A STUDY OF *Z*-MAGNITUDE DEPENDENCE IN THE SPATIAL ORIENTATION OF ANGULAR MOMENTUM VECTORS OF GALAXIES HAVING REDSHIFT < 30,000 km s^{-1}

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ABSTRACT

I present a study of spin vector orientations of 229,675z-magnitude SDSS (Sloan Digital Sky Survey) galaxies having red shift of 0.05 to 0.10. The z-magnitudes are observed through 913.3 nm CCD (charge coupled device) filter attached to SDSS telescope located at New Mexico, USA. We have converted two dimensional data to three dimensional by Godlowskian Transformation. Our aim is to find out non-random effects in the spatial orientation of galaxies. The expected isotropy distribution curves are obtained by removing the selection effects and performing a random simulation method. In general, spin vector orientations of galaxies is found to be random, supporting Hierarchy model of galaxy formation. In some samples (z12 and z13) of polar angle distribution is observed anisotropy supporting Primordial Vorticity Theory. For azimuthal angle distribution in more sample we observed anisotropy result. A local anisotropy is observed in few samples suggesting a gravitational tidal interaction, merging process and gravitational lensing effect.

Key Words: clusters, Supercluster, galaxies formation, evolution of galaxies, statistics, redshift, isotropy, anisotropy.

INTRODUCTION

The initial perturbations in matter density which is believed to be present in early Universe, gradually kept on being enhanced with time as the Universe expanded and 1000s of millions of years after Big Bang slowly the large scale structures viz. galaxies, clusters, Super clusters, Hyper clusters, filaments and walls, with great walls" of thousands of galaxies reaching more than a billion light years in length started getting formed. However, less dense regions did not grow, evolving into an area of seemingly empty space called voids. Hereby, we see that our universe is ever evolving and expanding; and cosmologists and astronomers are trying to discover what its final fate will be. Since the universe by its definition encompasses all of the space and time as we know it, it is beyond the model of the Big Bang to say what the universe is expanding

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into or what gave rise to the Big Bang. Although there are models that speculate about these questions, none of them have made realistically testable predictions as of yet. The Lambda Cold Dark Matter (or LCDM) model is the best model of our known universe about the origin of the large scale structures representing an improvement over the big bang theory (Blumenthal *et al.,* 1984). Large scale structure means the huge cluster and Super cluster of galaxies. These structures are one of the most mysterious discoveries, because their formation and evolution is not fully understandable yet. Thus, to know the origin of the expanding universe and large scale structures is one of the most fundamental question in the recent universe. One of the most accepted model on the evolution and expansion of the large scale structure is that it was the result of primordial fluctuations by gravitational instability. An additional factor complicating an understanding of galaxies is that their evolution is strongly affected by their environment. The gravitational effects of other galaxies can be important. Galaxies can sometimes interact and even merge.

Modern cosmology is based on two fundamental assumptions: First, the dominant interaction on cosmological scales is gravity, and second, the cosmological principle is a good approximation to the universe. The cosmological principle states that the universe, smoothed over large enough scales, is essentially homogeneous and isotropic. 'Homogeneity' has the intuitive meaning that at a given time the universe looks the same everywhere and 'isotropy' refers to the fact that for any observer moving with the local matter, the universe looks (locally) the same in all directions. Von Weizsacker and Gamow (1951 and 1952) made it clear that the observed rotation of the galaxies is important for cosmology: the fact that the galaxies rotation may be a clue to the physical conditions under which these systems are formed. In the instability picture, one imagines that large irregularity like galaxies grew under the influence of gravity from small imperfections in the early Universe (Gamow and Teller 1939, Peebles 1965, 1967). In this picture one must abandon the idea that the angular momentum of the galaxies was given as the initial value, or developed in some sort of primeval turbulence(as was proposed by von Weizsaker1951 and Gamow 1952), for otherwise the galaxies would have formed too soon (Peebles, 1967). On the other hand, huge low red shift galaxy surveys such as the 2-degree field galaxy red shift survey (2dFGRS, Colless *et al.* 2001) and the Sloan Digital Sky Survey (SDSS, York et al. 2000) have convinced most cosmologists that not only isotropy but also homogeneity is, in fact, a reasonable assumption for the universe. The Universe is homogeneous and isotropic on scales larger than 100 Mpc, but on smaller scales we observe huge deviations from the mean density in the form of galaxies, galaxy clusters, and the cosmic web being made of sheets and filaments of galaxies. How do structures grow in the universe and how we can describe them? 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. In the current favored model, smaller structures collapse first and are later incorporated in larger collapsing structures in a bottom-up scenario that provides a natural explanation for the formation of galaxies, clusters, filaments and Super clusters.

Galaxy clusters are gravitationally bound large scale structures in the universe. To understand the evolution of these aggregates, it is essential to know when and how they were formed and how their structures and constituents have been changing with time. Gamow (1952) made it clear that the observed rotations of galaxies are important for cosmology. According to them, the fact that galaxies rotation might be a clue of physical conditions under which these systems are formed. Thus, understanding the distribution of spatial orientations of the spin vectors (hereafter SVs) or angular momentum vectors of galaxies is very important. It could allow us to know the origin of angular moment of a galaxy.

