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## Study preferred alignments of angular momentum vector of $i$ – magnitude SDSS galaxies having redshift 0.54 – 0.60

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### ABSTRACT

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We present a study of the three-dimensional orientation of spin vector of  $i$  – magnitude having higher redshift ranging from 0.54 to 0.60 with respect to the equilateral co-ordinate system. The main aim of this work is to know the orientation and projection of the spin vector of distant galaxies. The database is taken from SDSS 14<sup>th</sup> data release (DR-14) and this redshift range contains 239,209 galaxies. SDSS provides two – dimensional observed data, we convert it into three-dimension rotation axes of the galaxy with the help of the ‘position angle inclination method’. The expected isotropy distribution curves are obtained by removing the selection effects and performing a random simulation generating  $10^7$  virtual galaxies. To check, isotropy or anisotropy we have to carry out four statistical tests: chi-square, auto-correlation coefficient, first-order Fourier series, and First-order Fourier probability. In the study, we observed random orientation of spin vector of galaxies in all twenty samples and supported a strongly Hierarchy model of galaxy evolution. Also, the projection of spin vector is found to be isotropic in samples  $i01$ ,  $i02$ ,  $i03$ ,  $i16$ ,  $i17$ ,  $i18$ ,  $i19$ , and  $i20$  and the remaining samples  $i04$  to  $i15$  are seen as local anisotropic due to the merging phenomenon of galaxies and tidal effect. This shows the problem in a coordinate system.

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### 1. Introduction

Generally, all human beings think that how the Universe was created or formed? This is a very interesting question or most active research work nowadays because there is no exact answer to this question was found to date. Astrophysicists day by day carried on their research work to know the evolution of stars, galaxies as well as the entire universe. Several authors were given different ideas about the creation or evolution of the Universe. Several theoretical models like Hierarchy Model, Li Model, Ostriker Model, Pancake Model, Primordial Vorticity Model etc. was predicted which is based on their own assumption, but none of them is suitable to convince all physicist. One of the most important models which almost believe maximum astrophysicist are Big-Bang model. This model suggests that before the big bang space and time existed, and the entity of the universe was believed to be compressed into a singularity called space-time singularity [1].

The processes of galaxies evolution are not well understood to date. One of the main reasons is that they are made of three very different entities: stars, an interstellar medium and dark matter. Galaxies contain a varying number of star systems, star clusters, and types of the interstellar medium of gas, dust and cosmic rays. The observable universe contains probably more than 170 billion galaxies [2].

The majority of galaxies are gravitationally organized into groups, clusters, and superclusters. From the formation of the first galaxies, and the way galaxy changes over a period of time the study of galaxy evolution and formation is mainly concerned with the processes that formed a heterogeneous universe from a homogeneous beginning and I think we all know it is one of the active areas of astrophysics where all the astrophysicists are concerned [3].

This paper is arranged in such a way that we present theory and formalism in section 2, methods of analysis are presented as in section 3, section 4 contains results and discussions and finally, the conclusion of this paper is presented as in section 5.

### 2. Theory and formalism

According to Wiezsacker [1] and Gamow [2], in order to know the origin of the spin vector of galaxies, the observed rotation of the galaxies is very important. There are only a few theories, which can describe the origin and evolution of stars, galaxies, superclusters etc., each of them with its different strengths and weakness, assumptions and predictions, especially the theories about galaxy cluster formation.

There are three models which described strongly the three-dimensional orientation of spin vectors of the galaxies which are ‘Pancake model’[4,5] predicts that the angular momentum vectors of galaxies are distributed primarily in parallel alignment to the reference plane, ‘Primordial vorticity model’ [6-8] described that the spin vectors of galaxies tend to lie perpendicular alignment to the reference plane and

‘Hierarchy model’ [9] gives the directions of the spin vectors are random alignment to reference plane.

### Godlowskian Transformation

The ‘position angle inclination’ method is used to know the three-dimensional information about the orientation of the spin vector with respect to any arbitrary coordinate system (in our study equilateral coordinate system). This method was introduced by Flin and Godlowski [10] and it is used to calculate the orientation of the spin vector using the position angle and the inclination of the galaxy plane with respect to the equilateral plane.

