International Journal of Leading Research Publication (IJLRP)

E-ISSN: 2582-8010 ● Website: www.ijlrp.com ● Email: editor@ijlrp.com

A Study Of Spatial Orientation Of Sdss Galaxies In Saraswati Supercluster

[1]Birendra Prasad Yadav, [2]Shiv Narayan Yadav, [3]Saroj Kandel, [4]Rabina Kadaria

[1]Central Department of Physics, TU, Kirtipur
[2,3,4]Patan Multiple Campus, M.Sc. Physics, TU, Lalitpur, Nepal

Abstract:
We present an investigation of spatial orientations of SDSS galaxies of Saraswati Supercluster using 15th data release (DR15) galaxies. The major goal of this study is to test nonrandom effect on spin angular momentum of galaxies within the given right ascension and declination limit in the framework of three alternative scenarios 'Hierarchy model', 'Pancake model' and the 'Primordial vorticity model'. Using the 'position angle -inclination' method, two-dimensional observable data (positions, position angles, and inclination angles) are translated into three-dimensional rotation axes (polar and azimuthal angles) of the galaxy. By removing the selection effects and running a random simulation with 107 virtual galaxies, the predicted isotropy distribution curves have been identified. Three statistical tests are used to compare the observed and expected distributions: Chi-square, Auto-correlation, and Fourier. The entire database is divided into nine samples. Some of our findings support the Hierarchy concept and some results support the Pancake model.
Here, we noticed the value of first order fourier coefficient increases as the distance from the centre of Supercluster increases. This indicates multipole i.e. several centre of gravity which shows the structure is less virial.

Keywords: galaxy, clusters, Supercluster, Saraswati Supercluster, position angles.

Introduction

How can massive things like galaxies come into being? Despite a remarkable rise in data and processing power, this is still the fundamental unresolved issue in cosmology. The fundamental unit of cosmology and the building blocks of the universe are galaxies [1]. Some of them have quite basic structures, with merely regular stars inside and no distinctive distinguishing traits. There are galaxies that are composed virtually exclusively of neutral gas. Others, on the other hand, are intricate systems made of numerous individual parts, including stars, neutral and ionized gas, dust, molecular clouds, magnetic fields, cosmic rays, etc. In space, the galaxies can join together in modest or massive clusters. There is a compact nucleus at the center of each galaxy, and it can occasionally be so luminous that it overpowers the galaxy's usual emission [2]. The largest structures in the universe are clusters of galaxies. They are thought to arise at the intersection of dark matter filaments through hierarchical accretion and fusion of smaller structures, according to the "concordant" cosmological model. Although they contain baryonic stuff like galaxies and heated intergalactic gas, the majority of their mass is made up of dark matter [3].

Supercluster

The clustering of galaxies does not end with individual galaxies. Groups of galaxies, called galaxy clusters, attract each other to form even larger structures known as Superclusters, which consist of tens to hundreds of clusters. Their mutual gravitational pull binds them together into long, thin filaments—string-like structures—ranging from 300 to 900 million light-years in length, 150 to 300 million light-years in width, and 15 to 30 million light-years in thickness on average [4].

The discovery of these enormous structures was made recently through years of studying the Doppler shifts of thousands of galaxies. These Doppler shifts were converted into distances using Hubble's Law. Between the filamentary Superclusters are vast empty regions called voids, which contain very few galaxies. These voids are typically about 150 million light-years across [5].

Superclusters of tens to hundreds of clusters are created when galaxy clusters attract one another. Great Attractor is the name of the largest Cluster known to science. Its gravity is so strong that the Milky Way galaxy and the Local Supercluster are moving towards it at speeds of several hundred kilometers per second. There are thought to be 10 million Superclusters in the observable universe. The Milky Way is a component of the Laniakea Supercluster, which is a component of the Virgo Cluster, which is a component of the Local Group galaxy group (which includes more than 54 galaxies) [6]. The Hubble flow is normally causing the component clusters to move apart. These enormous structures were found using the Doppler shifts of thousands of galaxies. The Hubble law was used to translate the Doppler shift of the galaxies into distances [7].
Supercluster observations can provide details on the state of the universe at the time these Superclusters were formed. Galaxies within Superclusters may reveal information about the early stages of galaxy formation by revealing the directions of their rotating axes. In 2014 saw the addition of the recently reported Laniakea Supercluster, which also included the newly discovered Hydra-Centaurus Supercluster, PavoIndus Supercluster, and Virgo Supercluster. Abell 2361, a galaxy cluster with a mass of roughly $2x10^{16}$ M and seen in the Pisces constellation, is one of 43 enormous galaxy clusters that make up the Saraswati Supercluster, another Supercluster [8].

