

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

M. Iye & M. Yagi

Background: Studies on scalar density fields, CMB ($z \sim 1000$) and SDSS ($z \sim 1$), was successful in establishing the Λ CDM model.

The next check could be studies on the vector field in the universe.

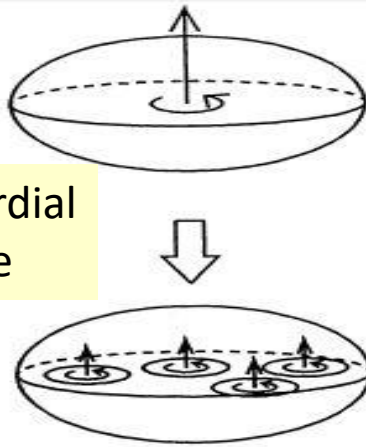
Question: Do galaxies spin randomly in the universe?

Data: Revised Spin Catalogue of HSC WIDE fields with spec- z provides for the first time a 3D distribution of spirals with S/Z annotation to attack on this question.

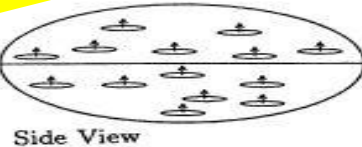
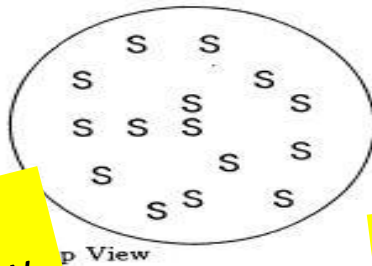
Methods: Dipole and Quadrupole asymmetry analysis for searched cubes of radius 20-200Mpc deployed in 4Gpc volume.

Implied symmetry breakings (Sugai & Iye 1995)

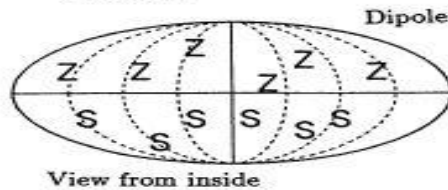
Primordial
Vortice



a) Primordial Vorticity Scheme

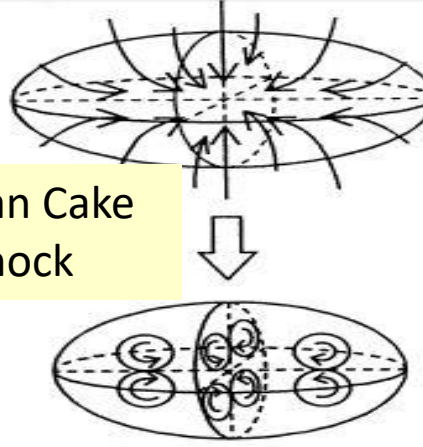


Side View

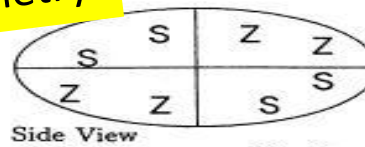
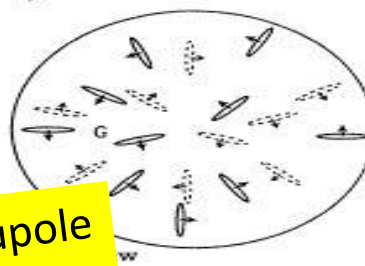


View from inside

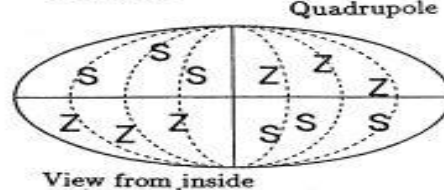
Pan Cake
Shock



b) Pancake Shock Scheme

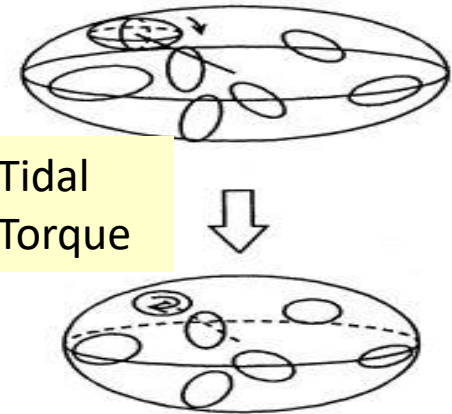


Side View

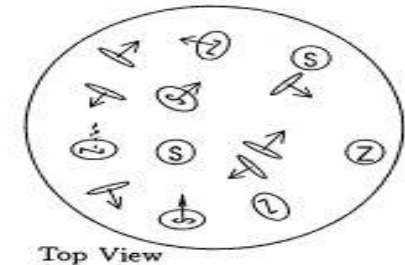


View from inside

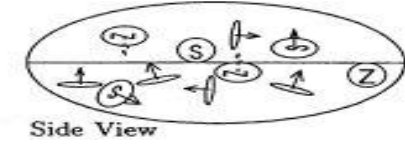
Tidal
Torque



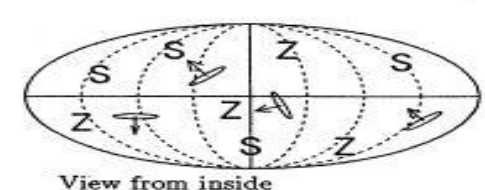
c) Tidal Spin-Up Scheme



Top View



Side View



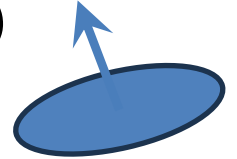
View from inside

Dipole
Asymmetry

Quadrupole
Asymmetry

Reported studies on spin distribution

- Many studies on the distribution of the **position angle** of the major axis (Shape Analysis for **tangential** component)



Controversial reports on spin-filament alignment.

