Anisotropy Analysis of Spin Vector Distribution in the HSC Survey Volumes

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Aim: Is the observed spin distribution of galaxies random?

Data: HSC Wide Spin Catalogues (Tadaki+2020)

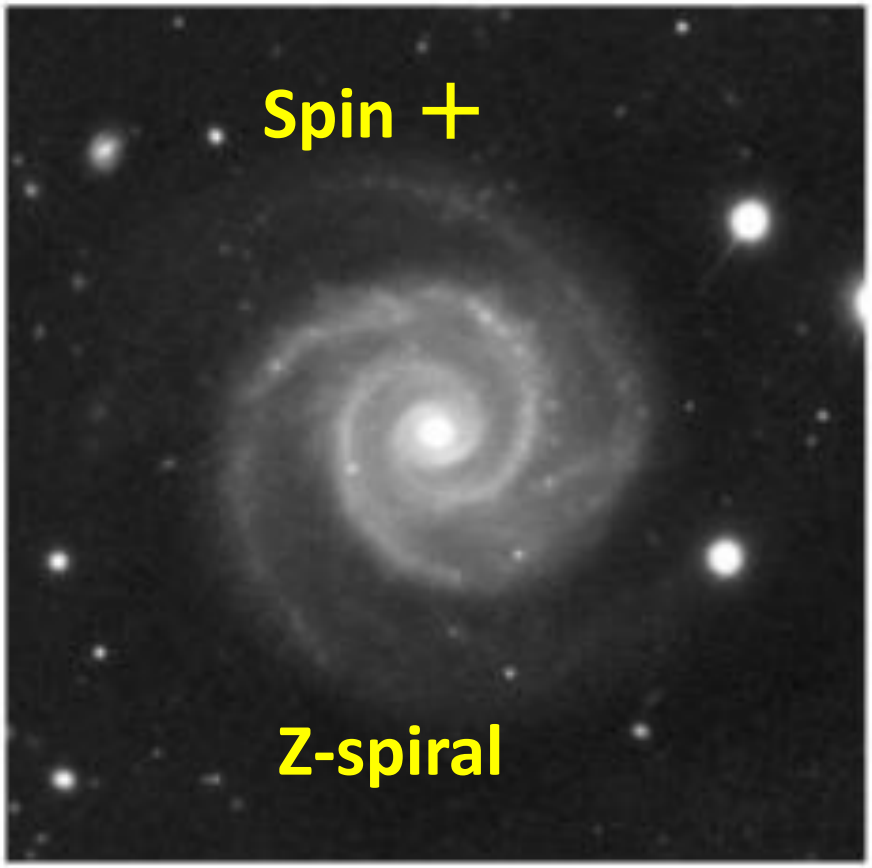
3D distribution of 15757 spiral winding S/Z annotations

(independent and complementary to intrinsic shape analysis)

Methods: Number Asymmetry Analysis for Searched Spheres

Correlation Analysis (TBD)

- Galaxy image database : SDSS, Pan Starrs, DES, ESO DSS, HSC
- Judgement of spiral winding (S or Z) : Eye Tutorial=>AI=>Eye check
- **Distance（15767 spec-z, 37968 PSF fillers TBD）**



