaxies. Recently the detection of an iron X-ray emission line in clusters of galaxies give some support to their existence (Vigroux, 1977). On an other hand, the large radial flow in the galactic center might be explained by such hot wind. We shall present here a preliminary version of our evolution model and the results obtained for the early evolution of a 1.2 x 10^{12} $M_\odot$ galaxy.

II. DESCRIPTION OF THE MODEL

In the present dynamical model, one dimensional spherical flow equations are written for gas density, velocity and pressure (including artificial viscous pressure). They are solved by a standard numerical difference scheme (Mc Cormack, 1971).

Each cell of the model is affected by star formation and mass loss, the former according to Schmidt's law and assuming a constant initial mass function. Stellar mass loss, along with chemical evolution are derived in term of the galaxy-averaged stellar population, as calculated by the evolutionary model used in our previous work on chemical evolution of galaxies (Vigroux et al., 1976), and then weighted by the actual stellar density in each cell.

Since the behaviour of the gas is strongly affected by the energy release of supernova explosions, the gross features of the stellar content of the galaxy are reproduced assuming an uniform spread of the newly formed stars over a galactic volume consistent with their total energy.

III. INTERNAL ENERGY SOURCES AND SINKS

It has been assumed that the collapsing gas can be described as a turbulent medium, whose turbulent velocities are at most sonic.

The equation of motion of the gas (averaged over a distance larger than the turbulent scalelength) is governed by the total pressure (thermal + turbulent). Therefore, the dissipation of turbulent energy is not to be considered as an energy source or sink.

Besides compression work, the internal energy sources are shocks and supernovae. Supernova heating is given by :

$$\dot{E}_s = \epsilon_{SN} \, \rho_S \, \alpha_{SN} \, e_{SN}$$

where ϵ_{SN} is the efficiency for the transfer of energy of the SNR to the interstellar medium, which is a (weak) function of interstellar density and temperature, ρ_S is the stellar mass density, α_{SN} the supernova mass loss rate, which depends on the composition of the stellar population, e_{SN} is the specific energy of supernova ejecta.

Following the above assumptions, the energy sink is determined by radiative losses. These have been obtained by adding bremsstrahlung losses to the collisional excitation of various ionic species (Cox and Tucker, 1969). The variation of the cooling function with metal abundance has been taken into account. There is a bump in the cooling function between 10^4K and 10^6K ; thus it is much more difficult to increase the temperature across this bump than to maintain it above 10^6K. This important feature has been taken into account in the present model.

IV. DESCRIPTION OF THE RESULTS

The initial state of the protogalaxy is taken as a sphere of uniform density 10^{-25} g/cc up to a radius R_o=30 kpc and decreasing out to the maximum mesh radius R_{max}=200 kpc. The gas is initially at rest and at a temperature of 10^4K (below the bump of the cooling function). At the beginning the velocity profile is linear ; after about 10^8 years, the motion is best described as an isothermal collapse with uniform velocity (Larson, 1969). Gas piles up in the central zone (off scale on fig. 1) after about 2.10^8 years. The gas density in the outer parts of the galaxy is small enough to allow efficient heating by the supernovae. A shock wave propagates outwards, leading to a hot wind, and inwards into the still collapsing gas (see fig. 1). The temperature discontinuity at R = 10 kpc is not truly a showk wave, because the final temperature is determined by the balance between supernova heating and bremsstrahlung rather than by the dissipation of kinetic energy.

The abunance of ^{16}O is larger outwards since there the interstellar gas is mostly due to supernova mass loss, while in the inner regions the infall of metal poor gas dilutes the stellar mass loss.

V. CONCLUSION

The results given in this paper are preliminary. However, they point out the necessity of a proper treatment of the evolution of the stellar population and the radiative losses. Several interesting possibilities arise, such as the appearance of a hot wind starting in the outer parts, and of a metal abundance increasing outwards during the early stages of galaxy evolution. More work is clearly needed to assess the impact of these effects on the later evolution of the galaxy.

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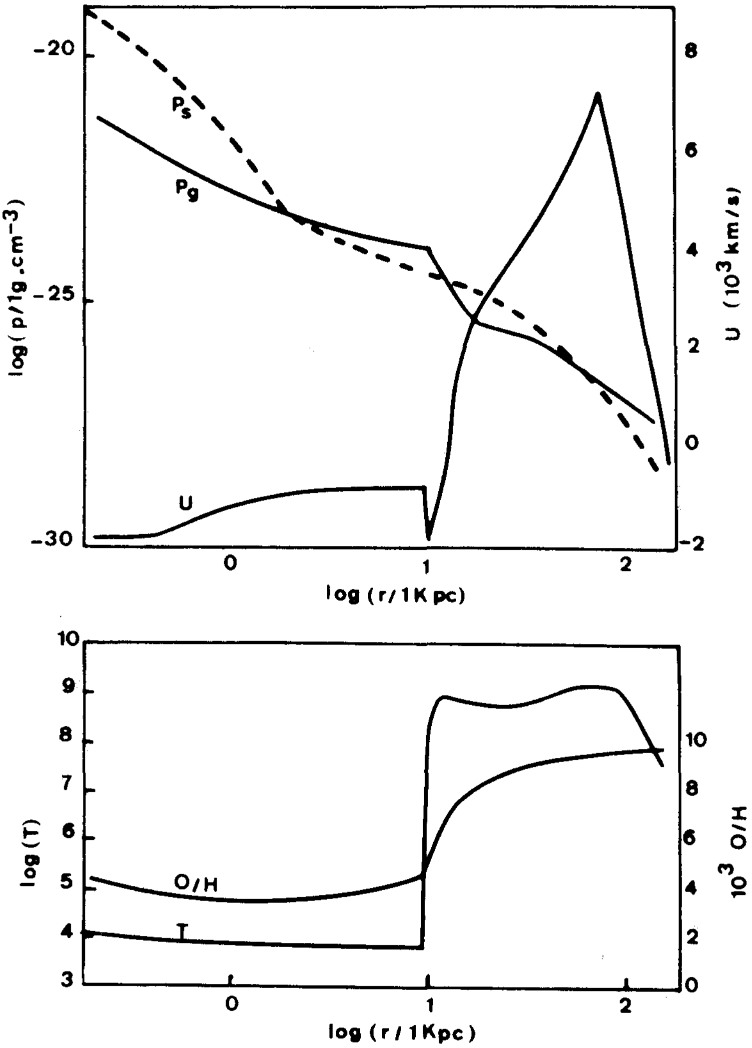

Fig. 1. Radial distribution of gas and stellar density, gas velocity, temperature and oxygen mass abundance. The velocity decrease around 100 kpc is due to the adoption of a fixed wall outer boundary condition. Time is 2.8 x 10^8 years.