NJ: NUTA

# Isotropy in Spatial Orientation of Galaxies in the SDSS CGG 23005 having Redshift $0.11<Z\leq 0.12$

**Janak Ratna Malla[1*] and Binil Aryal[2]**

[1]Amrit Campus, Tribhuvan University

[2]Central Department of Physics, Tribhuvan University

***Email:** janakratnamalla@gmail.com

**DOI:** https://doi.org/10.3126/nutaj.v11i1-2.77016

## Abstract

We studied the Spatial orientations of 1015 SDSS galaxies in the SDSS CGG 23005 using 7th data release. Our main goal is to examine the non- random effect and to study the spatial orientation of galaxies in the SDSS CGG 23005 of three different scenarios ('hierarchy model', 'primordial vorticity theory', and 'pancake model') using Godlowski theory. To check for anisotropy or isotropy we used three statistical tests: Chi-square, Auto-correlation, and the Fourier test. By analyzing the result evolution of galaxies in the SDSSCGG 23005 supports the "hierarchy model" (Peebles, 1969).

*Keywords:* angular momentum, cluster galaxy group (CGG), Galaxies, Marker galaxy, SDSS

## Introduction

The galaxy evolution processes are not well understood at present. Galaxies have evolved with time to give us the galaxy populations seen today. Most galaxies appear to have been formed fairly early on (>10 Gigayears ago). There remain many problems relating to their formation and evolution, and even with aspect of their structure. Fortunately, extragalactic research currently is very active and our understanding is changing, and improving, noticeably each year. Galaxies are difficult to understand is that they are made of three very different entities: stars, an interstellar medium and dark matter. The gravitational effects of other galaxies can be important. Galaxies can sometimes interact and even merge to form groups, cluster of galaxies, and Superclusters. Superclusters are so large that they are not gravitationally bound and consequently, partake in the Hubble expansion. Their mutual gravity binds them together into long filaments. Generally for closed structure of up to 50 galaxies, we call them groups. The galaxy groups and clusters are collection of galaxies that are held together by gravity. Those groups and clusters and additional isolated galaxies in turn form even larger structures called Superclusters.

In this work, we intend to study the preferred alignment of the spin vectors of galaxies using "position angle-inclination" method (Flin and Godlowski 1986).

In this work, we have studied the spatial orientation of 1015 galaxies in the Supercluster of SDSS CGG 23005.

## Materials and Methods

### Database

Liivamagi et al. (2012) published a catalogue of Superclusters using the data of galaxies from the SDSS survey. They used luminosity density fields to delineate Supercluster by defining it as a region above a threshold density. We selected a SDSS CGG 23005 from their catalogue and obtained photometric data of the galaxy in the Supercluster from SDSS data base. It contained 1023 galaxies out of which we selected only 1015 of them discarding with axial ratio (b/a) less than 0.13.

Determination of Inclination Angle

According to Holmberg [Holmberg E., 1946], the inclination angle (i) of a galaxy can be computed from the formula,

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

Where, q=b/a is the axial ratio and q* is the flatness factor (true axial ratio) of the galaxy taken from Heidmann et al. (1971).

### Flin-Godlowski Transformation

The angular momentum vector (SV) of a galaxy can be expressed by two angles: the polar angle (θ) and the azimuthal angle (ϕ). These angles are given by Flin and Godlowski (1986),

$$sin\theta = -cosisin\delta \pm sinisinpcos\delta; \qquad (2)$$

$$sin\phi = \frac{-cosicos\delta sin\alpha + sini(\mp sinpsin\delta sin\alpha \mp cospcos\alpha)}{cos\theta}; \qquad (3)$$

$$sin\phi = \frac{-cosicos\delta cos\alpha + sini(\mp sinpsin\delta cos\alpha \pm cospsin\alpha)}{cos\theta} \qquad (4)$$

Where, i, δ, α and P represent the inclination angle, declination angle, right ascension angle and position angle respectively.

## Result and Discussion

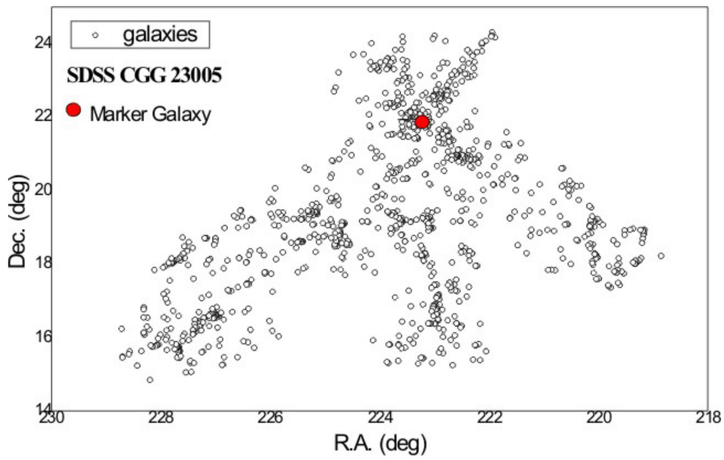


**Figure 1:** *All sky plot of galaxies in the SDSS CGG 23005. Each point represents a galaxy and the Marker galaxy (brightest galaxy of the SDSS CGG 23005) is shown as a red circle.*