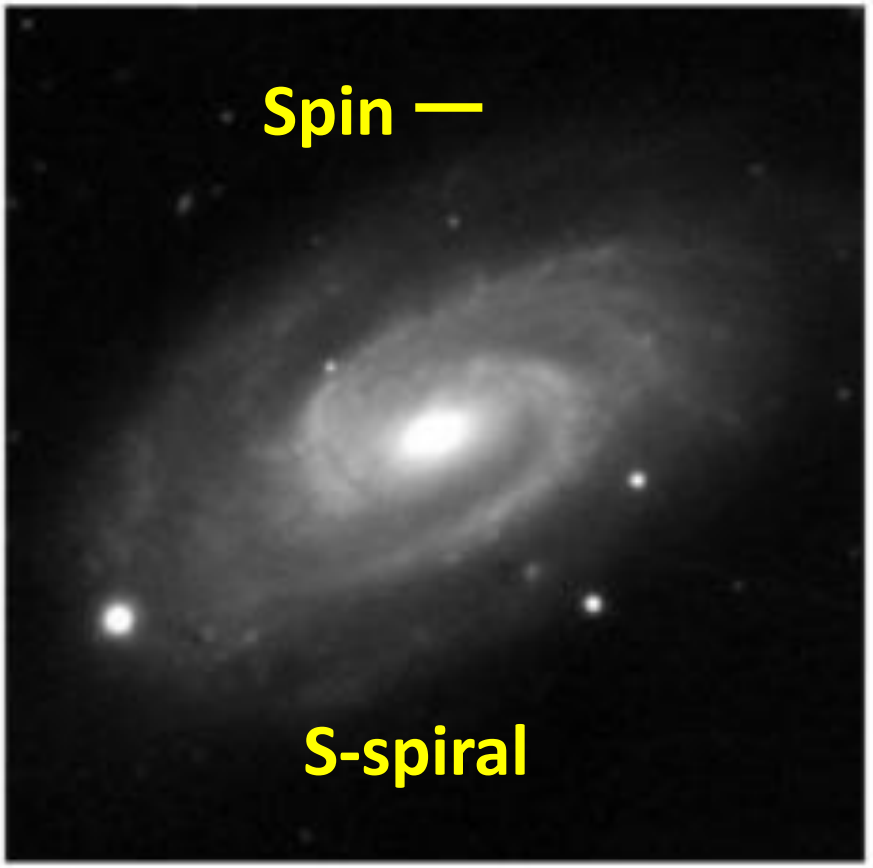
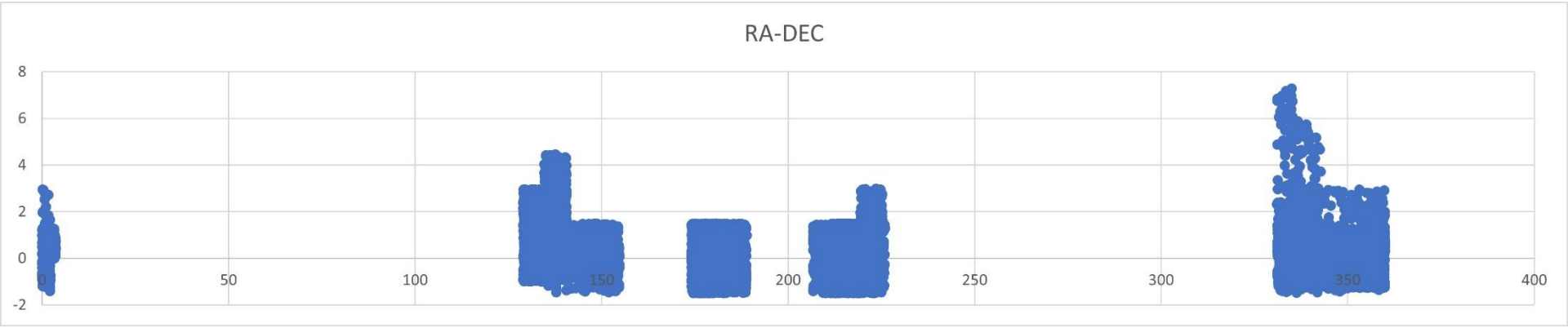
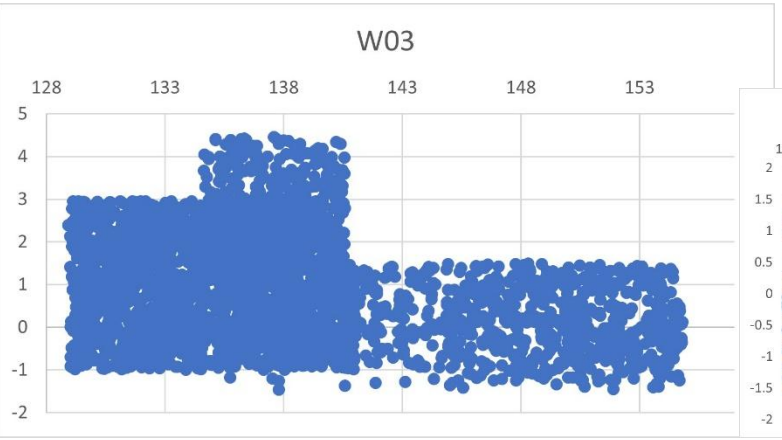
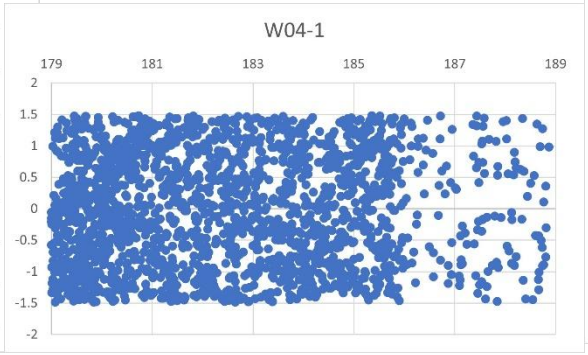


