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Research Article

THREE DIMENSINAL STUDY OF ORIENTATION OF SDSS DR-14 u- MAGNITUDE GALAXIES OF REDSHIFT 0.100 TO 0.125

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ABSTRACT

The three-dimensional orientations angular momentum of 105,728 SDSS DR-14 galaxies with redshift ranging from 0.100 to 0.125 are studied in the present article. The non-random effects associated with the orientations of angular momentum in galaxies within the specified redshift range are core objectives to investigate. The evolution of large structure formation is evaluated through three distinct scenarios: the Hierarchy model, the Pancake model, and the Primordial Vorticity model. The two-dimensional observational data–including positions, position angles, and inclination angles–into three-dimensional parameters called azimuthal angle and polar angle of rotation axes. This transformation is accomplished Flin-Godlowskian method (Flin & Godlowski, 1986). The principal work of the study is to establish relation between u-magnitude and the orientation of angular momentum vector. Isotropic curves expected data of are generated by accounting for selection effects and conducting a random simulation that produces 10^7 virtual galaxies. Three statistical tests: Chi-square analysis, Autocorrelation, and Fourier analysis are used to compare observed and expected results. The comprehensive sample is segmented into ten samples, each with a magnitude range of 0.5. Most of the findings lend support to the Hierarchy model of large-scale structure, which posits that the spin vectors are oriented randomly in relation to a chosen reference plane. An equatorial coordinate system has been selected as our reference. Despite this, localized anisotropies are evident in several samples, suggesting the potential influence of gravitational tidal interactions among neighboring galaxies and an early merging process that may alter the early arrangement of neighboring galaxies.

Keywords: Angular-momentum, Cluster of galaxies, Galaxy, Superclusters of galaxy

INTRODUCTION

Two fundamental presumptions underpin modern cosmology: first that gravity is the main force influencing the large-scale structures and second that the cosmological model is a reliable theory of the nature of the universe. Although Peebles (Peebles, 1965) suggested that galaxies originated more than 10 billion years ago the precise timing is still unknown. As a result, the evolution of galaxies has emerged as a major area of study with both theoretical and observational viewpoints. Knowing how and when these cosmic structures formed as well as how their composition and structures changed over time is essential to comprehending their formation and evolution (Peebles, 1969). The importance of angular momentum distributions in galaxies for cosmological research was highlighted by Gamow (1952) and Von-Weizsäcker (1951). There are some theories regarding the formation and evolution of galaxy shapes despite our limited knowledge of the various processes that contribute to their diversity (Peebles, 2023). Galaxies are believed to have been created by collapsing clouds of gas and dust after the Big Bang which occurred about 14 billion years ago (Aryal et al. 2006, 2007, 2008, 2008a, 2008b, 2010, 2012, 2013). Their evolution is greatly influenced by interactions especially collisions between galaxies. Although there are still many obstacles pertaining to their structure and evolution extragalactic astronomy research keeps advancing our knowledge year after year. The various components that make up galaxies such as stars an interstellar medium (gas and dust commonly referred to as ISM) and dark matter make studying galaxy evolution challenging (Bhattarai et al., 2023). Although it is not well understood at a fundamental level dark matter interacts through its strong gravitational pull. The foundation of galaxies and the emergence of the cosmos's structures are central questions in extragalactic astronomy. Early on the universe was extremely dynamic with galaxies rapidly changing as a result of the accretion of smaller galaxies. The formation and evolution of galaxies can be impacted by intergalactic gas particularly that which is present in clusters (Peebles, 1971). According to the cosmological principle the universe is isotropic and homogeneous on large scales (Yadav et al., 2015). Understanding the formation structural evolution and constituent changes over time of these aggregates is crucial because galaxy clusters which are large-scale structures bound by gravity offer insights into their evolution. The formation of a galaxy cluster is explained simply by the Lambda Cold Dark Matter (LCDM) model which includes light elements such as hydrogen lithium and deuterium (Chhattakuli et al., 2020).

Model galaxy evolution

There are various models of large structure formation based on different assumptions, of which three specifically relate to the orientation of spin vectors as described below.

Doroshkevich and Shandarin (Doroshkevich, 1973; Doroshkevich et al., 1978) suggest the 'pancake model' in which direction of spin vector of galaxies lies parallel to a reference plane. This model suggests that clusters were formed initially and then fragmented into smaller structure such as galaxies due to sudden fluctuations i.e. adiabatic. The non-linear theory of gravitational instability directs that the development of slight inhomogeneities which create a dense, thin and gaseous structure referred to as 'pancakes.'The hierarchy model (Peebles, 1969) asserts that spin vector of galaxies is randomly spread concerning reference plane. The model believes that galaxies formed first and later acquired angular momentum through tidal interaction though they were gravitationally coalescing in the formation of clusters (Peebles, 2022, 2023). The growth of these galaxies occurred through the subsequent merging of protogalactic condensations or even through the amalgamation of completely shaped galaxies (Holmberg, 1946). Ozernoy and Stein (Ozernoy, 1971, 1978; Stein 1974) proposed the 'primordial vorticity theory' suggesting that the galaxies rotation axes are oriented normally to the plane of reference coordinate system. This primordial vorticity refers to the early universe's vorticity, where density and pressure fluctuations led to galaxy formation. Consequently, this theory is also termed a top-down scenario.