Saraswati Supercluster
A group of Indian astronomers has discovered a Supercluster of galaxies, a cosmic behemoth located 4 billion light-years from Earth. The new find has been given the name Saraswati. The Supercluster, which contains more than 10 000 galaxies in 42 clusters, has a diameter of more than 650 million light years. Astronomers are being forced to reconsider the origins

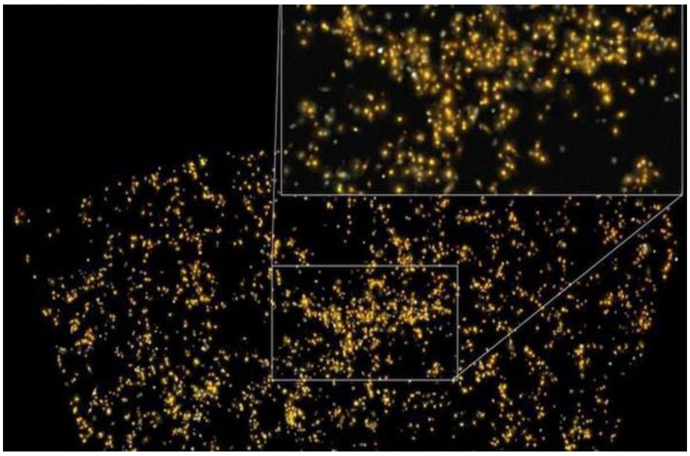


Figure 1; Diagram showing Saraswati Supercluster [9]

of the cosmos as a result of the discovery. Also, it offers critical hints on the enigmatic dark matter and dark energy. In the sky, the Saraswati Supercluster stands out as being particularly unusual and possibly one of the

mega Superclusters with a size greater than 500 million light years. This mammoth of a largescale construction

Galaxy Evolution Models

The study of galaxy creation and evolution differs significantly from the majority of other experimental physics fields from an empirical standpoint. This is primarily caused by the fact that, even at their shortest lengths, the time scales involved are vastly greater than those of a human. As a result, we are unable to see individual galaxies' real evolution. However, because the speed of light is limited, viewing galaxies farther away from us is equivalent to viewing galaxies earlier in the history of the universe. Therefore, by statistically comparing the features of galaxies at various epochs, we might be able to deduce how galaxies form and develop. Additionally, we can look for patterns and correspondences in the population of galaxies at each epoch. Even though galaxies have a vast variety of masses, sizes, and shapes, no two galaxies are alike.

Additionally, galaxies' structure properties follow a variety of scaling relations, some of which are surprisingly close. Any good theory of galaxy formation must be able to explain how these relations came to be, and they must contain significant information about the physical processes that underpin them. Galaxies are crucial to our understanding of the structure and evolution of the Universe in addition to being fascinating in and of themselves. They are visible in great numbers throughout cosmological distances and time scales because they are brilliant, durable, and numerous. Because of this, they serve as distinctive tracers of the development of the entire Universe, and thorough investigations of their large-scale distribution can yield valuable limits on cosmological parameters. The pancake theory [10,11], the hierarchical clustering hypothesis [12], and the primordial vorticity theory [13] are the three primary competing hypotheses of galaxy evolution. As things stand, no hypothesis can fully account for all the characteristics of galaxy evolution that can be observed. evolves quite slowly. As a result, it might be a reflection of the entire history of galaxy formation as well as the primordial conditions that gave rise to it [8].

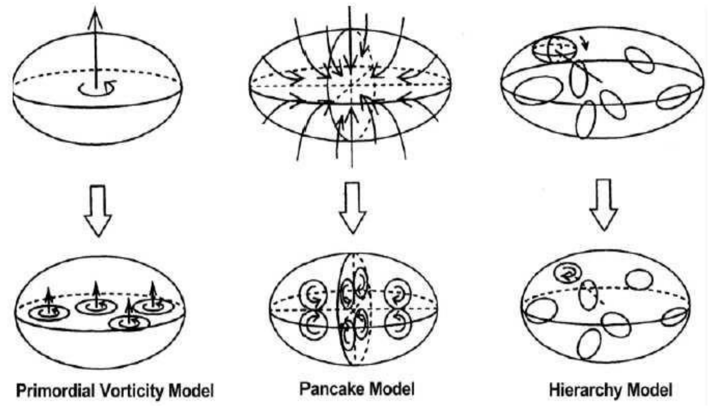


Figure 2 ; Schematic presentation of the distribution of galaxy spins in respect to the parent structure in three classic scenarios of galaxy origin: turbulence, pancake, and hierarchical. An arrow represents the preferred direction of the angular moment vectors of a galaxy in each model.[14]

Spatial Orientation of Galaxies

Weizscker [6] and Gamow [2,15] showed that for cosmology the observed rotations of galaxies are very important. They postulated that the rotation of galaxies might be a clue of physical conditions under which these systems formed. Thus, to understand the origin of the angular momenta of galaxies, understanding the distribution of spatial orientations of the spin vectors of galaxies is very critical. To study the spatial orientation of galaxies, two methods have been proposed viz- two-dimensional analytical method and three-dimensional analytical method.

Three-Dimensional analysis

This three-dimensional approach to analyzing the galaxy orientation was first developed by Jaaniste and Saar [16] in the late 1970s. In this unique approach, we simultaneously study and assess the position angle and axial ratios.

They looked at the galaxy PA distributions as well as another crucial factor, the galaxy's inclination with respect to the observer's line of sight. These two angles face-on and edge-on helped determine the galaxies' orientation. These two angles allow us to deter- mine the orientations of two potential vectors that are normal to the galactic plane, one of which is supposed to be the galaxy's angular momentum vector or rotational axis. Later, here after [17] carefully examined the JS technique and fixed a few inconsistencies. We talk about the Godlowskian model, which is currently used quite a bit.

Godlowskian Transformation

The basic formula's derivation is explained in light of how galaxies are distributed within the LSC and its PA in the galactic system. Let's think about an equatorial coordinate system, sometimes known as the E system. At the E system's origin, which is located in the galactic center, there is an observer. The coordinates α and δ stand in for the equatorial longitude and latitude, respectively, while the X-Y plane represents the plane of the E system (i.e., the Milky Way). The X-axis, called EX is directed towards the center of the equatorial plane ($\alpha = 0$, $\delta = 0$). The Y and Z-axis known as EY and EZ are directed towards the point $\alpha = \pi/2$, $\delta = 0$ and north equatorial pole ($\alpha = \pi/2$, $\delta = \pi/2$), respectively.