- **Spiral winding (S/Z) distribution (radial component)**

In the **Local Universe**



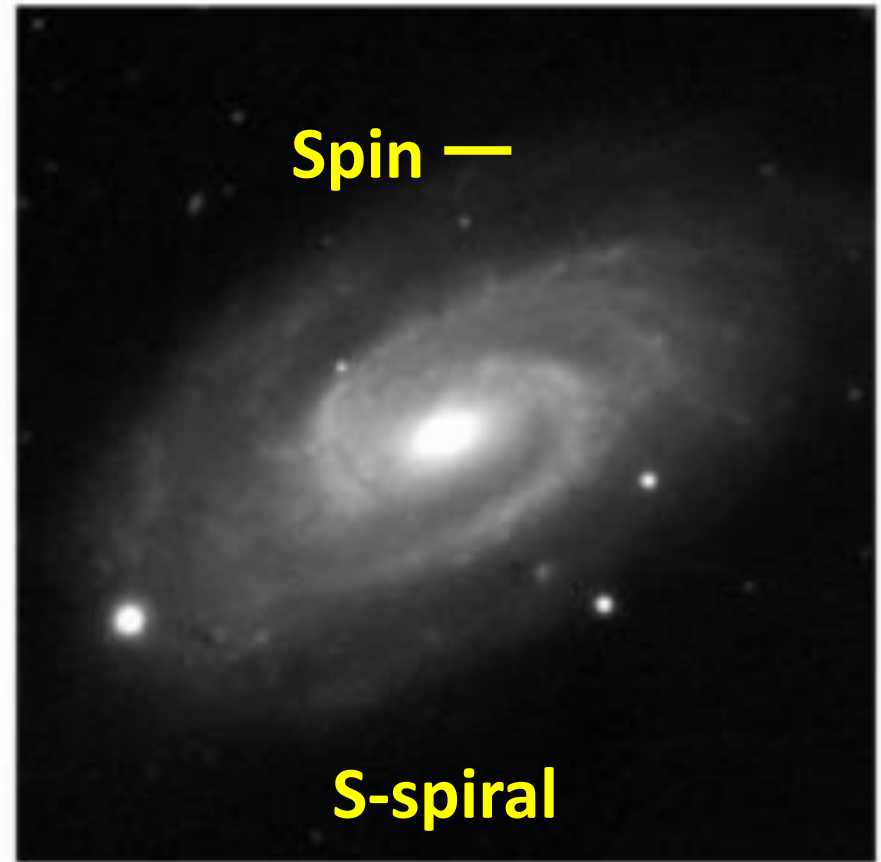
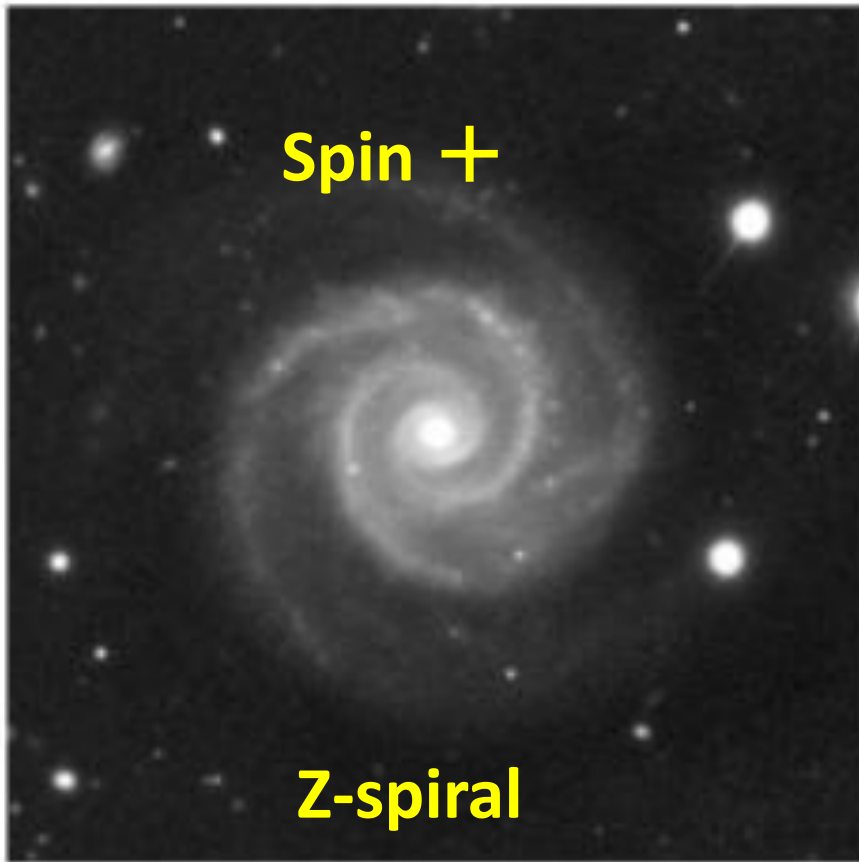
Shamir (2017) claimed to find a significant S/Z asymmetry

Iye et al.(2021) pointed out a problem in Shamir's paper and confirmed no significant S/Z asymmetry

