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Study of Substructures in SDSS Supercluster S[173+014+0082]

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Abstract. We present magnitude, color, redshift and number density distributions of 1302 galaxies in the supercluster S[173+014+0082]. Our aim is to identify substructures and study their redshift maps. The visual magnitude distribution suggests that the supercluster is dynamically unstable. We found 3 substructures in the supercluster region having mean redshift 0.083, 0.085 and 0.090. An empirical relation be-tween the number of galaxies in the substructures and their mean redshift is observed.

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INTRODUCTION

The largest virialized structure in the Universe is the supercluster of galaxies. It constitutes substructures in the form of clusters and groups of galaxies. A large database of Superclusters is available because of SDSS DR7 (Sloan Digital Sky Survey Data Release 7) [1] and the pioneer work by Einasto et al. [2, 3, 4, 5]. Einasto et al. [2] SDSS DR7 database and found that the clusters located at dense environment shows a factor of 5 - 10 times luminous than in normal environment. The morphology of superclusters are classified into three types: spider, filament and field [3]. They have calculated luminosity and density to determine superclus-ters from a flux-limited sample of galaxies and finally compiled superclusters with more than 300 galaxies. In the next paper, Einasto et al. [4] compared the galaxy populations in SDSS superclusters of different morphology in the nearby Universe (180 h^{-1} Mpc $\leq$ d $\leq$ 270 h^{-1} Mpc) to find whether the inner structure are important in shaping the galaxy. They concluded that the both local (group) and global (super-cluster) environments play an important role in the formation and evolution of galaxies in the supercluster. The dynamical state and evolution of galaxy super-clusters from the Sloan Great Wall (SGW) which is the richest galaxy system in the nearby Universe, are studied [5]. They concluded that the rich SGW superclus-ters with their high-density cores represent dynamically evolving environments for studies of the properties of galaxies and galaxy systems. It is therefore we aim to study physical properties of substructures in the supercluster.

The formation of supercluster is not well understood. To understand it, evolution of substructures in the supercluster is important. In this work, we study database of 1305 galaxies in SDSS DR7 [1] supercluster S[173+014+0082] having mean redshift 0.082. Our specific objectives are as follows: (a) study color-magnitude diagram, (b) study number density maps, (c) identify substructure and finally (d) produce redshift map of substructures.

REGION OF INTEREST AND METHODS

A database of positions, radshifts, $r-$ and $u-$magnitudes of 1305 galaxies in the supercluster S[173+014+0082] using SDSS DR7 database (`https://classic.sdss.org/dr7/`) is compiled [1]. The reason behind the selection of this supercluster is as follows: (a) It has several groups with spider [4] morphology (see Figure 1a), (b) total weighted luminosity L_{Tot} is 10^{13} h^2 $L_\odot$ [6] and (c) redshift and magnitudes of each galaxy is available.

We study magnitude (m_r), color (m_u-m_r), redshift (z), number density distributions of 1305 galaxies in the supercluster S[173+014+0082]. We have determined number density around each galaxy using a galaxy count algorithm. The variable is the radius (r) from each and every galaxy. We set the values of r from 0.1° to 2.0°in steps of 0.05°. In each step, we determined the standard deviation and finally selected the steps where it is found to be optimal. In addition, the minimum number of galaxies in the substructure has been set as the values of mean standard deviation. The algorithm (written in MATLAB6.1) to count number of galaxies within a radius r, 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=f open(str,'wt');
f printf(_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

All sky distribution of galaxies in the supercluster is shown in Figure 1a. A marker galaxy (shown by red square) in the supercluster S[173+014+0082] is the bright galaxy near the highest density peak in the supercluster volume [6]. Figure 1b shows the redshift map of the supercluster region. Redshift is found to be distributed in such a way that the marker galaxy lies in the low redshift region, whereas it is surrounded by group of galaxies with high redshift. The color (log($m_u - m_r$))– magnitude (m_r) diagram (Figure 1c) is found to be uniform, given by;

$$log(m_u - m_r) = -0.05m_r + 1.19 \quad (1)$$

Here the slope is small negative, suggesting that the color is mostly independent of magnitude.

