Study of substructure analysis of supercluster S [227+006+0078] radial velocity range of 21300 km/s to 23400 km/s

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Abstract: This paper presents the search for substructures within the Supercluster S [227+006+0078]. To use the spectroscopic database (7th data release) of galaxies, studied the number density, all-sky distribution, and redshift maps to identify substructures based on their richness and compactness. And also to find out the substructures within the Supercluster, using the contour plot of number densities of galaxies within the appropriate radius values and number of nearby galaxies.

Keywords: Large- scale structure of the universe- galaxies; Substructures; Supercluster; Orientation.

Introduction

The formation of the Universe is still an unsolved problem of astrophysical research. The Universe is based on observational evidence and a few theoretical concepts. The discovery of the Expansion of the Universe provided the most important established feature of the modern cosmological picture. In addition, the observation of the Cosmic Microwave Background Radiation (CMBR) provided a strong connection of the present cosmological picture to fundamental Particle Physics. Observational data support the picture of a Universe that is to a very good approximation homogeneous (all places are alike) and isotropic (all directions are alike). The hypotheses of homogeneity and isotropy are referred to as the Cosmological Principle. Such a Universe is called uniform. The most remarkable feature of the mega parsec-scale matter distribution in the Universe is the presence of a cosmic web the network of galaxies, groups, and clusters[1]. We have to understand the role of small-scale (group) and large-scale (Supercluster) environments in galaxy formation and evolution. We need to study the properties of Superclusters and their galaxy and group populations together. The large-scale structure of the Universe is formed by a hierarchy of galaxy systems from isolated galaxies to groups, substructures, and Superclusters of galaxies[2]. The clustering phenomenon does not stop with galaxies. Galaxy clusters attract each other to produce Superclusters. Superclusters are largest structures of the cosmos. Superclusters are important tracers of dark and baryonic matter in the Universe; they also provide information regarding the different orientations of angular momentum vectors of galaxies and their distribution which is beneficial to know about the initial condition of the formation of these

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large scale structures. We have to search substructures within Supercluster and to understand their properties. We need to know how to identify them and how to quantify their properties. Supercluster varies in its shape, extension, galaxy content, etc. Morphology of a Supercluster studied with the help of Minkowski functional. The determination of cosmic structure using the density field, to study their morphology with Minkowski functionals and shape finders is quite an interesting approach. These Minkowski functional used to differentiate Superclusters into various morphological types Spider, multi spider, filaments, and multi-branching filaments[2]. The study of the distribution of galaxies in the Supercluster can lead to the identification of substructure: visualized substructure cluster; galaxies group connected by filament etc.

Einasto et al. analyzed the structure of rich galaxy clusters in Superclusters of different morphologies and showed that clusters in Superclusters of spider morphology have higher probabilities of having substructure and their main galaxies have higher peculiar velocities than clusters in Superclusters of filament morphology[2, 3].

Data compilation

The database used in this work consists of galaxies within Supercluster S [227+006+0078] located within the survey regions of Sloan Digital Sky Survey (SDSS)[4] (7th data release). The Supercluster has a redshift limit in the range of 0.071 (or radial velocity 21300 km/s) to 0.078 (or radial velocity 23400 km/s). There were 1213 galaxies of Supercluster S [227+006+0078] after removing the galaxies having axial ratio, $q = b/a < 0.13$. Where a and b are semi-major and semi-minor axes. All-sky distributions of 1,213 galaxies were observed to identify substructures. Finally, we identified two substructures as S1 [228+006+0079], S2 [227+008+0078] with galaxy numbers 287, and 188, respectively.

Method of analysis

According to cosmological principles, the expected distribution of galaxies in the equatorial coordinate system should be homogeneous5. In contrast, the all-sky distribution of galaxies shows the inhomogeneous distribution. Thus, for a detailed study of the Supercluster, the substructure within the Supercluster needs to be identified. Density analysis of galaxy distribution could reveal the presence of substructures as a region of high galaxy aggregation, and their properties and distribution within a Supercluster6. The galaxies are not uniformly distributed within the Supercluster: they can consist of isolated individual galaxies, smaller galaxy groups, or rich clusters of galaxies. These substructures can be in the process of evolution through collision, merger, and fragmentation.

Thus, In order to identified substructure within the Supercluster S [227+006+0078], to classified database (total sample) into substructure based on the number density of galaxies. By analyzing the distribution of galaxy in the contour map in various radius values (0.25º, 0.5º, 0.75º, 1.0º), we choose the particular value of radius for which a clear substructure is seen. So, we choose the suitable counting bin size of (0.25º, 0.5º, 0.75º, 1.0º one by one) square degree in the RA-Dec all sky map of Supercluster to count number of galaxies within the neighborhood of each galaxies in the Supercluster.