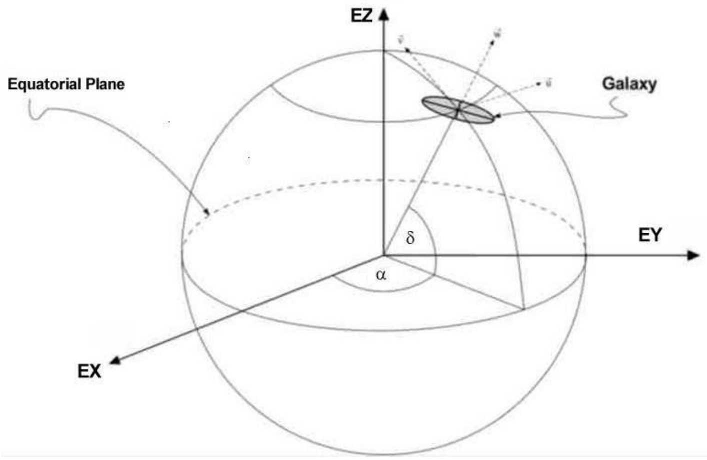


Figure 3: The coordinate system used for the derivation of the polar and azimuthal angle of the galaxy rotation axes. Here α and δ represent right ascension and declination of the galaxy. [17]

Let's think about a different coordinate system. The galaxy's nucleus is where this system got its start. In this system, the U and V axes are tangent to the celestial sphere and perpendicular to one another. Equatorial latitude and the U-axis run parallel. The W-axis, which extends the axis that connects the cluster and galaxy centers, is perpendicular to both the U and V axes. This axis is inclined away from the sphere. They are depicted in Figure 3. The detailed image of the galaxy using the above-mentioned vectors is shown in Figure 4. The angle is the angle formed by the U-axis and the galaxy's major axis' projection onto the celestial sphere. The symbol b stands for the minor axis. When measured in the equatorial coordinate system, the angle q is connected to the equatorial position angle p and is provided by the formula: $q = p - \pi/2$and ranges from $-\pi/2$ to $+\pi/2$.

Let's expand the normal to include the galaxy plane that passes through the equatorial system's origin. There are two potential normals, N_1 and N_2, for an inclination angle of i, and as a result, two potential positions for the galaxy rotation axis. One of these two normals corresponds to the direction of the rotational momentum vector. Consider the galaxy's angular momentum vectors N_1 and N_2. As can be observed from Figure 4, there are two more spin vectors, N_3 and N_4, which are directly opposite to N_1 and N_2. One rotation axis is represented by N_1 and N_3, while a second rotation axis is represented by N_2 and N_4. Hence, the spin vectors' four-solution ambiguity can be reduced to a two- solution ambiguity. Hence, only N_1 and $N_2$are employed in the statistical analysis.

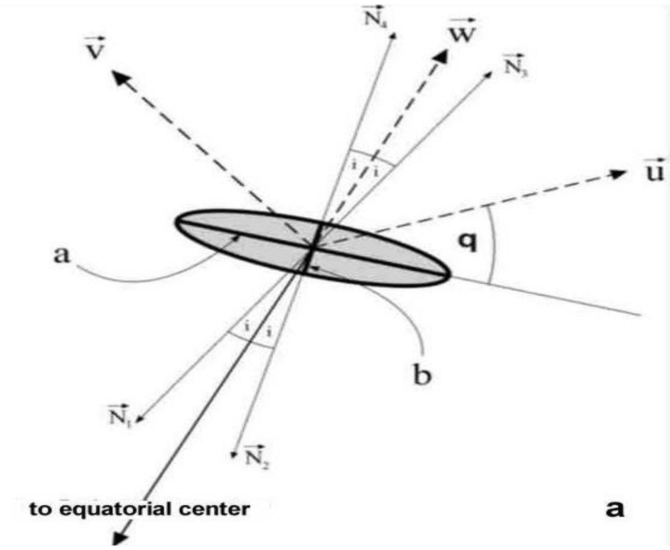


Figure 4: Detailed view on a galaxy: a and b are the major and the minor axes, q = p –π/2, N1 and N2 corresponds to the two possible rotation axes [17].

The vectors N_1 and N_2 in the E system are:

$$N_1 = -W\cos i + \sin i(V\cos q + U\sin q)$$
$$N_2 = -W\cos i - \sin i(V\cos q + U\sin q) \qquad (1)$$

Where $\cos i$ is given by Holmberg's equation with tl ss factor $q*$ and is

$$\cos^2 i = \frac{[(b/a)2 - (q*)2]}{1 - (q*)^2} \qquad (2)$$

and ($V\cos q + U\sin q$) is the projection of the normals to the U-V plane. Here, we are currently using the coordinate translation approach. The galactic reference frame is trans- lated to the E system's central point. We may express the coordinates U, V, and W, in the E system using this translation. These coordinates, which are just functions of right ascension (α) and declination (δ) in the E system, can be expressed as follows:

$$U = (-\sin\alpha, \cos\alpha, 0)$$
$$V = (-\sin\delta\cos\alpha, \cos\delta\sin\alpha, \cos\delta) \qquad (3)$$
$$W = (\cos\delta\cos\alpha, \cos\delta\sin\alpha, \sin\delta)$$

