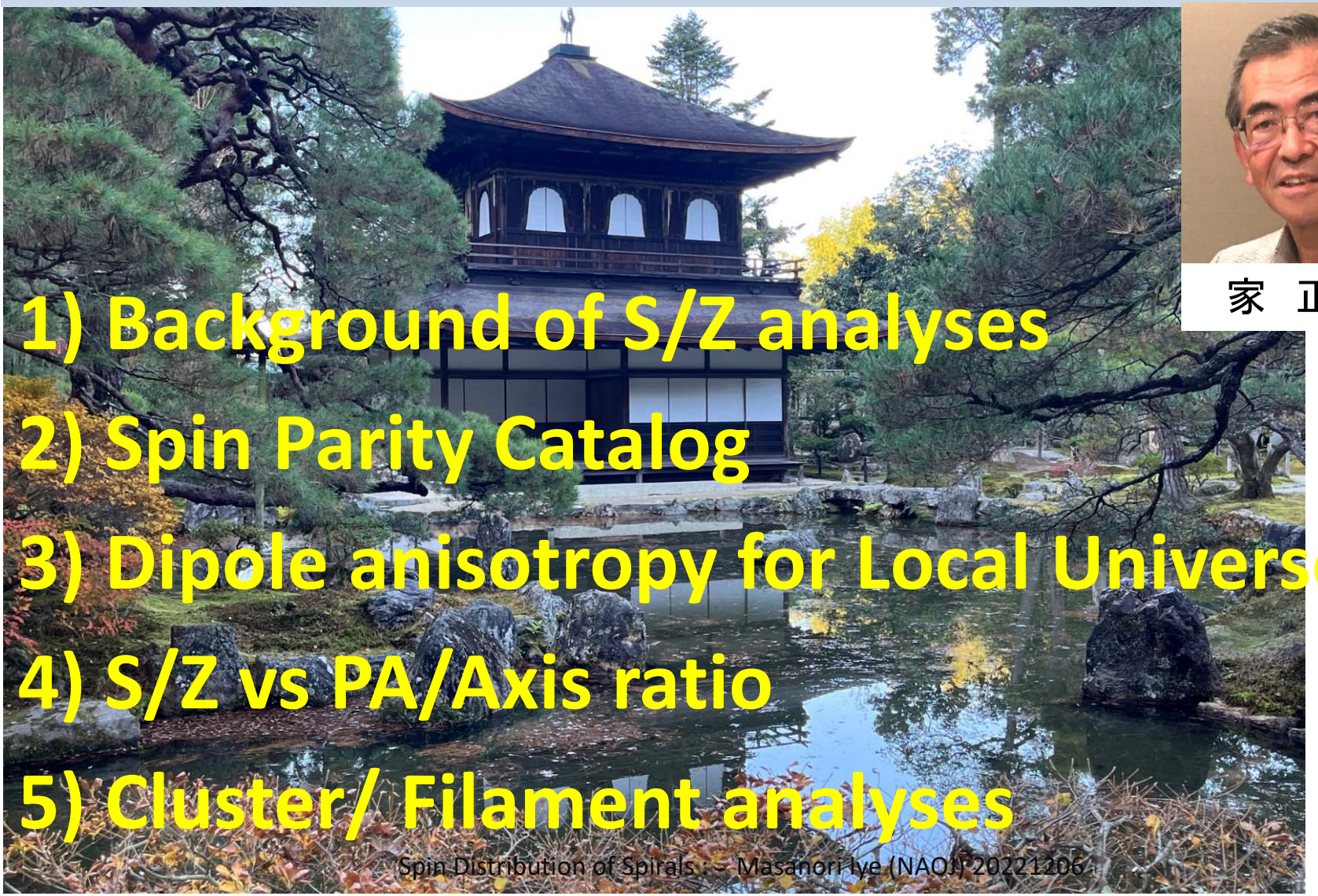
Symmetry Breaking in the Spin Parity Distribution of Spiral Galaxies？

M.Iye(NAOJ), M.Yagi(NAOJ) & H.Fukumoto(Open Univ.)