The polar angle ( $\theta$ ) and azimuthal angle ( $\phi$ ) are used to express the three-dimensional orientation of the spin vector of a galaxy by using a reference coordinate system and the polar angle ( $\theta$ ) is the angle between the spin vector of the galactic plane and an equilateral plane and azimuthal angle ( $\phi$ ) is the angle between the projection of a galactic spin vector onto the equilateral plane and the reference line within this plane. For equilateral co-ordinate system, the relation of  $\theta$  and  $\phi$  are given by

$$\sin\theta = -\cos i \sin\delta \pm \sin i \sin p \cos\delta \dots\dots\dots (1)$$

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

where,  $i$  is the inclination angle,  $\alpha$  is right ascension,  $\delta$  is declination and  $p$  is position angle. The inclination angle is obtained by using Holmberg formula [11]

$$\cos^2 i = \frac{q^2 - q^{*2}}{1 - q^{*2}} \dots\dots\dots (3)$$

where,  $q$  is the axial ratio ( $b/a$ ) and  $q^*$  is the intrinsic flatness of the galaxy. In the present work, we used  $q^* = 0.05$  for morphologically identified spiral galaxies.

### 3. Method of analysis

The database used in our present work involved galaxies with the survey region of Sloan Digital Sky Survey (SDSS) those have redshift in the range 0.54 to 0.60. This database is taken from SDSS 14<sup>th</sup> data release (DR-14) which contains 239,209 galaxies in our study region which have in the Petro-magnitude range from 14.47 to 34.61. Among these Petro-range, we couldn't take galaxies with the magnitude less than 18.0 and above 22.0 because in this region galaxies distribution is very poor. Now, we classified our total database of galaxies in the Petro-magnitude range from 18.0 to 22.0 into 20 sample with the equal class interval of width 0.2. All 20 samples contain more than 50 galaxies individually which is suitable for study.

The position and inclination angles generated by SDSS survey contained more error in the results. Theoretically, it is found that polar angle has cosine isotropic distribution curve whereas azimuthal angle has average isotropic distribution curve, with the condition that the database is taken free from selection effects. SDDS survey database contains positional and inclination selection effect and that cause several changes in the expected isotropic distribution curves, so to remove such type of effects Numerical Simulation Method is used which was proposed by Aryal & Saurer [12, 13]. In the numerical simulations,  $i$  can be distributed as  $\alpha \sin i$ ,  $\delta$  can be distributed as  $\alpha \cos \delta$  and the variables  $\alpha$  and  $p$  can be distributed randomly due to

the projection effects and the equations (1 to 3) can be used to calculate the corresponding values of  $\theta$  and  $\phi$ . To define expected isotropic distribution curves, we used numerical simulations including  $10^7$  virtual galaxies for both  $\theta$  and  $\phi$  distributions. MATLAB 15a is used to write programme and input files for the simulation.

Galaxy clusters do not provide perfect alignment when viewing at pictures, so statistical analysis is important to check preferred alignments. In this work, we used four statistical tests: the chi-square, auto-correlation coefficient, Fourier series and first order probability tests. The conditions for isotropy with the reference of Godlowski [10, 14] are as follows:

- the value of chi-square probability is  $P(>\chi^2) > 0.050$
- the value of correlation coefficient lies in  $C/\sigma(C) = -1$  to  $+1$
- the value of first order Fourier coefficient lies in  $\Delta_{11}/\sigma(\Delta_{11}) = -1.5$  to  $+1.5$  and
- the value of first order Fourier probability is  $P(>\Delta_1) > 0.150$ , otherwise angular momentum vector is anisotropic.

