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Anisotropy in Spatial orientation of Spin Vectors of SDSS galaxies in Supercluster S [230+027+0069]

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ABSTRACT

We present spin vector orientation of 1830 galaxies in the Supercluster S [230+027+0069] with respect to galactic coordinate system, having redshift 0.064 to 0.087 using 7th data released. The inclination angle and intrinsic flatness of galaxy are used to convert two-dimensional given parameters into three-dimensional spin vectors of the galaxy. We have performed Chi-square, Auto-correlation, and Fourier tests in order to examine non-random effects in the expected isotropic distributions. The spin vectors of galaxies in the total galaxies are found to be oriented perpendicular with respect to the equatorial coordinate system. A preferred alignment suggesting "primordial vorticity theory".

Keywords: *Evolution; galaxies; galactic coordinate system; inclination angle; Supercluser*

INTRODUCTION

Our accelerating universe has major constituents of the matters like hydrogen, helium and small amount of heavier elements. By large scale structures we basically mean huge clusters of galaxies which are essential for addressing the problem of the origin of the observed distribution of galaxies and how it forms and evolves is crucial to our understanding of the many properties of galaxies and of the inter-galactic medium. The most accepted view on the formation and evolution of large scale structure is that it was formed as a consequence of the growth of primordial fluctuations by gravitational instability. The basic picture of modern cosmology (Peebles 1993, Padmanabhan 1993) is that of a Universe that began from a hot and homogeneous state. Density fluctuations in the early Universe were exponentially amplified during a phase of inflation (Guth 1981), a theory that eliminates many of the problems called standard model. Galaxies and the structure formation is one of the most fundamental and challenging questions in contemporary astronomy. Galaxies are not isolated objects in space; rather, galaxies are distributed in a great cosmic web of filaments throughout the universe. The locations where the filaments meet are dense clusters of galaxies that began as small fluctuations in the early universe. SDSS (Sloan Digital Sky Survey) is one of the most ambitious and influential surveys in the history of astronomy. Its data have supported various fundamental works across an extraordinary range of astronomical disciplines, including the large-scale structure of the Universe.

In this work, we intended to study the preferred alignment of the spin vectors of SDSS galaxies using "position angle-inclination" method

(Flin and Godlowski 1986), to test galaxy evolution models, namely `primordial vorticity model'(Ozernoy, 1978; Stein 1974), hierarchy model' (Peebles, 1969), and `pancake model'(Doroshkevich, 1973); Doroshkevich&Shandarin, 1978).

DATABASE

The database used in this work was consists galaxies located within the survey regions of SDSS (Sloan Digital Sky Survey) those have redshift in the range 0.064 to 0.087. This database was searched from SDSS Data Release7 (York et al. 2000). There are 1830 galaxies in the Supercluster S [230+027+0069] in our region of interest. We have 1830 galaxies in our sample, of which the positions Right Ascension (α) and Declination (δ), major and minor diameters, position angles (P) are known.

Godlowskian transformation (Conversion: 2D to 3D

The data used in this work are taken from the optical observation. Our galaxies are mere the two dimensional projections of the real three dimensional galaxies in the celestial sphere. Because, all existing observations are collecting two dimensional data. The 'Position angle inclination' method is a method to convert two dimensional to three-dimensional information on the spin vector orientation with respect to an arbitrary coordinate system. This method was introduced by Flin and Godlowski (1986). It provides the possibility to calculate the spin vector orientation using the position angle and the inclination of the galaxy plane with respect the plane of the cluster. The distribution of galactic plane and its position angle are considered in the equatorial coordinate system. For each galaxy, two angles are determined: Polar angle (Θ) the angle between the normal to the galaxy and equatorial plane and Azimuthal angle (ϕ) the angle between the projection of normal to the galaxy on the equatorial plane and directed towards the equatorial center. A random simulation method suggested by (Aryal and Saurer 2000).

The following relations hold between the angles (Θ, ϕ) in equatorial coordinate system.

$$\sin\theta = -\cos i \sin\alpha \pm \sin i \sin p \cos\alpha \quad (1)$$

$$\sin\varphi = -\frac{\cos i \cos\delta \sin\alpha + \sin i(\mp \sin p \sin\delta \sin\alpha \mp \cos p \cos\alpha)}{\cos\theta} \quad (2)$$

Where, $\mp$ and $\pm$ signs indicate two possible solutions. To study the spin vectors orientation, Holmberg (1946) established a simple galaxy model. Heidmann et al. (1972) suggested a value of q=0.2 for oblate spheroid. The inclination angle (i) is calculated by using formula [Holmberg (1946)][10]

$$\cos^2 i = \frac{\left(\frac{b}{a}\right)^2 - q^{*2}}{1 - q^{*2}} \quad 3$$

RESULT AND DISCUSSION

Figures and tables are tools for visually displaying data or research results.

