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GAS DYNAMIC SIMULATIONS OF GALAXY FORMATION

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I will present results from a simulation modelling the formation of a group of galaxies in a "standard" cold, dark matter universe with $\Omega = 1$, $H_o = 50$ km s^{-1} Mpc^{-1}, baryon fraction $\Omega_b = 0.1$ and spectrum normalization $\sigma_8 = 0.6$ (bias parameter $b = 1.7$). This work is in collaboration with F. Summers and M. Davis of U.C., Berkeley (see F. Summers contribution to this meeting). Initial conditions are generated within a periodic box with comoving length 16 Mpc in a manner constrained to produce a small cluster of total mass $\sim 10^{14} M_\odot$. Two sets of 64^3 particles are used to model the dark matter and baryon fluids. Each gas particle represents $1.08 \times 10^8 M_\odot$, implying an L_* galaxy is resolved by ~ 1000 particles. The system is evolved self-consistently in three dimensions using the combined N-body/hydrodynamic scheme P3MSPH up to a final redshift $z = 1$. Evolving to the present is prohibited by the fact that the mean density in the simulated volume is above critical and the entire volume would be going non-linear beyond this point. We are currently analyzing another run with somewhat poorer mass resolution which was evolved to the present.

The baryons' thermal energy is subject to change due to adiabatic (PdV) work, shock heating and radiative cooling. The latter is assumed to be well described by a cooling function of a primordial plasma including line radiation and bremsstrahlung calculated assuming collisonal ionization. Star formation is not included. The baryons and dark matter are coupled gravitationally, the minimum scale resolved is ~ 10 kpc, roughly the optical size of a bright galaxy.

In collapsed regions, a two-phase structure develops in the baryons consisting a of cold, high density gas in rough pressure equilibrium with enveloping hot, tenuous halos at roughly the virial temperature of the dark matter halo. We identify a population of galaxy-like objects (*globs*) using a group finding algorithm designed to pick out concentrations of baryons above a fixed *physical* density of ~ 0.5 cm^{-3}. A minumum cutoff of 30 particles per galaxy, $3 \times 10^9 M_\odot$ in baryons, is imposed. The mass fraction of baryons in the galaxy population increases with time from roughly 5% at $z = 5.3$ to 18% at $z = 1.0$. During this time, the number of objects above the mass cutoff grows from 40 to 208.

A major result of this work is the formation of a significant population of rotationally supported baryonic disks. The accompanying figures show a prime example. Figure 1 shows face on (top row) and edge on (bottom row) views of the mass within 100 kpc of the center of the twelth largest glob found at the end of the simulation. The small bar in the panels denotes the 10 kpc resolution limit. Galaxies are clearly just barely resolved. The leftmost two panels, enlarged by a factor 3 compared to the rightmost two, show baryons in the cold phase $T < 3 \times 10^4$ K. The velocity field in the disk is regular, and an outer warp is apparent, most likely generated by interaction with a satellite just outside the region shown. *Of the total baryonic mass of* $1.2 \times 10^{11} M_\odot$ *within 100 kpc, 65% is in the cold disk* and 35% is in a hot halo with $T = 3 \times 10^6$ K shown in the right center panels. The dark matter halo is very nearly spherical and isothermal. The ratio of dark to baryonic mass is unity at 10 kpc, rising to 7.8 at 100 kpc.

Figure 2 shows the velocity field of the cold disk material in the principal component frame used in Figure 1. The solid line in 2a shows the mean tangential velocity as a function of radius while the dotted and dashed lines give the mean radial and z-components, respectively. The dispersion about the mean is shown in Figure 2b. The velocity field is very quiet, the major feature is a flat rotation curve of 200 km s^{-1} amplitude outside the resolution limit. Figure 3 shows the growth history of this disk. The only significant merger in its history involved a small satellite with mass $\lesssim 10\%$ of its own. Such quiet dynamical histories appear for the majority of galaxies identified in the simulation.

The poster will provide details on the formation and evolution of the galaxy population within the simulation.

