GALAXY MORPHOLOGY IN DISSIPATIVE MODELS

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ABSTRACT. Using numerical simulations in the context of a simple dissipative model (Abadi et al. 1990) we study the final morphologies and dynamical properties of galaxies under different initial conditions. The protogalaxies are embedded in dynamically relaxed potential wells of dark matter with different initial spin parameters λ and velocity dispersions σ in the dissipative component. We find that both λ and σ control the final morphology of the galaxies. The angular momentum might be acquired by tidal torques, and several sources may account for the velocity dispersion. For instance, under the assumption that supernovae explosions provide kinetic energy to the medium giving $\sigma \sim 8$-10 km/s (Mc Kee & Ostriker 1977) our models suggest that the border line spin parameter between early type and late type morphologies would be approximately $\lambda \sim 0.04$.

1. Introduction

More than 60 years have elapsed since Edwin Hubble proposed his concise classification of galaxies, but we still don't have a definite theory that is able to explain how the different morphological types form. In order to study the final morphologies and dynamical properties of galaxies, we have proposed a series of numerical simulations using a simple dissipative model for galaxy formation. Our aim is to find the physical parameters that at least explain the broad distinction between disks and spheroids.

2. Model

The models simulate a small volume of the universe that is enough overdense to form a galaxy. A protogalaxy is represented by a system of interacting gas clouds, embedded in a dynamically relaxed potential well of dark matter:

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 379–382.

$$\phi_{i,j} \propto m_i m_j / (r_{i,j}^2 + a^2)^{1/2} ,$$

where the subscripts i,j refer to the particles and 'a' is the softening parameter which suppresses two-body relaxation effects. The halo is simulated by means of a very massive particle with large softening. The total fraction of mass in the halo with respect to the mass in clouds M_H / M_D has been varied from 2 to 10. A gas cloud particle has a mass of the order of 10^6 $M_\odot$.

Dissipation of energy is produced by means of inelastic cloud-cloud collisions, under the following conditions:

minimum distance criteria.
limit in the number of effective collisions, (ncmax).
coalescence of two colliding clouds into one in the local rest frame.

A threshold for dissipation (ncmax) avoids the formation of a central massive particle (Blumenthal et al. 1986). This parameter ncmax is related to the gas physics and star formation process. If after several collisions a cloud has transformed a considerable fraction of mass into stars, a new collision with a similar cloud will result in the coalescence of the small fraction of gas remaining in the clouds, while the star components will interpenetrate each other with no energy dissipation, and continue with their trajectories.

2.1 Initial Conditions

The initial spatial distribution of the clouds was taken as a uniform sphere of radius 100 Kpc. Velocities were set as a solid body rotation corresponding to a total λ parameter that was varied in the range 0.01-0.1, where

$$\lambda = J \, |E|^{1/2} / G \, M^{5/2} ,$$

and different initial velocity dispersion of the gas clouds.

We assume that the system of clouds is initially at maximal expansion and that the gas is sufficiently cold to have clumped into discrete fragments represented by the particles. At maximal expansion the system has acquired roughly the total ammount of angular momentum by tidal torques from the neighbouring mass distribution. It is also assumed that the angular momentum per unit mass is the same for the clouds than for the halo and that the halo has already relaxed and is in virial equilibrium.

3. Analysis of the experiments

We have followed numerically the dynamical evolution of the system by means of the N-body2 code of S. Aarseth. We included a merging routine in order to search for collision candidates in the neighbour sphere. We have run several experiments with different initial conditions. The final configurations of two of them are shown in Figure 1.

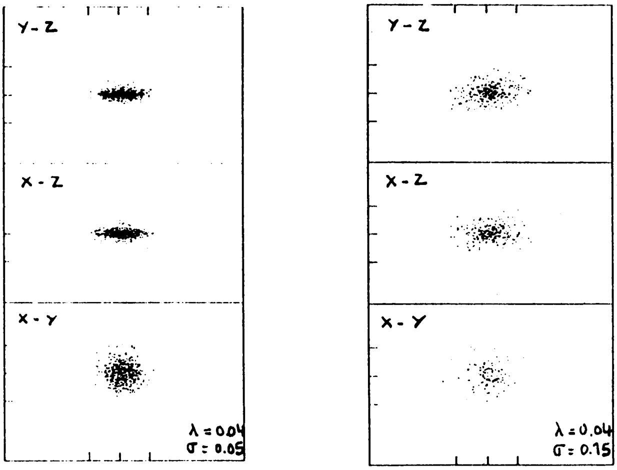

Figure 1: Final configurations of two experiments proyected in the z-x, z-y and x-y planes.

We have analyzed the final morphologies of the objects and its relation to the initial λ and σ. We show the results of a set of simulations in figure 2.

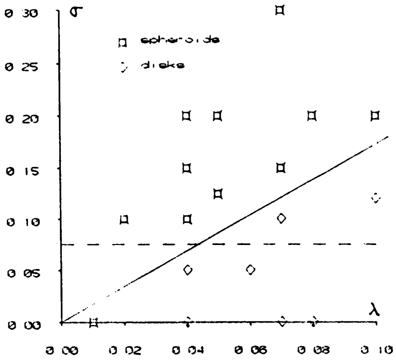

Figure 2: Distribution of several experiments in the initial σ-λ plane. We find that the initial velocity dispersion of the gas component is relevant in determining the morphology of the final object. The continuous line $\sigma \propto \lambda$, marks the transition from disks to spheroids. The dashed horizontal line corresponds to a velocity dispersion of the order of 8 km/s, expected in the gaseous component due to the input of kinetic energy by supernovae explosions(Mc Kee & Ostriker 1977).

4. Conlusions

- The final morphology is not sensible to the adopted fraction of mass in the halo with respect to the mass in clouds.
- Both λ and σ control the final morphology of the galaxies.
- In all simulations there is a redistribution of the angular momentum of the clouds:the larger the number of collisions, the larger the ratio Trot/Ttot of rotational to total kinetic energy.
- The border line separating spheroids from disks corresponds approximately to a linear relation between initial σ and λ (Vrot initial$\sim\sigma$ initial).
- We suggest the existence of a critical spin parameter dividing early and late type morphologies that would be $\lambda\sim0.04$, if an initial velocity dispersion of 10 km/seg is adopted. According to Hoffman (1988) and Tissera and Lambas (1990), this conclusions would be consistent with the morphology-density relation.

5. References

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