Effect of large-scale environment on the galaxy stellar mass function

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Abstract

To understand the role of the large-scale environment in galaxy formation and evolution, it is essential to study the present-day behavior of different galaxy populations under various environmental conditions. By studying the galaxy stellar mass functions in different environments defined by the large-scale luminosity density field, we have shown that the stellar mass functions of galaxies are different in low- and high-density, large-scale environments. The results contradict with the theoretical assumption that the properties of galaxy populations depend solely on their halo masses and do not depend on their large-scale environments.

Introduction

Galaxies and their dark matter halos have grown hierarchically, forming larger systems, such as groups, clusters, filaments and superclusters of galaxies, separated by enormous voids. In observations, this large-scale distribution of dark and baryonic matter manifests itself as a complex web of galaxies. This cosmic web includes a wide range of scales from the mega-parsec (Mpc) galaxy group scale to the supercluster and filament scales, several tens to hundreds of Mpc (Gregory & Thompson 1978; Zeldovich et al. 1982; Tempel et al. 2014a). As a result, galaxies may find themselves in a variety of local and large-scale environments during their evolution. It is a topic of debate if the interplay of various physical processes during the hierarchical growth of structures also has affected the properties of galaxies and if the cosmic web environment has played any role in galaxy and group evolution.

With the advent of various large-scale sky surveys in different wavebands, it has now become very realistic to test the dependence of galaxy properties on their large-scale environments using precise estimates of galaxy properties from their observed spectral energy distributions (SEDs).

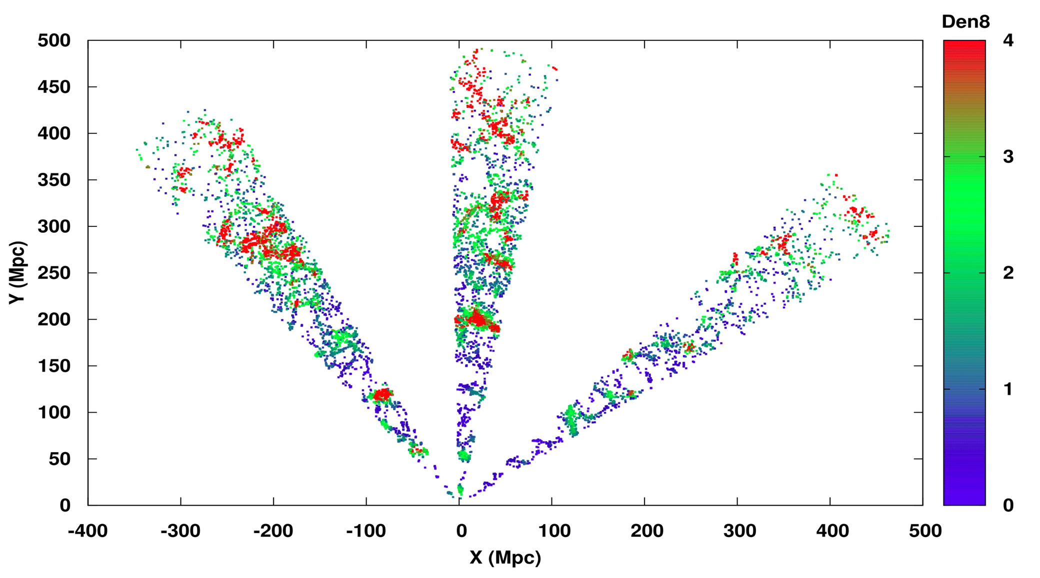

Figure 1. Galaxy distribution of the multifrequency catalog in Cartesian coordinates color coded with luminosity densities with 8 h^{-1}Mpc smoothing.

Data

Multifrequency group catalog: It is constructed by crossmatching optically selected groups from the SDSS DR10 group catalog (Tempel et al. 2014b) with GAMA DR2 (Liske et al. 2015) and WISE (Wright et al. 2010) data. The catalog consists of 1652 groups and 11436 galaxies containing photometric information in 15 different wavebands with wavelengths ranging from ultraviolet (0.15 μm) to mid-infrared (22 μm). The area of coverage of the sample is about 144 square degrees and extends up to redshift 0.2. The magnitude limit of the catalog is 17.77 mag in the SDSS *r* band.