There are three predictions about the spatial orientation of spin vectors of galaxies. These are the `*pancake model*', the `*hierarchy model*,' and the `*primordial vorticity theory*.' The `*pancake model*' (Doroshkevichmm, 1973; Doroshkevich and Shandarin, 1978) predicts that the spin vectors (SVs hereafter) of galaxies tend to lie within the cluster plane. According to the `hierarchy model' (Peeblesm, 1969), the directions of the SVs should be distributed randomly. The `Primordial Vorticity Theory' (Ozernoy, 1971, 1978; Stein, 1974) predicts that the spin vectors of galaxies are distributed primarily perpendicular to the cluster plane.

SDSS PHOTOMETRY

The term "photo" means light and the term "metry" refers to measurements. Photometry is the science of the measurement of light, in term of its perceived brightness to the human eye. In photometry, the standard is the human eye. The sensitivity of the human eye to different color is different. This has to consider in photometry. Since the human eye is only sensitive to visible light, photometry only falls in that range. Photometry and spectroscopy are two important applications of light measurements. These two methods have various applications in fields such as chemistry, physics, optics and astrophysics. It is vital to have a solid understanding in these concepts in order to excel in such fields.

The apparent magnitudes do not tell us about the true brightness of stars, since the distances differ. A quantity measuring the intrinsic brightness of a star is the absolute magnitude. The absolute magnitude M of any star is defined as the apparent magnitude at a distance of 10 pc from the star in the absence of astronomical extinction.

We know that the relation between magnitude, distance and opacity is given by Padmanabhan (2006),

$$m - M = 5\log r - 5 + (2.5\log e)\alpha r \quad (1)$$

Here m, M and α represent apparent, absolute magnitudes and opacity of the medium.

For r and u filter,

$$m_r - M_r = 5\log r - 5 + (2.5\log e)\alpha_r r \quad (2)$$

$$m_u - M_u = 5\log r - 5 + (2.5\log e)\alpha_u r \quad (3)$$

Subtracting equation (3) from (2) we get,

$$r = [(m_r - m_u)-(M_r - M_u)]/[2.5 \log e\,(\alpha_r-\alpha_u)] \quad (4)$$

This equation is useful to calculate the value of distance to the galaxy. Thus, the magnitude through various filters gives precise information about distance. The SDSS Telescope consists of five different filters of different pass band and different wave lengths given in Figure-1:

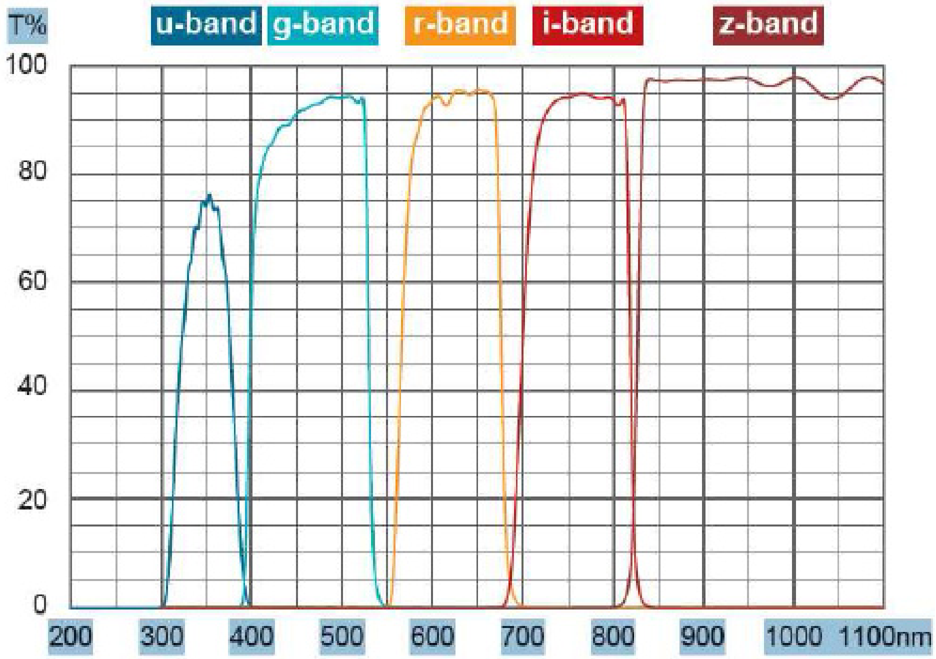


Figure-1: Wave length bands of the filters used by SDSS telescope

GODLOWSKIAN TRANSFORMATION

The three dimensional orientation of the SV of a galaxy is characterized by two angles: the polar angle (θ between the galactic SV and a reference plane (here equatorial plane), and the azimuthal angle φ between the projection of a galactic SV on to this reference plane and the X-axis within this plane. The detail derivations of the expressions of the angles *θ* and *φ* are given in Flin and Godłowski (1986). When using equatorial coordinate system as reference, then *θ* and *φ* can be obtained from measurable quantities as follows:

$$\sin\theta = -\cos i \sin\alpha \pm \sin i \sin p \cos\delta \quad (5)$$

$$\sin\phi = (\cos\theta)^{-1}\left[-\cos i \cos\delta \sin\alpha + \sin i(\mp \sin p \sin\delta \sin\alpha \mp \cos p \cos\alpha)\right] \quad (6)$$