In 1998, Li Xin proposed global rotation model. According to the cosmological principal, in a homogeneous and isotropic Universe, matter not only expands in space but also rotates with respect to local gyroscopes. Li (1998) investigated the cosmic effects of the global rotation. According to the model, in which the global rotation of the Universe provides angular momentum to the celestial bodies during their formation, resulting in rotating systems. As a result, the celestial bodies are supported by rotation. The theoretical scheme based on non-Gaussian processes is the explosion scenario for galaxy formation, initially proposed by Ostriker and Cowie (1981). They predicted that galaxies can originate because of a series of explosive events. They estimated that structures ($\sim$100 Mpc) could be created by this chain reaction of explosions. In the explosion scenario, the first objects to form are explosive seeds (stars or clusters of stars). These generate shocks which sweep up vast shells of gas; when the shells overlap, most of the gas gets compressed into thin sheets.

In the research of galaxy evolution, various models have been suggested to clarify the creation and progression of galaxies through the ages. In this discussion, we will concentrate on three particular models: the Hierarchy model, the Pancake model, and the Primordial Vorticity model. These models stand out because they give precise definitions for the direction of the spin vector, providing an organized insight into the rotation and evolution of galaxies in the universe.

MATERIALS AND METHODS

Transformation of coordinates

The three-dimensional parameters θ (polar angle) and Φ (azimuthal angle) can be obtained using Godlowskian Transformation of the position angle (p), inclination angle (i), right ascension (α) and declination (δ) are given in the equations (1) and (2) (Flin & Godlowski, 1986)

$$\sin\theta = -cosi\ sin\alpha \pm sini\ sinPcos\delta \qquad (1)$$

$$\sin\phi = (\cos\theta)^{-1}\left[-\cos i\cos\delta\sin\alpha + \sin i\begin{pmatrix}\mp\sin P\sin\delta\sin\alpha\mp \\ \cos P\cos\alpha\end{pmatrix}\right] \qquad (2)$$

Here, the ± refers expected two normal at the projection of galaxy on the celestial sphere. The inclination angle can be obtained using the Holmberg equation (Holmberg,1946)

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

In this equation, q = b/a is ratio of the semi-minor and semi-major axis and q* denotes the intrinsic flatness of the galaxy. The intrinsic flatness of a galaxy is determined by its shape, which is affected by the eccentricity of its projected elliptical form on the celestial sphere and its inclination angle.

To mitigate the selection effects that can distort the shapes of expected distribution curves in the galaxy database, the researchers generate virtual galaxies, following the methodology outlined by Aryal and Saurer (Aryal & Saurer, 2000, 2001, 2004, 2005a, 2005b, 2005c, 2006). The isotropic distribution curves are derived from simulations that include a massive dataset of 10^7 virtual galaxies. The virtual galaxies are created by using four parameters α, δ, P, i.

MATLAB version 2015a, is used to generate virtual galaxies by ensuring organized and precise mathematical calculation supervision in the generation process. This computational method allows for an inclusive inspection of the intrinsic characteristics of the galaxy distribution while minimizing biases introduced by selection effects.

Departure from isotropy is examined for both θ and ϕ using the statistical tests as given below

Chi-square test

The χ^2 test measures analogy between expected and observed data. It provides method to determine whether the observed distribution departs to the isotropic, as described by equations (4) and (5) (Godłowski, 1993,1994).

$$\chi_\nu^2 = \frac{\chi^2}{\nu} \quad (4)$$

$$\chi^2 = \sum_{i=1}^{n} \frac{(N_{0i}-N_{ei})^2}{N_{ei}} \quad (5)$$

Here n, N_{ei} N_{0i}, represents the number of bins, expected and observed distributions, respectively, and ν stand for degree of freedom (Godlowski, 1993].

Fourier test

Fourier test is a useful tool in this analysis, particularly when the distribution shows slow variations in θ or ϕ, facilitating a profounder thoughtful of the orientation patterns of the proposed evolutionary models. The expressions for the Fourier coefficients Δ_{11} and Δ_{21} are given in equation (6), and their standard deviations, $\sigma(\Delta_{11})$ and $\sigma(\Delta_{21})$, can be obtained using the expressions provided in equation (7) (Godłowski 1993, 1994).

$$\Delta_{11} = \frac{\sum_{k=1}^{n}(N_k-N_{0k})\cos 2\theta_k}{\sum_{k=1}^{n} N_{0k}\cos^2 2\theta_k}$$
$$\Delta_{21} = \frac{\sum_{k=1}^{n}(N_k-N_{0k})\sin 2\theta_k}{\sum_{k=1}^{n} N_{0k}\sin^2 2\theta_k} \quad (6)$$

$$\sigma(\Delta_{11}) = \left(\sum_{k=1}^{n} N_{0k}\cos^2 2\theta_k\right)^{-1/2}$$
$$\sigma(\Delta_{21}) = \left(\sum_{k=1}^{n} N_{0k}\sin^2 2\theta_k\right)^{-1/2} \quad (7)$$

Where $\Delta_1 = \left({\Delta_{11}}^2 + {\Delta_{21}}^2\right)^{1/2}$ is amplitude of the Fourier coefficient and the first-order Fourier probability can be calculated by formula

$$P(>\Delta_1) = exp\left(-\frac{n}{4}N_0{\Delta_1}^2\right)$$

is particularly significant because the first order probability indicates direction of departure $\sigma(\Delta_1) = \left(\frac{2}{nN_0}\right)^{1/2}$ reference to isotropy.

The symbol Δ_{11} is often used as a statistical test to calculate the alignment of galaxy rotation axes in relation to a defined reference frame, such as a plane that could represent the average orientation of other structures in the universe.

Autocorrelation test

The autocorrelation test is used to determine if there exists a linear relationship between galaxy orientations in angular bins. Essentially, it examines whether galaxies in one angular bin is related to galaxies in nearby angular bins. This can indicate whether the orientation of one galaxy has some influence on the orientation of others in close proximity.