**4. Results and discussion**

The polar angle ( $\theta$ ) gives the orientation of the spin vector of galaxies whereas the azimuthal angle ( $\phi$ ) gives the projection of spin vector of galaxies. Our aim is to study the random effects concerning i-magnitude dependence of spin vectors of galaxies. For the isotropic distribution of spin vectors, the four statistical tests with isotropic range are already described in section 3. In the polar angle ( $\theta$ ) distribution a significant negative value of first-order Fourier coefficient suggests that the angular momentum vectors of galaxies tend to be oriented perpendicular with respect to a reference coordinate system and supports ‘Primordial Vorticity model’ of galaxy evolution [6-8]. Similarly, a significant positive value of the first-order Fourier coefficient suggests that the angular momentum vectors of galaxies lie in parallel alignment to the equatorial coordinate system and support ‘Pancake model’ [4,5]. Also, the statistics for the azimuthal angle ( $\phi$ ) distribution, a significant positive value of first-order Fourier coefficient ( $\Delta_{11}/\sigma(\Delta_{11})$ ) predicts that the projections of the spin vector of galaxies tend to lie radially towards the center reference plane. Similarly, a significant negative value of ( $\Delta_{11}/\sigma(\Delta_{11})$ ) implies that the projection of the spin vector of galaxies tends to lie tangentially with the reference plane. We also study the ‘humps’ (the region where observed distributions are more than that of expected distributions) and ‘dips’ (the region where observed distributions are more than that of expected distributions) in the polar and azimuthal angle distributions. Table 1 and Table 2 respectively show the statistics of polar angle ( $\theta$ ) and azimuthal angle ( $\phi$ ) distributions of galaxies for all twenty samples.

**Table 1:** Table showing the statistics of polar angle ( $\theta$ ) distribution of galaxies in twenty sample. The first column represents the sample, second column  $P(>\chi^2)$  represents the Chi-square probability, third column

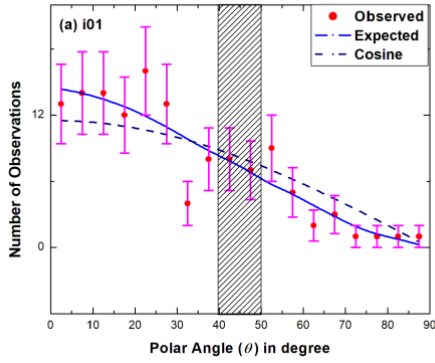
$C/C(\sigma)$  represents the Auto-correlation coefficient, fourth column  $\Delta_{11}/\sigma(\Delta_{11})$  represents the first order Fourier coefficient and last column represents first order Fourier probability  $P(>\Delta_1)$ .

Sample	$P(>\chi^2)$	$C/C(\sigma)$	$\Delta_{11}/\sigma(\Delta_{11})$	$P(>\Delta_1)$
Sample (i01)	0.864	+0.0	+0.0	0.999
Sample (i02)	0.092	-0.5	+0.4	0.877
Sample (i03)	0.767	-0.9	+0.1	0.994
Sample (i04)	0.679	-0.6	+0.1	0.993
Sample (i05)	0.276	-0.5	+0.1	0.980
Sample (i06)	0.477	-0.0	+0.8	0.511
Sample (i07)	0.812	+0.5	-0.2	0.001
Sample (i08)	0.440	+0.3	+0.3	0.898
Sample (i09)	0.415	+0.2	+1.5	0.106
Sample (i10)	0.029	+0.7	+0.5	0.798
Sample (i11)	0.313	-0.6	+1.2	0.223
Sample (i12)	0.840	+0.1	-0.9	0.018
Sample (i13)	0.336	-1.2	+0.3	0.937
Sample (i14)	0.374	-0.8	-0.6	0.743
Sample (i15)	0.639	+0.3	-0.2	0.957
Sample (i16)	0.733	-1.3	+0.0	0.997
Sample (i17)	0.423	-1.2	+0.2	0.971
Sample (i18)	0.729	-0.2	-0.4	0.885
Sample (i19)	0.099	-1.3	-0.4	0.864
Sample (i20)	0.196	-0.1	-0.3	0.914

**Table 2:** Table showing the statistics of azimuthal angle ( $\phi$ ) distribution of galaxies in twenty sample. The first column represents the sample, second column  $P(>\chi^2)$  represents the Chi-square probability, third column  $C/C(\sigma)$  represents the Auto-correlation coefficient, fourth column  $\Delta_{11}/\sigma(\Delta_{11})$  represents the first order Fourier coefficient and last column represents first order Fourier probability  $P(>\Delta_1)$ .

