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THE CHEMICAL EVOLUTION OF SPIRAL GALAXIES AND THEIR FORMATION PROCESS

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To analyse the chemical evolution of spiral galaxies we used the multiphase model of Ferrini and coworkers, that works with gas infall from the halo to the equatorial plane of spiral galaxies, forming out the disc in this process. The initial total mass radial distribution is used as input. The collapse time of the halo gas, and efficiencies of molecular-cloud and star formation are model parameters. In this new calculation we try to reduce the number of free parameters in order to have a more general theory about the chemical evolution of spiral galaxies. Therefore, we include a calculation of the mass radial distribution from a total mass input, assumed to be distributed in an isothermal sphere, that determines the collapse time and its radial dependence. We also include relations to calculate molecular cloud and star formation efficiencies. In this way, we obtain the chemical evolution of a galaxy using the initial density and the core radius of the initial protogalaxy or halo.

1. THE MODEL

Chemical evolution models are very useful tools to study the evolution of galaxies, predicting results with can be readily compared with observational data. A large number of models there exist, but usually they apply only to the Milky Way Galaxy ([21],[20],[12], [1],[2],[10],[11]) where the number of data is really large. Some attempts have been made to generalize these models for application to other spiral galaxies, but in most cases they have a large number of free parameters.

We used the galacto-chemical multiphase multizone evolution model, developed by Ferrini and coworkers ([5], [18]), and successfully applied to the Solar Neighbourhood ([15],[16]), to the galactic disc and bulge ([6], [13]) and to other six spiral galaxies ([14]). Input parameters of the models are: a) the initial total mass distribution; b) the collapse timescales; and c) the efficiencies of molecular-cloud and star formation processes.

The total mass radial distribution, calculated from the rotation curve, and initially distributed in a sphere, falls onto the equatorial plane as it collapses. The collapse timescale is function that decreases exponentially with the galactocentric radius. However, we know that this scale depends on the total mass affected in the process ([17],[19],[8],[9], [4]). If we can calculate the initial total mass radial distribution in the halo and, as a consequence, the value of the collapse timescale for every zone, it will not be a free parameter.

Following the scenario from [8] and [4], it seems that protogalaxies collapse and virialize to form an isothemal sphere. The cooling rate of the sphere gas determines what kind of galaxy will be formed: elliptical or spiral and also its morphological type. This cooling rate depends on the velocity dispersion (or on the angular momentum), related with the core radius. The overdensity of the fluctuation determines the total mass and the radius where it is enclosed, that is the final luminosity and size of the galaxy.

Therefore, we start with a total mass M_{tot} enclosed in a given radius R_{gal}, distributed as an isothermal sphere, with a core radius R_c:

$$\rho(R) = \frac{\rho_0}{(R/R_c)^2 + 1}$$

where the value ρ_0 is determined from M_{tot} and R_{tot}.

With this we have $M(R)$ from the integration up to a radius R:

$$M(R) = 4\pi R_c^3 \rho_0 \sqrt{\frac{R_{gal}^2}{R_c^2} - 1}[(\theta \cos\theta - \sin\theta) - (\theta_0 cos\theta_0 - sin\theta_0)]$$

where $\theta = \arctan\sqrt{\frac{R_{gal}^2 - R^2}{R^2 + R_c^2}}$ and $\theta_0 = \theta(R = 0)$.

Following [4], we can determine the collapse time $\tau_c(R)$, for every zone or radius R:

$$\tau_c \propto (\frac{R^3}{GM(R)})^{1/2}$$

and using the virial theorem, the velocity dispersion and the rotation velocity are calculated:

$$V_{rot}^2 = \frac{GM(R)}{R} = 2\sigma^2$$

On the other hand, the star formation rate has been modelled as a two-step process: the diffuse gas forms molecular clouds and stars are formed from cloud-cloud collision. These processes depend on the local density and on their efficiencies ϵ_μ and ϵ'_H. Those were fixed as free parameters. But, following [3] and [7] the dependence of the star formation rate law is somewhat more known: the molecular cloud formation efficiency ϵ_μ seems to depend on the instability increasing rate, and therefore depends on the ratio $\Omega = V_{rot}/R$. The star formation efficiency is proportional to the cooling rate, and it depends on the velocity dispersion.

Thus:

$$\epsilon_\mu(R) \propto \Omega(R),$$

$$\epsilon'_H(R) \propto \sigma^3(R)$$

2. RESULTS

The model calculates the time evolution of the galaxy. The gas is consumed and restituted, molecular clouds appear, star are formed and, after their life-times, they die, ejecting to the interstellar medium the elements formed in their interiors. We obtain as a result the final amount of both gas phases (neutral and molecular), stars, remmants, and the abundance of 15 elements in every zone.