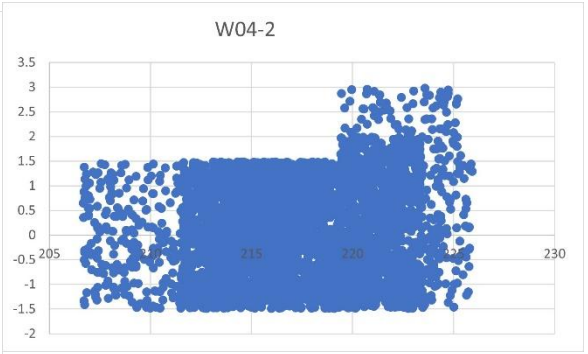
Figure 1. Examples of Z(left), S(center), and inside Z

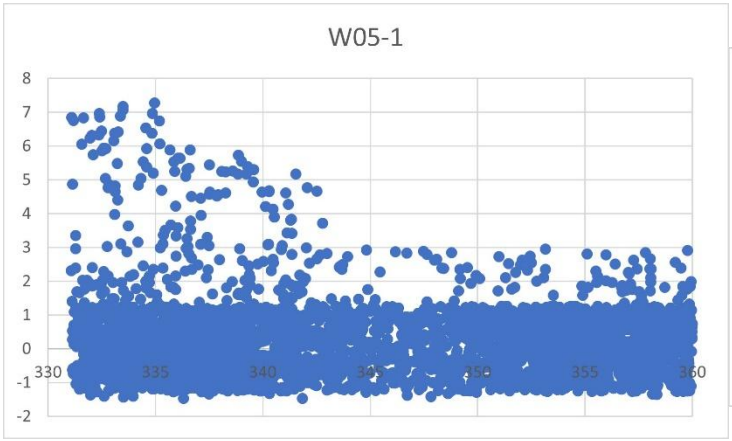
HSC Wide Regions

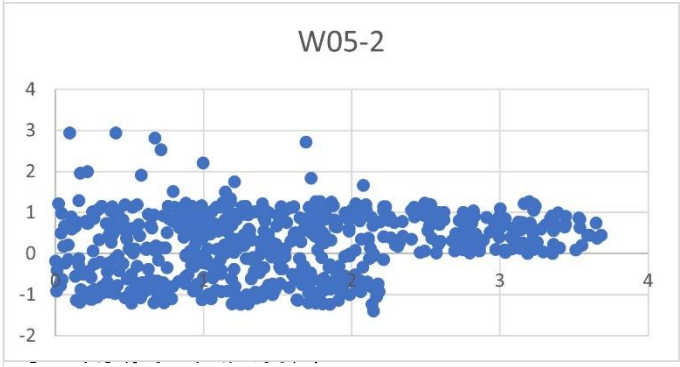


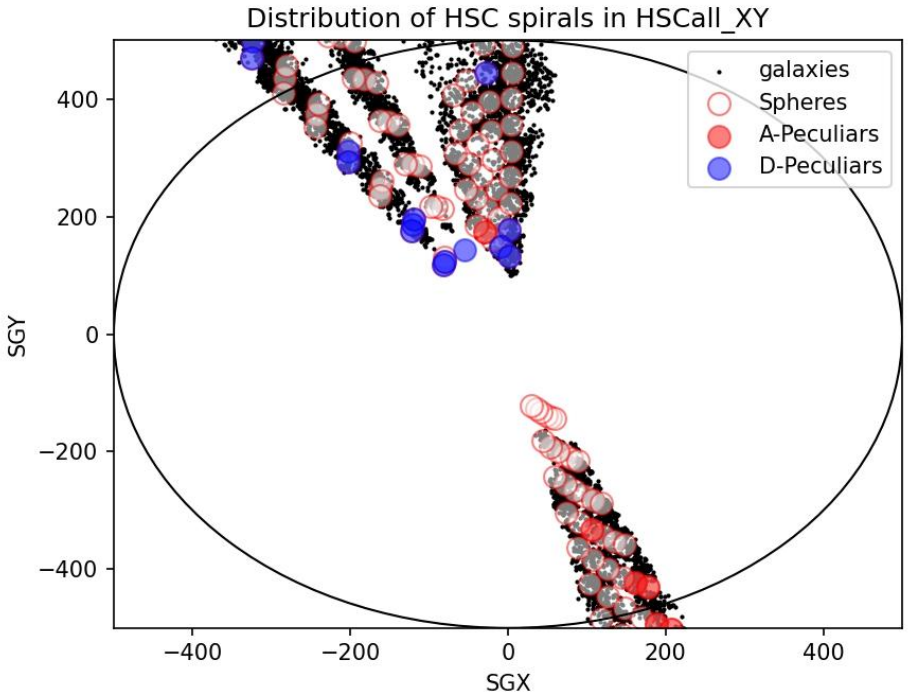