Figures

Figure 1 shows the distribution of galaxies in the Supercluster S [230+027+0069], various galaxy-rich regions can be noticed. Galaxy rich region started to form group of galaxies (Substructure).

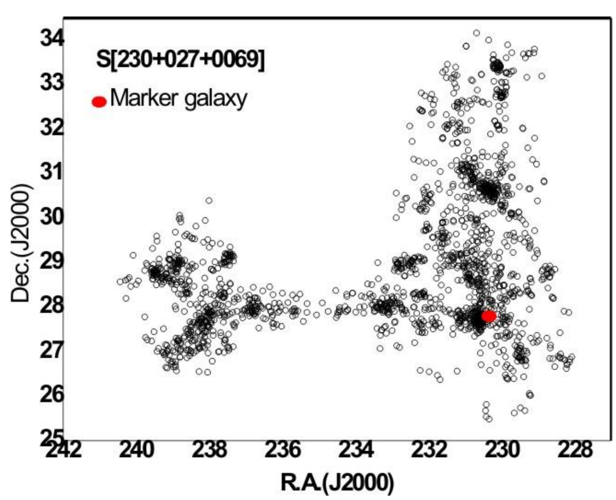

Fig. 1. Example All-sky plot of galaxies of Superclusters S [230+027+0069].

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Figure 2: shows regions of Supercluster with same radial velocity with the help of contours. The contour is highly fragmented. We can easily visualize high velocity regions and low velocity regions in the plot.

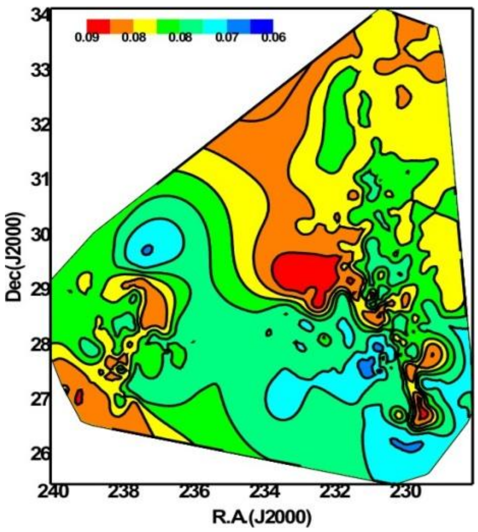


Figure 2: Radial velocity contour map of galaxies in the Supercluster S [230+027+0069]

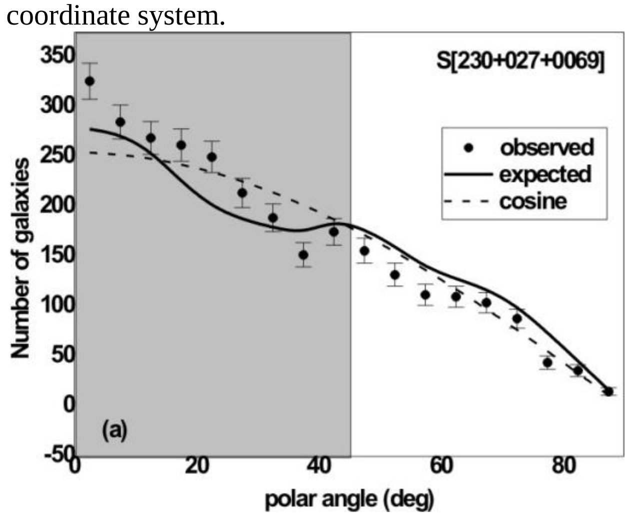
The statistics of the different parameters for the polar angle (ϴ) and azimuthal angles (ϕ) distribution are given in table 1. The Supercluster S [230+027+0069] consists of 1830 galaxies. The orientation of galaxies within Supercluster will be tested with the limit of chi-square probability P (>χ2) is <0.050, auto-correlation coefficient (C/C (σ)) is >1.0, first order Fourier coefficient (Δ11/ σ (Δ11)) is >1.5 and first order Fourier probability P (>Δ1) is <0.150 respectively these result gives anisotropy proposed by the Godlowski (1993-1994) in galaxy orientation studies. The statistics for the polar angle (ϴ) in the table 1 shows the value of chi-square probability P (>χ2) to be 0.000 (less than the significant level 0.050), auto-correlation coefficient (C/C (σ)) is found to be 76.365 (greater than the limit 1σ), first order Fourier coefficient (Δ11/ σ (Δ11)) is found -7.498 (greater than the limit 1.5σ), and first order Fourier probability P (>Δ1) is 0.000 (less than 15% limit). These entire statistics test suggest anisotropy.