Sample	$P(>\chi^2)$	$C/C(\sigma)$	$\Delta_{11}/\sigma(\Delta_{11})$	$P(>\Delta_1)$
Sample (i01)	0.826	+0.7	+1.2	0.207
Sample (i02)	0.456	+0.1	+0.7	0.642
Sample (i03)	0.507	-0.1	+1.2	0.044
Sample (i04)	0.682	+1.0	+2.0	0.015
Sample (i05)	0.003	+3.3	+3.5	0.000
Sample (i06)	0.000	+3.6	+4.2	0.000
Sample (i07)	0.000	+15.3	+8.5	0.077
Sample (i08)	0.000	+27.5	+11.1	0.000
Sample (i09)	0.000	+39.9	+13.2	0.000
Sample (i10)	0.000	+42.4	+14.0	0.000
Sample (i11)	0.000	+26.9	+11.5	0.000
Sample (i12)	0.000	+5.7	+6.0	0.000
Sample (i13)	0.003	+3.1	+4.3	0.000
Sample (i14)	0.011	+1.6	+3.7	0.000
Sample (i15)	0.350	+0.7	+2.3	0.004
Sample (i16)	0.634	-0.1	+1.4	0.134
Sample (i17)	0.229	-2.2	+1.1	0.283
Sample (i18)	0.708	-0.2	+1.1	0.307
Sample (i19)	0.544	-0.3	+1.1	0.310
Sample (i20)	0.596	-1.0	+1.4	0.135

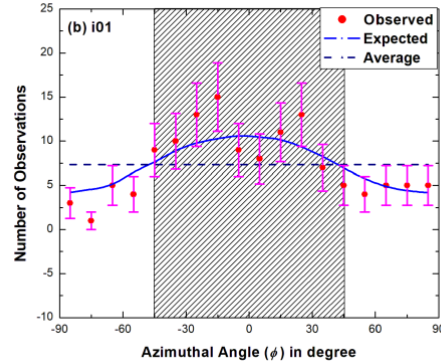
The second row of table 1 showed test statics for the polar angle distributions ( $\theta$ ) for sample i01. The value of chi-square probability, correlation coefficient, the first-order Fourier coefficient, and first-order Fourier probability are lies in the isotropic range. So, all these statistics suggest strongly isotropy and hence statistic suggests the random orientation of the spin vector. Similarly, for the azimuthal angle distribution ( $\phi$ ) of the sample (i01) all these values of test statics lie within the isotropic range (see in the second row of Table 2). All these statistics suggest strongly isotropy. Therefore, the projection of the spin vector is to be noticed as random.



**Figure 1(a):** The polar angle ( $\theta$ ) distributions of galaxies in the sample (i01). The solid line represents the expected distributions and the solid circles with  $\pm 1\sigma$  error bars represent the observed distribution whereas the dashed line is cosine distribution is shown for the comparison.

In Figure 1(a), the shaded portion represents the range  $40^\circ \leq \theta \leq 50^\circ$  is called a bimodal region in which if both ‘hump’ or ‘dip’ appears means they are canceled to each other and we cannot predict the orientation of the spin vector. A dip (or hump) in the unshaded region at the range  $0^\circ \leq \theta < 40^\circ$  suggests that the angular momentum vectors of galaxies tend to lie perpendicular or parallel with respect to the equatorial plane. Similarly, a hump (or dip) in the unshaded region in the range  $50^\circ < \theta \leq 90^\circ$  indicates that the spin vectors of galaxies are perpendicular (or parallel) with respect to the equatorial plane. In Figure 1(a), the number of observations for small-angle ( $0^\circ \leq \theta < 40^\circ$ ) are found to be 94 whereas the expected are 95. Thus, the number of observed distributions is less than by only one than that of expected distributions. In this region, there is only one significant dip is seen at an angle  $32.5^\circ$  with an error limit  $\sim 1.5\sigma$  and dip is seen because in this region there is a chance of Cluster and Supercluster and also three small dips are seen at angles  $2.5^\circ$ ,  $17.5^\circ$  and  $37.5^\circ$  with the error limits  $\sim 0.2\sigma$ ,  $\sim 0.1\sigma$  and  $\sim 0.1\sigma$  respectively but we cannot consider as significant dip because less than 5% error is coming from mathematical calculation not as an observational data so we cannot accept as the error in observation and hence such type of error we are excluded. Also, there are three small humps seen at angles  $12.5^\circ$ ,  $22.5^\circ$  and  $27.5^\circ$  with the error limit  $\sim 0.1\sigma$ ,  $\sim 0.5\sigma$  and  $\sim 0.3\sigma$  respectively and these three small humps and dips are canceled to each other. For the

