The Evolution of Compact Groups of Dwarf Galaxies

Christopher Wiens, Trey Wenger, Kelsey Johnson
University of Virginia

Introduction

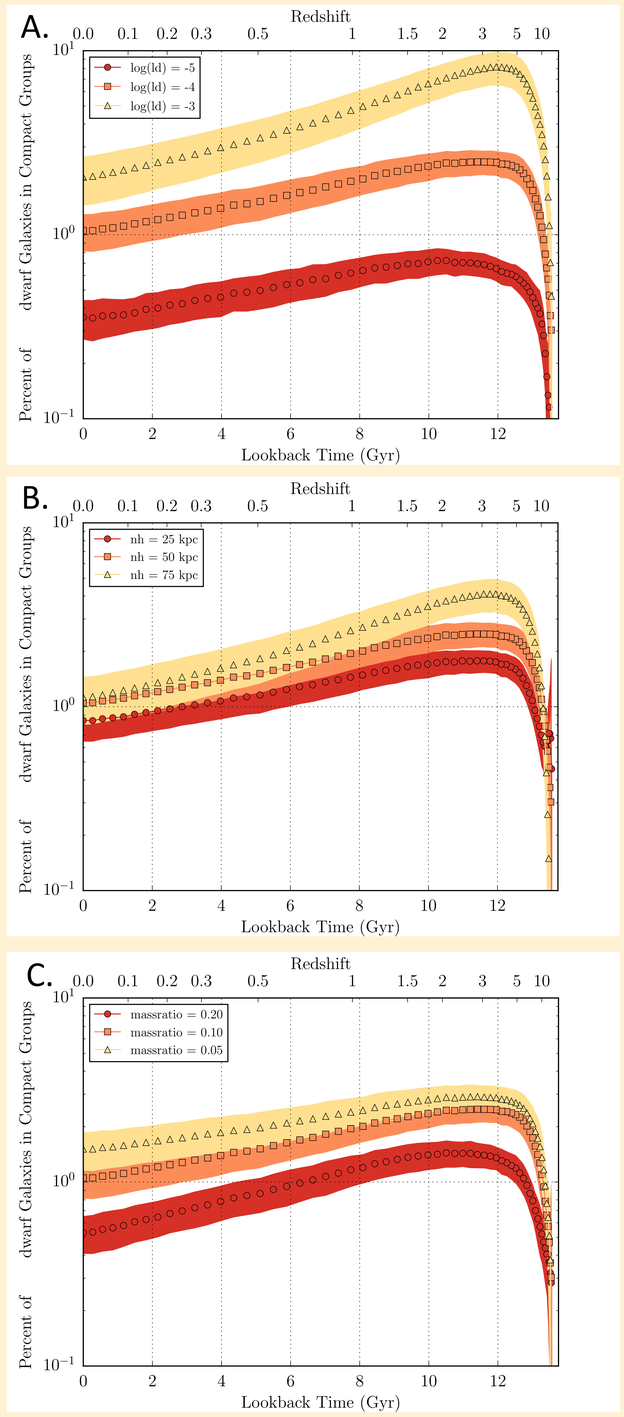
Compact groups are extremely dense clusters of at least three, but typically no more than 10, galaxies interacting gravitationally that will often merge (Hickson et al. 1992). These groups yield considerable information about galaxy interactions and mergers in dense environments but are impossible to observe at high redshifts.

The Millennium II Simulation is a massive n-body simulation of cold dark matter particles 125 time less massive than the Millennium Simulation on a time scale equivalent to the known universe (Boylan-Kolchin et al. 2009). Here we use computational analysis of the Millennium II Simulation combined with information from the Hickson surveys to examine the evolution of compact groups through time. We constructed an algorithm that analyzed galaxies in the Millennium II Simulation and fine-tuned the algorithm to various selection parameters.

