

A Search for Dynamical Memory in the Spin Distribution of Galaxies in HSC WIDE Survey Regions

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Objective: While the observations of the scalar field of CMB at $z \sim 1000$ and galaxy distribution at $z \sim 1$ provide a firm basis to support the standard Λ -CDM scenario, the observational studies on the vector fields of the universe are yet limited. We study the distribution of spin vectors of galaxies using the line-of-sight component of the spin vector robustly identified from the spiral winding parity. This is a complementary robust approach to the intrinsic shape analysis of galaxies.

Galaxy Data: We use 49494 spiral galaxies in four HSC WIDE fields, for which the Super Galactic Coordinates with spectroscopic redshift and the spiral winding parity (S-wise or Z-wise; Tadaki+2020) are known (Fig.1).

Search Domains: We deploy 46247 search cube volumes of size (20-200Mpc) and count numbers n_S and n_Z for S- and Z-wise spirals to compare with the expectation from the binomial distribution (Fig1).

One-sided Cumulative Distribution Function (OCDF): We use OCDF to evaluate if the observed parity distribution in the cube set is compatible with 1000 random mock simulations (Figs.3, 4)

Two-sided Cumulative Distribution Function (TCDF): We use TCDF to evaluate the level of rareness of observed n_S/n_Z asymmetry for a cube (Figs.2, 5, 6)

Results:

- 1) Six cubes showed number asymmetry exceeding 10 times the maximum expected from the random binomial distribution.
- 2) The statistics for the 200 Mpc cube set show a departure from the 1000 random mock simulations.
- 3) The statistics for 20 -150 Mpc cube sets are, however, consistent with a random binomial distribution.
- 4) The level of departure from the random binomial distribution as a whole is 2.4%, marginal but not significant enough.
- 5) Therefore, we found no clear evidence for non-random initial perturbation in the vortex distribution.

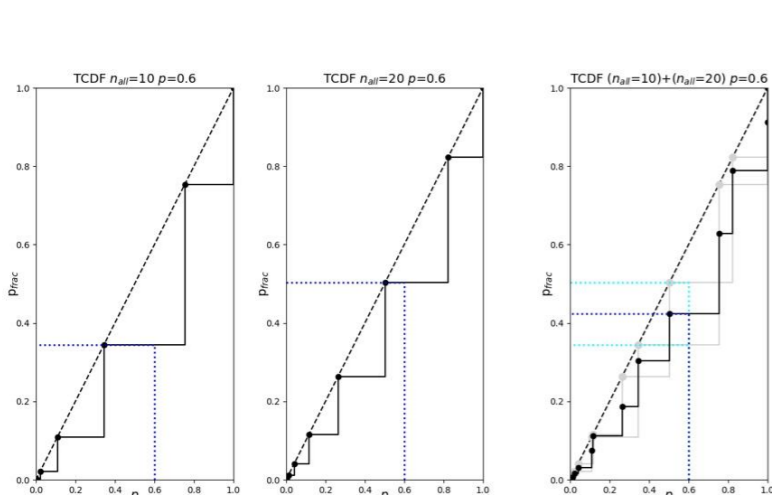


Fig.3. The left and middle panels show the theoretical binomial TCDF for cubes with $n_{all} = 10$ and 20, respectively. The right panel shows the TCDF for a combined set of the two cubes, in which the steps deviate from the normal distribution (dashed line).

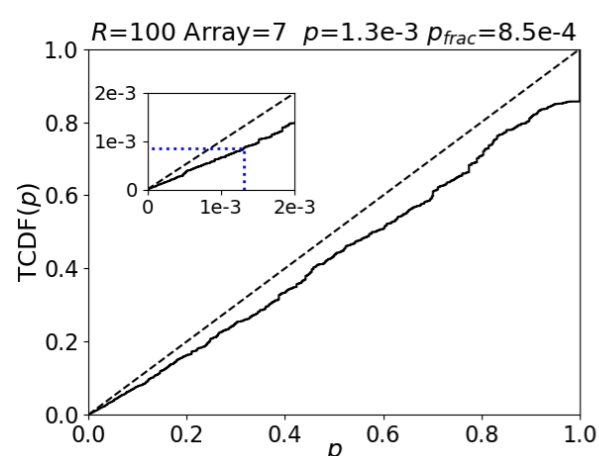


Fig.5. The solid curve shows the theoretical two-sided binomial cumulative distribution function TCDF(p) for a cube set. The probability of obtaining an asymmetry equal to or larger than that observed for this set is given by $p_{frac} = TCDF(p)$.