Here, $-\sin\alpha$, $\cos\alpha$ and 0 are the functions of the vector U along X, Y and Z axes, respectively. Similarly, $-\sin\delta\cos\alpha$, $-\sin\delta\sin\alpha$, $\cos\delta$, and $\cos\delta\cos\alpha$, $\cos\delta\sin\alpha$, $\sin\delta$ are the functions of the vectors V and W along X, Y and Z directions, respectively. Substituting the values of U, V and W from equation (3) in (1) we get,

$$N_{ix} = -\cos\cos\delta\cos\alpha + \sin i(\mp\cos q\sin\delta\cos\alpha \mp \sin q\sin\alpha);$$
$$N_{iy} = -\cos i\cos\delta\sin\alpha + \sin i(\mp\cos q\sin\delta\sin\alpha \pm \sin q\cos\alpha);$$
$$N_{iz} = -\cos i\cos\delta \pm \sin i\cos q\cos\delta; \qquad (4)$$

where the upper and lower signs are for i =1 and ectively.

The polar (θ) and azimuthal (ϕ) angles of the galaxy's rotating axis are now introduced. The angle formed by the N_i vector and the galactic plane is known as the polar angle (θ). The azimuthal angle (ϕ) is the angle formed by the X-axis and the projection of the N_i vector onto the galactic plane. It should be noticed that the values of θ and ϕ become $-\theta$ and $\phi + \pi$, respectively, when the vectors N_1 and N_2 are reversed.

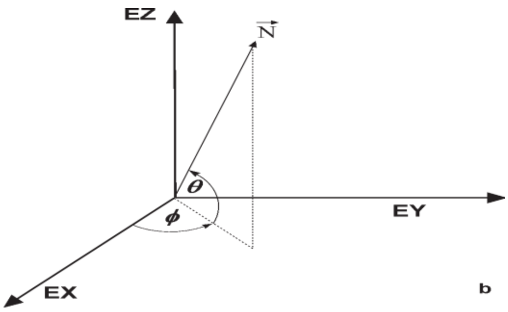


Figure 5: Definition of the two angles θ and ϕ which contain the orientation of the spin vector N with respect to the equatorial coordinate system [17].

From Figure (5), we can write,

$N_{ix} = \cos\theta \cos\phi$;

$N_{iy} = \cos\theta \sin\phi$; (5)

Comparing the equations 3 and 4 gives,

$\sin\theta = -\cos i \sin\delta \pm \sin i \cos q \cos\delta$;

$$sin\emptyset = \frac{-cosicos\delta sin\alpha + sini(\mp cosqsin\delta sin\alpha \pm sinqcos\alpha)}{cos\theta}$$

$$cos\emptyset = \frac{-cosicos\delta cos\alpha + sini(\mp \cdots \delta cos\alpha \mp sinqsin\alpha)}{cos\theta} \quad (6)$$

Substituting q = $p - \pi/2$ in equation 3.6,

$\sin\theta = -\cos i \sin\delta \pm \sin i$ sinp $\cos\delta$;

$$sin\emptyset = \frac{-cosicos\delta sin\alpha + sini(\mp sinpsin\delta sin\alpha \pm cospcos\alpha)}{cos\theta} \quad (7)$$

$$cos\emptyset = \frac{-cosicos\delta cos\alpha + sini(\mp sinpsin\delta cos\alpha \mp cospsin\alpha)}{cos\theta}$$

The spin vector orientation of a galaxy can be determined using equation (5). The above-mentioned equations (4) and (7) are known as the "Godlowski-Transformation" or "Godlowskian Model." The position parameters in equation (6) are equatorial system parameters. Moreover, we employ the following positional parameters for the galactic (l, b) and supergalactic (L, B) coordinate systems.

$\sin\theta = -\cos i\ sinb \pm \sin i\ sinp\ cosb$;

$$sin\emptyset = \frac{-cosicosbsinl + sini(\mp sinpsinbsinl \pm cospcosl)}{cos\theta}$$

$$cos\emptyset = \frac{-cosicosbcosl + sini(\mp sinpsinbcosl \mp cospsinl)}{cos\theta} \quad (8)$$

$\sin\theta = -\cos i\ sinB \pm \sin i\ sinP\ cosB$;

$$sin\emptyset = \frac{-cosicosBsinL + sini(\mp sinPsinBsinL \pm cosPcosL)}{cos\theta} \quad (9)$$

$$cos\emptyset = \frac{-cosicosBcosL + sini(+sinPsinBcosL \mp cosPsinL)}{cos\theta}$$

For a given value of i, expressions (7), (8), and (9) provide two solutions for both θ and ϕ. As a result, the galaxy's angular momentum vector has 4 solutions. It is difficult to establish which galaxy is the physically correct one for a wide sample of galaxies, though. For statistical analysis, we individually count each of these possibilities.

When a galaxy is observed exactly face-on ($i = 0^{\circ}$), the formulas (6), (7), and (8) provide a single solution for both θ and ϕ. Edge-on, the two solutions for both and only differ in sign ($i = 90^{\circ}$). When approaching the equatorial pole or for galaxies with equatorial PA = 0°, both solutions for θ converge. When $\alpha = 0^{\circ}$, both solutions for ϕ merely have a different sign. What's more intriguing is that the coordinate system that is being utilized has a significant impact on the properties of the solutions for and Flin & Godlowski [17] have already made a note of this. To eliminate these selection effects caused by locations, these authors proposed a technique.