The extended distribution of 1015 galaxies in the SDSSCGG 23005 is clearly seen from the all-sky map in the figure 1, which indicates the inhomogeneous distribution of galaxies. In the all sky distribution plot, we can see galaxies were found to be concentrated between at 223°(R.A.) and at 22° (Dec.). These concentrated galaxies forming subcluster region in future.

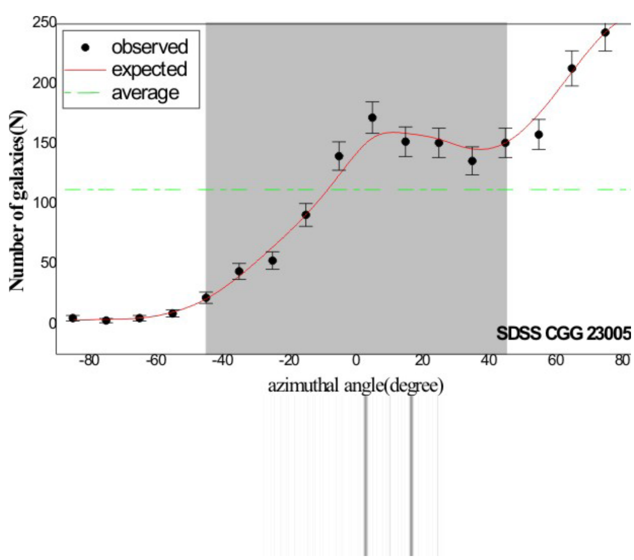


**Figure 2:** *Velocity contour maps of galaxies in SDSS CGG 23005.*

These are the galaxies those have redshift (z) in the range 0.11 to 0.12. Velocity contour maps will show how the galaxies with same radial velocity are distributed within the SDSS CGG 23005. Since a common radial velocity for a group of galaxies permits us to identify the group as a cluster of galaxies, which may be a great importance for study the structure evolution in large scale. Here, the velocity contour map of our database on the basis of redshift values as shown in the figure 2.

We describe our results concerning the polar (θ) and azimuthal angle (ϕ) distributions of galaxies. Any deviation from expected isotropic distribution will be tested using four statistical parameters, for anisotropy , namely chi-square probability ($P(>\chi 2)$) is <0.050, autocorrelation coefficient($C/C(\sigma)$) is > 1.0, first order Fourier coefficient ($\Delta 11/\sigma(\Delta 11)$) is > 1.5 and first order Fourier probability ($P(>\Delta 1)$) is < 0.150 respectively. The statistics for the polar angle (θ) and azimuthal angle (ϕ) distribution is given in Table 1.

The statistics for the polar angle (θ) distribution of total galaxies is given in table 1. Table 1 shows that chi-square probability ($P(>\chi 2)$) is 0.912 (greater than 0.050 limit), autocorrelation coefficient ($C/C(\sigma)$) is -0.074 ( less than the limit 1σ) , first order Fourier coefficient ($\Delta 11/\sigma(\Delta 11)$) is 0.988 (smaller than 1.5σ limit ) and first order Fourier probability ($P(>\Delta 1)$) is 0.401 (greater than 0.150 limit) respectively. These entire statistics test supports strong isotropic distribution.

Figure 2 shows the polar angle (θ) distribution for the total galaxies. In polar angle less than (θ>45°), Two dips (bins with less solution than the expected) are seen at angles 38° and 42° with ±σ error limit. There are no significant hump (bins with more solutions than the expected) are observed. In between 45°<θ>90°, there are significant hump are seen at an angle 48°. But no dips are seen between 45°<θ>90°. These humps and dips suggest that the projection of galaxies tend to oriented randomly and support hierarchy model.

The statistics for the azimuthal angle (ϕ) distribution (table 1) of total galaxies shows the value of chi-square probability ($P(>\chi 2)$) is 0.972 (greater than the significant level 0.050), auto correlation coefficient ($C/C(\sigma)$) is -0.034 ( less than the limit 1σ) , first order Fourier coefficient ($\Delta 11/\sigma(\Delta 11)$) is 0.059 (smaller than 1.5σ limit ) and first order Fourier probability ($P(>\Delta 1)$) is 0.256 (greater than 15%.) respectively. All these statistics test supports isotropy.