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1) Background of S/Z analyses

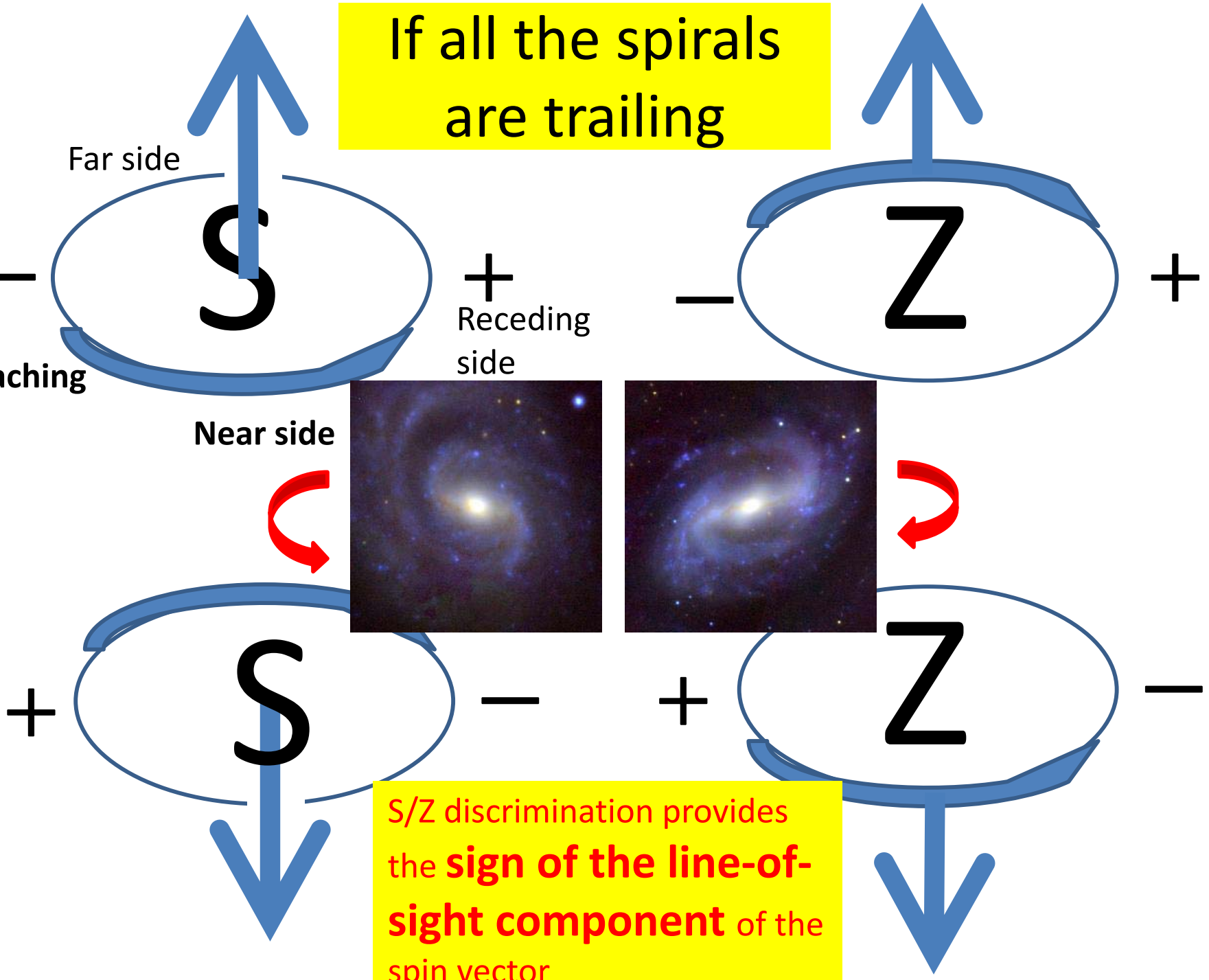
2) Spin Parity Catalog

3) Dipole anisotropy for Local Universe

4) S/Z vs PA/Axis ratio

5) Cluster/ Filament analyses

If all the spirals are trailing



S/Z discrimination provides the **sign of the line-of-sight component** of the spin vector

1) Background of S/Z analyses

Basic Question: Do galaxies spin randomly?