Where, *i* is the inclination angle, the angle between the normal to the galaxy plane and the observer's line-of-sight, α- is right ascension, δ is declination and p is position angle. The inclination angle can be computed from the formula,

$$\cos^2 i = \frac{(q^2 - q^{*2})}{(1 - q^{*2})} \quad (7)$$

This expression is valid for oblate spheroids (Holmberg 1946). Here, *q* and *q** represent the measured axial ratio (*b/a)* and the intrinsic flatness of the galaxy, respectively. Hiedmann *et al.* (1971) showed that the values of *q** range from 0.083 for Sd spirals to 0.33 for ellipticals. For the galaxies with unknown morphology *q**=0.20 is assumed Holmberge (1946).

NUMERICAL SIMULATION

Here we describe the procedure for the removal the selection effects to obtain the isotropic distributions for both θ and φ as given by Aryal and Saurer (2000). Theoretically, the isotropic distribution curve for polar angle is cosine and that for azimuthalangle is the average distribution curve, with the restriction that the database is free from selection effect. Aryal and Saurer (2000) concluded that any selections imposed on the database may cause severe changes in the shapes of the expected isotropic distribution curves. In their method, a true spatial distribution of the galaxy rotation axis is assumed to be isotropic. Then, due to the projection effects, *i* can be distributed as ~sin *i*, *B* can be distributed ~cos *B*, the variables α and *p* can be distributed randomly, and the equation (5,6) can be used to calculate the corresponding values of polar (*θ*) and azimuthal (*φ*). We run simulations in order to define expected isotropic distribution curves for both the θ and *φ* distributions. The isotropic distribution curves are based on simulations including 10^6 virtual galaxies. At first we observed the distributions of α, δ, p and i for the galaxies in our samples and distributed by creating 10^6 virtual galaxies for respective parameters. We use these numbers to make input file and the expected distribution by running simulation in MATLAB 7.0.

METHOD OF ANALYSIS

Our observations (real observed data set) are compared with the isotropic distribution curves (obtained from simulation) in both θ and φ distributions. For this comparison we use three different statistical tests: chi-square-, Fourier-, and auto correlation-test.

CHI-SQUARE TEST

The *Chi squire* test is a measure of how well a theoretical probability distribution fits a set of data. Chi squire test is an objective way to examine whether the observational distribution deviates from the expected distribution (in our case, to the isotropic distribution), which is based on the reduced value given by,

$$\chi_\nu^2 = \frac{\chi^2}{\nu} \quad (8)$$

$$\chi^2 = \sum_{i=1}^{n} \frac{(N_{0i} - N_{ei})^2}{N_{ei}} \quad (9)$$

Here, n represents the number of bins, N_{0i} and N_{ei} represent the observed and expected isotropic distributions and ν is the degree of freedom (ν = n-1). For an isotropic distribution, the χ_ν^2 value is expected to be nearly zero. The quantity P(> χ_ν^2) gives the probability that the observed χ_ν^2 value is realised by the isotropic distribution. The observed distribution is more consistent with the expected isotropic distribution when P(> χ_ν^2) is larger. We set P(> χ_ν^2) =0.050 as the critical value to discriminate isotropy from anisotropy, it corresponds to the deviation from the isotropy at 2≤ σ level.

FOURIER TEST

We compare the observed distributions of the polar and azimuthal angle (θ and φ) of the galaxy rotation axis with the expected isotropic distributions. If the deviation from isotropy is a slowly varying function of the angle θ (or φ), one can use the Fourier test

Here, the1st order Fourier coefficients Δ_{11} is given by

$$\Delta_{11} = \frac{\sum_{k=1}^{n} (N_k - N_{0k}) \cos 2\theta_k}{\sum_{k=1}^{n} N_{0k} \cos^2 2\theta_k} \quad (10)$$

The standard deviations σ (Δ_{11}) can be obtained using the expressions

$$\sigma(\Delta_{11}) = \left(\sum_{k=1}^{n} N_{0k} \cos^2 2\theta_k \right)^{-1/2} \quad (11)$$

The Fourier coefficient Δ_{11} is very important because it gives the direction of departure from isotropy. In the analysis of the polar angle (θ), if $\Delta_{11}<0$ an excess of galaxies with rotation axis parallel to the reference plane is present, whereas for $\Delta_{11}>0$ the rotation axis tend to be perpendicular to that plane. In the analysis of the azimuthal angle (φ), if $\Delta_{11}<0$ an excess of galaxies with rotation axis projections perpendicular to the direction of the Virgo cluster center, whereas with $\Delta_{11}>0$ the projections tend to be parallel to that direction.