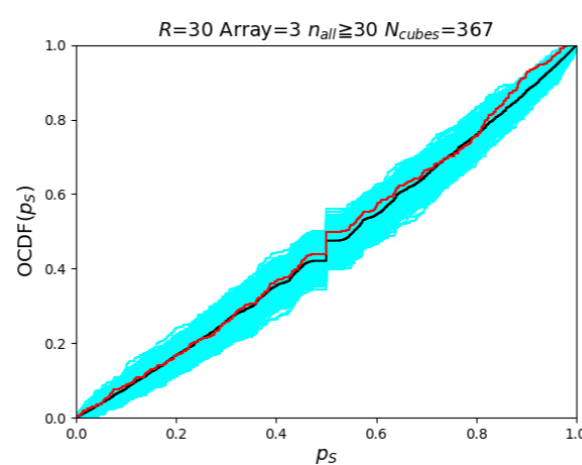


Fig.4a. OCDFs for observed Cube Set S127 (red), the theoretical binomial expectation (black), and the results from 1000 Monte Carlo simulations (cyan). The observed OCDF lies well within the range spanned by Monte Carlo simulations

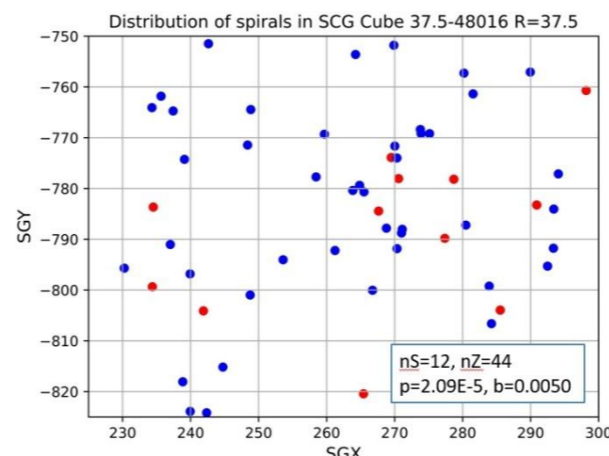


Fig.6a. Spatial distribution of S-spirals (red) and Z-spirals (blue) galaxies in the SGX-SGY plane for the most bizarre Cube 37.5-48016.

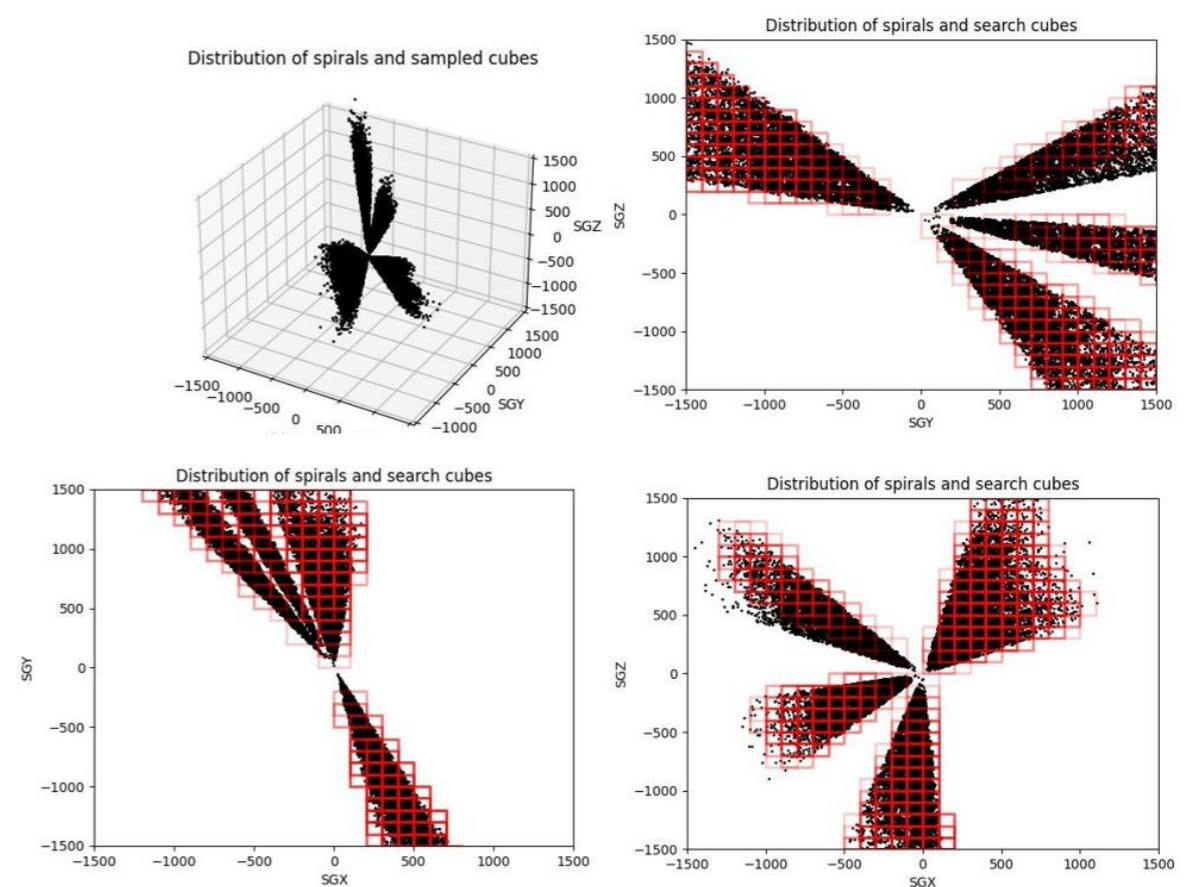


Fig.1. Distribution of 49494 spirals (black dots) in four HSC WIDE survey regions displayed in the Super Galactic Coordinates. Superposed red boxes are fiducial search cubes (with 100Mpc size in this case) deployed to cover the entire surveyed volume.