Patel & Desmond(2024): no asymmetry

- The current on HSC WIDE fields looks the **3d distribution** of S/Z spin in the outer Universe, **not centered on our galaxy**

- Galaxy image database : HSC WIDE Data Release 2
- Spin Parity (S/Z): (Tadaki+2020), **76635** spirals
- Distance (**49605** spec-z confirmed, **27030** PSF fillers TBD)

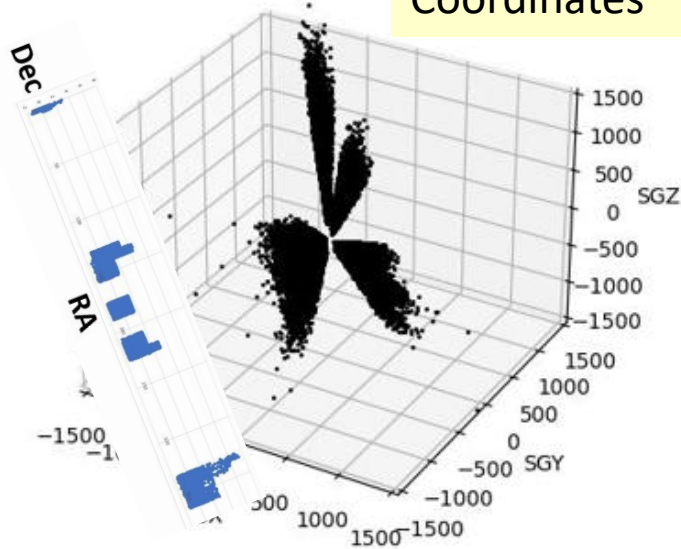


Spin parity provides a robust judgment for the l.o.s component of the galaxy spin vector.

