The Importance of Compact Group Environments Over Cosmic Time

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Abstract

The compact group environment ultimately impacts the evolution of the group members, but how, if at all, has this environment varied throughout the history of the Universe? We answer this question by identifying and following compact groups of galaxies in the Millennium Simulation from a redshift z=11 to z=0. We use the machine learning algorithm DBScan to identify compact groups based on certain criteria, then test how the identification of compact groups changes by varying the selection criteria. **The relative number of non-dwarf galaxies in compact groups peaks near z=2.** With our most liberal compact group selection criteria, the fraction of non-dwarf galaxies in compact groups peaks at ~2% and is ~1.5% at z=0. With the most conservative criteria, the fraction peaks at ~0.05% and is ~0.03% at z=0. In all cases, the fraction of non-dwarf galaxies in compact groups drops rapidly before z~4, consistent with a galaxy population dominated by low-mass systems. Finally, by tracking the evolution of compact groups through the simulation, we find that **between ~0.4% (most conservative) and ~15% (most liberal) of galaxies in existence today were members of compact groups or evolved from compact groups at some point in their history**.

Scientific Justification

Compact groups, with high galaxy number densities and velocity dispersions, provide a unique environment to investigate how gas processing is impacted by strong interactions between multiple galaxies simultaneously[1]. Recent work has demonstrated that the compact group environment has an impact on galaxy evolution that is not seen in other environments[2,3,4,5]. Most galaxies spend the majority of their lives in groups of some kind[6]. The fraction of galaxies that have ever been part of compact groups is unknown, but the recent advances in galaxy simulations, such as the Millennium Simulation[7] and associated galaxy evolution prescriptions[8], now allow us to investigate this outstanding question.

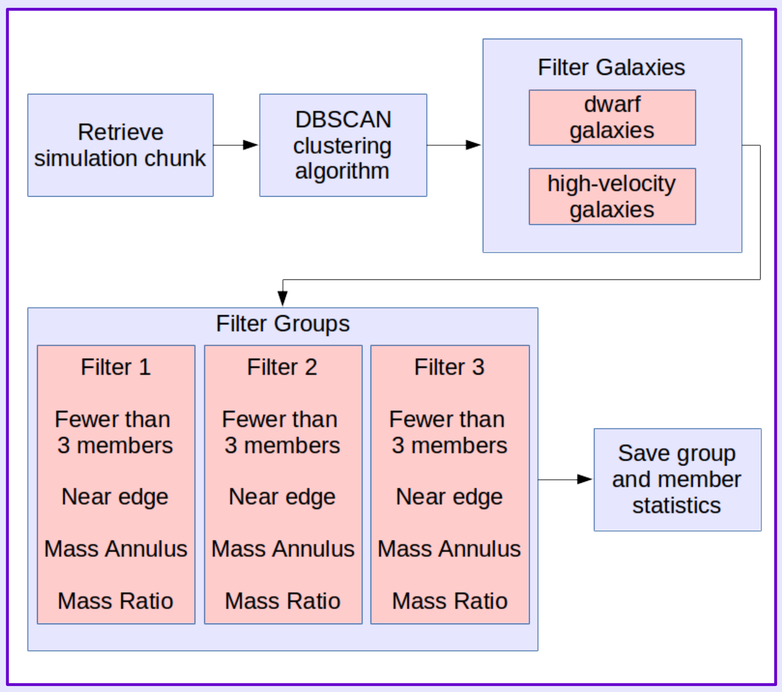

Figure 1: Schematic outline of our steps in identifying and filtering compact groups in the Millennium Simulation.

Analysis

We develop a code to identify and characterize compact groups in the Millennium Simulation. Clusters of galaxies are identified using the DBScan[9] machine-learning, clustering algorithm. We remove all dwarf galaxies and high-velocity "fly-by" galaxies from the identified clusters. Compact groups are then selected using the following tunable filters:

- Minimum number of members: compact groups must have more than 3 non-dwarf members (by definition)
- Near edge: compact groups within 1 Mpc/h of the edge of the simulation box are discarded
- Maximum annular mass ratio: the ratio of the virial mass of the compact group to an annulus surrounding the compact group (eliminates "groups" in or near large galaxy clusters)
- Minimum second-two largest galaxies mass ratio: the ratio of the virial mass of the second two largest galaxies to the largest galaxy in the compact group (eliminates systems with one large galaxy and two, smaller satellite galaxies)

A schematic of our analysis is in Figure 1.