The autocorrelation coefficient is, $C = \sum_1^n \frac{(N_k-N_{0k})(N_{k+1}-N_{0k+1})}{(N_{0k}N_{0k+1})^{1/2}}$ (8)

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

For isotropic, autocorrelation vanishes, ie C→0 (Godlowski 1993, 1994).

Source of data

We use data from the Sloan Digital Sky Survey Data Release 14 (SDSS DR-14) in the redshift interval of 0.100 to 0.125, concentrating on the u-magnitude, which relates to the ultraviolet band with a wavelength of roughly 354 nm (Gunn et al., 2006). This u-magnitude detects ultraviolet light and is mainly used to quantify the "Balmer break," a characteristic that helps in recognizing extremely hot, young, or far-off star-forming galaxies (Hogg et al., 2002; Blanton et al., 2003). Choosing a lower redshift range is deliberate, as it reveals more distinct morphological features than those seen in galaxies that are farther away.

RESULTS

The complete dataset has been categorized into ten samples, based on increments of 0.5 in u-magnitude, as detailed in Table 1. The classification relies on the equal width of the u-band. Notably, for magnitudes below 17.5, the number of galaxies is fewer than 250, and similarly, there are very few galaxies for magnitudes above 18. Therefore, these range extremes have been excluded from the analysis (Aryal et al., 2012).

Table 1. Name of sample, magnitude range and number of galaxies respectively

Sample	Magnitude range	Number of galaxies
u01	$17.5 \leq mu \leq 18.0$	425
u02	$18.0 \leq mu \leq 18.5$	2,822
u03	$18.5 \leq mu \leq 19.0$	11,694
u04	$19.0 \leq mu \leq 19.5$	26, 029
u05	$17.5 \leq mu \leq 18.0$	29, 326
u06	$17.5 \leq mu \leq 18.0$	22, 858
u07	$17.5 \leq mu \leq 18.0$	8, 974
u08	$17.5 \leq mu \leq 18.0$	2,402
u09	$17.5 \leq mu \leq 18.0$	829
u10	$17.5 \leq mu \leq 18.0$	369

The following requirements must be satisfied for a distribution to be deemed anisotropic: $\Delta_{11}/\sigma(\Delta_{11})$ larger than 1.5 or less than -1.5, C/C(σ) greater than 1.0 or less than -1.0, P (>χ2) less than 0.050, and P (>Δ_1) less than 0.150. Humps and dips are used to describe local effects in the samples. The θ and ϕ distributions are shown in Tables 2 and 3, respectively. The spin angular momentum of galaxies perpendicular to the reference coordinate when the first-order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11})$) for θ is significantly negative, whereas a positive value suggests a tendency for the vectors to be parallel. A significant positive value of ($\Delta_{11}/\sigma(\Delta_{11})$) in the ϕ statistics indicates that the angular momentum vector projections toward centre while negative values orient tangentially with respect to the reference coordinate system.

Table 2. Name of samples auto-correlation coefficient, Fourier probability, first-order Fourier coefficient and Chi-square probability respectively of polar angle distribution (θ)

Sample	***C/C (σ)***	***P* (> Δ1)**	**($\Delta_{11}/\sigma(\Delta_{11})$)**	***P* (>χ2)**
u01	0.2	0.750	0.4	0.370
u02	-0.6	0.968	0.0	0.857
u03	1.4	0.066	2.2	0.061
u04	1.7	0.014	2.7	0.132
u05	1.9	0.053	2.3	0.010
u06	2.1	0.215	1.6	0.106
u07	-0.4	0.146	1.8	0.583
u08	-1.5	0.758	0.7	0.204
u09	-1.0	0.987	0.1	0.324
u10	0.4	0.588	0.8	0.095

Table 3. Name of samples auto-correlation coefficient, Fourier probability, first-order Fourier coefficient and Chi-square probability respectively of ϕ distribution

Sample	***C/C (σ)***	***P* (> Δ1)**	**($\Delta_{11}/\sigma(\Delta_{11})$)**	***P* (>χ2)**
u01	-1.4	0.393	1.1	0.483
u02	2.9	0.000	3.9	0.055
u03	12.3	0.000	7.6	0.000
u04	21.8	0.000	10.2	0.000
u05	14.0	0.000	8.2	0.000
u06	9.6	0.000	6.4	0.000
u07	5.2	0.000	5.2	0.000
u08	-1.6	0.413	1.0	0.130
u09	-0.9	0.769	0.7	0.564
u10	0.4	0.592	0.3	0.687

Alongside the statistical tests, the analysis also includes examining the dips and humps in θ and ϕ distributions. The solid circles with error bars of ±1.5σ indicate the observed distribution. The θ-distribution, dips (or humps) in the small angle (0° < θ < 40°) recommends that spin vectors are more probable to be slanted towards perpendicular (or parallel) to the equatorial plane and vice versa.

The histogram of ϕ-distribution, with ±1σ error bars in solid circle also indicates the observed distribution. The interpretation of dips and humps in the ϕ-distribution is complex to explain than in the θ-distributions (Godłowski, 1993, 1994) because ϕ ranges from -90° to +90°. Here, $\phi = 0°$ signifies that the projections of the angular momentum vector are directed radially toward the center of the equatorial coordinate system. Peaks in the central ten bins indicates a tendency for the projections toward the center of the chosen coordinate system. In contrast, peaks in the first four and last four bins specifies the projections of spin vectors are tangential to reference plane.

The inspection of the θ and ϕ distributions offers important insights into the orientation of spin vector among galaxies within the u-magnitude range of 17.5 to 18.0, designated as the sample u01, which contains 850 observations. Analyzing on the θ-distribution, the statistics indicate $P(>\chi^2) = 0.37$ which is greater than 5%. the $C/C(\sigma) = 0.2$ less than 1 strengthens this indication of isotropy, as a low correlation suggests minimal dependence between the angles of various galaxies. Also, $\Delta_{11}/\sigma(\Delta_{11}) = 0.4$ less than 1.5 and $P(>\Delta_1) = 0.750$ greater than 15% further strengthen the conclusion of isotropy.

