An N-body tool to study the properties of groups and their member galaxies

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We present an N-body model of a galaxy group built to explore the formation of these structures within the framework of the standard 'concordance' flat Λ cold dark matter (ΛCDM) cosmology. Groups, which start as a spherical overdensity, can contain a varying number of live relaxed galactic halos of different mass, embedded on a, initially uniform, background of dark matter. The member galaxies are modeled by employing an updated version of the self-consistent multicomponent MaGaLie grid code by Boily et al. (2001) that allows to construct both spheroidal and exponential stellar distributions and incorporates the Navarro-Frenk-White (NFW) spherical halo profile. Tests of the quality of the derived equilibrium show that N-body realizations with a few hundred thousand luminous particles are enough to maintain the structural integrity of the simulated galaxies over a Hubble time. This dissipationless numerical model provides a powerful tool to investigate some of the most important nurturing effects of the group environment on galaxies.

MODEL CHARACTERISTICS

➲ Our simulations have been designed to adhere to the spirit of the hierarchical clustering scenario by defining initial conditions in which a group of galaxies starts being a spherical overdensity expanding before the nonlinear phase.

➲ The group model contains a varying number of randomly distributed live galactic halos on a uniform background of DM that, at the initial redshift of the simulations, $z = 3$, expand altogether with radial velocities matching the local Hubble flow. The value of the initial top-hat group overdensity is chosen so that the group perturbation collapses at $z \sim 0$.

➲ Galactic halos are modeled as virialized objects with an extended, dynamically dominant, DM component determining the structural and dynamical properties of a single, central distribution of stars. We adopt a DM to stellar particle mass ratio of 12.

➲ All galactic dark matter halos are assumed to be of the universal NFW form.

➲ The initial masses of galactic halos are sampled from a Schechter (1976) distribution function of asymptotic slope $\alpha = -1$.

➲ We generate stellar component models of early (spheroidal) and late (exponential disk) morphology that match the typical photometric and kinematic observations of the corresponding galaxy types.

➲ Initial conditions for late-type objects are generated from a self consistent analytical equilibrium model of an exponential disk embedded on a spherically symmetric NFW dark matter proto-halo truncated at the virial radius (**for details, see poster "An Analytic Model of Spiral galaxies" by Darriba & Solanes in this meeting**).

➲ Unlike the disks, the size measure, R_e, for the spheroids is obtained from an empirical formula: $R_e = 2.0\,[M/M^*]^{5/8}\,h^{-1}$ kpc, which is consistent with the SDSS early-type galaxy data for $z = 0$ on the i*-band (Bernardi 2003).

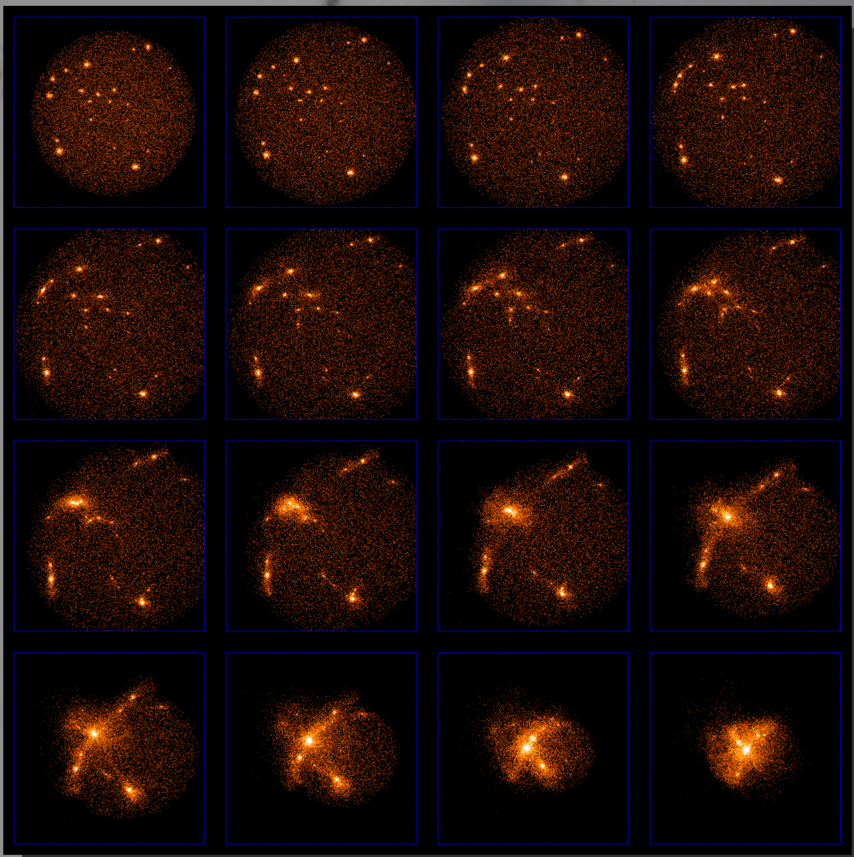
➲ The numerical realizations of the analytic disk-bulge-halo galaxy models are done with a modified version of the MaGaLie grid code (Boily et al. 2001), upgraded to allow one to choose either (two-component) spheroidal or (three-component) exponential galaxies and to incorporate halos with the NFW profile. For disk galaxies, we adopt a universal bulge/disk ratio of 0.125, characteristic of Sbc galaxies on the I-band (Graham & Worley 2008).