AUTO CORRELATION TEST

Auto correlation test is a measure of a degree to which there is a linear relationship between two variables. In our case, it takes account of the correlation between the numbers of galaxies in adjoining angular bins. The correlation function is

$$C = \sum_{1}^{n} \frac{(N_k - N_{0k})(N_{k+1} - N_{0k+1})}{(N_{0k} N_{0k+1})^{1/2}} \tag{12}$$

with the standard deviation $\sigma(C) = (n)^{1/2}$

In an isotropic distribution any correlation vanishes, so we expect to have $C \rightarrow 0$.

RELIABILITY OF STATISTICS IN GALAXY ORIENTATION STUDY

It is clear from the expression (9) that the χ^2 value increases when the number of solutions per bin for both the observed (N_{0i}) and the expected (N_{ei}) distributions is increased by the same factor. As the χ^2value increases, P (> χ^2) decreases. So, our result 'isotropic' can change into 'anisotropic', if the database is filled with additional galaxies. However, the result 'anisotropic' remains the same even if the database increases. Because of the incompleteness of database the numbers we deal with are lower limits. So, our result 'anisotropic' can be seen as more reliable than the result 'isotropic'. The same will happen in the case of the correlation coefficient *C* and the Fourier probability function P ($>\Delta_1$). However, the Fourier coefficient $\Delta_{11}/\sigma(\Delta_{11})$ value remains unchanged even if the database increases.

RESULTS AND DISCUSSION

Any deviation from expected isotropic distribution will be tested using four statistical parameters, namely chi-square probability (P $>\chi^2$), autocorrelation coefficient (C/C(σ)), first order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11})$) and first order Fourier probability (P $>\Delta_1$). For anisotropy, the limit of chi-square probability P($>\chi^2$) is <0.050, auto correlation coefficient (C/C(σ)) is >1.0, first order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11})$) is >1.5 and Fourier probability P($>\Delta_1$) is <0.150, respectively. Any `hump' (more solutions than the expected) or `dip' (less solutions than the expected) in the histogram will be discussed as a local effect in the samples. The statistics for the polar and azimuthal angle distributions is given in Table-1. In the statistics of θ, a negative value of first order Fourier coefficient suggests that the spin vectors of galaxies tend to be oriented perpendicular with respect to the equatorial coordinate system. Similarly, a positive value of first order Fourier coefficient suggests that the spin vectors of galaxies tend to be oriented parallel with respect to the equatorial coordinate system. Whereas, in the statistics of φ, a positive $(\Delta_{11}/\sigma(\Delta_{11})$with significant value suggests that the spin vector projections of galaxies tend to point radically with respect to the center of the equatorial coordinate system. Similarly, a significant negative value of $(\Delta_{11}/\sigma(\Delta_{11})$implies that the spin vector projection of galaxies tend to orient tangentially with respect to the equatorial coordinate system.

In addition to the statistical tests, we also study the `humps' and `dips' in the polar and azimuthal angle distributions. The solid curve, in the histogram of the φ-distribution, represents the expected isotropic distribution whereas dashed curve is the cosine distribution. The solid circles with $\pm1\sigma$error bars represent the observed distribution. The shaded portion represents the range $0^o<\theta<45^o$. A hump (or dip) in the smaller suggests that the spin vectors of galaxies tend to orient parallel (or perpendicular) with respect to the equatorial coordinate system.

Similarly, a hump (or dip) in the larger θ indicates that the spin vectors of galaxies tend to be oriented perpendicular with respect to the equatorial coordinate system. In the histogram of the θ-distribution, solid curve represents the expected isotropic distribution whereas dashed curve is the average distribution. The solid circles with $\pm1\sigma$ error bars represent the observed distribution. The shaded portion represents the range $-45^o< \varphi <+45^o$. The humps and dips in the histograms of *φ distribution* are not so easy to interpret as compared to θ-distributions. It is because the range of φ is $-90^o$to $+90^o$. In the histogram of the -distribution, $\varphi = 0^o$means spin vector projections tend to point radially towards the center of the equatorial coordinate system. A hump in the middle (central eight bins) of the histogram suggests that the spin vector projections of galaxies tend to point towards the center of the chosen co-ordinate system. Similarly, a hump at first four and last four bins indicates that the spin vectors projections of galaxies tend to be oriented tangentially with respect to the chosen reference co-ordinate system.