Literature Review

A method for figuring out the galaxy's orientation was suggested by Howley and Peeble [18]. They employed the Fourier method to analyze the position angle histogram in ad- dition to observing the distribution of position angle and axial ratio. The galactic plane inclination to the observer's line-of-sight, another significant parameter, was also taken into account in the second method, which Jaaniste and Saar [16] proposed. Flin and Godlowski [17] later modified this method under the name of position angle-inclination method, which converts the 2-D projected data of the image to 3-D information about the orientation. Three time periods can be distinguished in the research of spin vector galaxies: before 1986, between 1986 and 2001, and after 2001.

In 2001, Aryal and Saurer[19] created a technique to use numerical simulation to decrease the selection effect. The majority of the investigation that followed was then based on the PA-inclination method along with a numerical simulation of the galaxies.

P. Flin [22] analyzed the morphologically defined galaxies with radial velocity of <3000 km^{-1}. They determined that LSC spirl galaxies support the Pancake model, Barred and irregular galaxies support the Hierarchy model, and the orientation of early and late type galaxies has variations. The study of Poudel, A., and B. Aryal[23] showed that galax- ies' angular momentum vectors have a random orientation. Few samples show local anisotropy, indicating gravitational tidal interaction.

Bag, S., Liivamägi, L. J., and Einasto, M. [20] investigated the shape distributions of Superclusters in SDSS DR12 in 2022 and determined that, while the number and filling factor of Superclusters detected in these two methodologies varies greatly, the morphologies are relatively comparable. The shape distribution described in the article is quite robust because it is very dependent on the convention of designating the Superclusters.

Objectives

Our objectives are as follows:

- We intend to check which model of galaxy evolution (Hierarchy or Turbulence or Pancake) is supported by our result.
- We intend to perform numerical simulation by generating 10^7 virtual galaxies to find the expected isotropic distribution of angular momentum vectors of galaxies.
- We are interested to study the reliability of equatorial coordinate system to study the orientation of galaxies.
- We intend to study the bounding of galaxies in the Supercluster.
- We intend to find the Supercluster has common centre of gravity or not.
- We intend to examine the variation of anisotropy with increase in distance from centre of Supercluster.

Statistical Tests

In order to determine the preferred alignment of galaxy clusters, statistical analysis is needed. We employed the chi-square test, auto-correlation test, and Fourier test in this study. These statistical tests are performed using computer programs that are Microsoft Excel 2010 and Origin 5.0

Sample Classification

Our entire database consists of nine different groups of galaxies by increasing values of α & δ that were observed using u filter. In this case, Saraswati Supercluster has right ascension of $23^h\ 37^m\ 40^s$ and Declination of $00^\circ 16' 17''$. We converted right ascension into degree.

Right ascension = $\alpha = 23^h\ 37^m\ 40^s$

$(23+\frac{37}{60}+\frac{40}{60\times60})^h$= 23.627x15°
=354.4166°

Declination= δ = 00° 16′ 17″=0.271°
The fact that we have 9 samples should be noticed. The first sample consists only 44 galaxies while last sample consist 12449. The classification of data was according to the right ascension and declination in cumulative form.

Results

The Spatial Orientation

We have classified our database into nine samples on the basis of their right ascension and declination values and u -magnitude. Here we discuss the distribution of the polar (θ) and azimuthal (ϕ) angles of galaxy rotation axes in each sample. We study the spatial orientation of spin vectors of galaxies with respect to equatorial coordinate system. Any deviation from the expected isotropic distribution will be tested using four statistical parameters, namely the chi-square probability (P>χ^2), auto-correlation coefficient (C/C(σ)), first order Fourier coefficient ($\Delta_{11}/\sigma(\Delta_{11})$), and first order Fourier probability (P>Δ_1). For anisotropy, the limit of chi-square probability (P>χ^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 the Fourier probability (P>Δ_1) is < 0.150 respectively. These statistical limits were proposed by Godlowski [18] in galaxy orientation studies. Any 'humps' or 'dips' in the histogram will be discussed as a local effect in samples or result of binning or selection effects. Here 'hump' and 'dip' are defined as having more or less solutions than expected in a bin respectively.

Table 1: Statistics of the polar angle (θ) distribution of galaxies in the different samples. The first column lists the samples. The second, third, and fourth column list the corresponding chi-square probability P(> χ^2), auto-correlation coefficient C/C(σ), the first order Fourier coefficient $\Delta_{11}/\sigma(\Delta_{11})$,and the first order Fourier probability P(> Δ_1) respectively.

