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DISK FORMATION IN A HIERARCHICAL CLUSTERING MODEL

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RESUMEN

Se presenta un estudio de la formación de galaxias espirales en un escenario de agregación jerárquico, utilizando simulaciones numéricas hidrodinámicas en un contexto cosmológico. Se evalúa la influencia de un bulbo estelar en la evolución del momento angular de la componente bariónica gaseosa durante fusiones y encuentros.

ABSTRACT

We investigate the formation of disk-like structures in a hierarchical clustering model using hydrodynamical cosmological simulations. We study the effects of the presence of a stellar bulge on the evolution of the angular momentum content of the gaseous disks during mergers and encounters.

Key Words: **COSMOLOGY — GALAXY FORMATION**

How galaxies form and evolve to have the properties observed today has been the subject of continuous study for decades. Within the Hubble sequence, spiral galaxies have been devoted an important effort. In 1978, White & Rees set the bases for the so-called standard model for disk formation, developed later on by Fall & Efstathiou (1980). This model, based on general physical principles, shows that, in order to form a disk-like structure with observational counterpart from a gaseous diffuse component in a dark matter halo with a certain amount of initial angular momentum, the gas has to cool and collapse conserving its angular momentum (J). The dark matter and the gas component are initially distributed in a uniform isolated sphere. The success of this model is due to its simplicity and the fact that, when applied in seminalytical and analytical studies, it is able to reproduce several properties of observed spirals (e.g., Mo, Mao,, & White 1997). However, it considers a density perturbation evolving in isolation, suffering no mergers or close encounters.

In a hierarchical clustering model, this is unreal since the structure forms bottom-up by mergers of sub-structures. Simulations in a cosmological context have detected an important loss of J by the baryons during mergers, so that disks form, but the hypothesis that the specific J of the final gaseous disk should be equal to that of the dark matter halo, is no longer satisfied. The resulting disk structures are too small and concentrated (e.g., Navarro & Steinmetz 1997). There have been several attempts to overcome this problem by introducing star formation (SF). However, if no heating sources are included, the gas is tranformed into stars very efficiently from high redshifts, depleting the gas reservoirs to form disks at later times. On the other hand, supernova feedback is a complex process and its inclusion in hydrodynamical simulations remains to be properly done.

In this paper, we report results on the formation of disk-like structures in a hierarchical clustering model. We performed two hydrodynamical cosmological simulations representing a typical box of the Universe (L=10 Mpc, H=50 km/s/Mpc) with 64^3 particles using an AP3M + SPH code (Tissera, Lambas, & Abadi 1997). The initial mass distribution is consistent with a standard Cold Dark Matter model with $b = 2.5$ and $\Omega_b = 0.1$. All, gas and dark, particles have the same mass, $2.6 \times 10^8 M_\odot$ (gravitational softening, 3 kpc; minimun hydrodynamical length, 1.5 kpc). The simulations, S1 and S2, share the initial conditions. Run S2 is a typical hydrodynamical one and run S1, includes SF implemented in such a way that only the gas in the *very dense regions* is transformed into stars (see Tissera, Lambas, & Abadi 1997 for details). In this way, a *stellar bulge* is formed soon after the first mergers, but the disk continues to be mainly gaseous. A comparative analysis of systems with disk-like structures (and $N_{\rm baryonic} > 150$) in S2 and their bulge+disk counterparts in S1, allows us to follow the process

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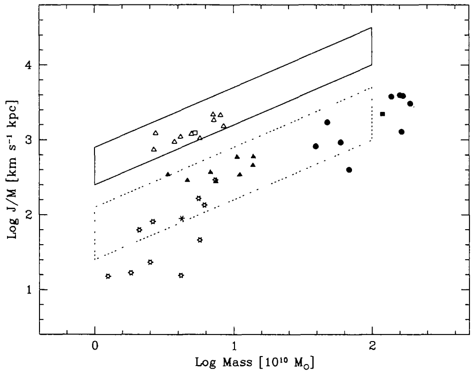

Fig. 1. The specific angular momentum at $z = 0$ versus the mass, for haloes in S1 or S2 (*filled circles*); the inner 83% of the gas component in disks S1 (*open triangles*) and S2 (*filled triangles*); the stellar component in S1 (*open stars*); and *filled and open squares and asterik* represents the same parameters for a high resolution run. The *solid* and *dotted* boxes show the regions occupied by spiral and elliptical galaxies, respectively.

of formation of the disks and stellar bulges, and the evolution of the angular momentum content of the different components.

From this analysis we see that disks are natural configurations for the cold gas. However, these disks can be highly unstable against bar instability according to the X_2 parameter criterium (Toomre & Toomre 1972), if baryons dynamically dominate at the centre. In this case, the strong tidal fields devolped during mergers may trigger radial inflows with an important loss of angular momentum, producing a concentration of the baryonic mass within the very central regions (Sellwood & Moore 1999). We detect that the major losses are produced during the orbital decay phase of the satellites. When the actual mergers occur, most of the gas is already at the centre with low angular momentum. This process works in every merger in S2 so that baryons lose most of their orbital and spin J, forming small and concentrated disks at $z = 0$ (filled triangles in Fig. 1). In run S1, where stellar bulges are able to form from the low J gas concentrated at the centre as a result of the first mergers, the gaseous disks that form afterwards from new gas infall, are stable ($X_2 > 3$ for $r > 3$ kpc). These disks do not developed strong inflows during the orbital decay phase and the major spin J loss is now produced in the actual fusion of the baryonic cores (the colliding baryonic clumps lose their orbital J to the dark matter haloes during the orbital decay phase, as in S2). However, in this case, the loss is not that strong and the remanent gas is able to retain part of it. This non-zero J gas settles inmediately onto a new intermediate disk helped by the axisymmetric character of the potential well which is assured by the presence of the compact stellar bulge. This intermediate disk is the crucial outcome of the merger from where a full disk structure is continued to be build up as new gas particles fall in from the diffuse component. The final disks have observational counterparts (see Fig. 1). Hence, compact stellar bulges provide an axisymmetric potential well during mergers preventing excessive J losses by stabilizing the disks (Mihos & Hernquist 1994; Domínguez-Tenreiro, Tissera & Sáiz, 1998). This mechanism may be a clue to provide the right conditions for the FE model to remain valid for the formation of massive disks in a hierarchical scenario.

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