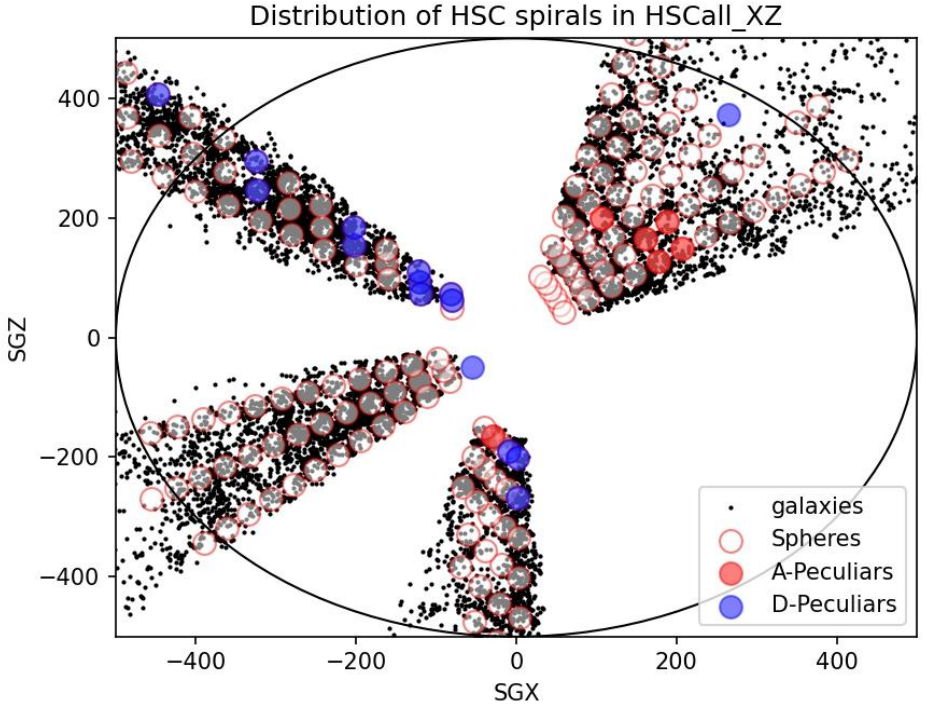


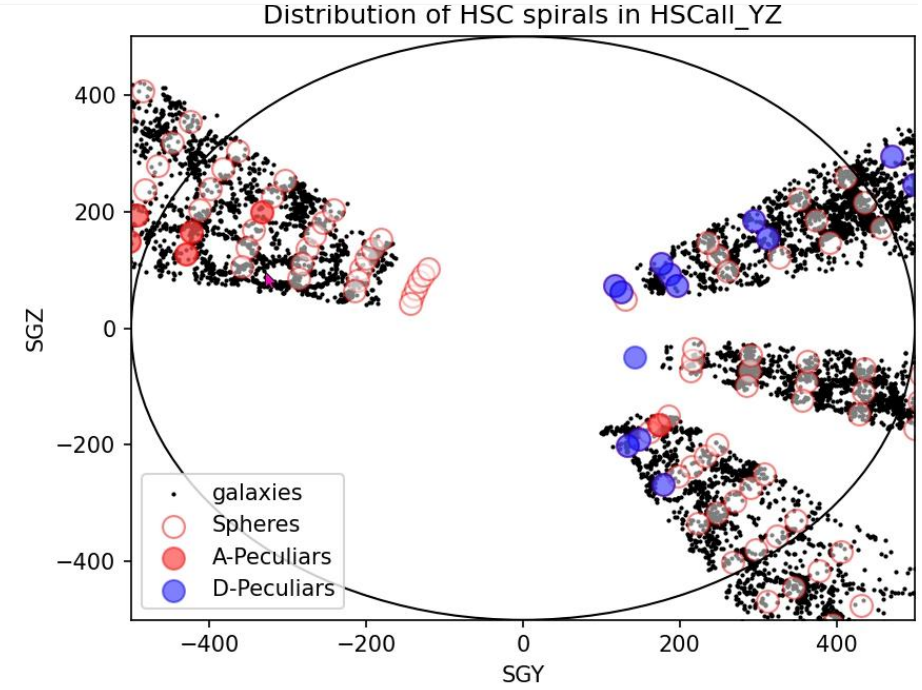








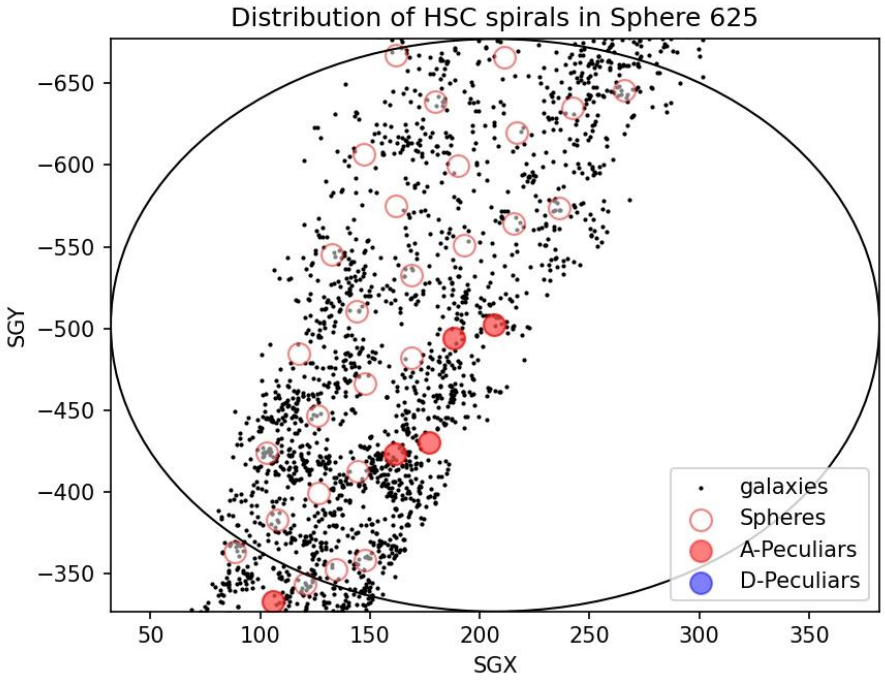


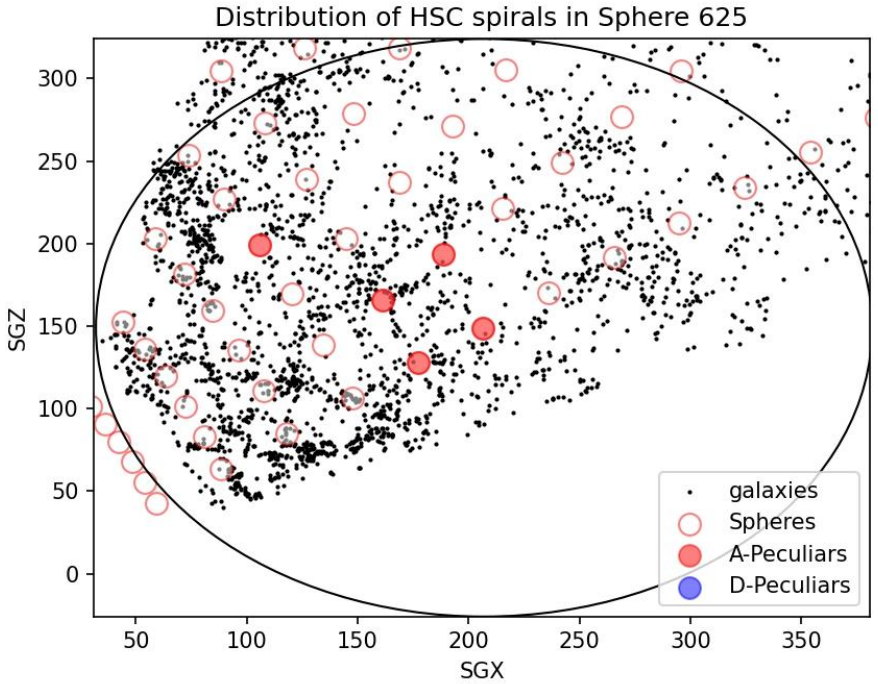


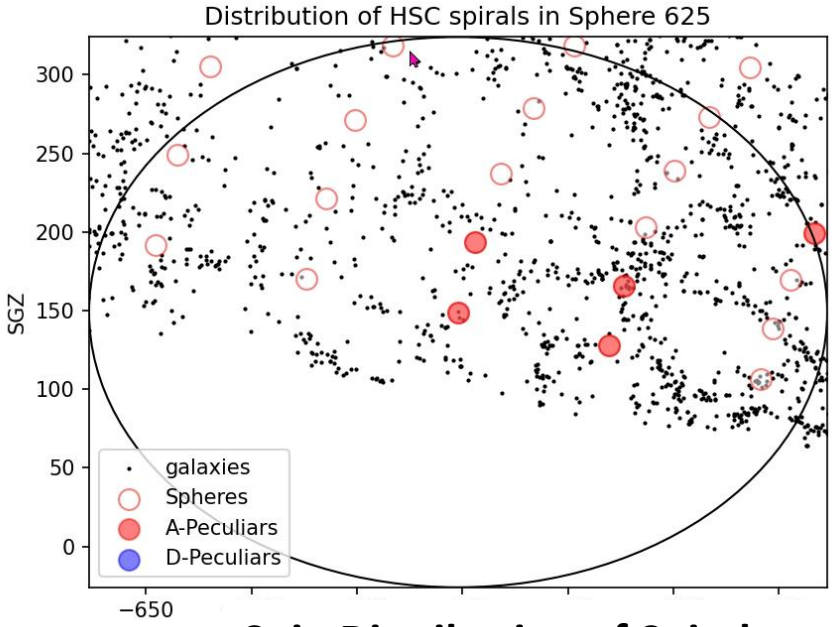
$$A=\{n(S)-n(Z)\}/\{n(S)+n(Z)\},$$
$$\sigma A=\{n(S)-n(Z)\}/\sqrt{\{n(S)+n(Z)\}}$$

187 searched sphere centers
with radius 20~200Mpc

Red spheres :|σA|>3







SphereID652_SA
R=175Mpc, n(all)=887
N(S)=499, n(Z)=388,
A=0.125, σA=3.727

Regions with spin asymmetry appear connected.