Samples	P(>χ^2)	C/C(σ)	$\Delta_{11}/\sigma(\Delta_{11})$	P(>Δ_1)
1	0.147	1.3	0.7	0.672
2	0.000	0.2	2.9	0.000
3	0.109	-0.6	0.4	0.903
4	0.188	-0.3	0.2	0.939
5	0.176	-0.4	0.4	0.889
6	0.000	18.8	-0.8	0.033
7	0.000	26.3	-1.2	0.006
8	0.000	53.3	-2.5	0.000
9	0.000	105.1	-4.4	0.000

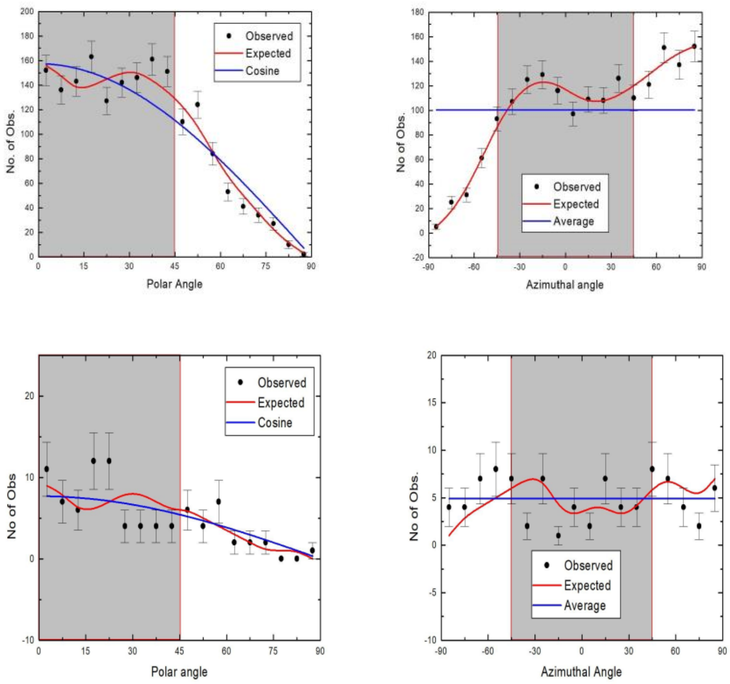
The statistics for the polar angle (θ) and azimuthal angle (ϕ) distribution is given in Table 1 and Table 2 respectively. In the statistics of θ, a negative value of first order Fourier coefficient suggests that the spin vectors of galaxies tend to be oriented perpendicular with respect to the equatorial 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 radially towards 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.

Table 2: Statistics of the azimuthal angle(ϕ) distribution of galaxies in the different samples. The first column lists the samples. The second, third, and fourth column list the corresponding chi-square probability $P(>\chi^2)$, auto-correlation coefficient $C/C(\sigma)$, the first order Fourier coefficient $\Delta_{11}/\sigma(\Delta_{11})$, and the first order Fourier probability $P(>\Delta_1)$ respectively.

Samples	$P(>\chi^2)$	$C/C(\sigma)$	$\Delta_{11}/\sigma(\Delta_{11})$	$P(>\Delta_1)$
1	0.041	1.1	-0.7	0.766
2	0.000	37.1	0.0	0.000
3	0.775	0.8	0.0	0.680
4	0.078	-0.8	-0.2	0.905
5	0.571	-0.9	0.2	0.468
6	0.000	254.9	-10.5	0.000
7	0.000	365.1	-13.5	0.000
8	0.000	1326.3	-16.7	0.000
9	0.000	666.6	-25.4	0.000

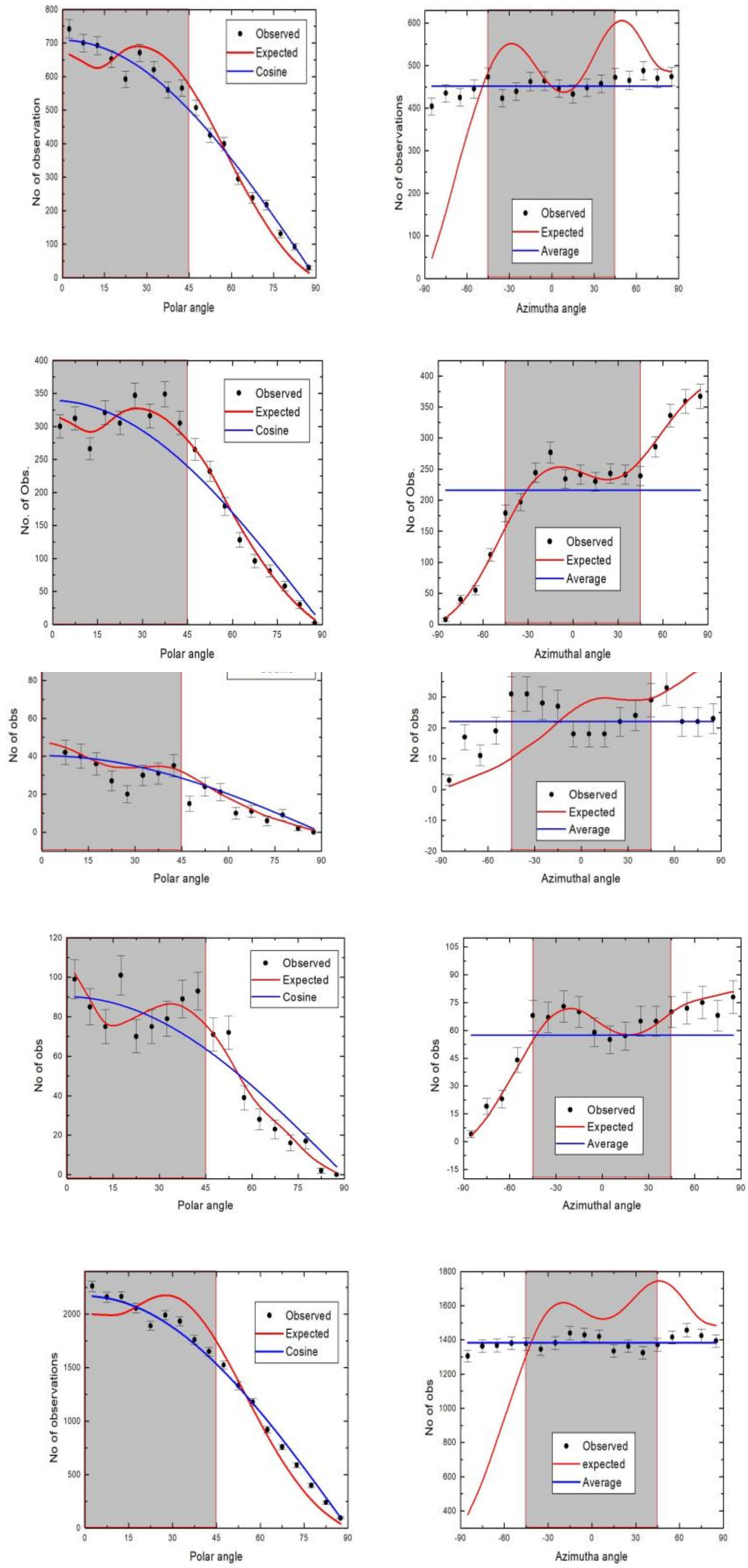
In the graph of the θ-distribution solid curve represents the expected isotropic distribution whereas blue line curve is the cosine distribution. The solid circles with $\pm 1\sigma$ error bars represent the observed distribution. The shaded portion represents the range $0^\circ \leq \theta \leq 45^\circ$. A dip (or hump) at $\theta < 45^\circ$ suggests that the spin vectors of galaxies tend to orient perpendicular (or parallel) with respect to the equatorial coordinate system. Similarly, a hump (or dip) in the larger θ ($\theta > 45^\circ$) indicates that the spin vectors of galaxies tend to be oriented perpendicular with respect to the equatorial coordinate system.