Also, the negative value of first order Fourier coefficient (Δ11/ σ (Δ11)) suggests the perpendicular alignment of the spin vectors.

Fig 3(a) shows the polar angle (ϴ) distribution of the galaxies. There are continuous humps in the first six bins within the bimodal region (~45°). The humps at angles 2.5°, 18°, 22° and 28°are significant with error limit > 6σ. Also, the humps are at angles 7.5° and 12° are most significant with error limits > 3σ. Similarly, there are remarkable dips at an angle 38°. At (ϴ>45°) three dips at 47°, 50°and 58° can be observed. Thus we conclude that the spin vectors of galaxies in the spin vectors of galaxies tend to lie perpendicular with respect to the equatorial coordinate system.

In the azimuthal angle (ϕ) distribution of the galaxies Fig 3(b), there are continuous humps at an angles -30°,-19°,-10°, 2°, and 5°. In these bins the numbers of observed solutions are greater than that of expected. This suggests that the projections of the spin vectors of the galaxies tend to orient radially towards the center of the reference coordinate system. There are dips in the azimuthal angle at ϕ =38°, 44°, 58° and 85° but they are the observed solutions are less than that of expected. So, we can conclude that there is preferred alignment of spin-vectors of galaxies.

The statistics for the azimuthal angle (ϕ) distribution (table 1) of the galaxies shows the value of chi-square probability P (>χ2) to be 0.000 (less than the significant level 0.050 i.e. 5.0%), auto-correlation coefficient (C/C (σ)) is found to be 110.034 (greater than the limit 1σ), first order Fourier coefficient (Δ11/ σ (Δ11)) is found -2.519 (greater than the limit 1.5σ), and first order Fourier probability P (>Δ1) is 0.000(less than 15% limit). Here all the statistics suggest anisotropy. And we conclude that the projections of the spin vectors of the galaxies tend to orient radially towards the center of the reference coordinate system.



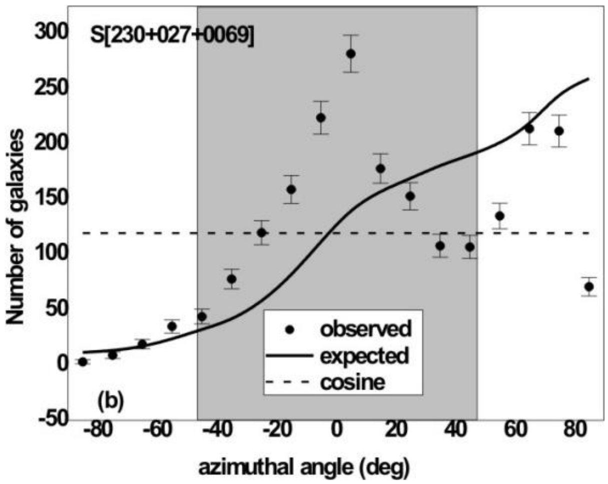


Figure 3: (a) Polar and (b) azimuthal angle distribution of galaxies in Supercluster S[247+040+0029].

Tables

Table 1. Table showing the Statistics of the polar (θ) and azimuthal (ϕ) angle distributions of galaxies in the Supercluster S [230+027+0069].

Statistics	Polar angle (θ)	Azimuthal angle (ϕ)
$P(>\chi)$	0.000	0.000
$C/C(\sigma)$	76.365	110.034
$\Delta_{11}/\sigma(\Delta_{11})$	-7.498	-2.519
$P(>\Delta_1)$	0.000	0.000

CONCLUSION

We have studied 1830 galaxies in the Supercluster S [230+027+0069]. We applied "position-angle inclination method" to analyze spin-vector orientation of galaxies in all our samples. This method is proposed by Flin and Godlowski (1986). Then, we used various statistics to test anisotropy in galaxy orientation in our samples. The conclusions are:

The spatial orientation of spin vectors of galaxies in the total sample is found to be oriented perpendicular with respect to the equatorial coordinate system. The spin vector projections of galaxies tend to be aligned radially towards the centre of the equatorial coordinate system. A preferred alignment suggesting "primordial vorticity theory".

We performed simulation creating 107 virtual galaxies. The result of simulation is smooth and well consistent with the observed distribution.

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Competing Interests: The authors declare that he has no competing interests.

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