Finally conclude that, all statistical indicators for the polar angle distribution within the sample suggest isotropic arrangement of angular momentum vectors, pointing to a lack of preferential orientation in these vectors within the specified u-magnitude range (Peebles, 1969).

In Figure 1, for small angles ($\theta \leq 40°$), observed value is 584, while the expected value is 579 i.e., 5 more observed data than expected. There is, one hump appears at $\theta = 2.5°$ with <1.5σ error, and three dips at θ = 12.5°, 22.5°, 32.5° with <1σ errors.

In the bimodal region ($40° < \theta < 50°$), the observed and expected values are 94 and 97, respectively, so there are 3 less observed values than expected, and no humps or dips are observed.

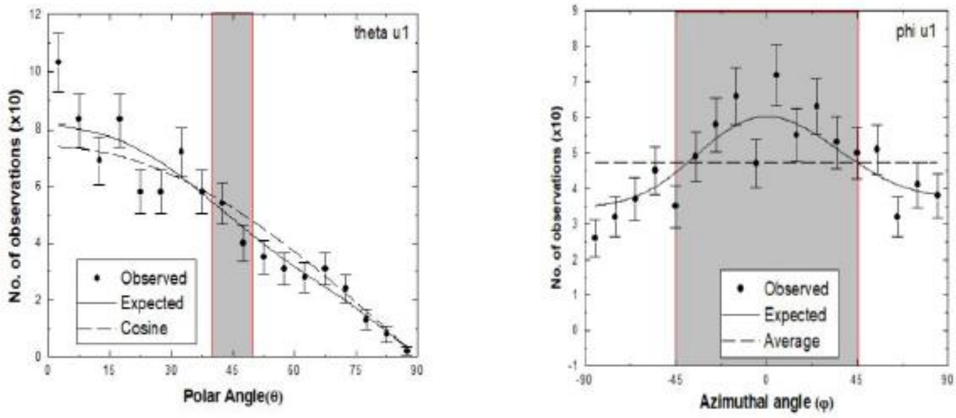

Figure 1. Illustrates θ and Φ distributions for u01 sample. The expected distributions are shown by the solid line, while the observed distribution is represented by the solid circles accompanied by ±1σ error bars. For comparison, the cosine and average distribution are shown as dashed lines

For large angles ($50° < \theta < 90°$), expected and observed values are 174 and 172, respectively, with 2 fewer observed galaxies than expected, and again, significant humps or dips are seen.

The first row of Table (2) shows the statistics of Φ distribution sample u01. In this sample, $P(>\chi^2)$, $C/C(\sigma)$, $\Delta_{11}/\sigma(\Delta_{11})$ and $P(>\Delta_1)$ are 0.483, -1.41, 1.1 and 0.393. respectively All these statistics suggest isotropy except Auto-correlation coefficient which suggest anisotropy.

In Figure 1, the observed galaxies and expected galaxies in ten central bins are found to be 548 and 539. Thus, the observed galaxies are more than that of expected by 9. In this region, no significant humps and dips are observed. At the outer region, also similar results observed. Hence, no preferred alignment is found to be noticed.

Overall, the galaxies appear randomly distributed, consistent with the Hierarchy model (Peebles, 1969).

We analyze θ and Φ distributions of observations for u-magnitudes in the range 18.0 to 18.5. In this sample, u02, there are 5,644 galaxies. The second row of Table 2 gives the statistics of samples for θ. According to Table 2, all statistics i.e. $P(>\chi^2) = 0.857$, $C/C(\sigma) = 0.564$, $\Delta_{11}/\sigma(\Delta_{11}) = 0.01$, and $P(>\Delta_1) = 0.968$. These statistics indicate strong isotropy (Yadav, 2020).

In Figure 2, for small angles ($0° < \theta < 40°$), the number of observed distributions is 3,794, while the expected number is 3,812, meaning 18 less observations than expected. Not significant Humps or dips are detected in this region. In the bimodal region ($40° < \theta < 50°$), the observed and expected observations are 651 and 541, respectively, with 110 more observed galaxies than expected. Again, no humps or dips are noted. For large angles ($50° < \theta < 90°$), 1,199 and 1,191, observed and expected data are observed in the region respectively, with 8 more observed galaxies than expected. Significant dips and humps are not detected. Overall, the polar angle shows a random alignment of galaxies spin vectors, consistent with a random distribution.

The second row of Table 3 presents the statistics for Φ distribution in sample u02. Here, $P(>\chi^2) = 0.055$, $C/C(\sigma) = 2.87$, $(\Delta_{11}/\sigma(\Delta_{11})) = 3.86$, and $P(>\Delta_1) = 0.000$. These statistics suggest anisotropy (Yadav, 2016).