In the graph of the ϕ-distribution, solid curve represents the expected isotropic distribution, whereas dashed curve is the average distribution. The solid circles with $\pm 1\sigma$ error bars represent the observed distribution. The shaded portion represents the range $-45^\circ \leq \phi \leq +45^\circ$. In the histogram of the ϕ-distribution, $\phi = 0^\circ$ means spin vector projections tend to point radially towards the center of the equatorial coordinate system. A hump in the middle of the histogram suggests that the spin vector projections of galaxies tend to point towards the center of the chosen coordinate 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 coordinate system.



International Journal of Leading Research Publication (IJLRP)

E-ISSN: 2582-8010 ● Website: www.ijlrp.com ● Email: editor@ijlrp.com



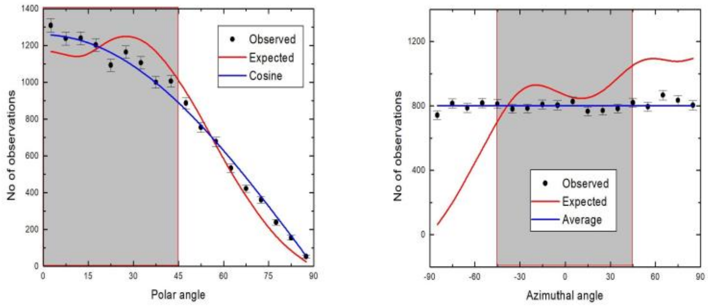


Figure 6: Plots of polar and azimuthal distributions.

Conclusion

With respect to the equatorial coordinate system, we have looked into the spatial orientation of SDSS galaxies in the Saraswati Supercluster with right ascension of $23^h\ 37^m\ 40^s$ (i.e., 354.4166°) and declination of $00^{\circ}\ 16'\ 17''$ (i.e.0.271°). The 354.3 nm Charge Coupled Device (CCD) filter mounted to the SDSS telescope in New Maxico USA is used to observe the u-magnitudes. The u-filter reacts extremely sensitively to the Lymen and almost Balmar lines of the H and He atoms, which are less energetic. We convert two-dimensional observed data into three-dimensional galaxy rotation axes proposed by Flin, P., & Godlowski, W. [17] by employing the "position angle inclination method." The theoretical isotropic distribution of galaxy rotation axes is found by doing the ran- dom simulation, which is done by creating 10^7 virtual galaxies and following the ap- proach described by Aryal, B., & Saurer, W. [19], or by removing the various selection effects. Three statistical tests—the chi-square, auto-correlation, and Fourier—were used to analyze the discrepancy between theoretical and observed distributions. The primary objectives of this thesis are to investigate the non-random influences in the galaxy and determine whether the chosen coordinate system is suitable for illuminating the true orientation scenario of distant galaxies [24, 25]. The following is the conclusion we have drawn from these observations:

- In samples 1,3,4, 5 and 6, we observed a random distribution or no preferential alignment in the spatial orientation of spin vector projections of galaxies. There- fore, our results in these samples support the Hierarchy model.
- There are preferred alignment of the spin vector and its projection in sample 2. The spin vector has a tendency to lie parallel to the reference plane, and its projection has a tendency to point radially towards the reference coordinate system, implying the Pancake model.
- There is preferred alignment of spin vectors in samples 7, 8, and 9, and spin vector projections are perpendicularly distributed. This adopts support to the Primordial Vorticity model.
- However, we noticed local effects in the majority of the samples, suggesting a local tidal connection between the rotation axis of galaxies during the merger process. As a result, the angular momentum vectors of a few galaxies get changed.
- Humps and dips in the angular momentum distribution have been observed in various samples due to the local effect of the galaxy. We expected density fluctuations and found them in the deep field on a small scale.
- We used the equatorial coordinate system as a physical reference to explore non- random effects on galaxy orientation. The hierarchy model predicts that changing coordinate systems has no effect on preferred alignments. However, the Pancake model emphasizes the significance of a physical reference system. In general, we observed mixed outcomes.