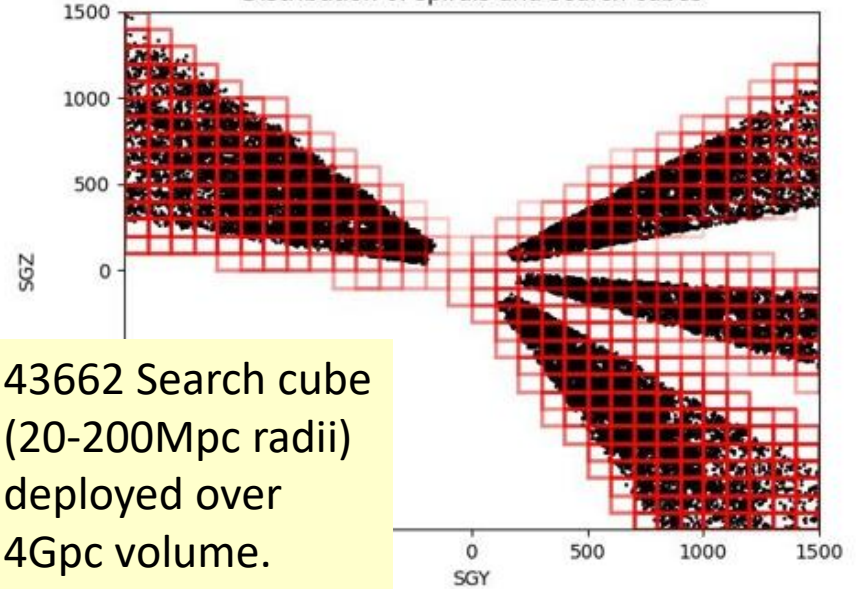
Z c

Distribution of spirals and

Super Galactic Coordinates

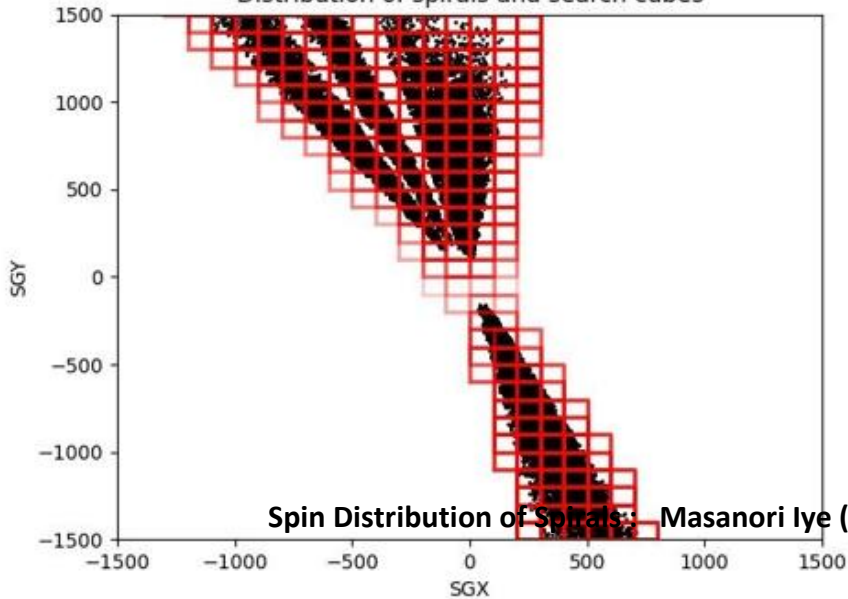


Distribution of spirals and search cubes



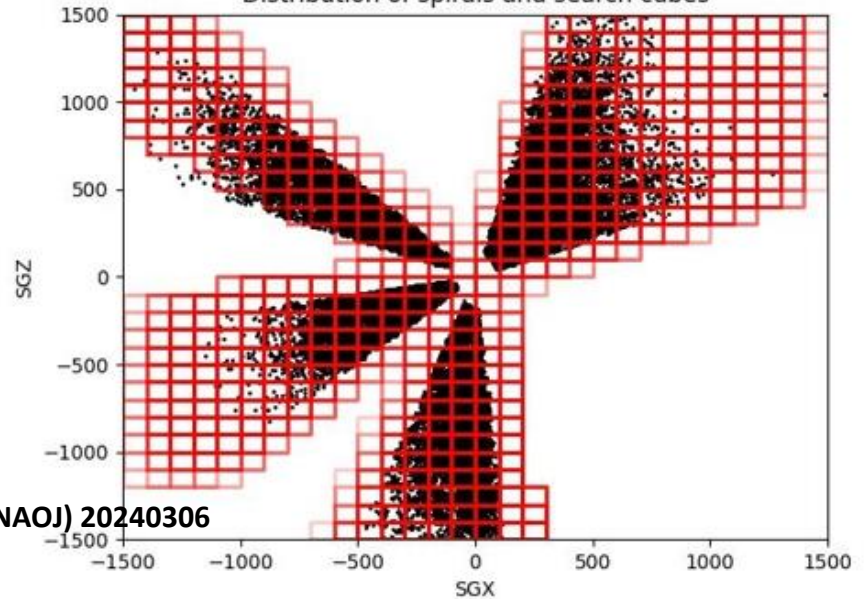
43662 Search cube
(20-200Mpc radii)
deployed over
4Gpc volume.

Distribution of spirals and search cubes



Spin Distribution of Spirals: Masanori Iye (NAOJ) 20240306

Distribution of spirals and search cubes



Spin Distribution of Spirals: Masanori Iye (NAOJ) 20251030

Analysis Outline

- Monopole: Count $n(S)$, $n(Z)$ in each cube and calculate A and σ_A .
- Dipole: Count $n(S)$, $n(Z)$ in hemicubes dissected by 9 section-planes.
- Compare the largest $|\sigma_A|$ with σ_{crit} expected for an ensemble of n_{cube} searched cubes.
- Compare the distribution function $f(\sigma_A)$ with the binomial distribution to judge the existence of spin parity asymmetry.

Asymmetry: $A = \{n(S) - n(Z)\} / n(\text{all})$, where $n(\text{all}) = n(S) + n(Z)$

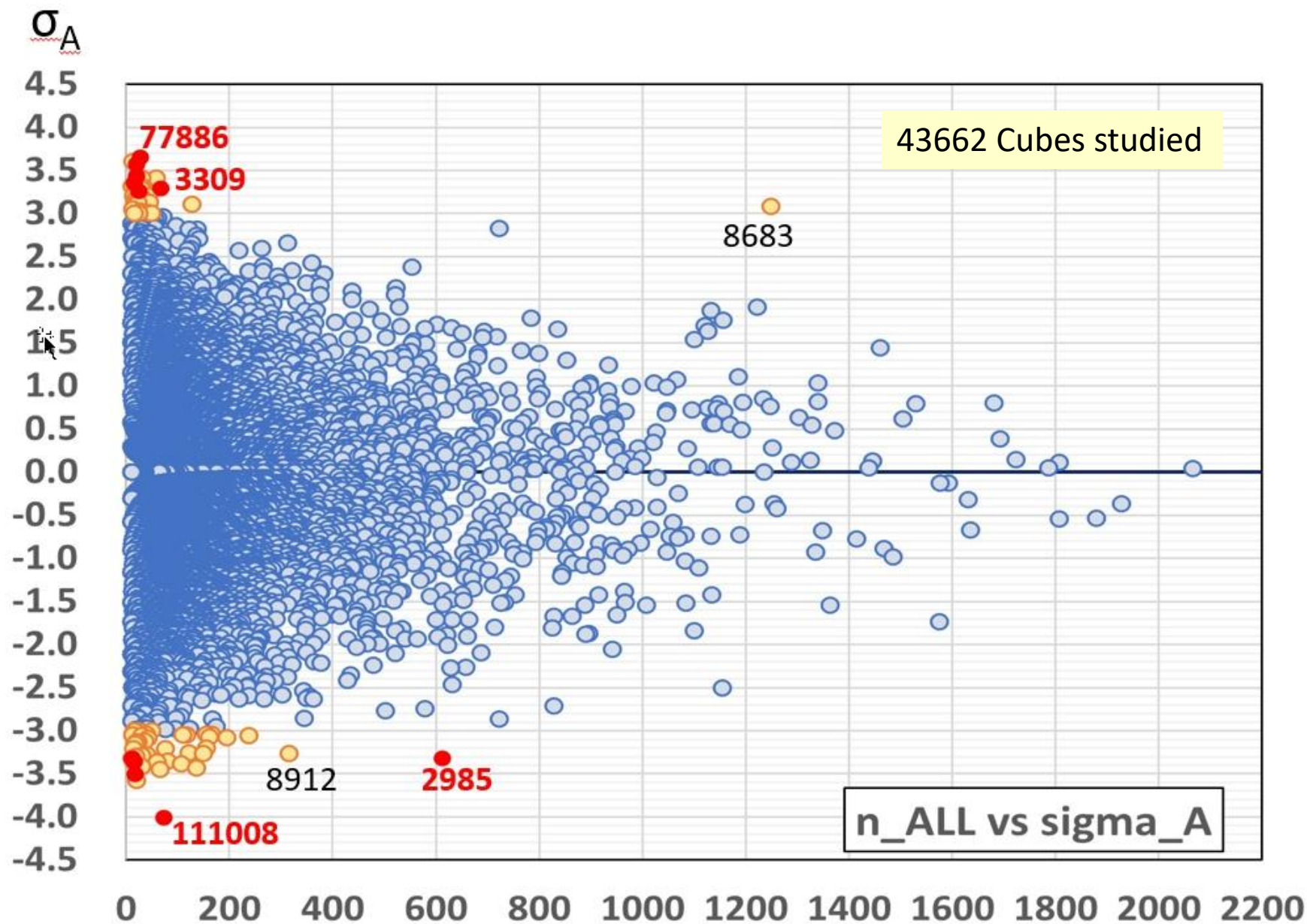
Associated estimate errors: $\epsilon = \sqrt{\epsilon_{\text{Poisson}}^2 + \epsilon_{\text{annotation}}^2}$

