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No preferred alignments of angular momentum vectors of galaxies in the SDSS supercluster S[202-001+0084]

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Abstract. We present spatial orientation of angular momentum vectors of 3038 galaxies in the SDSS supercluster S[202-002+0084] having mean redshift 0.084. The selection effects in the database are removed using random simulation method. The observed distributions of angular momentum vectors of galaxies are compared with expected theoretical distribution using chi-square, auto-correlation and Fourier tests. No preferred alignments of angular momentum vectors of galaxies are noticed in the supercluster S[202-001+0084], supporting hierarchy model.

Keywords. Galaxies: evolution, galaxies: superclusters, galaxies: statistics

1. Introduction

Von Weizsacker and Gamow (1951 & 1952) predicted that the angular momentum of galaxies might reveal the physical conditions under which they formed. The distribution of the angular momentum of galaxies is closely related to the physics of the early universe. There have been handful of studies in the past, predicting various galaxy formation scenarios. The 'pancake model' (Shandarin 1974) predicts that the rotation axes (i.e., angular momentum) of galaxies tend to lie within the cluster plane whereas the 'primordial vorticity model' (Ozernoy 1978) says that the rotation axes of galaxies tend to be oriented perpendicular the cluster plane. The 'hierarchy model' (Peebles 1969) predicts random orientation. In the present study, we analyse preferred alignments of angular momentum vectors of 3038 galaxies in SDSS supercluster S[202-001+0084].

2. Methods

We adopted the method proposed by Flin & Godlowski (1986) to find angular momentum vectors of a galaxy. In their method, this vector is defined by two angles: polar (θ) and the azimuthal (ϕ):

$$\begin{aligned} \sin\theta &= -\cos i \sin\delta \pm \sin i \sin P \cos\delta \\ \sin\phi &= (\cos\theta)^{-1}[-\cos i \cos\delta \sin\alpha + \sin i \\ &\quad (\mp \sin P \sin\delta \sin\alpha \mp \cos P \cos\alpha)] \end{aligned} \tag{2.1}$$

where α, δ, P and i are the right ascension, declination, equatorial position angle, and the inclination angle, respectively. These two angles allowed us to find the orientations of the two possible vectors normal to the galactic plane, one of them assumed to be the galactic rotation axis or spin vector of the galaxy. The position angle of the galaxy

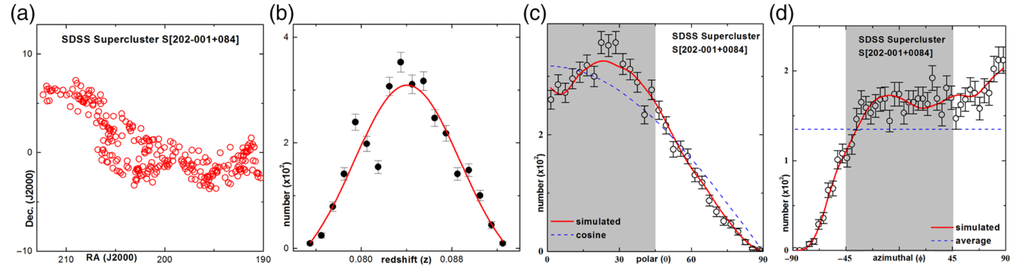

Figure 1. (a) All sky (b) redshift (c) polar and (d) azimuthal angle distributions of galaxies in the supercluster S[202-001+0084]. The solid curves represent Gaussian (b) and expected (c,d) distributions. The dashed curves show cosines (c) and average (d) distributions. The statistical $\pm 1\sigma$ error bars are shown.

(angle between major diameter and north reference direction) with respect to equatorial coordinate system is called equatorial position angle. The inclination angle (i) of galaxies are calculated using Holmberg's (1946) formula: $\cos^2 i = [(b/a)^2 - q^2]/(1-q^2)$ with b/a the measured axial ratio (b/a) and q the intrinsic flatness. We have included only spiral and lenticular galaxies because of their precise intrinsic flatness. Since elliptical galaxies are not supported by rotation, their intrinsic flatness can not be measured precisely. We have not calculated magnitudes of angular momentum because of lack of mass and rotational velocity of galaxy. We run numerical simulation to find the expected isotropic distribution (Aryal & Saurer 2000). We assumed a spatial isotropic distribution of angular momentum vectors of galaxies as a theoretical reference. Our observations are compared with isotropic distribution curves in both θ and ϕ. For this we use three statistical tests: chi-square, Fourier, and auto correlation, as suggested by Aryal *et al.* (2007).

3. Result & Discussion

Fig. 1a shows all sky distribution of 3038 galaxies in the supercluster S[202-001+0084]. Four substructures are seen when making number density map. These substructures are found to be connected from eastern to western part. Fig. 1b shows redshift distribution of galaxies in the supercluster. This distribution is found to be Gaussian with Gaussian center 0.0841 and width 0.0094. The distribution of angular momentum vectors (polar angle) of galaxies and their projections are shown in Fig. 1c,d. A very good agreement between the solid curve and the observed distributions can be seen. Any hump in the grey shaded region in Fig. 1c represents that the supercluster galaxies preferred to lie in the reference plane, supporting pancake model. Similarly, any hump in the non grey shaded region suggest primordial vorticity theory. In the polar angle distribution, chi-square probability ($P(>\chi^2)$) is found to be 0.226, suggesting no preferred alignments. Similar trend is shown by auto-correlation test ($C/C(\sigma) = 0.95$). The first order Fourier coefficient ($P(>\Delta_1)$) and probability ($P(>\Delta_1)$) are found to be 0.001 and 0.222, advocating isotropy. In the azimuthal angle distribution, the statistical parameters are found as follows: $P(>\chi^2) = 0.630$, $C/C(\sigma) = 0.36$, $P(>\Delta_1) = -0.001$ and $P(>\Delta_1) = 0.983$. These values suggest that the angular momentum vectors of galaxies in the supercluster S[202-001+0084] do not show any preferred trend, however their projections tend to be oriented towards the center of the chosen co-ordinate system. The reason of this will be studied in the future.

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