We used Saraswati Supercluster data in this case. The size of subsamples grows as one move away from the Supercluser's core. It has been found that samples 1,3,4,5, and 6 are isotropic in nature, but samples 2,7,8, and 9 are anisotropic. Based on the data from $\Delta_{11}/\sigma(\Delta_{11})$, we conclude that the Supercluster does not have a fixed center of gravity and that the structure is not virilized.

REFERENCES:

1. [1] H. Karttunen, P. Kröger, H. Oja, M. Poutanen K. J. Donner (Eds.), Fundamental Astronomy, 5 th edition, Springer Berlin Heidelbrgg New York, 13 (2006)
2. Gamow, G. (1952). The role of turbulence in the evolution of the universe. Physical Review, 86(2), 251.
3. Yadav, Shiv N., Binil Aryal, and Walter Saurer (2017). "Preferred alignments of angular momentum vectors of galaxies in six dynamically unstable Abell clusters." *Research in Astronomy and Astrophysics* 17.7 (2017): 064.
4. 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.
5. Godłowski, W., & Mrzygłód, B. (2023). A New Method of Investigation of the Orientation of Galaxies in Clusters in the Absence of Information on Their Morphological Types. *Applied Sciences*, *13*(8), 4845.
6. Von Weizsäcker, C. F. (1951). The Evolution of Galaxies and Stars. *Astrophysical Journal, vol. 114, p. 165, 114, 165.*
7. Chon, G., Böhringer, H., & Zaroubi, S. (2015). On the definition of superclusters. Astronomy & Astrophysics, 575, L14.
8. Raj, V., Swapna, M. S., Soumya, S., & Sankararaman, S. (2019). Fractal study on Saraswati supercluster. Indian Journal of Physics, 93, 1385-1390.
9. https://www.thehindu.com/sci-tech/science/what-is-the-saraswati-supercluster/article19279697.ece[Online; accessed 25-April-2023]
10. Zeldovich, Y. B. (1978). The theory of the large scale structure of the universe. In Symposium-International Astronomical Union (Vol. 79, pp. 409-421). Cambridge University Press.
11. Doroshkevich, A. G., Shandarin, S. F., & Saar, E. (1978). Spatial structure of pro- toclusters and the formation of galaxies. Monthly Notices of the Royal Astronomical Society, 184(3), 643-660.
12. Peebles, P. J. E. (1969). Origin of the angular momentum of galaxies. Astrophysical Journal, vol. 155, p. 393, 155, 393.
13. Ozernoy, L. M. (1978). The whirl theory of the origin of structure in the universe. The Large Scale Structure of the Universe, 427-438.
14. S.P. Paudel, Role of Optical search Limit in the Spatial Orientation of Local Supercluster Galaxies, M.Sc.(Physics) Dissertation, Tribhuvan University, Kritipur, Nepal (2009)
15. Gamow, G. (1952). The role of turbulence in the evolution of the universe. Physical Review, 86(2), 251.
16. Jaaniste, J., & Saar, E. (1978). Orientation of spiral galaxies as a test of theories of galaxy formation. In Large Scale Structures in the Universe (Vol. 79, p. 448).
17. Flin, P., & Godlowski, W. (1986). The orientation of galaxies in the Local Super- cluster. Monthly Notices of the Royal Astronomical Society, 222(3), 525-541.
18. Hawley, D. L., & Peebles, P. J. E. (1975). Distribution of observed orientations of galaxies. Astronomical Journal, vol. 80, July 1975, p. 477-491. NSF-supported re- search., 80, 477-491.
19. Aryal, B., & Saurer, W. (2001). The Influence of Selection Effects on the Isotropic Distribution Curve in Galaxy Orientation Studies. In Galaxy Disks and Disk Galaxies (Vol. 230, pp. 145-146).
20. Bag, S., Liivamägi, L. J., & Einasto, M. (2023). The shape distribution of super- clusters in SDSS DR12. Monthly Notices of the Royal Astronomical Society, 521(3), 4712-4730.
21. Godłowski, W. (1994). Some aspects of the galactic orientation within the Local Supercluster. Monthly Notices of the Royal Astronomical Society, 271(1), 19-30.

22. Flin, P. (2001). The anisotropy of galaxy orientation in the Coma/A1367 superclus- ter. Monthly Notices of the Royal Astronomical Society, 325(1), 49-54.
23. Poudel, A., & Aryal, B. (2015, April). A Study of u-Magnitude Dependence in the Spatial Orientation of Spin Vectors of SDSS Galaxies. In APS April Meeting Abstracts (Vol. 2015, pp. L1-006
24. Aryal, B., Yadav, S. N., & Saurer, W. (2012). Spatial orientation of galaxies in the Zone of Avoidance. *Bulletin of the Astronomical Society of India*, *Vol. 40*, *p. 65*, *40*, 65.
25. Sah, S. S. P., & Yadav, S. N. (2022). Study preferred alignments of angular momentum vector of i–magnitude SDSS galaxies having redshift 0.54–0.60. *BIBECHANA*, *19*(1-2), 68-74.