（1）Scalar Density Perturbation : CMB, Galaxy Distribution

Vector Field Perturbation: Vortex Distribution

（2）Theoretical Scenarios of galaxy spin in 1980s

(a) Primordial Swirl, (b) Pan-cake Shock, (c) Tidal Torque,

・・・・・ (d) ΛCDM fluctuation

（3）Observational Test Methods

(a) galaxy axis ratio distribution, (b) position angle distribution

(c) Spin Parity distribution

（4）S/Z Database

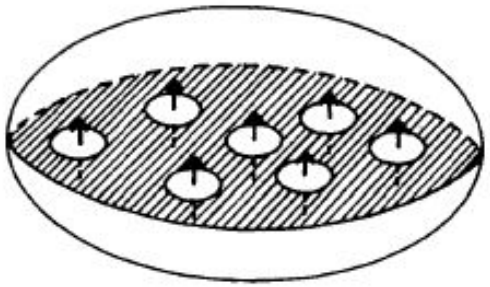
SDSS, Pan Starrs, DES, ESO DSS, HSC, => DL Classification of S/Z

（5）Formalism of dipole analysis and disproving Shamir's papers.

(Iye, Yagi & Fukumoto, 2021, ApJ 907,123)

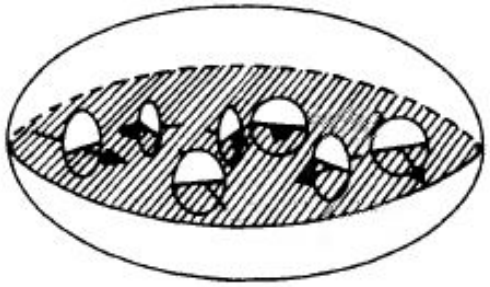
(1) Origin of cosmic vortex field Galaxy Formation Schemes

(a) Primordial Whirl
Weizsaecker 1951
Gamow 1952
Ozernoi 1974



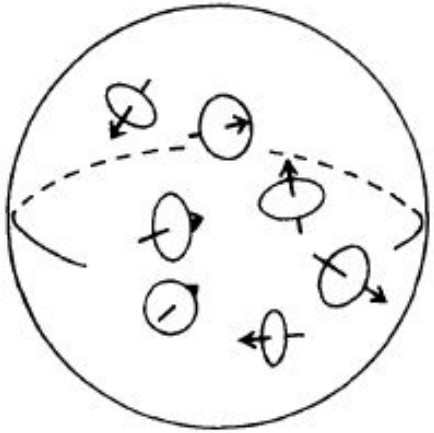
a)

(b) Pan cake collapse
Zeldovich 1978
Doroshkevich 1973
Shandarin 1974



b)