Figure 2 shows the r- and u-magnitude maps (a, c) and their histograms (b, d). In both r- and u-maps, low magnitudes galaxies are found to be off-centered. In the visual band (r), the magnitude distribution is found to be non-Gaussian (Figure 2b), suggesting unstable structure. In the ultraviolet band, the distribution fits well with the Gaussian, suggesting UV-stable supercluster. The star formation rate in the supercluster and its substructures should be studied in the future.

Figure 3a,b shows number density maps of the galaxies in the supercluster S[173+014+0082]. The contour levels and the color bars are shown. We consider region of high density as substructure of the supercluster. In the supercluster S[173+014+0082], we noticed 3 such regions in which the number density of galaxies exceeds the limits of standard deviation. The number of galaxies in these substructures is found as 214, 184 and 94. The name of substructures are shown as S1[173+014+0083], S2[173+014+0085] and S3[173+014+0090]. Figure 2c shows a plot between the number of galaxies in the substructures and the mean redshift ($|z|$) of that substructure. The best fit line is,

$$N = -1.7 \times 10^4 |z| + 1660.3 \quad (2)$$

This is an empirical relation between mean redshift of substructures and its populations in the supercluster. Other SDSS DR7 superclusters should be study to verify this result. Figure 4 shows radial velocity distributions of galaxies in the substructures. Groups of several high radial velocity galaxies can be seen in the substructures S1 and S2, whereas no such aggregations are found in the S3 substructure. This indicates that the velocity dispersion profile might be stable in the substructures S1 and S2, whereas it is different in S3. The mean value of magnitude (m_r) in S3 is also found to have higher values (Table 1). Melkonian and Nikogosian [7] studied core of the Perseus supercluster of Galaxies, found two substructures having 35 galaxies and 13 galaxies. They noticed radial segregation of these galaxies. However, position angle distributions are found to be uniform. Haines et al. [8] mapped the structure of the Shapley supercluster core and its surroundings by carrying out a new redshift survey named Shapley Supercluster Survey (ShaSS). They presented redshift measurements of 957 galaxies, identified new groups, substructures and clusters and finally concluded the existence of a stream of galaxies connecting A3559 to the supercluster core. Kopylovaand Kopylov [9] studied galaxy clusters in the Hercules supercluster region using observational data from the SDSS and 2MASS catalogs and the NED. They have selected 13 galaxy clusters from the supercluster region, found that the number density of galaxies increase with cluster mass

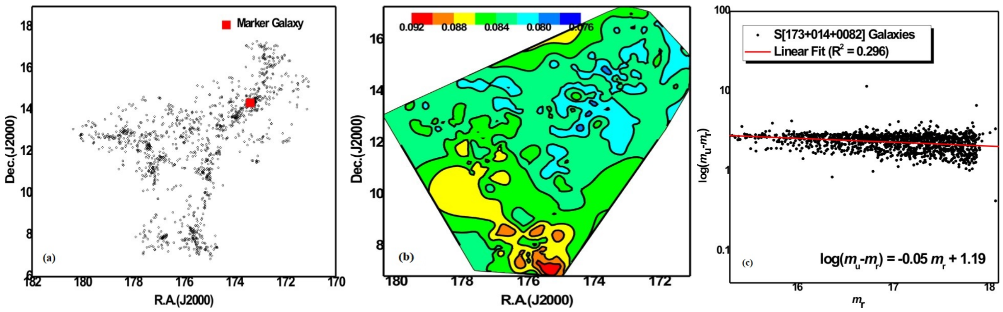

FIGURE 1. (a) All sky distribution of total galaxies in the supercluster S[173+014+0082]. Each hollow circle represents a galaxy. Marker galaxies are denoted by Solid Square. A spider like morphology can be seen. (b) Redshift map of supercluster region. Color bars are shown. (c) Color ($\log(m_u - m_r)$)-magnitude (m_r) diagram of galaxies in the supercluster S[173+014+0082]. Each black dot represents a galaxy. The best fit lines and equation are shown.