Methods

- Clustering algorithm written in Python
  - Used DBSCAN method to find groups
- The Millennium II simulation was divided into overlaying sub-boxes to ensure all galaxies were included
  - Results were checked to make sure no galaxies were double counted
- Clusters were selected based on varying conditions:
  - Neighborhood - proximity one galaxy was to other galaxies in the group, measured in kiloparsecs
  - Mass ratio – ratio of the 2nd and 3rd most massive galaxy added together then multiplied by a value versus the mass of the most massive galaxy in the group
    - $M_{largest} / (M_{2nd\ largest} + M_{3rd\ largest}) \leq$ (Mass ratio)
    - Dimensionless number
  - Local Density – stellar mass in group divided by spherical volume versus stellar mass in annulus around inner sphere with an otter diameter of 1 Megaparsec
    - $\varrho_{outer} \leq \varrho_{inner}$ * (local density)
- Default values for local density, mass ratio and neighborhood were 10^{-4}, 10 and 50 respectively
  - Default values are seen as most center value for selection parameters
  - When testing different criteria, the other two variables are held at their default values

Figure 1: The percent of galaxies in compact groups increases as a function of redshift and then decreases after z = 3. Selection criteria: Varying Local Density (A), Varying Neighborhood (B) and Varying Mass Ratio (C), Maximum and Minimum (D).



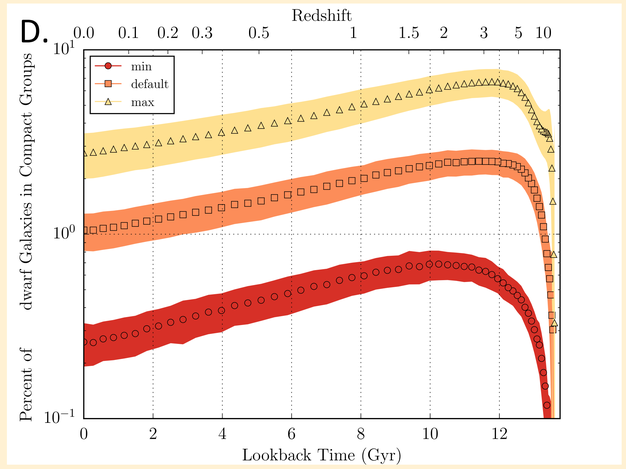
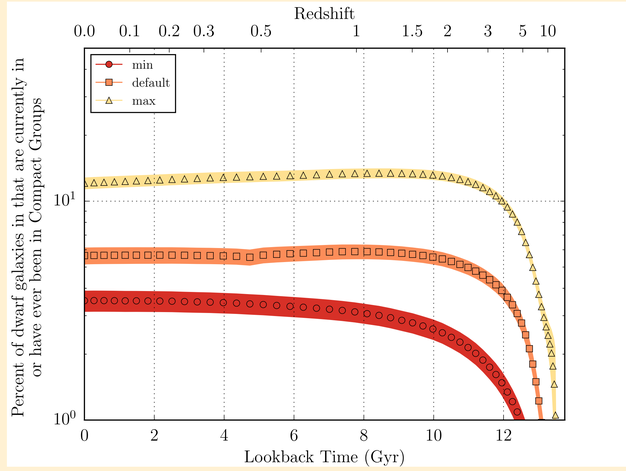


Figure 2: The percent of galaxies that have been or are currently in compact groups continually increases as a function of time for the minimum, default and maximum criterias.



Conclusions

- All peaks occur before or at z = 2.
- Large number of compact groups of dwarf galaxies in the universe at any given time.
- Local Density provides the largest difference in number of groups at a given redshift.
- Neighborhood does not affect results as much as it did the compact groups of non-dwarf galaxies.
- 13 percent of galaxies in the present day universe have been or are current apart of compact groups with the most liberal criteria.

References

Hickson, P., Mendes de Oliveira, C., Huchra, J.P., Palubo, G.G. 1992, ApJ, 399, 353

Boylan-Kolchin, M. et al. 2009 MNRAS 398