(c) Tidal torque
Peebles 1978
Barnes Efstathiou 1987

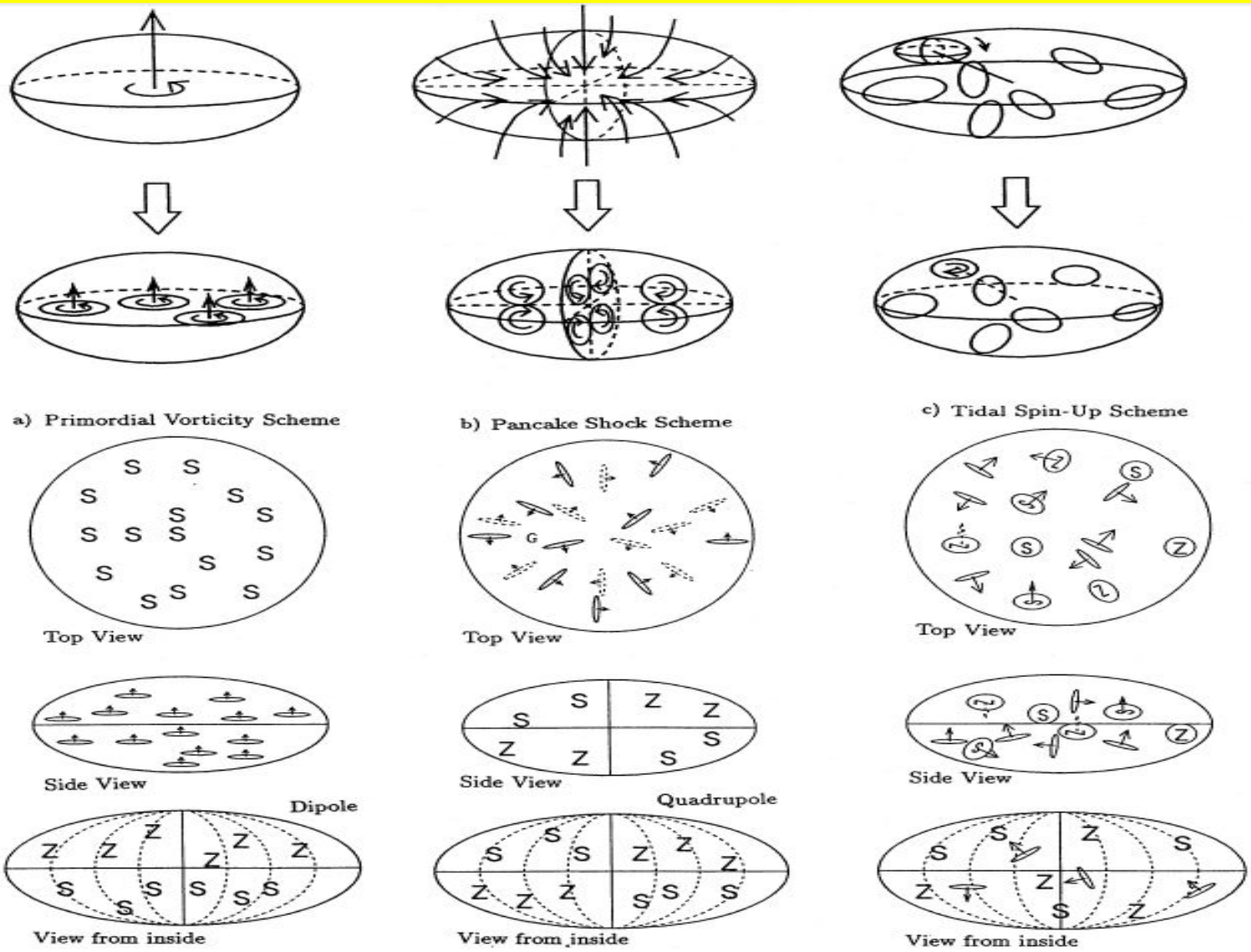


c)

Modern Standard
(d) ΛCDM Structure Formation
Random Gaussian,
Harrison-Zel'dovich spectrum

cluster-galaxy tidal force
galaxy-galaxy tidal force
Orbital mixing

Inferred anisotropy Sugai & Iye 1995



Studied 8,800 spirals but found none.

Only for M31, we knew for sure its near side from differential reddening of GCs.