$\epsilon_{\text{Poisson}} = 1 / \sqrt{n(\text{all})}$ > $\epsilon_{\text{annotation}} = 0.04$ for cubes with $n(\text{all}) < 628$.

Significance: $\sigma_A = \{n(S) - n(Z)\} / \sqrt{n(\text{all})}$

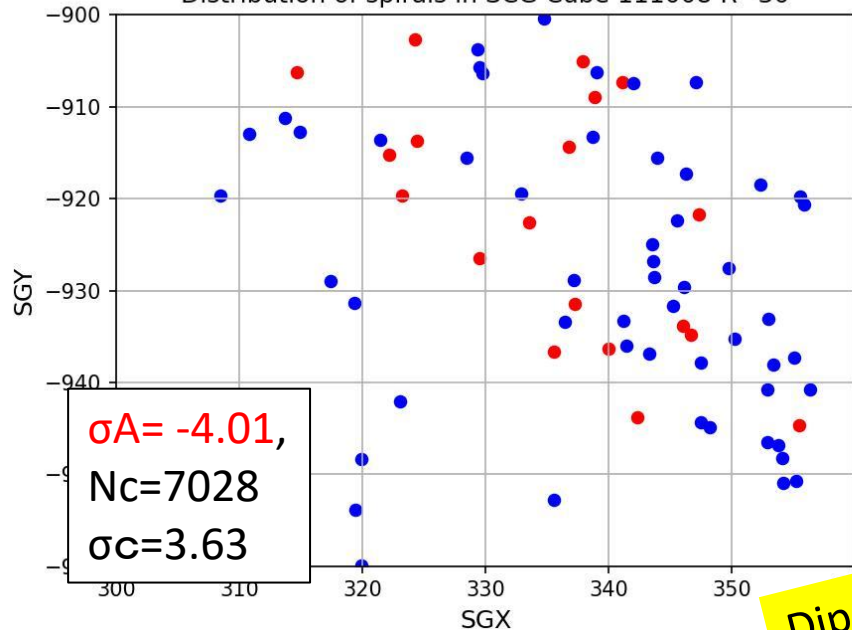
$\sigma_{\text{crit}}(n_{\text{cube}})$: maximum deviation for a Gaussian distribution

of n_{cube} cubes. $\sigma_{\text{crit}} = 3.0$ (4.0) for $n_{\text{cube}} = 370$ (15900)

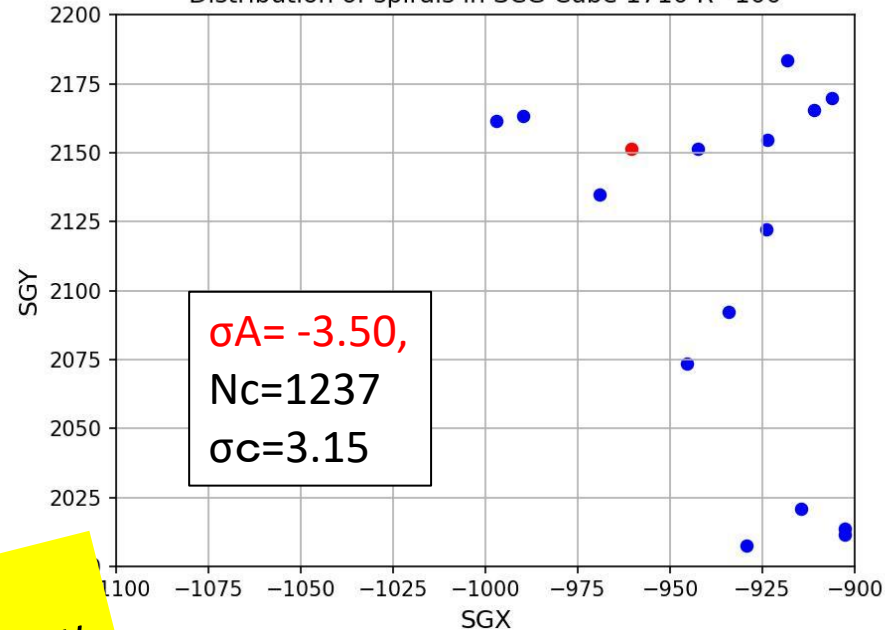


13 odd cubes where the number asymmetry σ_A exceeds σ_{crit} .