bimodal region ( $40^\circ \leq \theta \leq 50^\circ$ ), the observed and expected number of observations are found to be 15 and 14 respectively such that observed and expected number of observations are nearly equal. Also, no humps and dips are seen at the bimodal region. For large angles ( $50^\circ < \theta \leq 90^\circ$ ), the observed and expected numbers are 23 and 21 respectively implies that the observed is slightly more than that of the expected solution by only two. There are two small humps seen at angles  $52.5^\circ$  and  $87.5^\circ$  with the error limits  $\sim 0.5\sigma$  and  $\sim 0.4\sigma$  respectively and also two small dips are seen at angles  $62.5^\circ$  and  $72.5^\circ$  with the error limit  $\sim 0.6\sigma$  and  $\sim 0.4\sigma$  respectively. Therefore, in all together one significant dip with so many small dips and humps are seen. But all these humps and dips are cancelled to each other and hence, no preferred alignment of the spin vector is found to be noticed. Thus, we have noticed that, there is a random distribution of spin vectors of galaxies in the  $\theta$  distribution.



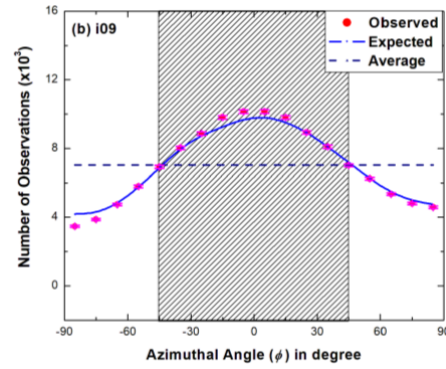
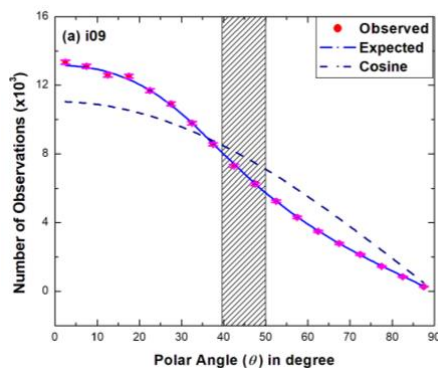
**Figure 1(b):** The azimuthal angle ( $\phi$ ) distributions of galaxies in the sample (i01). The solid line represents the expected distributions and the solid circles with  $\pm 1\sigma$  error bars represent the observed distribution whereas the dashed line is the average distribution is shown for the comparison.

In Figure 1(b), the humps and dips in the scatter diagram of azimuthal angle ( $\phi$ ) distribution are very difficult to interpret as compared to polar angle ( $\theta$ ) distributions. It is because the azimuthal angle is the angle normal to the equatorial coordinate system and it ranges from  $0^\circ$  to  $360^\circ$  (or  $-180^\circ$  to  $+180^\circ$ ) but when we take the projection of azimuthal angle on the equatorial coordinate system, we take an only range of  $\phi$  is from  $-90^\circ$  to  $+90^\circ$ . The shaded portion represents the range  $-45^\circ \leq \phi \leq +45^\circ$ . In the scatter diagram of the azimuthal angle ( $\phi$ ) distribution, a hump (or dip) in the middle (central eight bins) of the scatter diagram suggests that the direction of the spin vector is clockwise (or counterclockwise) and its projections of galaxies tend to point towards (or outwards) the center of the reference plane. Similarly, a hump (or dip) at the first four and last four bins represents that the projections of the spin vector of galaxies lie tangentially towards (or outwards) to the center of the reference plane.