Iye & Richter 1985

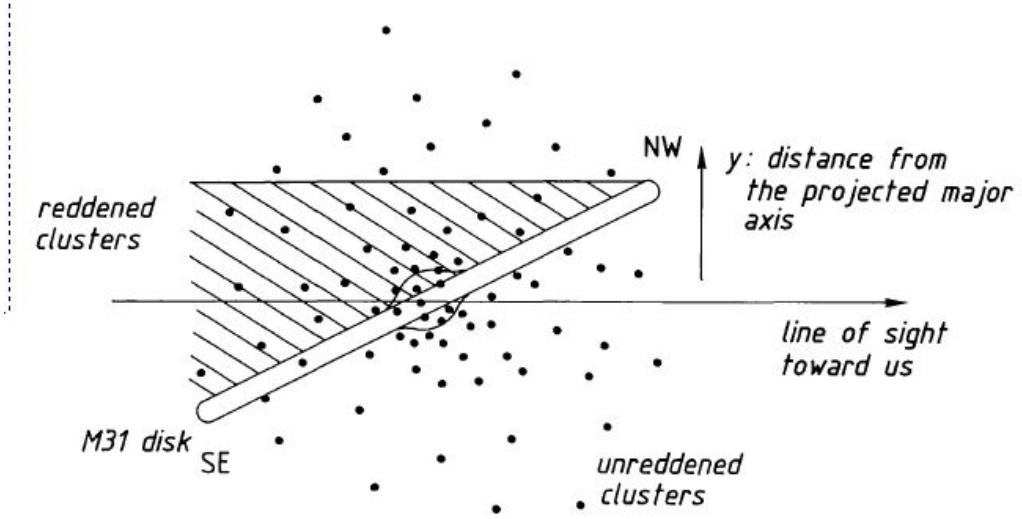
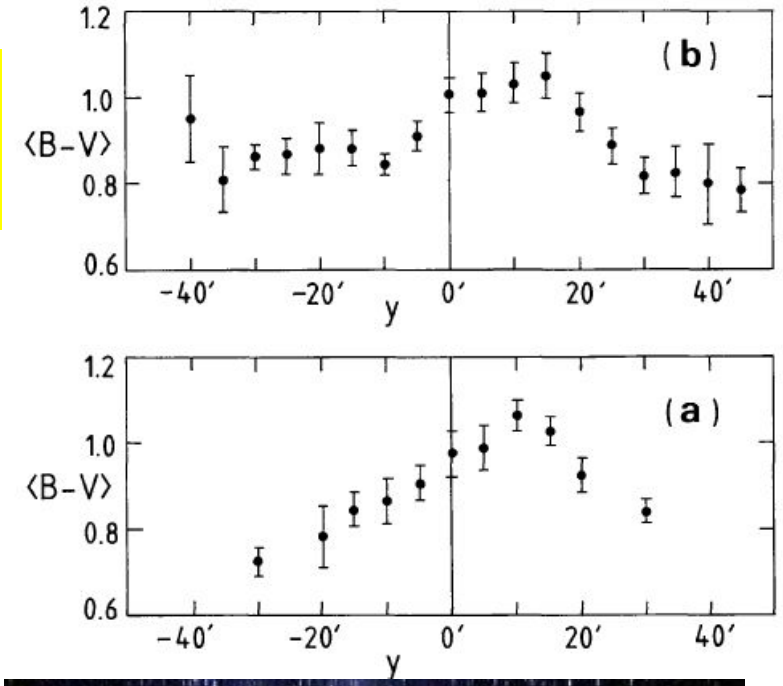
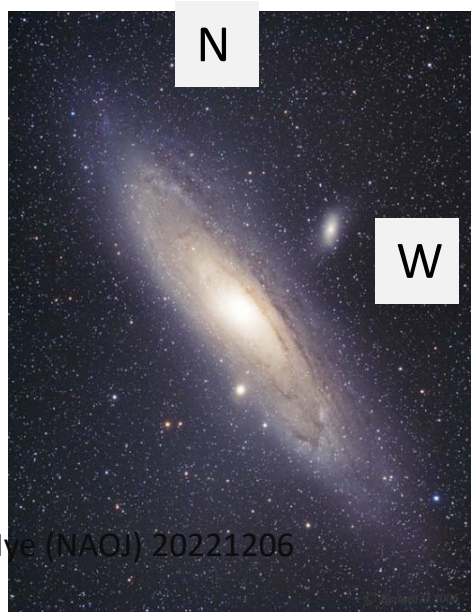