Distribution of spirals in SCG Cube 111008 R=30

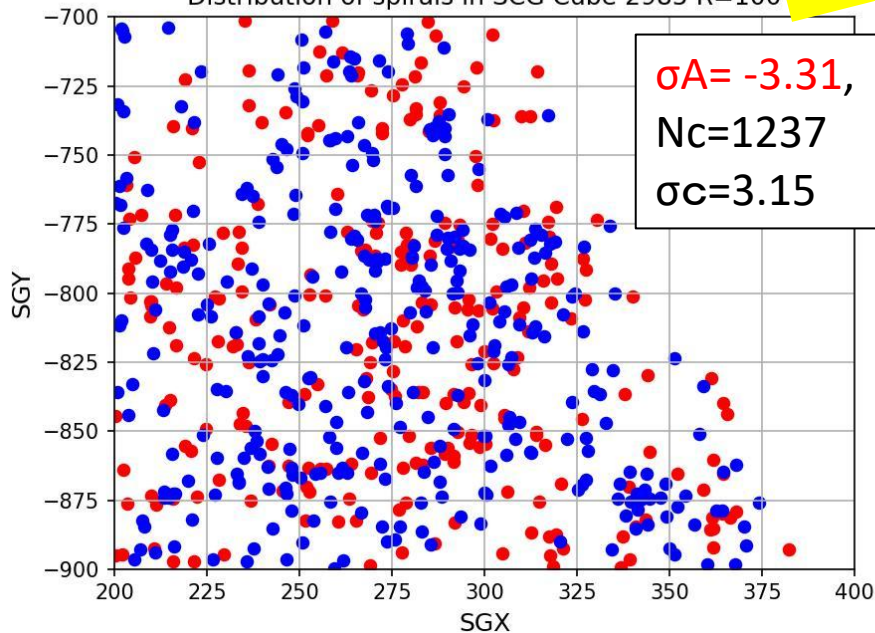


Distribution of spirals in SCG Cube 1710 R=100

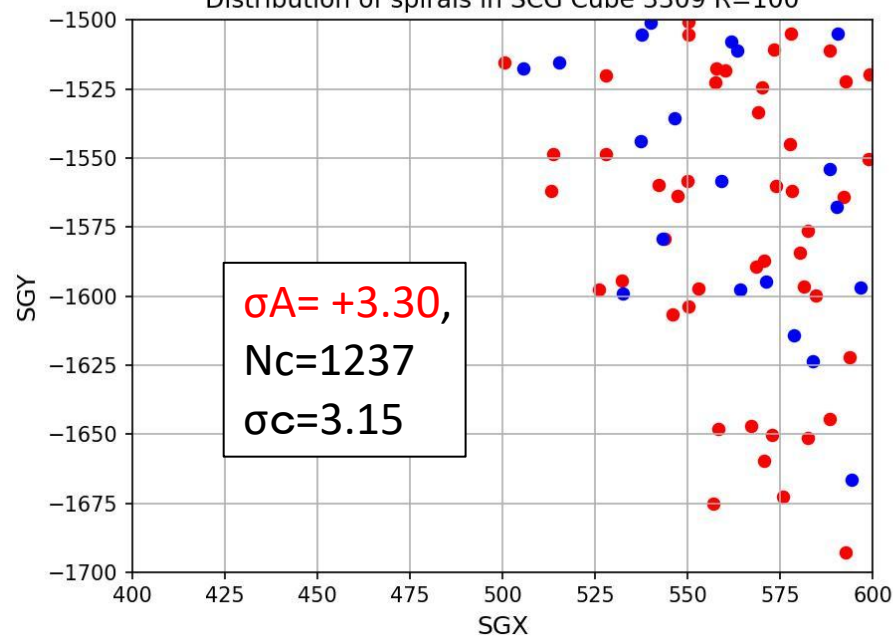


Dipole
Asymmetry

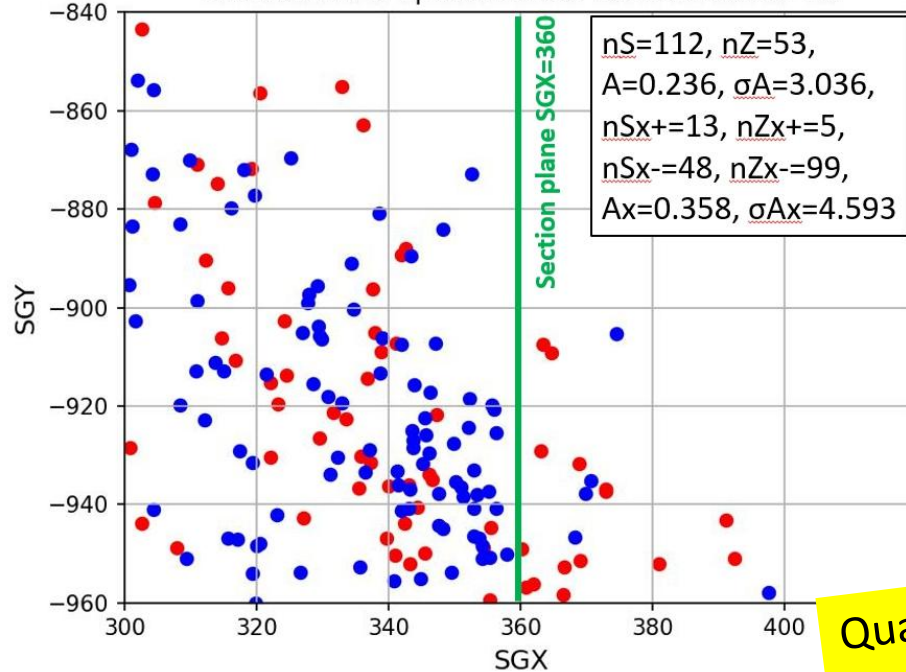
Distribution of spirals in SCG Cube 2985 R=100