Figure 3, shows the azimuthal angle (ϕ) distribution of galaxies, at (ϕ < 45°), small 'dip' is seen at

In the bimodal region (−45° < ϕ < +45°) three small dips at -22°, 18°, and 38° are seen and two 'humps' at -5°and 8° are seen. At (ϕ > +45°), one dip at 58° can be observe. We again conclude that there is no preferred alignment among spin vectors of galaxies.

After careful examination of the statistics and graphs of polar and azimuthal angles, we found isotropy in spin-vector orientation of galaxies in the SDSS CGG 23005. This supports hierarchy model of galaxy evolution.

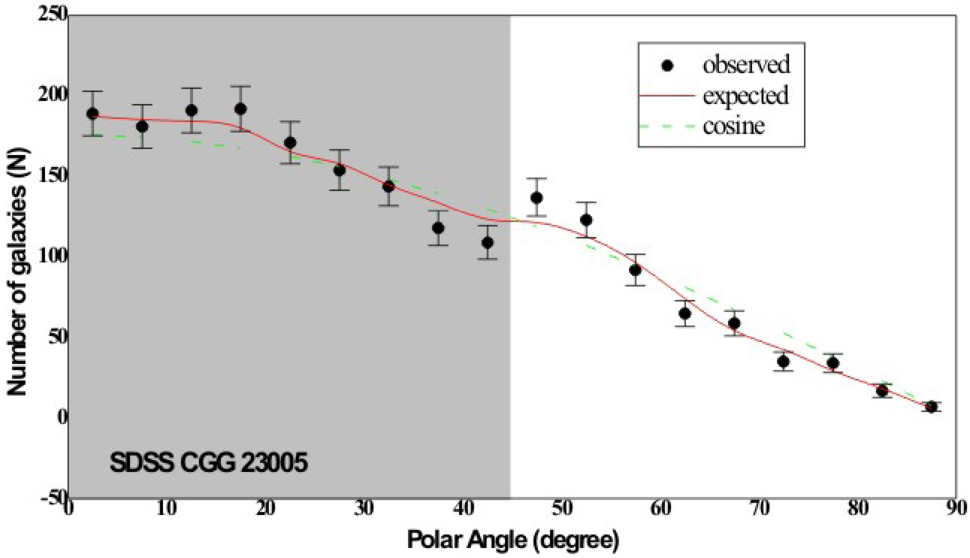


**Figure 2:** *The polar angle (θ) distribution of galaxies in the SDSS CGG 23005.*

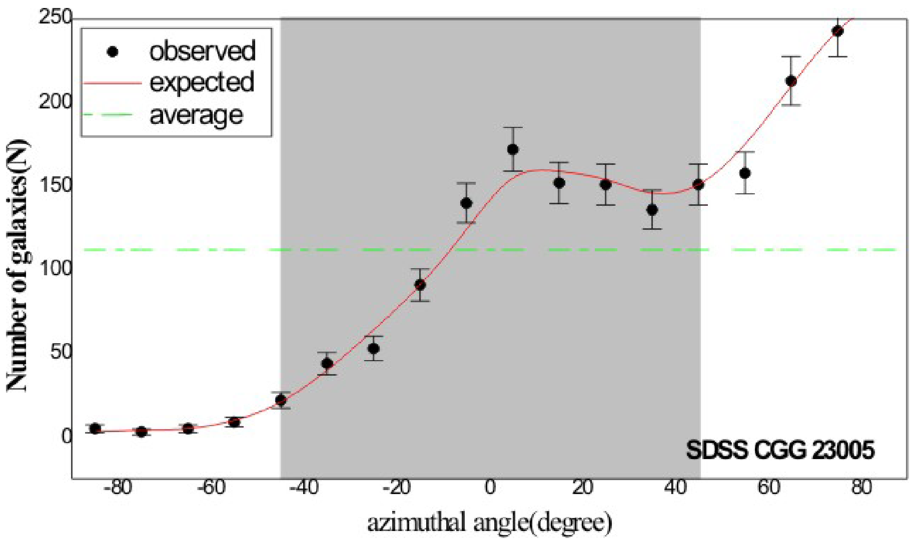


**Figure 3:** *The azimuthal angle (ϕ) distribution of galaxies in the SDSS CGG 23005.*

**Table 1.** Table showing the *Statistics of the polar* (θ) *and azimuthal* ($\phi$) *angle distributions of galaxies in the* SDSS CGG 23005.

| Statistics | Polar angle($\theta$) | Azimuthal angle($\phi$) |
|---|---|---|
| $P(>\chi^2)$ | 0.912 | 0.972 |
| $C/C(\sigma)$ | -0.076 | -0.034 |
| $\Delta_{11}/\sigma(\Delta_{11})$ | 0.988 | 0.059 |
| $P(>\Delta_1)$ | 0.401 | 0.256 |

## Comparison with previous works

Aryal and Saurer (2000) found anisotropy when analyzing 296 galaxies in A3558 region in both two dimensional (equatorial PA-distribution) and three dimensional analysis (θ and $\phi$ distributions).In the three-dimensional analysis, they studied the preferred orientation with respect to the Supergalactic coordinate system and found that the spin vector orientation of galaxies tend to lie parallel to the Local Supercluster center (Virgo cluster center). However, no preferred alignment is noticed in our work.