This sample contains a small number (51) of galaxies that have apparent magnitude in the range 13.25 to 13.55 in the z-band (913.4 nm wavelength). The smaller the value of magnitude the brighter the object. Significant infrared emission indicates the enhanced star formation activity and the relatively higher abundance of metal-rich elements in these galaxies. Thus, these are the brightest galaxies in the z-filter. Figure, 2 shows the polar angle (θ) distribution of total galaxies of database in the sample z01. The statistics for the θ-distribution of galaxies of this sample is shown in the Table-1. The statistics for the polar angle distribution in this sample shows that the value of chi-square probability ($P(>\chi^2)$) to be 0.458 i.e., 45.8% (greater than the significant level 0.050 i.e., 5.0%). The auto-correlation coefficient (C/C(σ)) is found to be 1.4 (greater than 1σ limit). The first order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11})$)is found to be +0.5 (smaller than 1.5σ the limit). The first order Fourier probability (P>(1)) is found to be 0.849 i.e., 84.9% (greater than 15% limit). Except auto-correlation coefficient, other statistical tests suggest isotropy. Anisotropy in the auto-correlation test suggests either binning effect or local anisotropy that should be seen in the humps/dips in the histogram. In, Figure-2, the number of observed solutions that have $\theta < 45^0$ is found to be equal to the expected solutions i.e., 64. There is no any significant humps and dips in the lower angles ($<45^0$) region. At bimodal region ($\theta \approx 45^0$), there are 2 more observed solutions than the expected in this region. For the large angles ($> 45^0$), the number of expected solutions is more by 2 than that of observed and there is a significant dip at 63.75^0 with >2σ error limit in this region. Thus, we conclude that there is no preferred alignment of spin vectors of galaxies that are brightest when observed through filter.

The statistics of the φ-distribution (Table-1) for the sample z01 brings the results as: P (>χ2) = 0.187 i.e., 18.7% (greater than the 5.0% significant level), C/C(σ) = 0.0 (less than the limit 1σ), $\Delta_{11}/\sigma(\Delta_{11}) = 1.6$ (greater than the limit 1.5σ), $P >(\Delta_1) = 0.223$ i.e.,22.3% (greater than 15% limit). The values of chi-square probability (P(>χ2)), the auto-correlation coefficient C/C(σ) and the first order Fourier probability support strong isotropy. However first order Fourier coefficient suggests the weak anisotropy. In the azimuthal angle distribution, as shown in Figure-2, the observed solutions of central six bins (shaded region) are found to be 65, whereas the expected solutions are only 57. This shows that observed solutions exceeded the expected solutions by 8. In this region, one dip at an angle $7.5^0$is observed with ≈1.5σ error limit and two humps are observed at 22.5^0 and $7.5^0$with≈1.5σ error limit. Since, there are no significant dips and humps outside the shaded part. Owing to the extremely poor statistics (i.e., the number of solutions per bin), we conclude no preferred alignments. The bright infrared galaxies that have red shift in the range 0.05 to 0.10 showed no preferred alignments in the spatial orientation of their spin vectors.

Table-1: Statistics of the polar (left) and azimuthal angle (right) distributions of *z*-magnitude SDSS galaxies having red shift in the range 0.01 to 0.10in the samples. The P(>χ^2) represents the chi-square probability (second column). Similarly, C/C(σ) represents the auto-correlation coefficient (third column). The last two columns give the first order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11}$) and first order Fourier probability P(>Δ_1).