In Figure 1(b), the number of observed distribution in central eight bins ( $\phi \sim \pm 45^\circ$ ) are found to be 100 and that of expected is 92. Thus, the number of the observed distribution are more than by 8 than that of expected. In this region, there is no any significant hump and dip are seen but six small humps are seen at the angles  $-45^\circ$ ,  $-35^\circ$ ,  $-25^\circ$ ,  $-15^\circ$ ,  $15^\circ$  and  $25^\circ$  with the error limit  $\sim 0.3\sigma$ ,  $\sim 0.2\sigma$ ,  $\sim 0.4\sigma$ ,  $\sim 0.7\sigma$ ,  $\sim 0.2\sigma$  and  $\sim 0.5\sigma$  respectively. Also, for smaller angle ( $\phi < -45^\circ$ ), the observed distribution are found to be 13 where as expected are 20 and observed distribution are less than by 7 than that of expected. In this region, there is no any hump seen but one significant dip is seen at an angle  $-75^\circ$  with an error limit  $\sim 1.5\sigma$  with two small dips are also seen at the angles  $-85^\circ$  and  $-55^\circ$  with the error limits  $\sim 0.4\sigma$  and  $\sim 0.6\sigma$  respectively. For larger angles ( $\phi > 45^\circ$ ), the observed and expected number of galaxies are found to be equal and which is 19. Also, in this region, there is no significant hump and dip are seen but two small humps are seen at the angles  $75^\circ$  and  $85^\circ$  with the both have nearly equal error limits  $\sim 0.1\sigma$  and only one small dip is seen at an angle  $55^\circ$  with an error limit  $\sim 0.5\sigma$ . Therefore we found that, altogether one significant dip as well as so many small humps and dips are seen but all these humps and dips are cancel to each other and hence, no preferred alignment of projection of angular momentum vector is found to be noticed i.e random is seen.

After careful examination of the statistics, graphs and hump or dip of polar and azimuthal angles, we concluded that orientation and projection of the spin vector are isotropic and hence randomly distributed in the sample i01. The sample i01 supports strongly the Hierarchy model of galaxy evolution.

In sample i09, the observed distribution of galaxies is 63,312 which is more among all these samples. The test statics for the  $\theta$  distributions is shown in the tenth row of table 2. All these statistics suggest isotropy except first-order Fourier probability which suggests an anisotropy. Overall statistic suggests random orientation of the spin vector. Similarly, for  $\phi$  distributions the test statistics is shown in tenth row of table 2. All these statistics shows strongly anisotropy and a significant positive value of first order Fourier coefficient suggests that the projections of the spin vector of galaxies tend to lie radially towards the center reference plane.



**Figure 2:** (a) The polar angle ( $\theta$ ) and (b) azimuthal angle ( $\phi$ ) distributions of galaxies in the sample (i09). The solid line shows the expected distributions and the solid circles with  $\pm 1\sigma$  error bars show the observed distribution. The cosine and average distribution (dashed) are shown for comparison.

In Figure 2(a), the number of observations for a small angle ( $0^\circ \leq \theta < 40^\circ$ ) are found to be 92,511 whereas the expected are 92,217. Thus, the number of observed distributions is more than 294 than that of expected distributions. There is no significant hump and dip is seen in a smaller range of angles. For region ( $40^\circ \leq \theta \leq 50^\circ$ ), the observed and expected number of observations are found to be 13,554 and 13,671 respectively such that an observed number of observations is less than by 117 than that of expected observations. In this region, also not any significant hump and dip are seen. For large angles ( $50^\circ < \theta \leq 90^\circ$ ), the observed and expected numbers are 20,559 and 20,734 respectively implies that the observed distribution is less than that of the expected solution by 175. In this region, also there is not any significant hump and dip are seen and also we found so many very very small humps and dips are seen in a different range of angles. So, finally, we conclude that these small humps and dips are not considered as significant and hence, no preferred alignment is found to be noticed. Thus, we have noticed that there is a random distribution of spin vectors of galaxies in the  $\theta$  distribution.

In Figure 2(b), the number of observed distributions in the central eight bins ( $\phi \sim \pm 45^\circ$ ) are found to be 87,768 and that of expected is 85,959. Thus, the number of the observed distributions is more than 1,809 than that of expected observations. In this region, there are three significant humps seen at the angles  $-15^\circ$ ,  $-5^\circ$ ,  $5^\circ$  with the error limits  $\sim 2.5\sigma$ ,  $\sim 2.0\sigma$  and  $\sim 1.5\sigma$  respectively but there is only one small dip is seen at an angle  $45^\circ$  with an error limits  $\sim 0.8\sigma$ . Also, for smaller angle ( $\phi < -45^\circ$ ), the observed distribution are found to be 17,874 whereas the expected are 19,122 and the observed distribution is less than by 1,248 than that of expected. In this region, there is no hump seen but two significant dips are seen at angles  $-85^\circ$  with an error  $\sim 4.0\sigma$  and  $-75^\circ$  with an error  $\sim 2.5\sigma$ . For larger angles ( $\phi > 45^\circ$ ), the observed and expected number of galaxies are found to be 20,982 and 21,542 respectively and the observed

distribution is less than by 560 than that of expected distributions. In this region, there is no hump seen but three small systematic dips are seen at angles  $65^\circ$ ,  $75^\circ$ , and  $85^\circ$  with all are nearly equal error limit  $\sim 0.8\sigma$ . After studying the graph, preferred alignment is found to be noticed. This suggests that projections of spin vectors of the galaxies tend to orient radially towards the center of the equilateral co-ordinate system.