Godlowski et al. (2011) found that the cluster galaxies that are at > 300 Mpc show random alignments of angular momentum vectors of galaxies with respect to equatorial coordinate system. Their result is similar to that of our result. They concluded hierarchy model for the galaxy evolution in the cluster.

## Conclusion

We studied the spatial orientation of 1015 SDSS DR7 galaxies, using the 'position angle-inclination' method (Flin & Godlowski 1986) and a random simulation method (Aryal & Saurer 2000, 2001). Our conclusion is as follows:

The angular momentum vectors of galaxies in the SDSS CGG 23005 are found to be random orientation, which support the 'hierarchy model', as suggested by Peebles (1969).

The redshift of galaxies in the SDSS CGG 23005 are found to be independent of the distribution of angular momentum vectors and its projections, supporting the hierarchy model of galaxy formation as suggested by Peebles (1969).

## Acknowledgement

One of the authors (JRM) wishes to thank authorities of the SDSS for providing DR7 data.

## References

Aryal, B., & Saurer, W. (2000). Comments on the expected isotropic distribution curves in galaxy orientation studies. *Astronomy and Astrophysics, 364*, L97-L100.

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).

Aryal, B., & Saurer, W. (2004). Spin vector orientations of galaxies in eight abell clusters of bm type i. *Astronomy & Astrophysics, 425*(3), 871-879.

Doroshkevich, A. (1973). The origin of rotation of galaxies. *ASTROPHYS. LETTERS*, 14(1), 11-13.

Doroshkevich, A., & Shandarin, S. (1978). A statistical approach to the theory of galaxy formation. *Soviet Astronomy*, 22, 653-660.

Flin, P. & Godlowski, W.(1986) The Orientation of Galaxy Groups and formation of the local Supercluster. *Monthly Notices Royal Astronomy Society*, 222, 525.

Gamow, G. (1952). The role of turbulence in the evolution of the universe. *Physical Review*, 86(2), 251.

Godlowski, W., Panko E. and Flin P. (2011). The environmental effects in the origin of angular momenta of galaxies. *Acta Physica Polonica B,*42, 2313-2322.

Hawley, D., & Peebles, P. (1975). Distribution of observed orientations of galaxies. *The Astronomical Journal, 80*, 477-491.

Heidmann J., Heidmann N., de Vaucouleurs G. (1971), Orientation of Galaxies in the Local Supercluster *Memoirs of the Royal Astronomical Society, 75, 85.*

Holmberg, E. (1946). On the apparent diameters and the orientation in space of extragalacticNebulae. *Meddelanden fran Lunds Astronomiska Observatorium Serie II, 117*, 3-82.

Jaaniste, J., & Saar, E. (1978). in the large scale structure of the universe, ed. longair ms,einasto j.(dordrecht: Reidel). In *Proc. iau symp*. (Vol.79, p. 448).

Joeveer M.,Einasto J.,Tago E.(1978).Spatial distribution of galaxies and of cluster of galaxies in the southern galactic hemisphere. *Monthly notice of the Royal Astronomy Society,185,*357.

Liivamagi L.J.,Tempel E.,and Saar (2012). SDSS DR7 Superclusters The catalogues. *Astronomy and Astrophysics.539,*A80.

Ozernoy, L. M. (1974). Whirl theory of the origin of galaxies and clusters of galaxies. In *Symposium-International Astronomical Union* (Vol. 63, pp. 227-240).

Ozernoy, L. (1978). The whirl theory of the origin of structure in the universe. *In Symposium-international astronomical union* (Vol. 79, pp. 427-438).

Peebles, P. (1969). Origin of the angular momentum of galaxies. *The Astrophysical Journal,155*, 393.

Von WeizsÃ¤cker, C. (1951). The evolution of galaxies and stars. *The Astrophysical Journal,114*, 165.

Zel'Dovich, Y. B. (1970). Gravitational instability: An approximate theory for large density perturbations. *Astronomy and astrophysics, 5*, 84-89.

Zwicky F. and Kowal C.T. (1968). Catalogue of galaxies and of Clusters of Galaxies, Volume VI. *California Institute of Technology, CGCG6.*