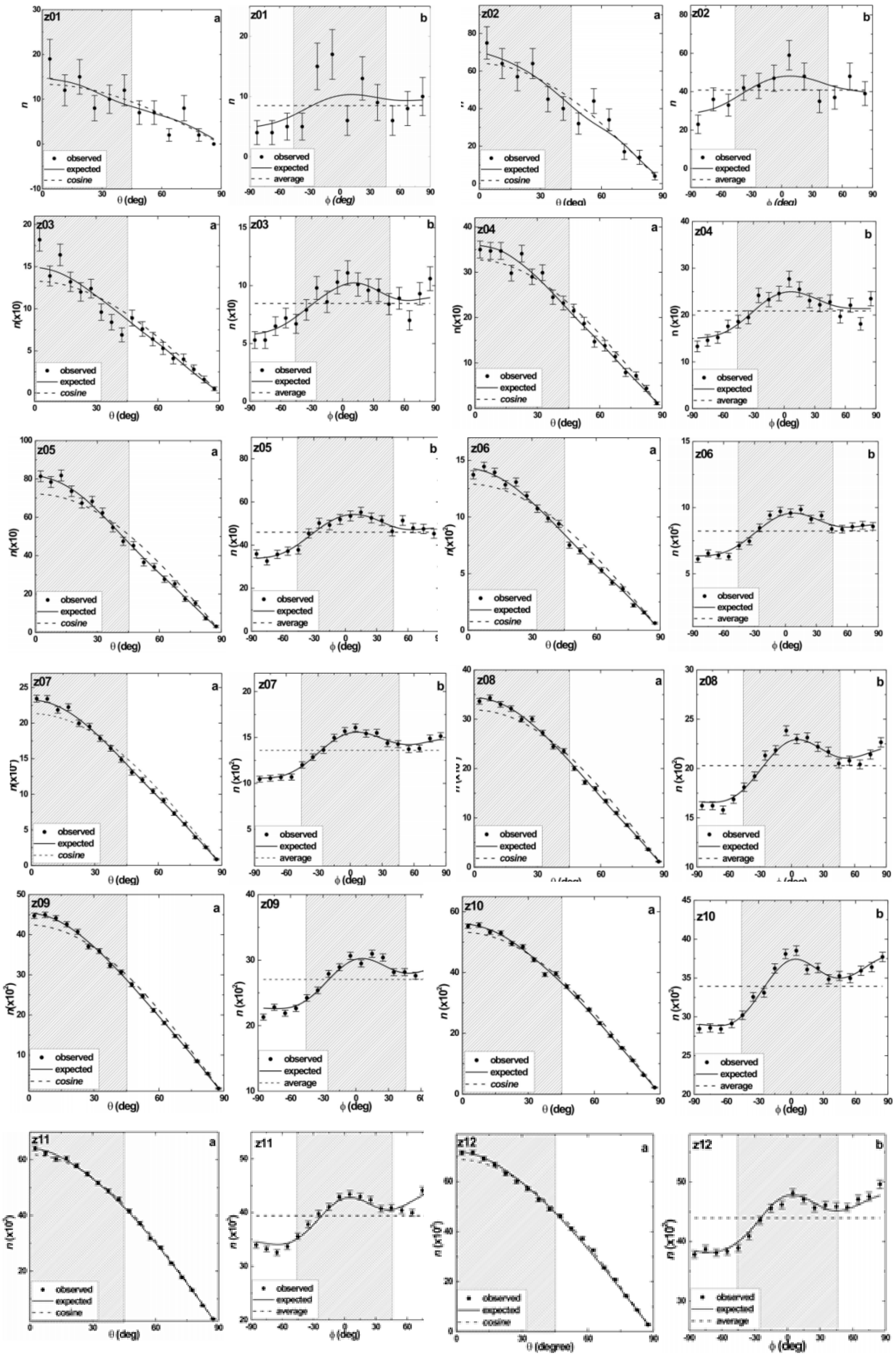
sample	$P(>\chi^2)$	$C/C(\sigma)$	$\Delta_{11}/\sigma(\Delta_{11})$	$P(>\Delta_1)$
$z01$	0.458	−1.4	+0.5	0.849
$z02$	0.399	−0.3	−0.8	0.695
$z03$	0.071	+0.5	+0.6	0.365
$z04$	0.637	−1.1	−1.0	0.541
$z05$	0.620	−1.6	−0.4	0.907
$z06$	0.281	−1.8	+0.4	0.900
$z07$	0.913	−1.1	+0.1	0.956
$z08$	0.287	−1.0	−0.7	0.739
$z09$	0.843	−0.4	−0.7	0.766
$z10$	0.045	−1.2	−1.4	0.356
$z11$	0.478	+0.2	−0.5	0.643
$z12$	0.002	+5.6	−3.2	0.004
$z13$	0.001	+4.8	−4.2	0.000
$z14$	0.900	−0.4	+0.9	0.620
$z15$	0.053	−2.5	−0.3	0.923
$z16$	0.429	−1.2	+0.0	0.866
$z17$	0.954	+0.4	−0.2	0.941
$z18$	0.412	−1.3	+0.2	0.986
$z19$	0.347	+0.2	−0.4	0.658

sample	$P(>\chi^2)$	$C/C(\sigma)$	$\Delta_{11}/\sigma(\Delta_{11})$	$P(>\Delta_1)$
$z01$	0.187	+0.0	+1.6	0.223
$z02$	0.619	−0.4	+0.5	0.756
$z03$	0.777	−0.3	+0.3	0.812
$z04$	0.327	+0.1	+1.5	0.173
$z05$	0.740	−0.7	−0.1	0.882
$z06$	0.729	−0.3	+1.5	0.319
$z07$	0.860	+0.2	+1.0	0.606
$z08$	0.137	+1.3	+2.5	0.027
$z09$	0.032	−0.1	+2.9	0.016
$z10$	0.549	−0.4	+1.6	0.233
$z11$	0.005	+2.9	+3.5	0.002
$z12$	0.099	+1.9	−2.7	0.001
$z13$	0.002	+5.8	−4.5	0.000
$z14$	0.006	+4.4	+2.2	0.009
$z15$	0.506	+0.2	+0.3	0.073
$z16$	0.255	−1.0	−1.1	0.518
$z17$	0.255	+0.2	+2.8	0.020
$z18$	0.752	−0.6	−0.7	0.684
$z19$	0.954	+0.0	−0.4	0.703

Similar to this, most of the samples showed isotropy in the polar except in the sample z12 and z13. In general, our results support Hierarchy model (Peeble, 1969).