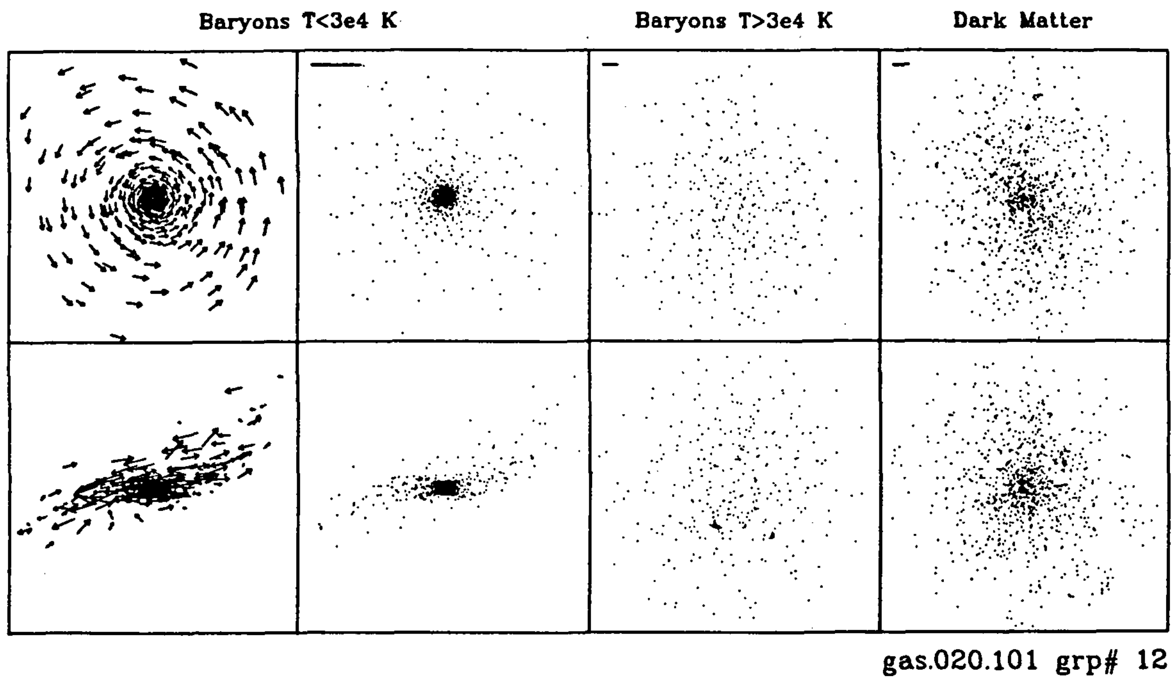

FIG. 1

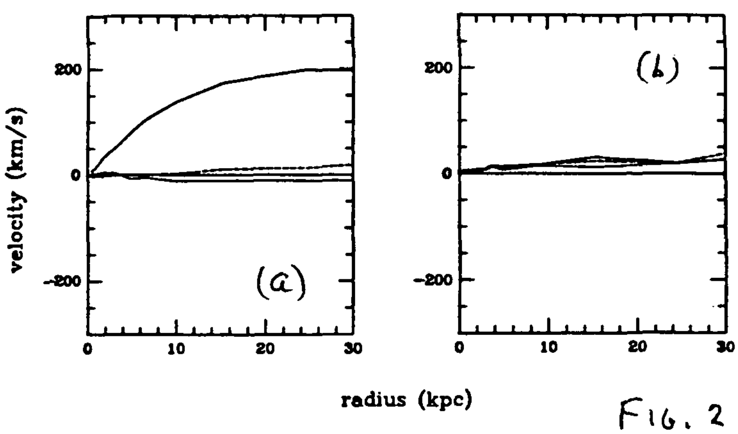

FIG. 2

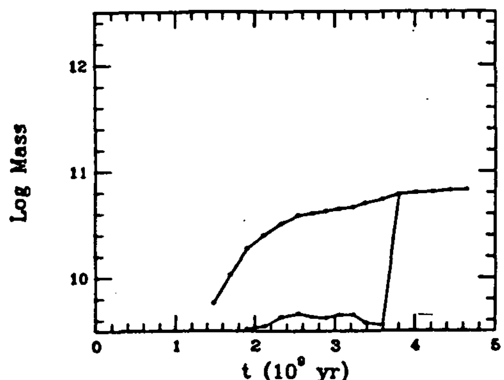

FIG. 3