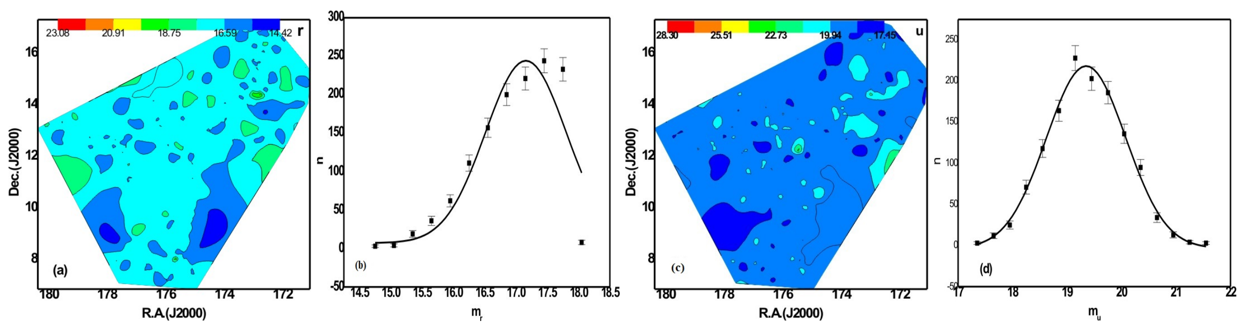

FIGURE 2. Magnitude maps (a, c) and their histograms (b, d) of galaxies in the supercluster S[173+014+0082]. The color bar is shown. The contour levels are at 14.42, 16.59, 18.75, 20.91, 23.08 for r-filter and 17.15, 19.94, 22.73, 25.51, 28.30 for u-filter, respectively. The distributions of r and u-magnitude show non-Gaussian and Gaussian-like distributions, respectively

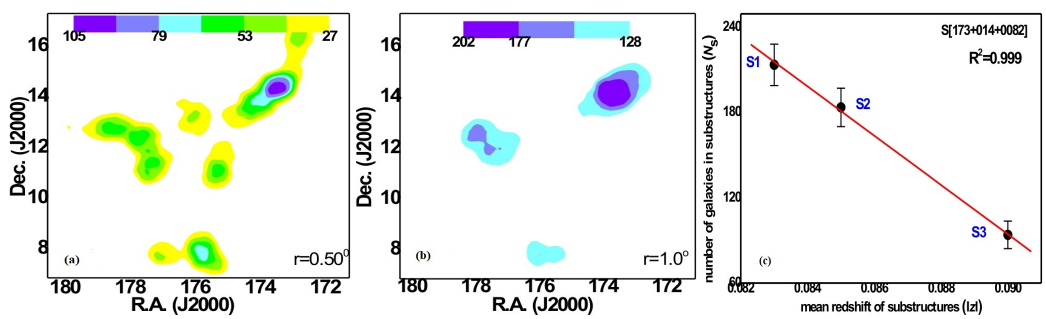

FIGURE 3. Number density map of galaxies in the supercluster S[173+014+0082]. Nearest neighbor distance of each galaxies at r = 0.5° (a) and 1.0° (b). The color bars are shown. (c) Number of galaxies in substructures versus mean redshift plot in S[173+014+0082]. The statistical $\pm 1\sigma$ error bars are shown. Here S1, S2 and S3 represent substructures. A coefficient of regression (R^2) is shown.

TABLE I. Substructures of S[173+014+0082]. The positions are given in the second and third columns. The next two columns list the values of mean redshift ($|z|$) and number (N) of galaxies in the substructures. The last two columns give the mean values magnitudes in u - and r- bands.

Substructure	R.A.(J2000)	DEC.(J2000)	|z|	N	$\|m_u\|$	$\|m_r\|$
S1[173+014+0083]	$11^h32^m52^s$	$+14°27'40''$	0.083	214	16.3	18.3
S2[173+014+0085]	$11^h53^m20^s$	$+13°00'00''$	0.085	184	16.2	18.1
S3[173+014+0090]	$11^h42^m02^s$	$+08°13'37''$	0.090	94	16.3	18.2

and luminosity. Therefore a relation between total luminosity and number of galaxies in the clusters is noticed.