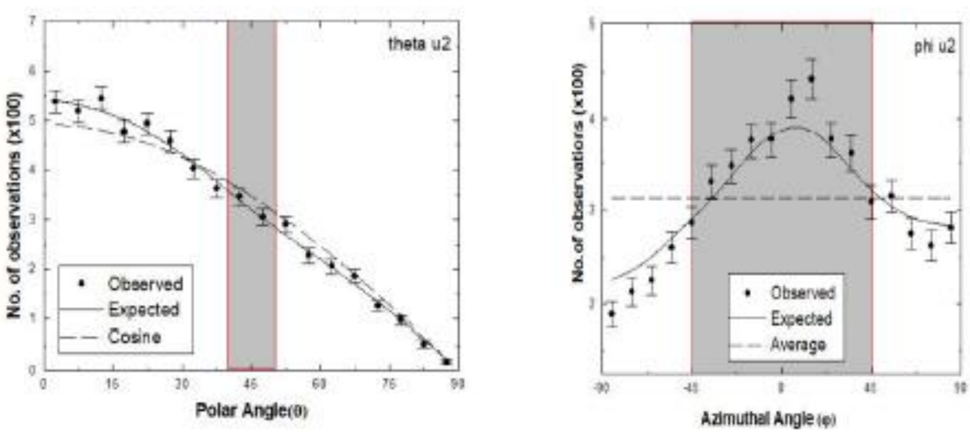

Figure 2. Illustrates θ and Φ for sample u02. The expected distributions are represented by the solid line, while the observed distribution is represented by the solid circles accompanied by $\pm1\sigma$ error bars. For comparison, the cosine and average distribution are shown as dashed lines

In Figure 2, for $\Phi \approx \pm45°$, the observed and expected numbers of observations in the ten central bins are 3,624 and 3,498, respectively, meaning 126 more galaxies are observed than expected. Two weighty humps are detected at 5° and 15° with ($>1.5\sigma$) error limits, respectively. In the outer region ($\Phi < -45°$), three dips are observed at -85° ($<1.5\sigma$), -75°, and -65° (both $<1\sigma$). At $\Phi > 45°$, there is one dip at 75° ($<1\sigma$).

After careful analysis of the statistics and the graphs for both θ and Φ, we conclude that the spin vectors of galaxies in sample u02 are isotopically and randomly distributed. This result supports the Hierarchy model of galaxy evolution. The anisotropic results in azimuthal angle indicates that the next reference coordinate should be used in this case.

We now examine θ and Φ distributions of sample u03 with u-magnitudes in the range 18.5 to 19.0. There are 23,388 observations in this sample, u03. The third row of Table 2 presents the statistics for θ in sample u03. The values are as follows: $P(>\chi^2) = 0.061$, $C/C(\sigma) = 1.4$, $\Delta_{11}/\sigma(\Delta_{11}) = 2.21$, and $P(>\Delta_1) = 0.066$. A substantial positive value of $\Delta_{11}/\sigma(\Delta_{11})$ indicates that the spin vectors tend to be parallel to the reference plane. These statistics suggest anisotropy, except for the chi-square probability, which slightly supports isotropy.

In Figure 3, for $0° < \theta < 40°$, the observed number of observations is 15,942 and 15,753 is expected number of distributions, i.e. 189 more observed than expected. In this region, one significant hump is seen at 2.5°. For the bimodal region ($40° < \theta < 50°$), the observed and expected numbers are 2,644 and 2,706, respectively, with no significant humps or dips. For large angles ($50° < \theta < 90°$), the expected and observed numbers are 4,929 and 4,802, respectively, with no significant humps or dips. Overall, the θ-distribution shows a tendency for parallel alignment of galaxy spin vectors (Yadav & Sah, 2021).

The third row of Table 3 presents the statistics for the Φ distribution in u03. Here, $P(>\chi^2) = 0.000$, $C/C(\sigma) = 12.31$, $(\Delta_{11}/\sigma(\Delta_{11}))= 7.62$, and $P(>\Delta_1) = 0.000$, indicating strong anisotropy.

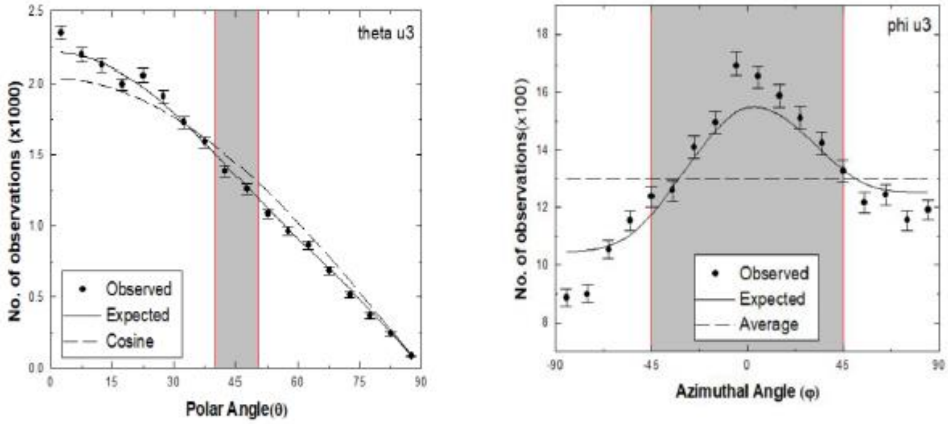

Figure 3. Illustrates the θ and the Φ distribution of u03 sample. The solid line represents the expected distributions, while the solid circles accompanied by ±1σ error bars the observed distribution. For comparison, the cosine and average distributions are shown

In Figure 3, for *Φ* ≈ ±45°, the observed number of galaxies in the eight central bins is 14,592, while the expected number is 14,090, meaning 502 more galaxies are observed than expected. In this region, four humps are observed at -45° (<1.5σ), -5° (2.5σ), 5° (<2.0σ), and 15° (<1.5σ). In the outer region, five dips are observed at -85° (2.5σ), -75° (<2.5σ), 55° (<1.5σ), 75° (<2.5σ), and 85° (<1.5σ). These humps and dips arise due to local effects of galaxies. The results suggest that the projection of spin vector of galaxies tend to orient toward the center of the reference coordinate system.

After careful examination of the statistics and the graphs of polar and azimuthal angles, we conclude that the spin vectors of galaxies in sample u03 tend to align parallel to the plane, supporting the Pancake model of galaxy formation (Doroshkevich, 1973; Doroshkevich et al., 1978).