Figure-2 (z12) shows the polar angle (θ) distribution of total galaxies of database in the sample z12. The statistics for the -distribution of galaxies of this sample is shown in the Table-1.The statistics for the polar angle distribution in this sample shows the value of chi-square probability ($P(>\chi^2)$) to be 0.002(smaller than 5.0% significant level). The auto-correlation coefficient ($C/C(\sigma)$) is found to be 5.6 (greater than 1 limit). The 1st order Fourier coefficient ($\Delta_{11}/(\Delta_{11})$) is found to be 3.2 (greater than the limit 1.5). The 1st order Fourier probability is found to be 0.004, (smaller than 15% limit). Thus, all statistical tests strongly advocate weak anisotropy. In Figure-1 (z12), the number of observed solutions for< $45^0$is 51,249, which is less than the number of expected solutions by 539. Hence, a large number of galaxies are moved from shaded to unshaded part, supporting Primordial Vorticity model. There are three dips at angles 22.5^0, $27.5^0$and $37.5^0$with 1.5 error limit in this region. At bimodal region (45^0), the number of observed solutions is less by 11 than that of expected? No any significant humps and dips are observed in this region. For the large angles (> 45), the number of observed solutions is more by 550 than that of expected and there are three significant humps at angles 57.5^0, 62.5^0 and$72.5^0$with > 2error limit. Hence, the spatial orientation of spin vectors of galaxies that have z -magnitude in the range16.55<mz< 16.85 supports primordial vorticity theory. This theory predicts that the spatial orientation of spin vectors of galaxies tend to be oriented perpendicular with respect to equatorial plane. Thus, formation of protocluster before the galaxy formation cannot be ruled out (Shanderin, 1974).

The auto-correlation coefficient $C/C(\sigma)$, the 1st order Fourier coefficient $\Delta_{11}/(\Delta_{11})$ and the 1st order Fourier probability support anisotropy for φ- distribution. In the distribution, as shown in Figure-2 (z12), the observed solutions of central eight bins (shaded region) are found to be 36,318.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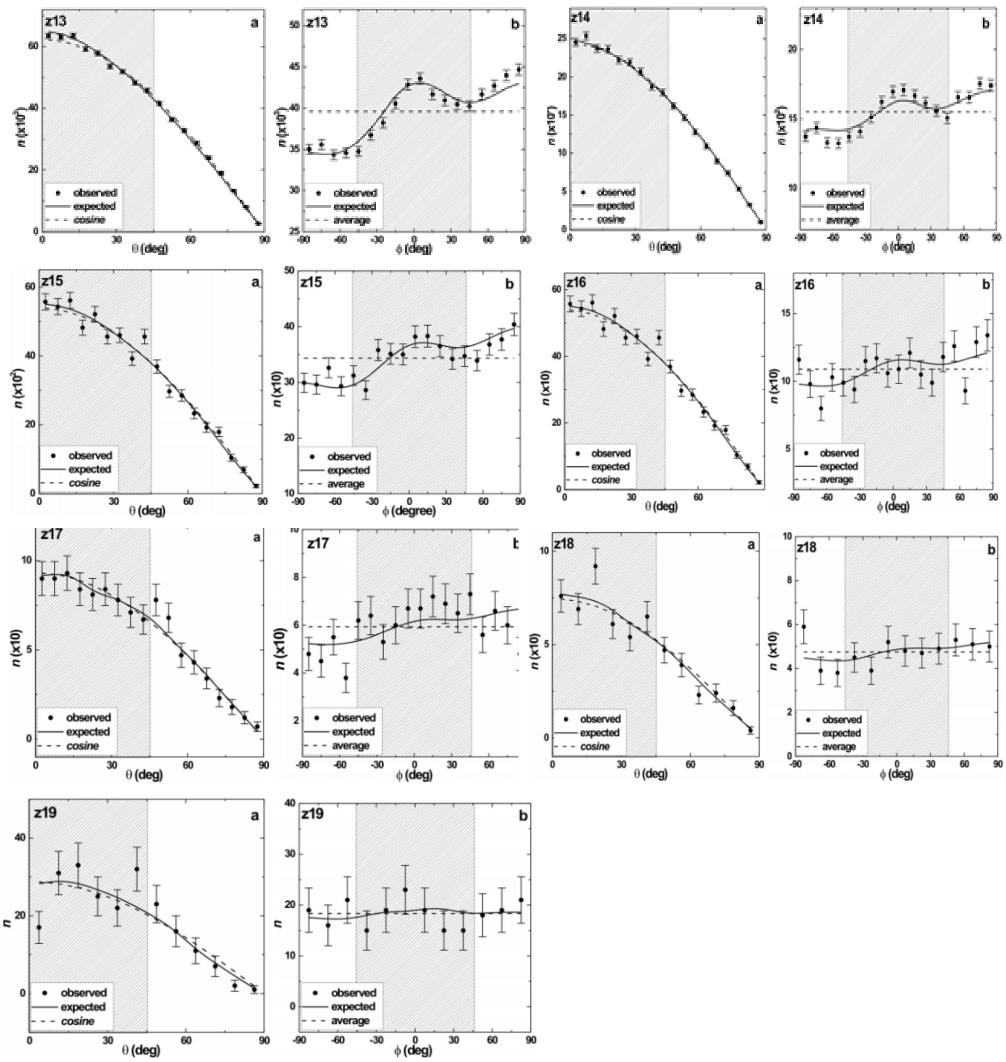