13/187 regions identified with $|\sigma A_e|>3$

=> Have we discovered anisotropy?

sphere	RA	DEC	ns	nz	nall	nflip	sigDE	sigDF	sigD	asymA	sigma/	fliprate	proE	thetaE	proF	thetaF
652	-2.1	0.311	499	388	887	329	1.859	2.476	1.867	0.125	3.727	0.371	0.94	19.88	-0.38	112.5
378	-2.1	0.311	568	454	1022	366	1.223	2.549	0.419	0.112	3.566	0.358	0.843	32.49	-0.5	119.8
2275	-7.1	0.311	372	285	657	368	0.197	2.948	-1.92	0.132	3.394	0.56	-0.19	100.8	-0.4	113.3
1199	-2.1	0.311	498	397	895	392	0.676	2.783	-0.83	0.113	3.376	0.438	0.544	57.06	0.239	76.16
2001	-7.1	0.311	391	305	696	386	0.2	2.882	-1.91	0.124	3.26	0.555	0.018	88.99	-0.43	115.3
651	-2.1	0.311	637	526	1163	497	0.466	2.368	-1.31	0.095	3.255	0.427	0.316	71.55	0.143	81.78
1473	-2.1	0.311	422	335	757	320	0.461	2.438	-1.32	0.115	3.162	0.423	0.797	37.15	0.154	81.15
925	-2.1	0.311	572	471	1043	461	0.514	2.44	-1.2	0.097	3.127	0.442	0.662	48.55	0.281	73.71
1727	-7.1	0.311	438	351	789	422	0.395	2.498	-1.47	0.11	3.097	0.535	0.789	37.9	-0.54	122.6
84	-7.1	0.311	797	679	1476	677	0.931	2.12	-0.25	0.08	3.071	0.459	0.988	8.897	-0.38	112.2
632	-7.1	0.311	624	521	1145	580	0.909	2.292	-0.3	0.09	3.044	0.507	0.945	19.08	-0.28	106.5
4429	-17.1	0.311	201	145	346	147	1.159	2.58	0.273	0.162	3.011	0.425	0.564	55.64	-0.88	151.2
5629	148.3	0.984	90	54	144	114	1.745	2.136	1.607	0.25	3	0.792	0.315	71.66	-0.05	92.94