In Figure 4, plots for azimuthal angle distributions for samples u02, u03, u04, u05, u06, and u07 can be seen outside the region of isotropy, advocating anisotropy in the azimuthal angle distribution.

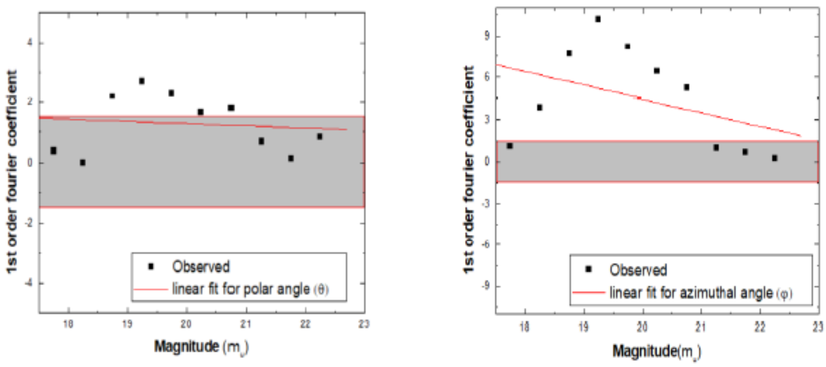

Figure 4. The scatter plots of θ and Φ distributions of all samples. Here, the solid straight lines represent best fit line

DISCUSSION

We know that the preferred orientation can be calculated mainly by the parameter $\Delta_{11}/\sigma(\Delta_{11})$. In above scattered plot, shaded area show the isotropy region for θ and ϕ distributions. In Figure 4, five points lie in shaded region, i.e., the isotropic region represents random alignment and independent of u-magnitude of galaxies and also five scatter point lie above the shaded region showing slightly weak anisotropy nature (Stephanovich et al., 2025). However, this effect is not strong the slope of best fitted line is very small (Mrzyglod, & Godlowski, 2025). The slope of best fitted line for *Φ* in Figure 4, is large. The large slop indicates the reference co-ordinate system is not suitable for few samples (Yadav et al., 2017).

CONCLUSION

We have examined the spatial orientation of 105,728 u-magnitude galaxies surveyed by SDSS, with redshifts in the range 0.100 to 0.125. The equatorial coordinate system is taken as reference coordinate system. u-magnitudes galaxies were observed using a 354.3 nm Charged Coupled Device (CCD) device attached to the telescope. The u-filter is highly sensitive to low-energy Lyman lines and almost all Balmer lines of hydrogen and helium atoms. Our observations led to the following conclusions:

In samples u01, u08, u09, and u10, the spin vectors and their projections show a random distribution. These results support the Hierarchy model (Peebles, 1969).

The sample u02 shows isotropic in polar angle distribution and anisotropic in azimuthal angle distribution. The controversy is due to problem in reference coordinate system and hence we have to test the result by taking galactic or Supergalactic coordinate system (Yadav et al., 2017)

In samples u03, u04, u05, u06, and u07, a preferred alignment of spin vectors and their projections is observed. The spin vectors lie parallel to the equatorial plane, and projections point radially toward, supporting the Pancake model (Doroshkevich 1973; Doroshkevich et al., 1978).

Overall, mixed results are seen in the study but values of first order coefficient are not so large. However, local effects are observed in most samples, which may indicate tidal interactions between rotation axes or the merging process, affecting the rotation axes of some galaxies (Cao et al., 2012).

Dips and humps are observed in different samples of polar as well as azimuthal angle distributions. These features likely correspond to density fluctuations at local scales in deep fields (Godłowski et al., 2010).

Our outcomes show a mixture of both models across different samples (Pajowska et al., 2019). To further investigate, other systems such as the Galactic or Supergalactic coordinates were also considered.

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AUTHORS CONTRIBUTION

Conceptualization: BPY, SNY; Methodology: BPY, AKJ; Validation: SNY; Investigation: BPY, KG; Data analysis: BPY, KG; Writing-original draft: BPY; Writing-review & editing: SNY

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

ETHICAL STATEMENT

The authors affirm that there was no misconduct, and they are committed to ensuring the integrity and transparency of their research findings.

DATA AVAILABILITY STATEMENT

The data are compiled from the website of NASA https://www.sdss4.org/dr14/ for which we are responsible for the use of data.

SUPPLEMENTARY INFORMATION

None

REFERENCES

Aryal, B., & Saurer, W. (2000). Comments on the expected isotropic distribution curves in galaxy orientation studies. *Astronomy & Astrophysics Journal*, *364*, L97–111.

Aryal, B., & Saurer, W. (2001). The influence of selection effects on the isotropic distribution curve in galaxy orientation studies. *ASP Conference Series*, *230*, A145–154.

Aryal, B., & Saurer, W. (2004). Spin vector orientations of galaxies in eight Abell clusters of BM type I. *Astronomy & Astrophysics Journal*, *425*, 871–879. https://doi.org/10.1051/0004-6361:20041228

Aryal, B., & Saurer, W. (2005a). Spin vector orientations of galaxies in seven Abell clusters of BM type III. *Astronomy & Astrophysics Journal*, *432*, 841–831. https://doi.org/10.1051/0004-6361:20041975

Aryal, B., & Saurer, W. (2005b). Morphological dependence in the spatial orientations of local supercluster galaxies. *Astronomy & Astrophysics Journal*, *432*, 431–439. https://doi.org/10.1051/0004-6361:20041679

Aryal, B., & Saurer, W. (2005c). Spin vector orientation of galaxies in the region 15h48m<= (2000)<=19h28m, -68°<= (2000)<=-62°. *Monthly Notices of the Royal Astronomical Society*, *360*, 125-135.

https://doi.org/10.1111/j.1365-2966.2005.09015.x

Aryal, B., & Saurer, W. (2006). Spatial orientations of galaxies in 10 Abell clusters of BM type II-III. *Monthly Notices of the Royal Astronomical Society, 366*, 438–449. https://doi.org/10.1111/j.1365-2966.2005.09667.x

Aryal, B., Bachchan, R. K., & Saurer, W. (2010). Optical search limit and preferred position angles of galaxies in 35 clusters. *Bulletin of Astronomical Society of India, 38,* 165–176.