Results

Our results can be summarized as follows:

- The fraction of galaxies in compact groups peaks between ~0.05% and ~2% (depending on the selection criteria) at z~2
- The fraction of galaxies in compact groups falls rapidly before z ~ 4
- The fraction of galaxies that have ever been a member of a compact group is between ~0.4% and ~15% today (depending on the selection criteria)

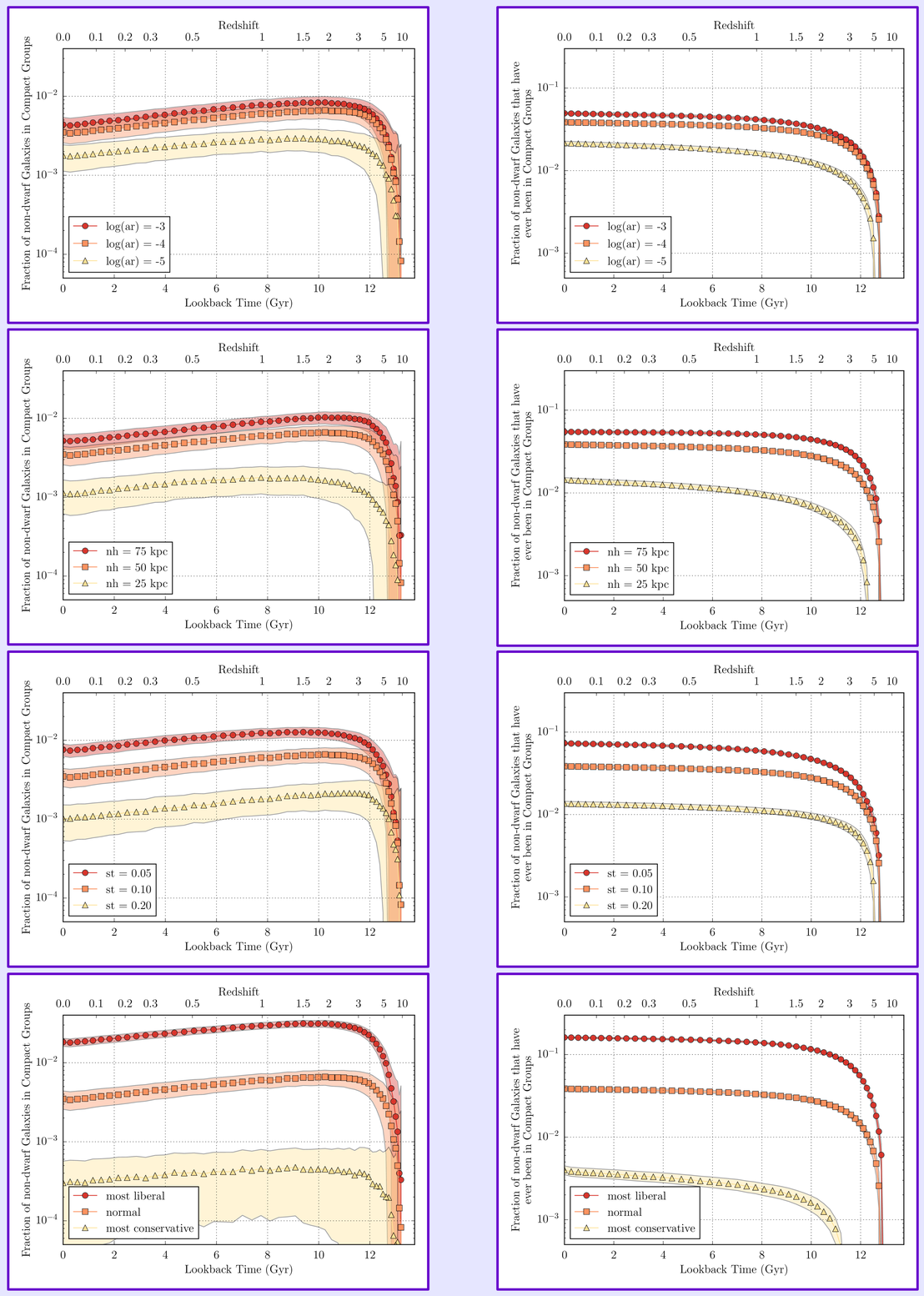

Figure 1: Fraction of non-dwarf galaxies in compact groups (left) and fraction of non-dwarf galaxies that have ever been in compact groups (right) for varying compact group identification and filtering criteria. The parameters varied (from top to bottom) are the annular mass ratio, neighborhood, and second-two mass ratio. The bottom figures use the maximum and minimum values of the three varied parameters. The width of the shaded regions is 50 times the formal Poisson uncertainty.

References

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