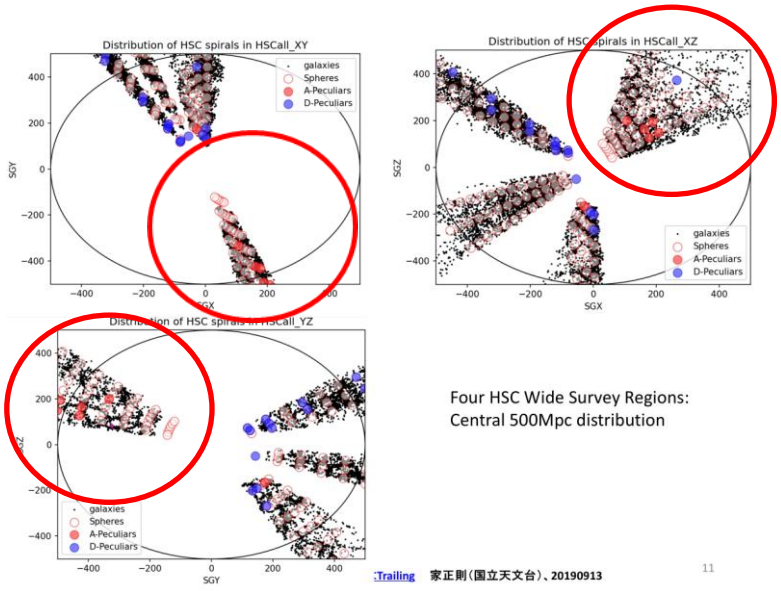
Analysis Outline of HSC volumes

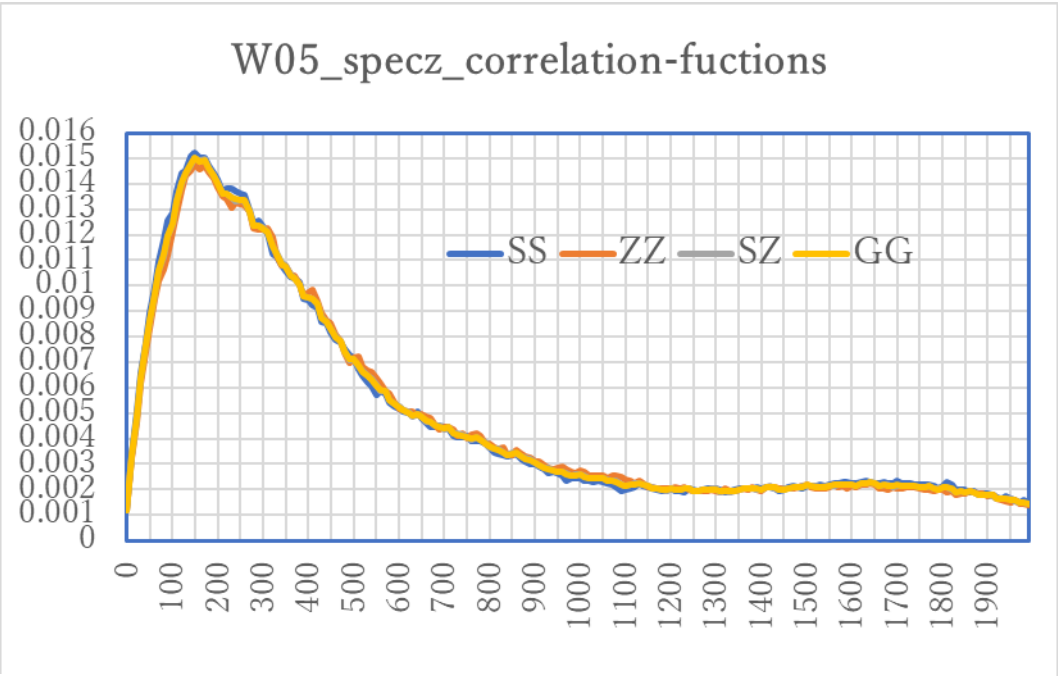
- Use 76355 (S/Z) data of Tadaki+2020 for 4 HSC WIDE regions
- distributed in 4 fan beam regions up to 1 Gpc
  of which 15757 are with spec-z
- 58449 photo-z samples to be measured as PFS Fillers
  Distance = cz (for z<0.3)
- Set up 275 Searched Spheres at 80.4Mpc (dz=0.02) step and corresponding steps in RA & Dec. *Search radius 20 ~200 Mpc.*
- Count n(S), n(Z) and calculate A and sigma.
- 187 spheres contained more than 100 spirals with known S/Z
- 13 spheres in 3 groups with 3σ anisotropy in sigmaA.
- P(σA>3)=0.003
- Inconsistent with random distribution?

S/Z correlation functions

before normalization by random samples

HSC PDR2 W05 Specz sample（RA width 26deg, Dec width 3deg, Distance<3360Mpc)
(SGX, SGY, SGZ) for S-spiral:2206, Z-spiral:2021, G-total:4227 galaxies
Is there a standard cosmological model adopted for HSC analysis?
Pairs: SS＝2432115、ZZ=2041210、GG＝8931651、SZ＝4458326
Distribution functions 0<d<2000Mpc, 10Mpc pitch