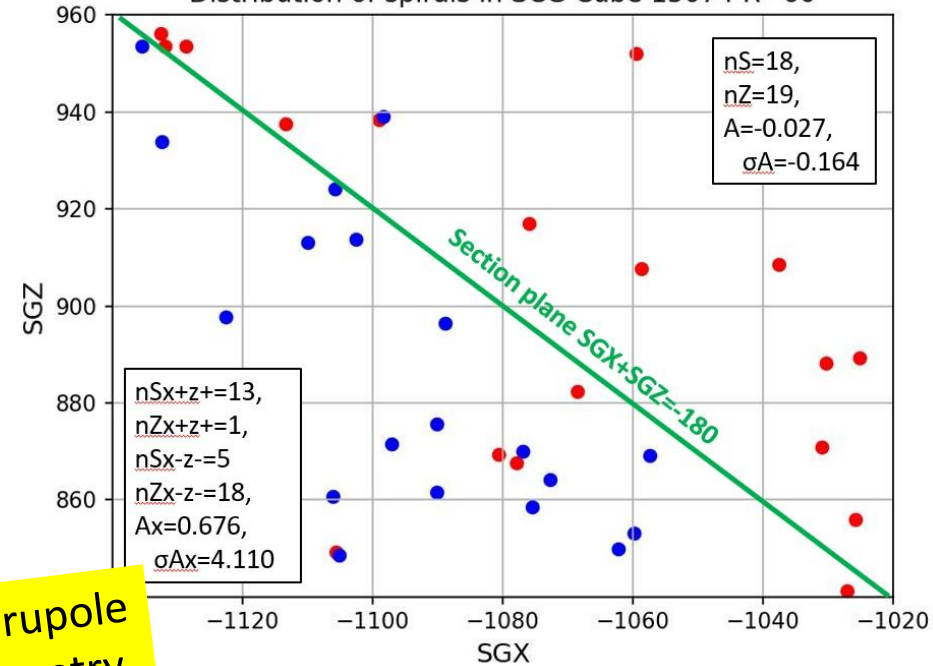
Distribution of spirals in SCG Cube 3309 R=100