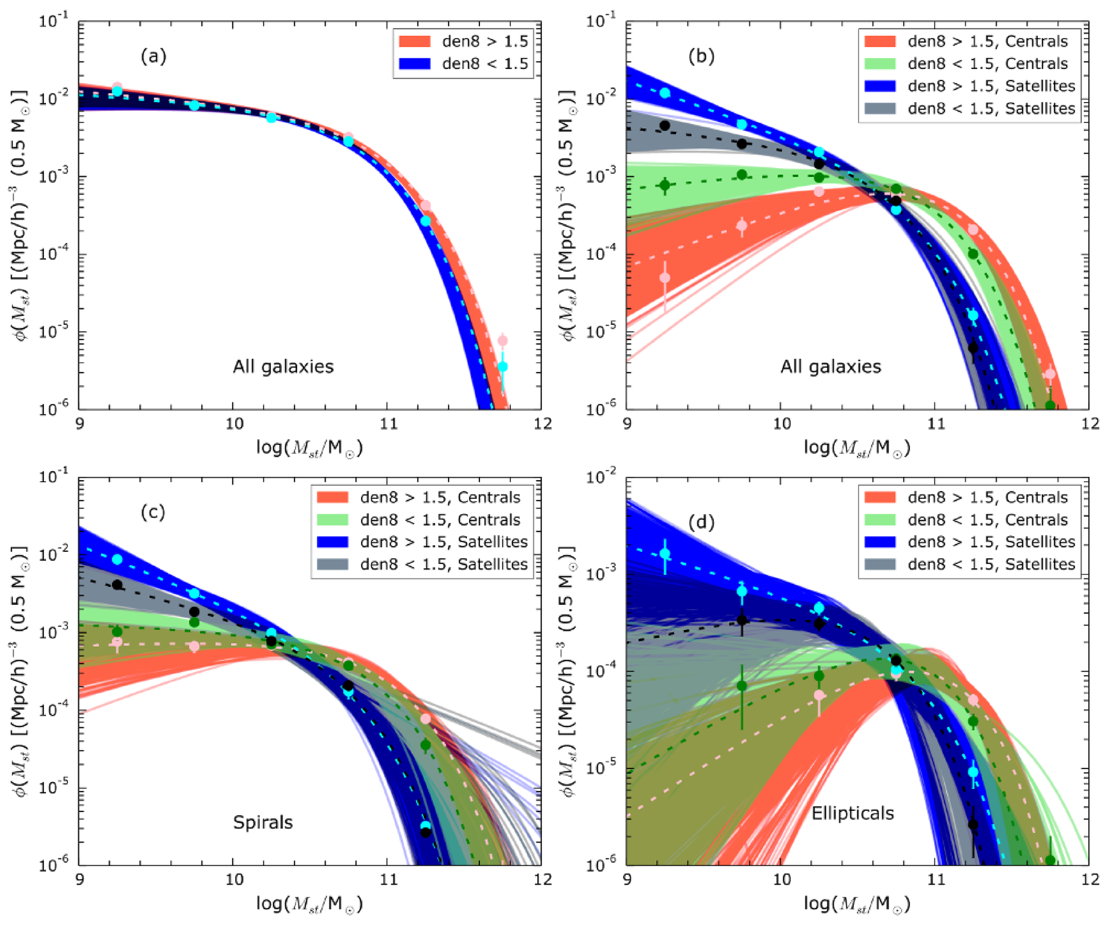

Figure 2. Stellar mass functions of different galaxy populations in groups in high- and low- density large-scale environments. Solid lines represent the stellar mass functions for 1000 different bootstrap samples. Dotted lines represent the best fit.

Methods

SED fitting: We use a publicly available MAGPHYS SED fitting code (http://www.iap.fr/magphys) to fit the observed galaxy SEDs extending from UV to IR wavelengths to a library of model SEDs based on da Cunha et al. (2008). The fitting produces the best-fit, rest-frame magnitudes and stellar masses of galaxies and also provides the range of their likelihood values using the Bayesian approach.

Defining large-scale environments: We use the luminosity density field of galaxies to characterize their large-scale environments. In this method, the galaxy luminosities, corrected by observational biases and selection effects, are smoothed with an appropriate kernel, the width of which determines the characteristic spatial scale (Liivamägi et al. 2012). This approach leads to the total three-dimensional luminosity density field of the survey, where different density levels in units of cosmic mean density represent different characteristic structures: filaments, voids, and superclusters (Figure 1).