Aryal, B., Bhattarai, H., Dhakal, S., Rajbahak, C., & Saurer, W. (2013). Spatial orientation of angular momentum vectors of galaxies in six rotating clusters. *Monthly Notices of the Royal Astronomical Society, 434*, 1939–1951. https://doi.org/10.1093/mnras/stt1124

Aryal, B., Bhattarai, H., Dhakal, S., Rajbahak, C., & Saurer, W. (2013). Spatial orientation of angular momentum vectors of galaxies in six rotating clusters. Monthly Notices of the Royal Astronomical Society, *434*, 1939–1951. https://doi.org/10.1093/mnras/stt1124

Aryal, B., Kafle, P. R., & Saurer, W. (2008). Radial velocity dependence in the spatial orientations of galaxies in and around the local supercluster. Monthly Notices of the Royal Astronomical Society, *389*, 741–749. https://doi.org/10.1111/j.1365-2966.2008.13494.x

Aryal, B., Kandel, S., & Saurer, W. (2006). Spatial orientation of galaxies in the core of the Shapley concentration - the cluster Abell. Astronomy & Astrophysics Journal, *458*, 357–367. https://doi.org/10.1051/0004-6361:20065179

Aryal, B., Neupane, D., & Saurer, W. (2008a). Morphological dependence in the spatial orientations of galaxies around the local Supercluster. Astrophysics & Space Science, *314*, 177–186. https://doi.org/10.1051/0004-6361:20041679

Aryal, B., Paudel, S., & Saurer, W. (2007). Spatial orientations of galaxies in seven Abell clusters of BM type II. Monthly Notices of the Royal Astronomical Society, *379*, 1011–1021. https://doi.org/10.1111/j.1365-2966.2007.11874.x

Aryal, B., Paudel, S., & Saurer, W. (2008b). Coexistence of chiral symmetry restoration and random orientation of galaxies. Astronomy & Astrophysics Journal, *479*, 397–407. https://doi.org/10.1051/0004-6361:20077810

Aryal, B., Paudel, R., & Saurer, W. (2012). Spatial orientation of the angular momentum vector of galaxies in three merging binary clusters. Astrophysics & Space Science, *337*, 313–324. https://doi.org/10.1007/s10509-011-0820-9

Aryal, B., Yadav, S. N., & Saurer, W. (2012). Spatial orientation of galaxies in the Zone of Avoidance. *Bulletin of Astronomical Society of India*, *40*, 65–76.

Bhattarai, S., Paudel, M. S., Yadav, S. N., & Jha, A. K. (2023). Properties of dust in the North-East part of Perseus Cloud within the open cluster IC 348 using data from IRIS and AKARI. *BIBECHANA*, *20*(1), 92–102. https://doi.org/10.3126/bibechana.v20i1.49392

Blanton, M. R., Hogg, D. W., Bahcall, N. A., Baldry, I. K., Brinkmann, J., Csabai, I., ... & Weinberg, D. H. (2003). The broadband optical properties of galaxies with redshifts $0.02 < z < 0.22$. *The Astrophysical Journal*, *594*(1), 186–207. https://doi.org/10.1086/375528

Cao, S., Pan, Y., Biesiada, M., Godlowski, W., & Zhu, Z. H. (2012). Constraints on cosmological models from strong gravitational lensing systems. *Journal of Cosmology and Astroparticle Physics, 2012*(03), 016–016. https://doi.org/10.1088/1475-7516/2012/03/016

Chhatkuli, D., Paudel, S., & Aryal, B. (2020). Study of star formation rate and metallicity of an interacting dwarf galaxy NGC 2604. *Journal of Institute of Science and Technology*, *25*(2), 55–60. https://doi.org/10.3126/jist.v25i2.33736

Doroshkevich, A. G. (1973). The origin of rotation of galaxies. *The Astrophysical Journal*, *14*, 11–13.

Doroshkevich, A. G., Shandarin, S. F., & Saar, E. (1978). Spatial structure of protoclusters and the formation of galaxies. *Monthly Notices of the Royal Astronomical Society*, *184*(3), 643–660. https://doi.org/10.1093/mnras/184.3.643

Flin, P., & Godlowski, W. (1986). The orientation of galaxies in the Local Supercluster. *Monthly Notices of the Royal Astronomical Society, 222*(3), 525–541. https://doi.org/10.1093/mnras/222.3.525

Gamow, G. (1952). The role of turbulence in the evolution of the universe. *Physical Review, 86*, 251–260. https://doi.org/10.1103/PhysRev.86.251

Godlowski, W. (1993). Galactic orientation within the local supercluster. *Monthly Notices of the Royal Astronomical Society*, *265*, 874–880. https://doi.org/10.1093/mnras/265.4.874

Godlowski, W. (1994). Some aspects of the galactic orientation within the local supercluster. *Monthly Notices of the Royal Astronomical Society, 271*, 19–30. https://doi.org/10.1093/mnras/271.1.19

Godłowski, W., Piwowarska, P., Panko, E., & Flin, P. (2010). The orientation of galaxies in galaxy clusters. *The Astrophysical Journal, 723*(2), 985–992. https://doi.org/10.1088/0004-637X/723/2/