The MATLAB7.0.1 code used for this purpose is as follows:

Galaxy Counting Code

```
ra = importdata('ra.m'); dec = importdata('dec.m');

sc = [ra,dec];  n = numel(ra)

repeat = 'y';

while repeat =='y'

radius =input('Enter the radius of circle in degree: ')

for i=1 : n count=0;

for j=1 : n

r = (ra (i) - ra (j)) ^2 + (dec (i) - dec (j)) ^2;

if r <= radius*radius
```

count =count+1;

end

neighgal (i)=count;

str = input('enter a _le name to store near galaxy numbers: ','s')_d=fopen (str,'wt');

fprintf (_d,'fclose(_d);

repeat =input('enter c if you wish to continue another size or to exit: 'end')

We have used ORIGIN8.0 for the calculation and plotting.

Results and discussion

The contour plot for different radius (0.25º, 0.5º, 0.75º, and 1.0º) values of Supercluster S [227+006+0078] is shown in Figure 1 below. To identify, substructure within the Supercluster S [227+006+0078] through looking at the contour plot of different radius values, we can be distinguished, in which radius value of the clear substructure.

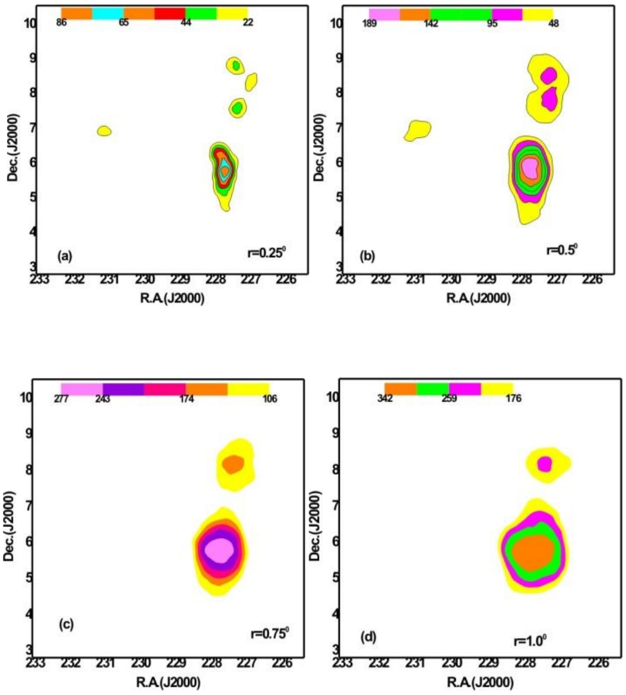

Figure 1: Number density map of Supercluster S [227+006+0078]. In the above diagram, a, b, c, d and represent the contour map along the different radius of circle namely, 0.25º, 0.5º,0.75º, and 1.0º respectively. The X-axis and Y-axis represent right ascension (R.A.) and declination (Dec.), respectively.

In Figure 1(a), here r = 0.25º, we can see five high-density contrast regions at the different regions in the equatorial coordinate system. If we increase the radius value (r = 0.5º) in Figure 1(b), even though we can visualize different substructures, there is no prominent structure because the density contrast region begins to overlap. Due to this region, it is very difficult to separate substructures to study precisely. Similarly, in Figure 1(c) r = 0.75º and (d) r = 0.1º, there only seen two different substructures, however, we are searching for as many as different strong density regions. For radius values, 0.75º and 0.1º, found two substructures, namely S1 [228+006+0079] and S2 [227+008+0078], and found galaxy numbers 287 and 188, respectively.

The all-sky distribution of the total number (1213) of galaxies in the Supercluster S [227+006+0078] is shown in Figure 2. This distribution reveals that the galaxies are not equally distributed throughout the whole region: a heterogeneous distribution. The inhomogeneous nature of the distribution of galaxies in this Supercluster shows that a large number of galaxies are concentrated in the region of right ascension between 227º to 228º. The morphology of this Supercluster can be defined as a spider-type as shown in Figure 2.

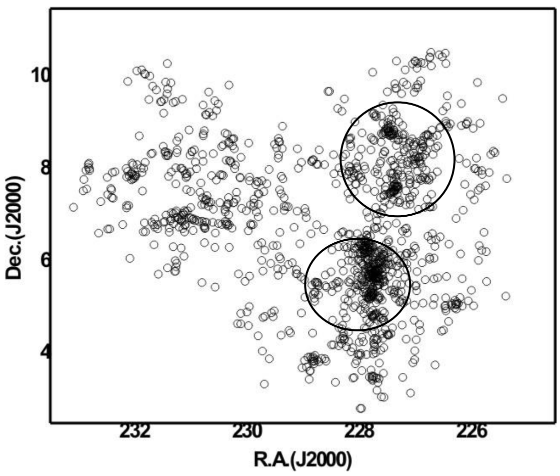

Figure 2: All sky distribution of galaxies in the equatorial co-ordinate system for Supercluster S [227+0067+0078]. Each circle represents a galaxy. The X-axis and Y-axis represent right ascension and declination respectively.

Similarly, as shown in Fig. 3, all-sky view of the galaxy of substructures S1 [228+006+0079] and S2 [227+008+0078] with numbers of galaxy 287 and 188, respectively.