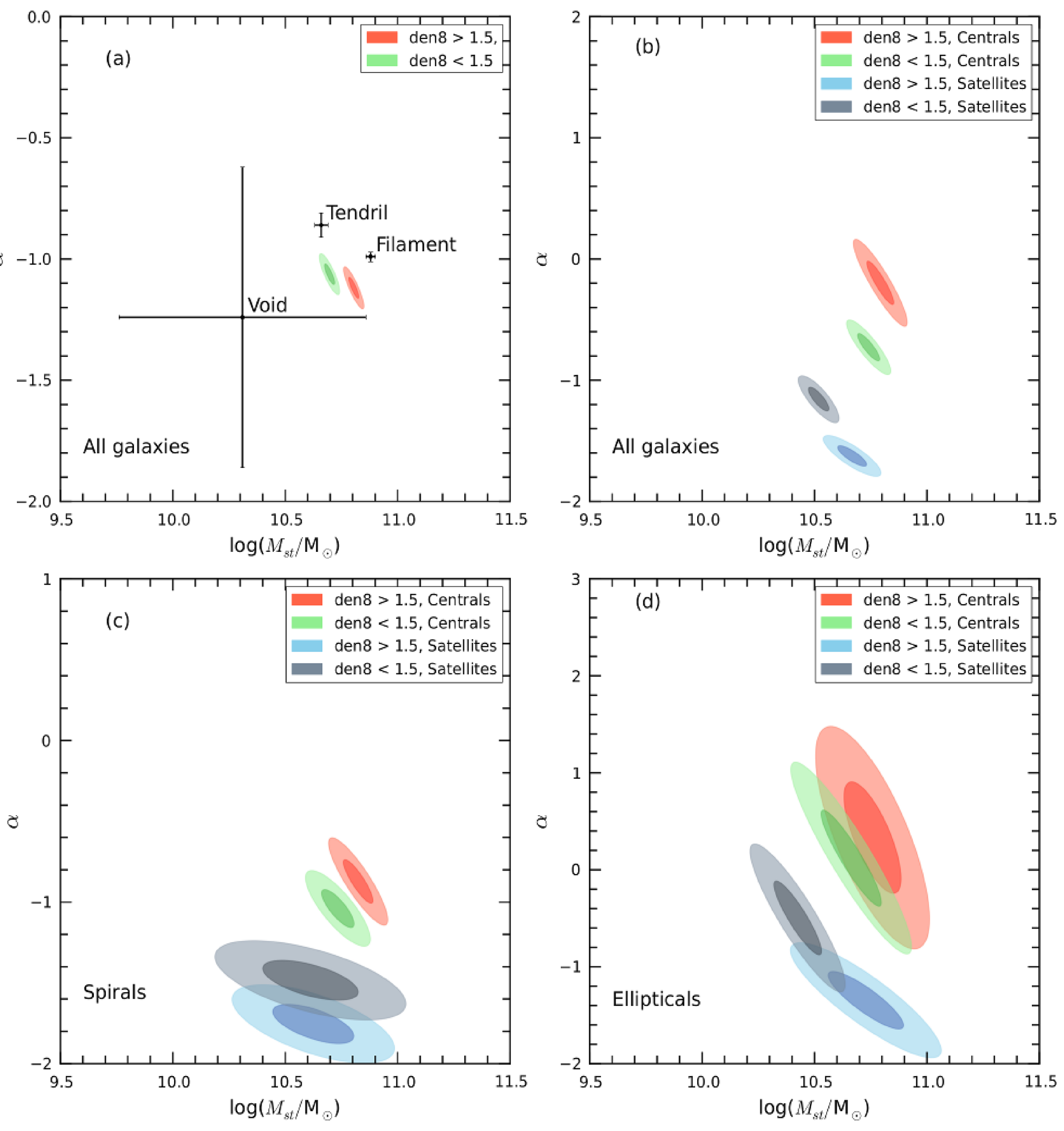

Figure 3. Error ellipses of the Schechter fit parameters, characteristic stellar mass (M_{st}) and low-mass end slope (α) for Figure 2.

Results

The stellar mass functions of both central and satellite galaxies in groups are different in low- and high-density, large-scale environments.

Satellite galaxies in high-density environments have a steeper low-mass end slope compared to low-density environments, independent of the galaxy morphology. At a fixed group mass, groups in high-density environments have more satellites than in low-density environments.

Central galaxies in low-density environments have a steeper low-mass end slope, but the difference disappears for fixed galaxy morphology.

The characteristic stellar mass of satellite galaxies is higher in high-density environments and the difference exists only for galaxies with elliptical morphologies.

Discussions

The results disagree with the theoretical assumption that the halo-occupation distribution at fixed halo mass is independent of the large-scale environment.

For similar halos, galaxy formation is more efficient in high-density environments compared to low-density environments. A plausible scenario is that the high-density environments have more filaments, which supply cold gas to halos resulting in increased galaxy formation efficiency.

My ongoing project is the study of the impact of the filamentary structures on galaxy and group evolution.

Contact

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