Gunn, J. E., Siegmund, W. A., Mannery, E. J., Owen, R. E., Hull, C. L., Leger, R. F., Carey, L. N., Knapp, G. R., York, D. G., Boroski, W. N., Kent, S. M., Lupton, R. H., Rockosi, C. M., Evans, M. L., Anderson, J. E., Annis, J., Barentine, J. C., Bartoszek, L. M., Bastian, S., … Wang, S. I. (2006). The 2.5 m telescope of the Sloan Digital Sky Survey. *The Astronomical Journal, 131*(4), 2332. https://doi.org/10.1086/500975

Hogg, D. W., Blanton, M., Strateva, I., Bahcall, N. A., Brinkmann, J., Csabai, I., Doi, M., Fukugita, M., Hennessy, G., Ivezić, Ž., Knapp, G. R., Lamb, D. Q., Lupton, R., Munn, J. A., Nichol, R., Schlegel, David J., Schneider, D. P., & York, D. G. (2002). The luminosity density of red galaxies. *The Astronomical Journal*, *124*(2), 646–651. https://doi.org/10.1086/341392

Holmberg, E. (1946). On the apparent aiameters and the orientation in space of extragalactic nebulae. *Meddelanden fran Lunds Astronomiska Observatorium Series* II, *117*, 3–82.

Li, L.-X. (1998). Effect of the global rotation of the universe on the formation of galaxies. *General Relativity and Gravitation*, *30*(3), 497–507. https://doi.org/10.1023/A:1018867011142

Mrzyglod, B., & Godlowski, W. (2025). New possibilities for investigation of the orientation of galaxies in clusters. *Advances in Astronomy and Space Physics*, *13*,23–27. https://ui.adsabs.harvard.edu/link_gateway/2025AASP...13...23M/doi:10.17721/2227-1481.13.23-27

Ostriker, J. P., & Cowie, L. L. (1981). Galaxy formation in an intergalactic medium dominated by explosions. *The Astrophysical Journal*, *243*, L127–L131. https://doi.org/10.1086/183458

Ozernoy, L. M. (1971). Dynamical parameters of galaxy clusters as a consequence of Cosmological turbulence. *Soviet Astronomy, 15*, 923-933.

Ozernoy, L. M. (1978). The whirl theory of the origin of structure in the universe. In *Symposium - International Astronomical Union*, *79*, pp. 427–438). Cambridge University Press. https://doi.org/10.1017/S0074180900144900

Pajowska, P., Godłowski, W., Zhu, Z. H., Popiela, J., Panko, E., & Flin, P. (2019). Investigation of the orientation of galaxies in clusters: The importance, methods and results of research. *Journal of Cosmology and Astroparticle Physics*, *2019*(02), Article 005. https://doi.org/10.1088/1475-7516/2019/02/005

Peebles, P. J. E. (1965). The black-body radiation content of the universe and the formation of galaxies. *The Astrophysical Journal*, *142*, 1317–1321. https://doi.org/10.1086/148434

Peebles, P. J. E. (1969). Origin of the angular momentum of galaxies. *The Astrophysical Journal*, *155*, 393–401. https://doi.org/10.1086/149876

Peebles, P. J. E. (1971). Rotation of galaxies and the gravitational instability picture. *Astronomy and Astrophysics*, *11*, 377–386.

Peebles, P. J. E. (2022). The extended local supercluster. *Monthly Notices of the Royal Astronomical Society*, *511*(4), 5093–5103. https://doi.org/10.1093/mnras/stac429

Peebles, P. J. E. (2023). Flat patterns in cosmic structure. *Monthly Notices of the Royal Astronomical Society*, *526*(3), 4490–4501. https://doi.org/10.1093/mnras/stad3051

Stein, R. (1974). Galaxy formation from primordial turbulence. *Astronomy & Astrophysics Journal*, *35*, 17-29.

Stephanovich, V., Godłowski, W., & Biernacka, M. (2025). The influence of dark matter halos on galaxies' orbital momenta alignment. *Research in Astronomy and Astrophysics*, *25*(11), Article 115002. https://doi.org/10.1088/1674-4527/adf9a1

Von Weizsäcker, C. F. (1951). The evolution of galaxies and stars. *The Astrophysical Journal*, *114*, 165–186. https://doi.org/10.1086/145462

Yadav, S. N. (2016). A study of z-magnitude dependence in the spatial orientation of angular momentum vectors of galaxies having redshift < 30,000 km s^{-1}. *Tribhuvan University Journal*, *30*(2), 195–210. https://doi.org/10.3126/tuj.v30i2.25564

Yadav, S. N. (2020). A study of R-magnitude dependence in spatial orientation of spin vectors of SDSS DR-7 galaxies of redshift 0.10 < Z < 0.11. *Scientific World*, *13*(13), 42–45. https://doi.org/10.3126/sw.v13i13.30506

Yadav, S. N., Aryal, B., & Saurer, W. (2017). Preferred alignments of angular momentum vectors of galaxies in six dynamically unstable Abell clusters. *Research in Astronomy and Astrophysics*, *17*(7), Article 064. https://doi.org/10.1088/1674-4527/17/7/64

Yadav, S. N., & Sah, S. K. (2021). Study of spatial orientation of angular momentum of z-magnitude SDSS DR-13 galaxies with red shift 0.50 to 0.53. *Journal of Institute of Science and Technology*, *26*(1), 1–7. https://doi.org/10.3126/jist.v26i1.37805

Yadav, S. N., Saurer, W., & Aryal, B. (2015). A Study of co-existence between the Hubble flow and the random alignments of spin vectors of SDSS galaxies. BIBECHANA, *12*, 114-127. DOI**:** https://doi.org/10.3126/bibechana.v12i0.11787