Figure 4a shows a redshift map of galaxies in the Supercluster that have a mean redshift of 0.077. The color map shows that the velocity dispersion is minimum in the region where the number density of galaxy is minimum. The color bars for redshift are shown. The yellow region is the region of high redshift galaxies sky blue region consists of low redshift galaxies in this Supercluster. It seems that there is a linear relationship between redshift dispersion and the number density of galaxies in the substructures and found to be a good correlation coefficient as shown in Figure 4b.

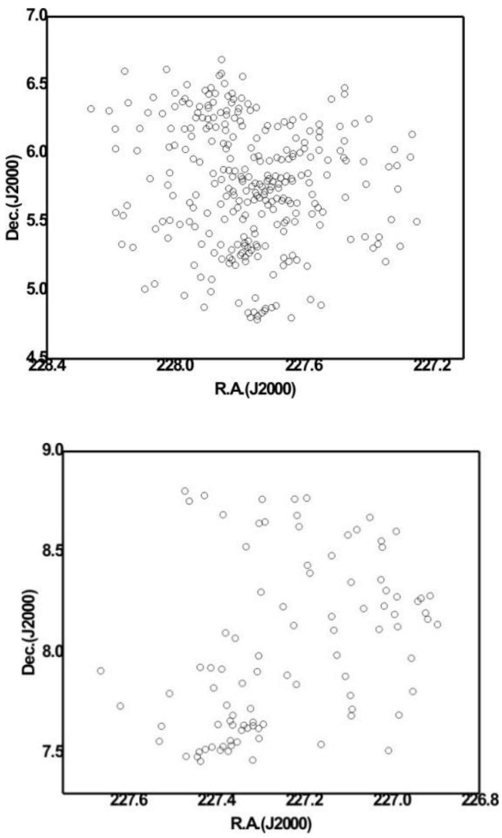

Figure 3: All sky view of substructures S1 [228+006+0079] and S2 [227+008+0078].

The redshift or radial velocity of galaxies in the Supercluster and substructures are found to be independent of the distribution of angular momentum vectors and its projection, supporting the hierarchy model of galaxy formation as suggested by Peebles (Figure 4).

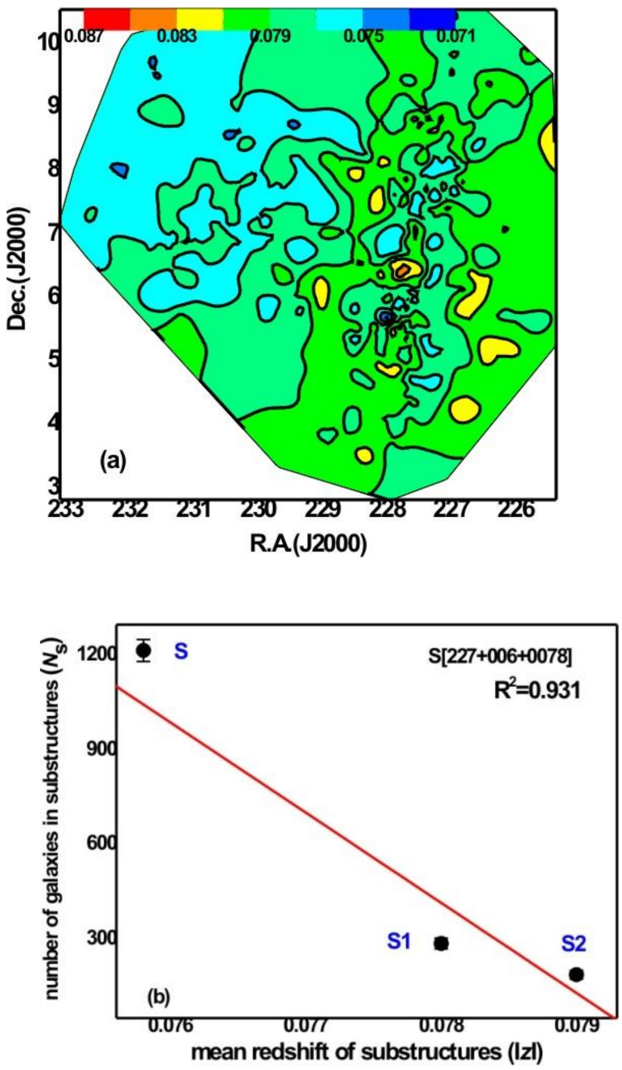

Figure 4: (a) Redshift map is shown for galaxies in the Supercluster S [227+006+0078]. (b) The Number of galaxies in two substructures and Supercluster itself versus redshift dispersion plot. The statistical ±1σ error is shown.

Conclusion

This paper identified two substructures S1 [228+006+0079] and S2 [227+008+0078], to the study of the number density map of galaxies, all-sky distribution of galaxies, and redshift map of galaxies in the Supercluster S [227+006+0078]. This Supercluster consists of 1213 galaxies, and two substructures have 287 and 188 galaxies, respectively.

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