➲ The smallest galactic halos of total mass $M \leq 0.1\,M^*$ (see green box below) are assumed to host only spheroidal stellar distributions. Above this mass threshold, we adopt a late-type galaxy fraction of 0.6, typical of the field.

PRELIMINARY RUNS

We have begun to study the dynamical evolution of groups and their effects on member galaxies, by running a first batch of simulations with several million particles (in the future we plan to build a catalog of 10.000.000-particle groups). Gravitational forces are computed by using public versions of the N-body codes GADGET-2 (Springel 2005) and gyrfalcON (Dehnen 2000}. We show here a series of 16 snapshots of one of these preliminary simulations showing the evolution of the dark matter density in a group of total mass of 10 M* = 1.0E+13 $h^{-1}\,M_\odot$ that initially contains 25 galaxies. The number of dark particles in the simulation is ~ 2.780.000. The run starts at $z = 3$ and is evolved for about 11 Gyr (from left to right and top to bottom) until the present epoch when the entire group collapses. The lighter the color in the snapshots, which are uniformly spaced in time in steps of 0.4 units (see the green box for the equivalence between simulation and physical units), the higher the density of particles. We have adopted a force softening parameter $\varepsilon = 0.002$ and a typical integration time step of $\Delta t = 0.0005$, both expressed in simulation units.

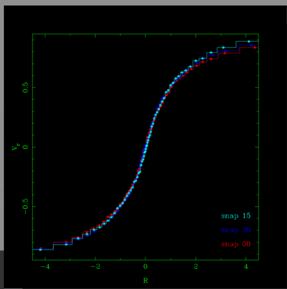
We are using these first simulations to investigate the formation of the extraordinarily large fractions of diffuse intragroup light found in some of the compact groups cataloged by Hickson (1982). **These are the largest *N*-body simulations ever conducted to study the dynamics of galaxy groups.** ▼

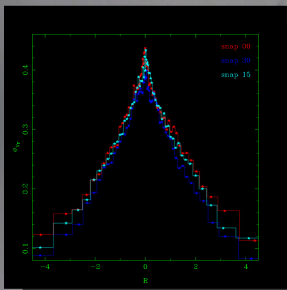


Simulation units

(for H_0 = 70 km/s/Mpc)

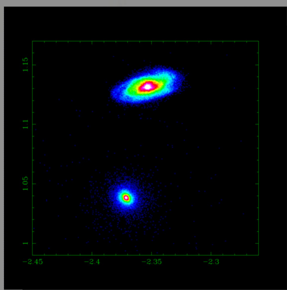
[M] = M* = 1.43E+12 $M_\odot$
[L] = R* = 292.3 kpc
[v] = V* = 145.5 km s^{-1}
[T] = R* / V* = 1.96 Gyr

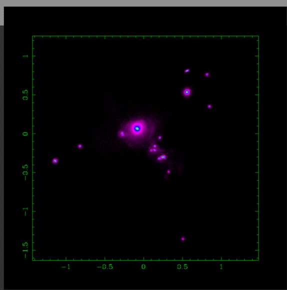




◄ ▲ **Stability tests.** Isolated disk galaxies with about 10^5 luminous particles conserve their structural and dynamical integrity for a Hubble time. Rotation curve (top) and velocity dispersion perpendicular to the disk (left) of an M* disk-galaxy of 360000 particles (120.000 stellar). Color curves in both plots correspond to 150, 225, and 300 revolutions (~ 10 Gyr) at the half-mass radius (snaps 15, 30, & 60).

Distribution of luminous matter. Left: Zoom onto the stellar components of two of the galaxies existing at t = 0.4 (top-left snapshot of the simulation). Each object in this frame contains about thirty thousand luminous particles. Right: Distribution of stellar particles in the group center when the simulation ends at t = 6.4 (bottom-right snapshot). In this simulation, we see the formation of a large merger remnant resembling a giant elliptical galaxy and substantial amounts of intragroup light. ▼





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