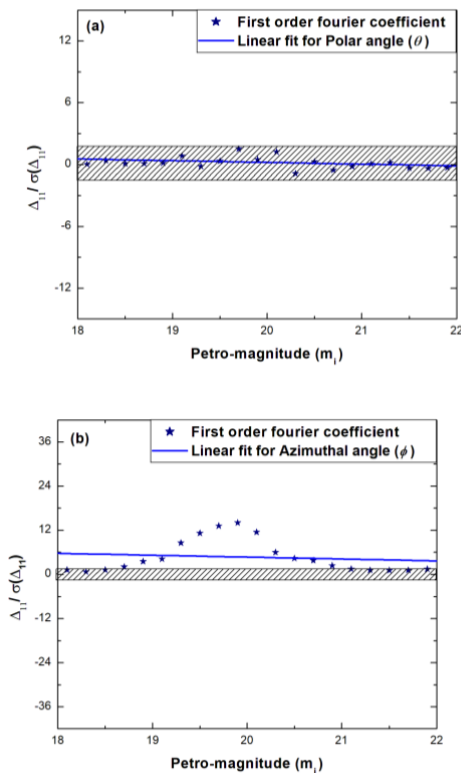
After careful examination of the sample (i09), we found that the orientation of the spin vector is isotropic which implies random orientation and projection of angular momentum vector is preferred alignments and found to be radially towards the center of the equilateral co-ordinate system in the sample i09. This sample i09 supports the Hierarchy model of galaxy evolution.

Similarly, we studied statistics and graphs of polar and azimuthal distribution of all remaining samples in which we found that all the samples have the three-dimensional orientation of the spin vector is isotropic which suggests that random orientation of spin vector and Supports the Hierarchy model of galaxy evolution. The projection of spin vector is found to be isotropic for sample i03 and lastly five samples i16, i17, i18, i19, and i20 which suggests that random projection of spin vector. The projection of spin vector in middle range samples i04 to i15 is found to be anisotropy and after careful study of these samples we found that projection of spin vector is radially towards the center of equilateral coordinate system.

We know that the preferred orientation and projection of the spin vector of galaxies can be studied by the general parameter First order Fourier coefficient ( $\Delta_{11}/\sigma(\Delta_{11})$ ). The plot of Petro-magnitude of i-filter and first-order Fourier coefficient is shown in Figure 3 above. In the figure, the shaded region shows the region of isotropy in both the polar and azimuthal angle distributions. The lower value of the i-magnitude represents the brighter galaxies. Thus, along the X-axis, the brightness profile of galaxies decreases. The distance magnitude relation:  $mM = 5\log r - 5 + 2.5\log e$  or says that the magnitude is roughly proportional to the distance. We know that, according to Hubble's law, distance to the galaxy is proportional to its radial velocity or redshift. Thus, we can roughly assume that the low magnitude galaxies (which is brighter) might have low radial velocity or redshift.

In Figure 3(a), we see that all these scatter points lie inside the shaded region, i.e., the isotropic region. All these points lie near the linear fit line for polar angle distribution ( $\theta$ ). Thus, we conclude that the three-dimensional orientation of spin vectors of galaxies is isotropic and is independent of the i-magnitude of galaxies. This implies that all these samples support strongly the Hierarchy model of galaxy evolution.