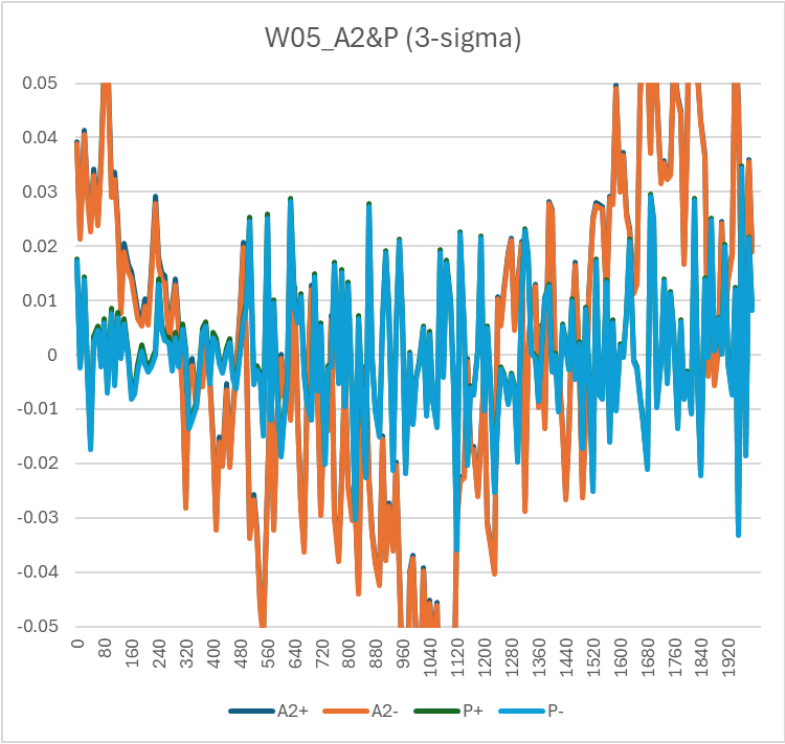


Asymmetry

- A2(d)=(SS-ZZ)/(SS+ZZ)
- P(d)=(SS+ZZ-SZ)/GG

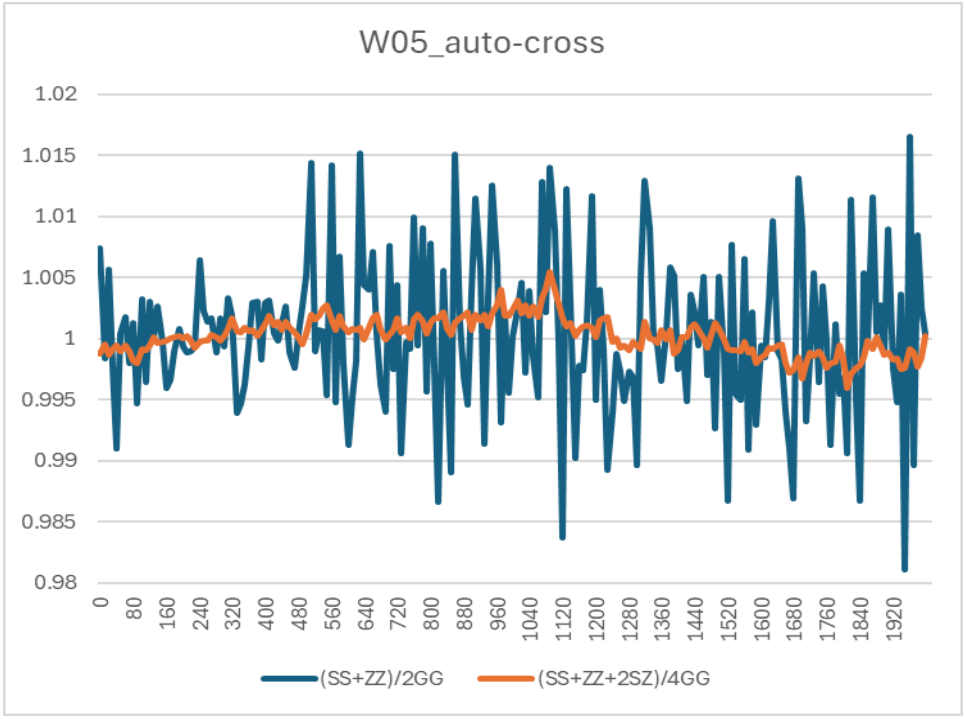
- Analysis normalized

by random data (TBD)



AutoCorr vs CrossCorr

- (SS+ZZ)/2GG
- (SS+ZZ+2SZ)/4GG



(1) Random Assignment Sample

- Observed: S/Z, randomly assigned: s/z for n sets
- Normalization all by GG, where G=S+Z=s+z

SS, Ss, ss, ZZ, Zz, zz, SZ, Sz, sZ, sz, GG

SG, sG, ZG, zG, expect GG=ss=zz, sG=zG

Underscore for n sets ensemble

<SS>=(SS+$\underline{GG}$-2$\underline{SG}$)/$\underline{GG}$, <SZ>=(SZ+$\underline{GG}$-$\underline{SG}$-$\underline{ZG}$)/$\underline{GG}$

<ZZ>=(ZZ+$\underline{GG}$-2$\underline{ZG}$)/$\underline{GG}$

A(d)=(<SS>-<ZZ>)/(<SS>+<ZZ>)

P(d)=(<SS>+<ZZ>-2<SZ>)/(<SS>+<ZZ>+2<SZ>)

(2) Randomly Generated Sample

- Regions : common to observed, sky mask, boundary?
- Distribution: random with common redshift distrib'n
- Depth, Halo Occupation Distribution?, no photo-z
- Normalization:

SS=SS/RR, ZZ=ZZ/RR, SG=SG/RR

SR=SR/RR,ZR=ZR/RR,

<SS>=(SS+RR-2SR)/RR, <SZ>=(SZ+RR-SR-ZR)/RR

<ZZ>=(ZZ+RR-2ZR)/RR

A(d)=(<SS>-<ZZ>)/(<SS>+<ZZ>)

P(d)=(<SS>+<ZZ>-2<SZ>)/(<SS>+<ZZ>+2<SZ>)