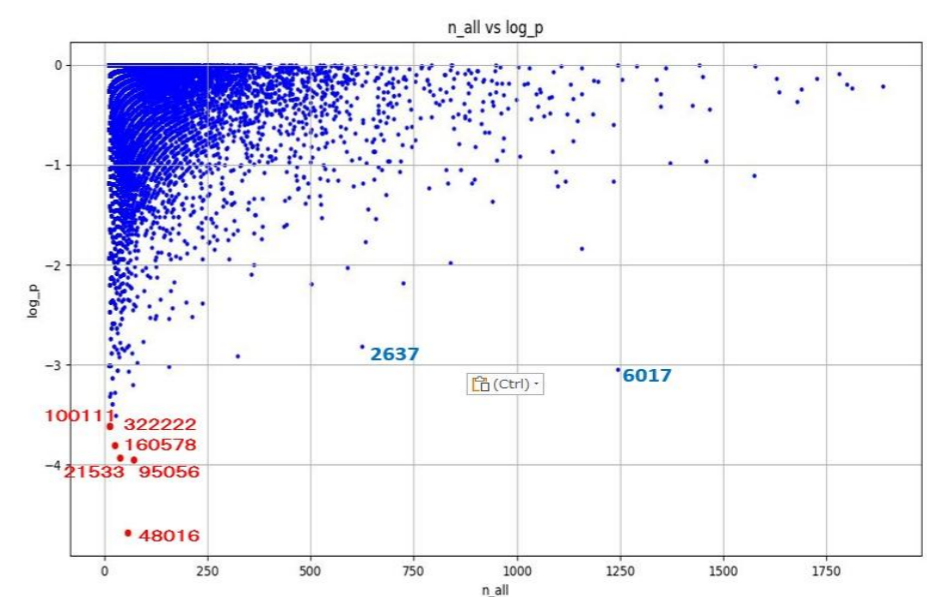


Fig.2. Distribution of binomial probability p versus n_{all} for the 46,247 search cubes (blue points). The labelled cubes are "highly bizarre" with the occurrence probability less than once in a thousand realizations.

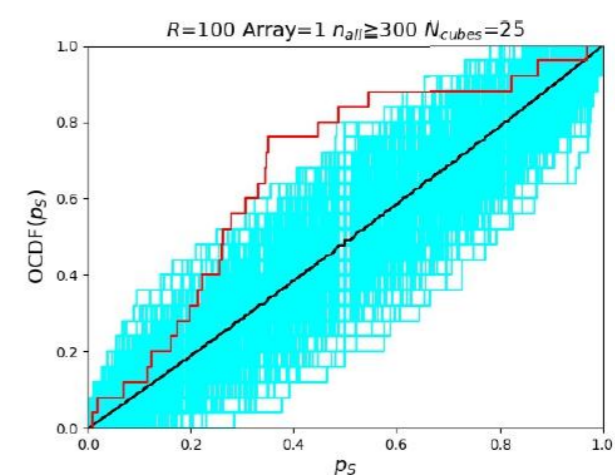


Fig.4b. OCDF for observed Cube Set S1 (red) lies beyond the range covered by 1000 Monte Carlo simulations.

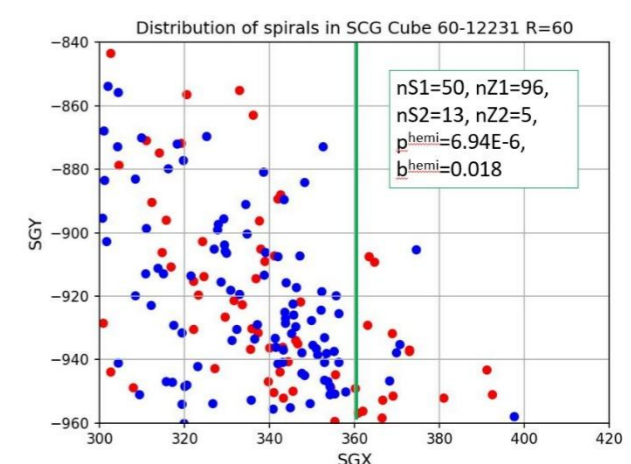


Fig.6b. Distribution of S-spirals (red) and Z-spirals (blue) in the most bizarre hemicube Cube 60-12231. The hemicube on the left of the green section plane contains a larger number of Z-spirals, while the other hemicube is dominated by S-spirals.

Reference

Iye, M. & Yagi, M.: 2026 AJ, 172, 19
Tadaki, K. et al.: 2020, MNRAS, 496, 4276