We show in Figure 1: a) the radial mass distributions, b) the rotation curve, c) the corresponding diffuse gas and d) molecular gas radial distributions, e) the Oxygen abundance and f) the star formation rate surface density radial distributions, for galaxies with different masses and radii, and the same core radius.

These results show a similar behaviour for spiral galaxies of different total masses to the models calculated with radial mass distributions derived from observed rotation curves.

3. CONCLUSIONS

We have computed chemical evolution models using two galaxy formation inputs: the initial mass and the core radius. The construction of a grid of models is in progress in order to check whether the chemical evolution of different types of spiral galaxies can be successfully reproduced.

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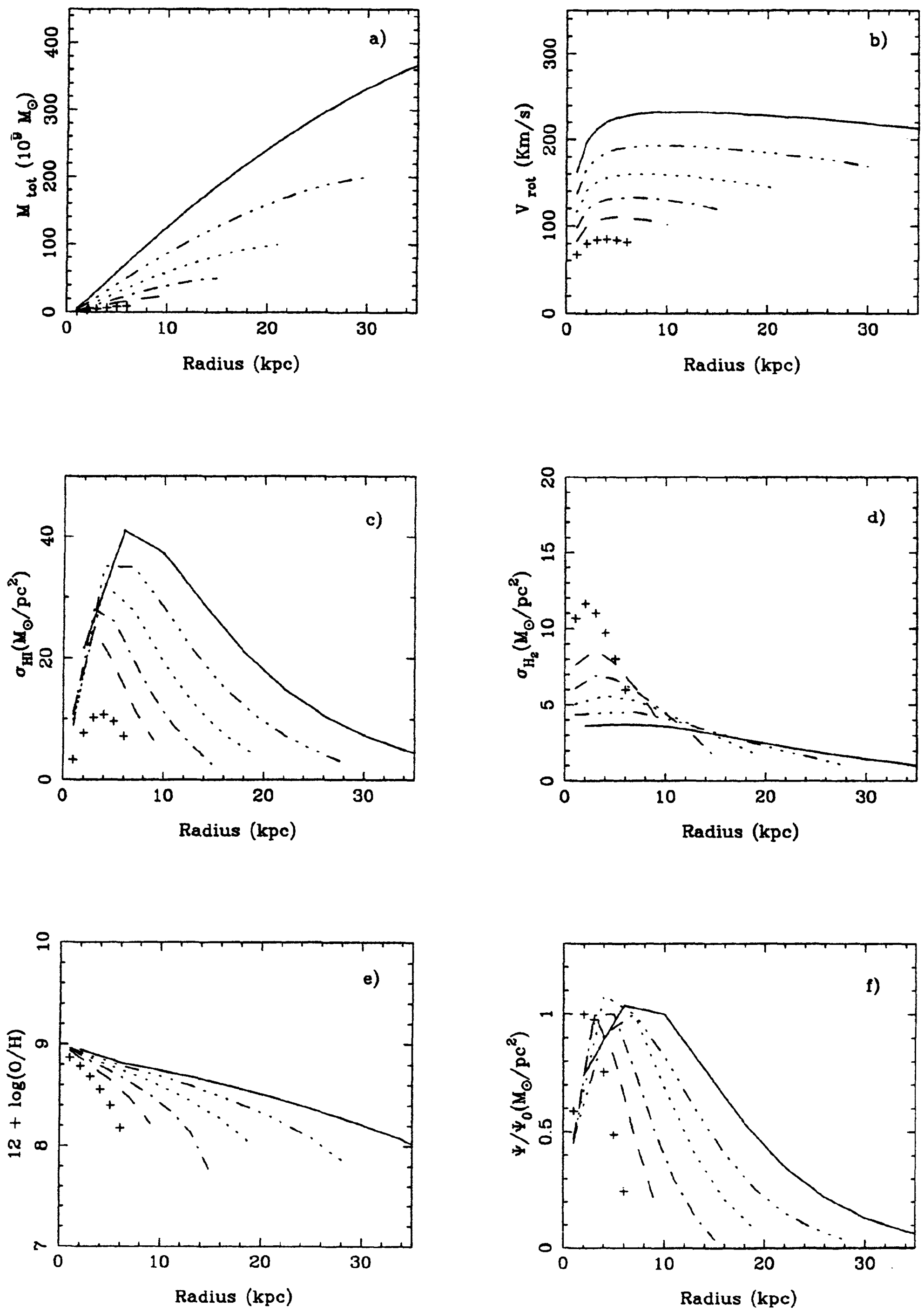

FIGURE 1. Results for models with different total masses: 10 (+ line), 25 (long dashed line), 50 (dot-dashed line), 100 (dotted line), 200 (three dot-dashed line) and 400 (solid line), 10^9 $M_\odot$. Radial distributions of a) Total mass, b) Rotation velocity, c) Difuse gas surface density, d) Molecular clouds surface density, e) Oxygen abundance, f) Normalized star formation rate surface density.