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Dependence of the clustering properties of galaxies on galaxy age

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A B S T R A C T

From the Main galaxy data of the Sloan Digital Sky Survey Data Release 10 (SDSS DR10), we construct two volume-limited samples with the luminosity $-20.5 \leq M_r \leq -18.5$ and $-22.5 \leq M_r \leq -20.5$, respectively, and explore the dependence of the clustering properties of galaxies on galaxy age by cluster analysis. Statistical analyses in two volume-limited Main galaxy samples can reach the same conclusions: young galaxies preferentially form isolated galaxies, close pairs and small groups at all scales, whereas old galaxies preferentially inhabit dense groups and clusters.

1. Introduction

The distribution of galaxies in the Universe has been a long-term obligatory topic in cosmology. In the past, many authors focused on the dependence of the clustering properties of galaxies on various galaxy parameters [1–27]. For example, Brown et al. [4] and Deng et al. [16] observed strong dependence of the clustering properties of galaxies on colors of galaxies. Some authors reported that the clustering amplitude of the correlation function of galaxies increases with absolute magnitude [6–8,28–30]. Galaxies with different morphologies also show large variations of the clustering properties [1,3,15]. Deng [27] found that the clustering properties of galaxies has a strong dependence on the star formation rate (SFR) and specific star formation rate (SSFR): isolated galaxies or galaxies in close pairs and small groups have preferentially high SFR and SSFR, whereas member galaxies of dense groups and clusters have preferentially low SFR and SSFR. In this work, we explore the dependence of the clustering properties of galaxies on galaxy age.

When investigating the distribution of galaxies, one often applied the correlation function [1,4,6,9,31–34]. Moreover, some authors measured the baryon acoustic oscillation (BAO) signature in the correlation function of galaxies at intermediate and high redshifts [31–34], using the data of the Baryon Oscillation Spectroscopic Survey (BOSS) of the SDSS-III project [35]. However, as indicated as Deng [27], the correlation function also has its own limitations [36]. For such an analysis, one quantifies the clustering properties of galaxies only by two statistical parameters: the clustering amplitude and the slope of the best-fitting power law. Clearly, they cannot describe the geometry of the galaxy distribution in detail. In the past, astronomers successively observed some important characteristic structures, such as voids [37], “the Strings” [38] and “the Great Wall” [39,40]. The correlation function also cannot probe such super-large -scale structures. Considering these factors,

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we use an alternative approach and apply cluster analysis [41] for investigating the clustering properties of galaxies, like Deng et al. [15–19] did.

The tenth data release (DR10) [42] of the SDSS-III includes the data set of age. The Main galaxy sample [43] of the SDSS is the largest and the most valuable galaxy sample in the local Universe, which contains galaxies brighter than $r_{petro} = 17.77$(r-band apparent Petrosian magnitude). The primary goal of this study is to investigate the dependence of the clustering properties of galaxies on galaxy age in this sample. The outline of this paper is as follows. In Section 2, we describe galaxy samples. In Section 3, we present and discuss statistical results. Section 4 summarizes our conclusions.

In calculating the distance, we used a cosmological model with a matter density of $\Omega_0 = 0.3$, a cosmological constant of $\Omega_\Lambda = 0.7$, and a Hubble constant of $H_0 = 70\text{km } s^{-1}\text{ Mpc}^{-1}$.

2. Description of galaxy samples

The data of the Main galaxy sample was downloaded from the Catalog Archive Server of SDSS Data Release 10 [42] by the SDSS SQL Search (http://www.sdss3.org/dr10/). In the SDSS, the target flags can be used to select out objects that were targeted for some particular reason. The Main galaxy targets have one of the LEGACY_TARGET1 bits "GALAXY", "GALAXY_BIG" and "GALAXY_BRIGHT_CORE" set (bits 6, 7 and 8). This corresponds to the requirement: LEGACY_TARGET1 & (64 |128| 256) > 0. We extract 633172 Main galaxies with the spectroscopic redshift $0.02 \le z \le 0.2$.

Maraston et al. [44] employed two template fittings (passive and star-forming) and two adopted Initial Mass Functions (IMFs) (Salpeter and Kroupa). The passive model does not include the possibility of a non-zero SFR (star formation rate). The selection of the star-forming template and the Kroupa IMF leads to the largest number of non-zero SFR galaxies. Considering that further investigation would likely shed light on the SFR of galaxies, we use best-fit age of galaxy[in Gyr] obtained with the star-forming template and the Kroupa IMF [44]. The data set of age measurement is from the StellarMassStarFormingPort table.

When constructing volume-limited galaxy samples, it is necessary to estimate the r-band absolute magnitude M_r. Here, we make use of the K-correction formula of Park et al. [45]: $K(z) = 2.3537 \times (z-0.1)^2+1.04423 \times (z-0.1)-2.5 \times log(1+0.1)$. Following Deng [46], we work with two different volume-limited Main galaxy samples: luminous and faint, to examine the difference of statistical results between luminous galaxies and faint galaxies. The luminous volume-limited sample is constructed by selecting 129515 galaxies with the r-band absolute magnitudes $-22.5 \le M_r \le -20.5$, in the redshift range $0.05 \le z \le 0.102$; the faint volume-limited sample is constructed by selecting 34573 galaxies with $-20.5 \le M_r \le -18.5$ and $0.02 \le z \le 0.0436$.

To investigate the dependence of the clustering properties of galaxies on galaxy age, we divide each volume-limited Main galaxy sample into two subsamples with different ages: young and old, and then compare the clustering properties of young galaxies with those of old galaxies. Table 1 lists some parameters of subsamples. It is important to note that the application of cluster analysis leads to richer and larger systems more easily being formed in high-number density samples. In this condition, one often used dimensionless radii to express distances. However, Deng et al. [15,16] argued that such an replacement cannot completely remove this bias. Considering this factor, Deng [27] acquired that the number density of the two subsamples is nearly the same when creating subsamples with different parameters of galaxies. Here, we also base the age thresholds on such a consideration, and select the age thresholds in volume-limited samples for ensuring that the number density of the two subsamples must be nearly the same.

3. Results and discussion

The cluster analysis [41], often referred to as the friends-of-friends (FoF) algorithm, is a simple and straightforward method of studying the distribution of galaxies, which is especially suitable for volume-limited samples. It often was used for studies of superclusters [41,47–49]. For example, Einasto et al. [41] applied the cluster analysis and explored the structure of the Local Supercluster. This method also was successfully employed in the compilation of catalogs of galaxy groups [50,51].

Section 4 of Einasto et al. [41] describes this method in detail. In such a method, various systems of objects are searched for at a certain neighbourhood radius r. Finally, the galaxy sample is separated into galaxy systems of different size and density contrast, such as isolated galaxies, galaxy pairs, galaxy groups or clusters and superclusters.

The Poisson radius is the one of the sphere with unit population, and is defined as $R_0 = [3V/(4\pi N)]^{1/3}$, where N and V are the number of galaxies in the sample and the volume of the sample, respectively. Following Deng et al. [15–17], the

Table 1
Some parameters of two subsamples in each volume-limited Main galaxy sample.

Sample	Subsamples	Galaxy number	Poisson radius R_0(Mpc)
Luminous volume-limited main galaxy sample	Young (age <2.7[in Gyr])	65791	5.864
	old (age ≥2.7[in Gyr])	63724	5.927
Faint volume-limited main galaxy sample	Young (age <1.8[in Gyr])	17076	4.021
	old (age ≥1.8[in Gyr])	17497	3.988