In Figure 3(b), We see that for the azimuthal angle distribution ( $\phi$ ) first three points i01, i02, i03 and last five points i16, i17, i18, i19 and i20 lies inside the shaded region i.e., isotropic region this implies that the projection of spin vector is not preferred alignment and this suggests that projection of spin vector is random. And the remaining scatter points i04 to i15 lie outside the shaded region which means the projection of the spin vector is anisotropic and found that projection of the spin vector of the galaxies tend to be orient radially toward the center of the equilateral co-ordinate system. In the study of azimuthal distribution of all samples, we have seen that initially, a number of observed galaxies is less in the sample which is isotropic, after increasing the Petro- magnitude, a number of galaxies are increases and these high galaxies contained sample shows local anisotropic because in this region galaxies are in merging process and merged due to shearing or tidal effect to form a cluster, so the position of galaxies is not constant i.e., variable. We found that the equilateral co-ordinate system is not suitable for studying these maximum number of galaxies contained sample and to study such types of samples better to use Galactic or Super galactic Co-ordinate system. Further increase of magnitude the observed number of galaxies is less in the sample and hence isotropic is seen. After this observation, we conclude that an equilateral coordinate system is suitable for a smaller number of observed galaxies samples and for more observed galaxies samples we prefer better to use Galactic or Super-galactic Co-ordinate system. Hence, our study region of i- filter of redshift 0.54 to 0.60 supports a strongly Hierarchy model of galaxy evolution.



**Figure 3:** The plot of i-magnitude (Petro) versus first-order Fourier coefficient ( $\Delta_{11}/\sigma(\Delta_{11})$ ) for (a)  $\theta$  and (b)  $\phi$  distributions for all samples.

### Comparison with Previous Works

Malla et al., [15-18] studied the non-random orientation of spin vector of supercluster S[202-002+0084] in 2019 having to mean redshift 0.084, supercluster S[195+027+0022] in 2019 that had redshift in the range 0.07 to 0.09, supercluster S[227+006+0078] in 2020 that had redshift in the range 0.07 to 0.09 and supercluster S[231+030+0117] in 2020 that had redshift in the range 0.107 to 0.123. In all these three studies, they found that spatial orientation and projection of spin vector in all samples had not preferred alignments and which implies that random orientation and projection of spin vector with respect to the equilateral coordinate system. Finally, their study concluded that all these four superclusters support strongly the Hierarchical model of galaxy evolution. This result matches with our results in all the sample orientation of spin vector and some differences in the projection of the spin vector. Our results also support strongly the Hierarchy model of galaxy evolution. Hence, our and their results are found to be nearly similar.

### Conclusions

In this article, we have to present a study of the *i*-magnitude galaxies of redshift range 0.54 to 0.60 with respect to the equilateral co-ordinate system. The database is taken from SDSS 14<sup>th</sup> data release (DR-14) and this redshift contains 239,209 galaxies. SDSS provides two-dimensional data, we convert a two-dimensional database into a three-dimensional galaxy rotation axis: polar & azimuthal angles, with the help of the method proposed by Flin & Godlowski [10,14]. SDSS survey database contains positional and inclination selection effects and that cause several changes in the expected isotropic distribution curves, so to remove such types of effects Numerical Simulation Method is used which was proposed by Aryal & Saurer [12, 13]. The main aim of this work is to know the random effects in the galaxy and to find out the relevance of the choice of the coordinate system in order to explain the true orientation scenario and projection of spin vectors of distant galaxies. For simplicity, we divide our total database into twenty samples with the help of the Petro-magnitude range by considering equal sample bins. To check, isotropy or anisotropy we have to carry out four statistical tests: chi-square, auto-correlation coefficient, first-order Fourier series and first-order Fourier probability tests. The conclusion of our work is as follows:

1. We found in all twenty samples, three - dimensional orientation of the spin vector of galaxies is isotropic with the equatorial plane and independent of the *i*-magnitude of galaxies.
2. The projection of angular momentum vector in the first three samples *i*01, *i*02, *i*03 and the last five samples *i*16, *i*17, *i*18, *i*19 and *i*20 are seen isotropic.

3. And, the remaining samples *i*04 to *i*15, the projection of spin vector of the galaxies are seen anisotropy and found that tend to be orient radially towards the center of the equilateral plane.
4. The sample which contains a maximum number of observed galaxies shows a local anisotropic angular momentum vector because in this region galaxies are in the merging process and merged due to shearing or tidal effect to form a cluster.
5. After this observation we conclude that an equilateral coordinate system is suitable to study, a smaller number of observed galaxies sample and for more observed galaxies sample we prefer better to use Galactic or Super-galactic Co-ordinate system for the study of orientation and projection of angular momentum vector.
6. Hence, our study region of *i* - magnitude of redshift 0.54 to 0.60 supports strongly the Hierarchy model of galaxy evolution.

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