Figure-2: The polar (θ) and azimuthal angle (φ) distributions of SDSS galaxies having *z*-magnitude. The solid line represents the expected isotropic distributions. The cosine and average distribution (dashed) is shown for the comparison. The statistical error (±1σ) bars are shown for the observed counts, whereas the expected solutions are only 36,628. This shows that observed solutions lagged the expected solutions by 310. In this region, one dip at an angle 5^0 is observed with > 2σ error limit. Also, one significant hump is observed at 85 with 2 error limit outside the shaded part. Thus, a preferred alignment is noticed in this sample. We found that the spin vector projections of galaxies in this sample tend to be directed towards the equatorial center. We conclude that there is a strong anisotropy in this sample. The spin vectors of galaxies tend to be oriented perpendicular with respect to equatorial plane whereas spin vector projection of galaxies tend to point towards the equatorial center. Thus, the infrared activity is found to be non-random indicating either star forming activity in this large number of galaxies ormetalicity might be higher than the one expected. Similar result to this anisotropy is observed in sample z13 (Table-1 and Figure-2), supporting Primordial Vorticity Theory (Ozernoy, 1971, 1978, Stein 1974).

No preferred alignment is noticed in the spatial orientation of spin vectors of z-magnitude SDSS galaxies that have red shift in the range 0.05 to 0.10, suggesting Hierarchy model. However, local effects, tidal effects, effect of reference co-ordinate system are found in the samples z01, z05, z06,*z*07,z15 and *z*18.

CONCLUSION

We have studied the *z*-magnitude dependence in the preferred alignment of spin vector orientation of 44,749 SDSS galaxies that have red shift in the range 0.05 to 0.10. We used the method proposed by Flin and Godlowski (1986) in order to compute two-dimensional data to three dimensional galaxy rotation axis (polar and azimuthal angles). We have carried out random simulation by creating 10^7 virtual galaxies and adopting the method proposed by Aryal and Saurer (2000) in order to find out theoretical distribution of galaxy rotation axes. We have compared the differences between theoretical distributions and observed distributions using three statistical tools, namely chi-square, auto-correlation and the Fourier. We conclude our results as follows:

(1) The distribution of spin vector and spin vector projections of *z*-magnitude SDSS galaxies that have red shift in the range 0.05 to 0.10 are found to be random in all samples, except in the subsample *z*12 and z13. In general, our results support Hierarchy model (Peeble, 1969).The galaxies of sample z12 and z13 show anisotropy. The spin vector orientation of these galaxies tends to be oriented perpendicular to the equatorial plane, suggesting Primordial Vorticity model. It is probably due to strong tidal connection between the galaxies of this group. The cause of this anisotropy should be studied in the future.

(2) No preferred alignment is noticed in the spatial orientation of spin vectors of galaxies, suggesting Hierarchy model, as suggested by Peebles (1969). However, a local effect is noticed in the samples z01, z04, z06, z07, z10, z12, z13, z15, z16 and z18. In these samples, we suspect a local tidal connection between the rotation axes of galaxies or due to the merging process, the angular momentum vector of few galaxies get distorted. The luminosity

profile of these groups should be studied in order to understand the effect of intra galactic medium.

(3) A local effect that causes the humps and dips in the angular momentum distribution is observed in different subsamples. In the deep field, density fluctuation is expected and observed in the local scale. Existence of super clusters in the region of interest cannot be ruled out.

(4) We have used equatorial system as a physical reference in order to study non-random effects concerning galaxy orientation. Hierarchy model predicts that the choice of co-ordinate system do not alter preferred alignments.

(5) A random simulation for 10^7virtual particles (i.e., galaxies) carried out successfully by using 4 GB RAM pc. We intend to carry out simulation generating 10^8virtual galaxies in order to find out sufficiently smooth expected isotropic distribution curves in the future.

In general, our results support Hierarchy model. This model predicts that the spatial orientation of angular vectors of a system of rotationally supported large scale structure (e.g. Spiral galaxies) should vanish. In other words, these vectors should align randomly. The spatial orientation of galaxies in 112 clusters were studied till date (Godlowski et al. 1986-2011; Flin *et al.* 2001, Aryal *et al.* 2004-2011). In most cases no preferred alignment is noticed (Hierarchy model). However, few clusters strongly support Pancake model. Aryal *et al.* (2007) noticed a systematic change in the galaxy alignments from early-type (BM I) to late-type (BM III) clusters. This result suggests that the spiral-rich (late-type) clusters (BM II-III and BM III) show a preferred alignment than that of elliptical-rich (early-type) clusters.

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