Distribution of spirals in SCG Cube 16485 R=60

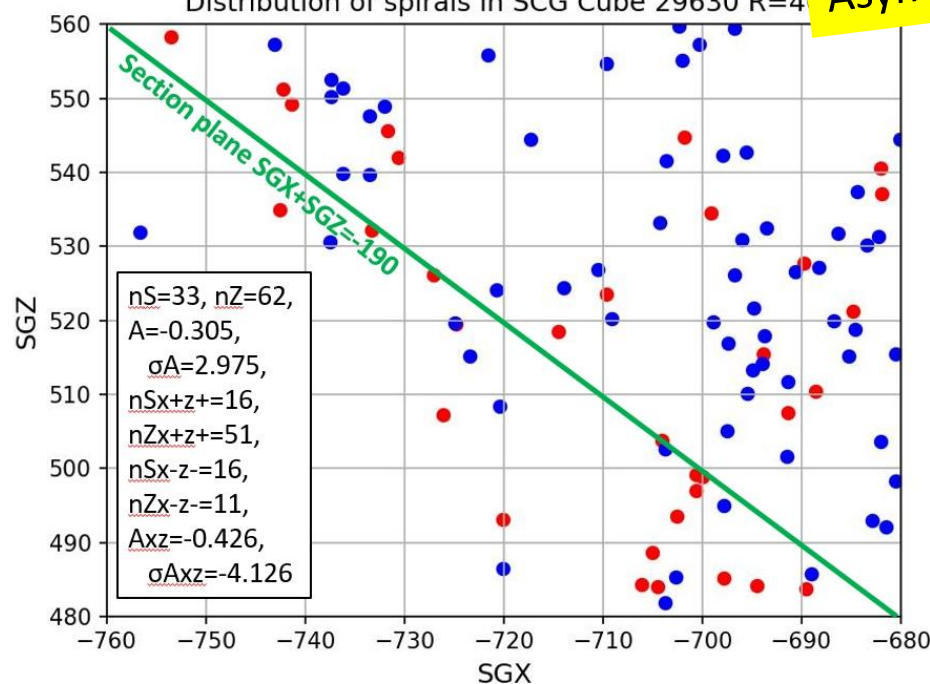


Distribution of spirals in SCG Cube 15074 R=60

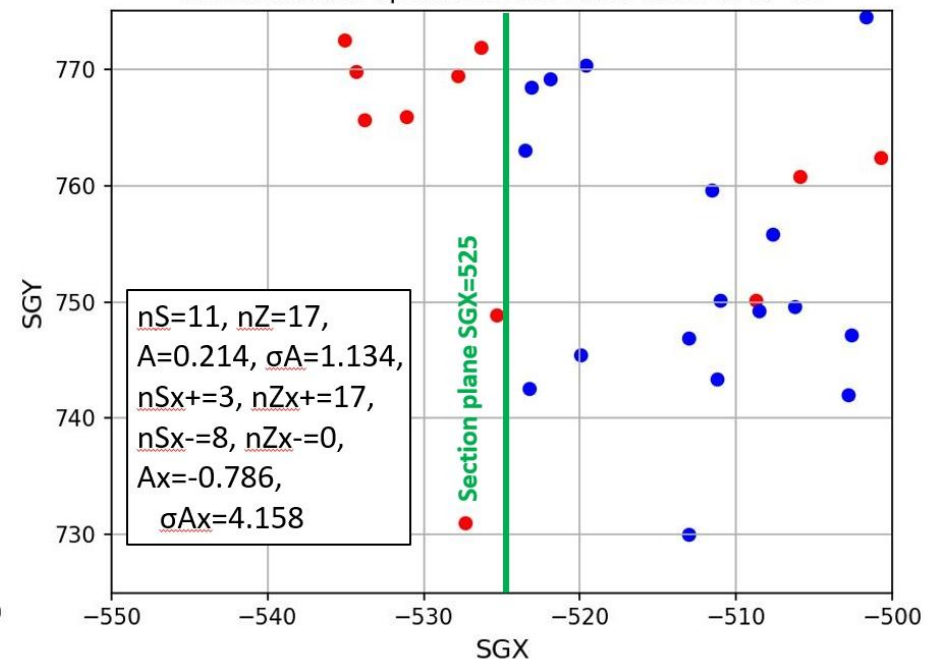


Quadrupole
Asymmetry

Distribution of spirals in SCG Cube 29630 R=4

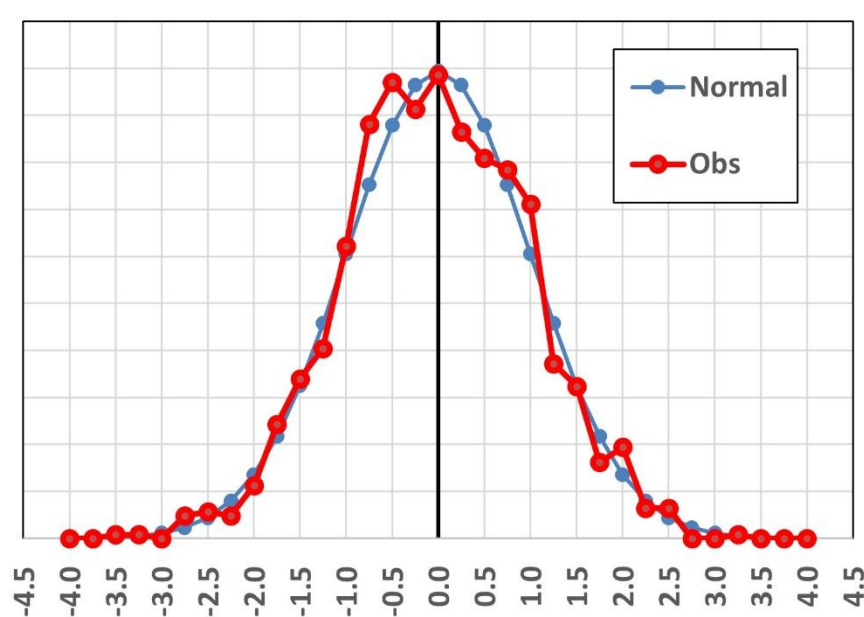


Distribution of spirals in SCG Cube 178946 R=25

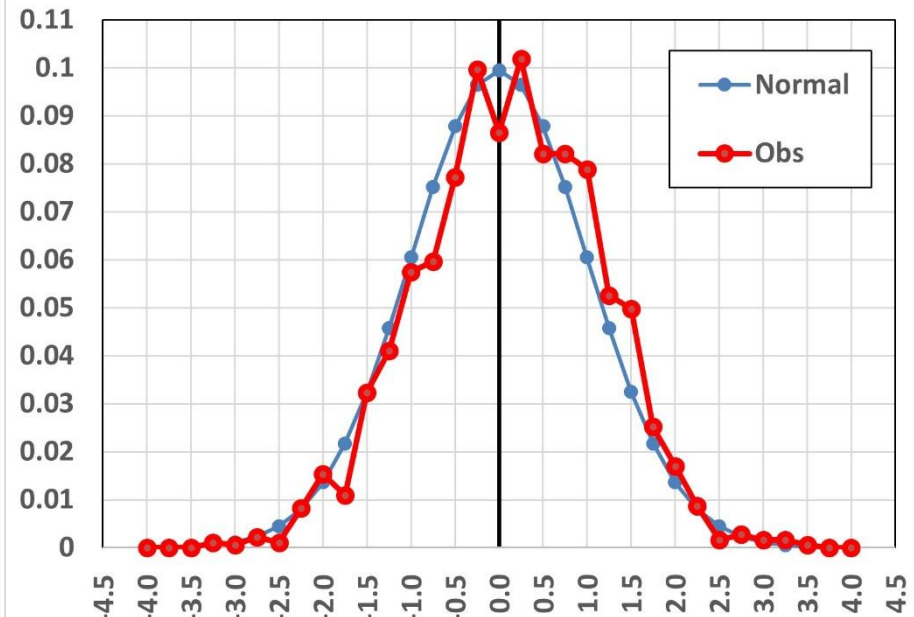


Observed and simulated distributions $f(\sigma_A)$

$f(\sigma_A)$ for R100



$f(\sigma_A)$ for R10



Results

- 13 odd cubes, showing asymmetry σ_A significantly exceeding the statistical expectation level σ_{crit} for an ensemble of n_{cube} searched cubes, were identified in the HSC WIDE survey.
- However, the overall distribution of $f(\sigma_A)$ of 43662 searched cubes appears compatible with the binomial distribution function.
- This implies either that the initial embedded kinematical perturbation was Gaussian or that any memory of initial non-Gaussian perturbation was lost during its later dynamical history.
- Two-point correlation analysis is under way.