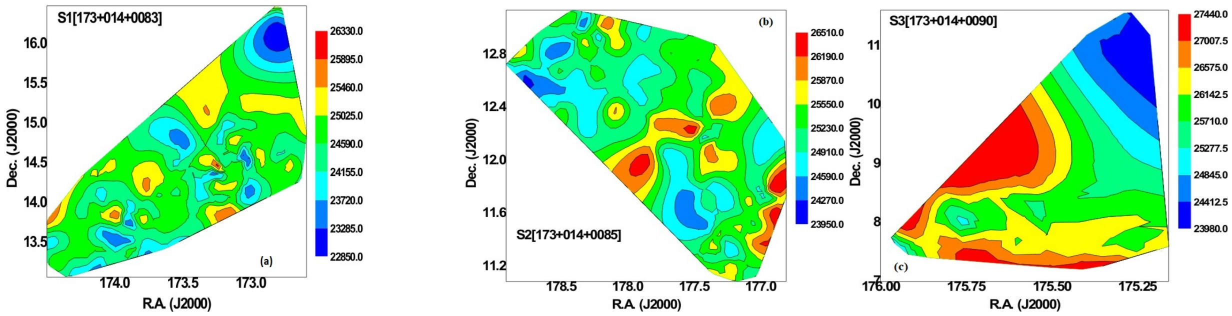

FIGURE 4. The radial velocity distribution of galaxies in three substructures: (a) S1[173+014+0083] (b) S2[2173+014+0085] and (c) S3[S2173+014+0090]. Color bars represent the radial velocity, in km/s.

We also found similar relations as of substructures.

CONCLUSION

We have studied distribution of nearest neighbor galaxies to find substructures in the supercluster S[173+014+0082] region and found our results as follows:

1. Three substructures are found in the supercluster S[173+014+0082]. These are S1[173+014+0083], S2[2173+014+0085] and S3[S2173+014+0090] with mean redshift 0.083, 0.085 and 0.090, respectively. An empirical relation between mean redshift ($|z|$) and the number of galaxies (N) in the sub-structures is noticed.

2. The substructures showed higher values of mean redshift than that of the supercluster S[173+014+0082]. This corresponds to the fact that the subclusters are moving with higher radial velocities than that of the supercluster. Thus, the gravitational sharing effect cannot be ruled out in the large scale structure formation [10].

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EDITORS' NOTE

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REFERENCES

1. K. N. Abazajian, J. K. Adelman-McCarthy, M. A. Agüeros, S. S. Allam, C. A. Prieto, D. An, K. S. Anderson, S. F. Anderson, J. Annis, N. A. Bahcall, *et al.*, "The seventh data release of the sloan digital sky survey," The Astrophysical Journal Supplement Series **182**, 543 (2009).
2. J. Einasto, G. Hütsi, M. Einasto, E. Saar, D. Tucker, V. Müller, P. Heinämäki, and S. Allam, "Clusters and superclusters in the sloan digital sky survey," Astronomy & Astrophysics **405**, 425–443 (2003).
3. M. Einasto, L. Liivamägi, E. Saar, J. Einasto, E. Tempel, E. Tago, and V. J. Martínez, "Sdss dr7 superclusters-principal component analysis," Astronomy & Astrophysics **535**, A36 (2011).
4. M. Einasto, H. Lietzen, E. Tempel, M. Gramann, L. Liivamägi, and J. Einasto, " appendices are available in electronic form at http://www. aanda. org," Astronomy & Astrophysics **562**, A87 (2014).
5. M. Einasto, H. Lietzen, M. Gramann, E. Tempel, E. Saar, L. J. Liivamägi, P. Heinämäki, P. Nurmi, and J. Einasto, "Sloan great wall as a complex of superclusters with collapsing cores," Astronomy & Astrophysics **595**, A70 (2016).
6. L. J. Liivamägi, E. Tempel, and E. Saar, "Sdss dr7 superclusters-the catalogues," Astronomy & Astrophysics **539**, A80 (2012).
7. A. Melkonian and E. Nikogosian, "Substructure of the core of the perseus supercluster of galaxies," Astrophysics **41**, 41–46 (1998).
8. C. Haines, G. Busarello, P. Merluzzi, K. Pimbblet, F. Vogt, M. Dopita, A. Mercurio, A. Grado, and L. Limatola, "Shapley supercluster survey: mapping the filamentary network connecting the clusters," Monthly Notices of the Royal Astronomical Society **481**, 1055–1074 (2018).
9. F. Kopylova and A. Kopylov, "Investigation of properties of galaxy clusters in the hercules supercluster region," Astronomy Letters **39**, 1–16 (2013).
10. P. Anninos, "Physical and relativistic numerical cosmology," Living Reviews in Relativity **1**, 1–24 (1998).