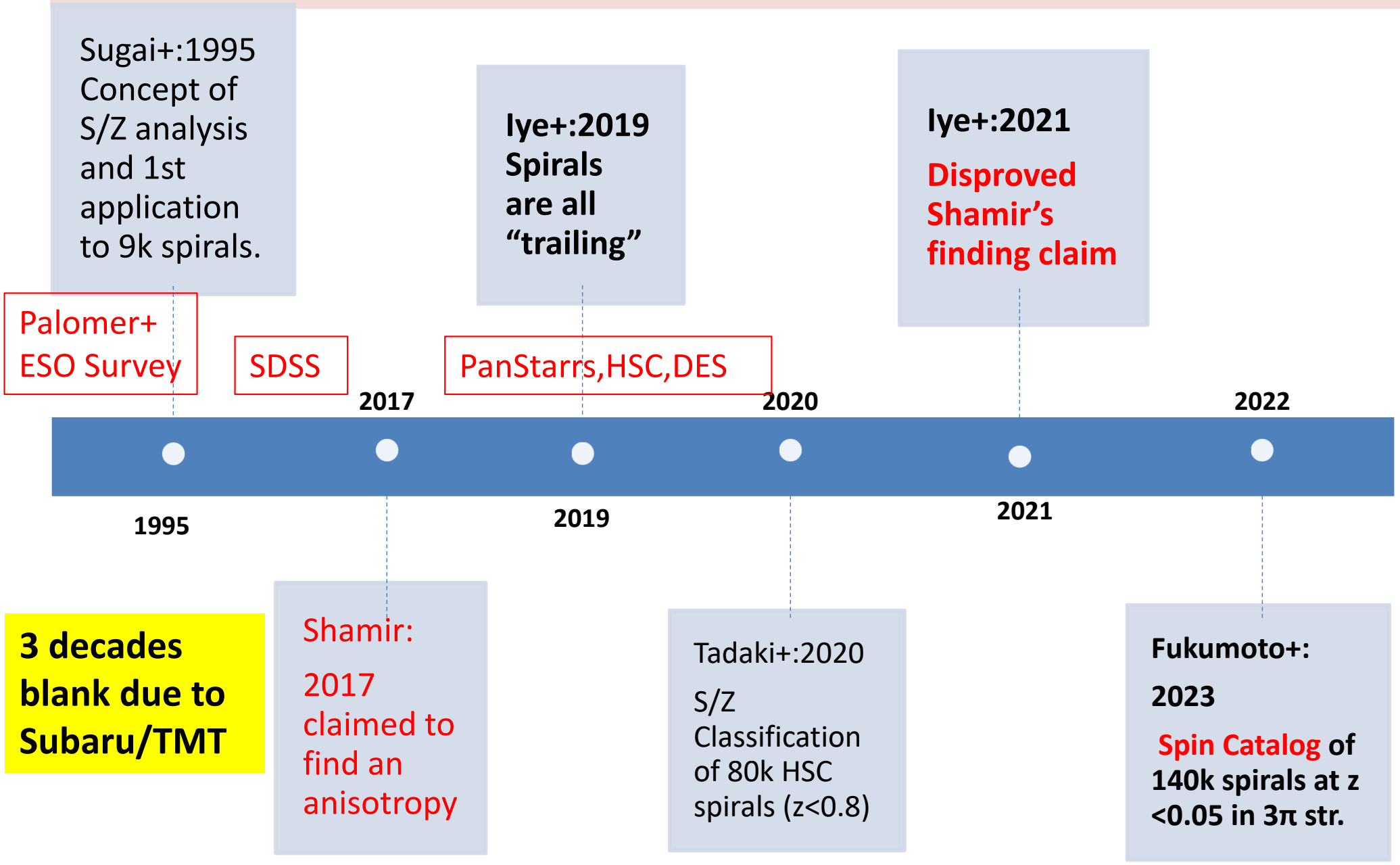
Fig. 1. Sketch of the distribution of reddened and unreddened globular clusters in M 31





For M31, the NW dark side is the near side.

1) Background: *Any asymmetry in galaxy spin vector distribution?*



"Corroborative Evidence for Trailing Spirals"

— 146 Spiral Galaxies—

Iye, Tadaki, Fukumoto 2019: ApJ

Table 1. Observationally confirmed spin parity of spiral galaxies

ID	S/Z Side	Dark Side	Appr.	T/L	Image1	Image2	Image3	Image4
Circinus Galaxy	S	SE	NE	T				
IC1683	Z	W	N	T				
IC1755	S	SW	SE	T				
IC2101	S	NE	NW	T				
IC5376	Z	W	N	T				
MCG-02-02-030	Z	SW		T				
NGC224	S	NW	SW	T				
NGC247	S	E	N	T				

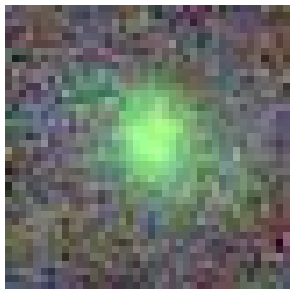
All the spirals are Trailing!

Enables identification of the sign of the line-of-sight component of the spin angular momentum vector just from S/Z spiral patters

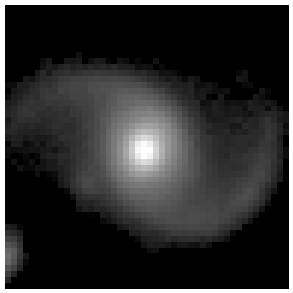
=>

Galaxy Image Archives

	HSC	DES	PanStarrs	SDSS
Depth	**r<26.5**	R<24.4	r<23.2	r<20.8
redshift	<0.8	<0.1	<0.1	<0.05
Area(deg^2)	456	5,000 (**South**)	**30,000**	14,055



PS2

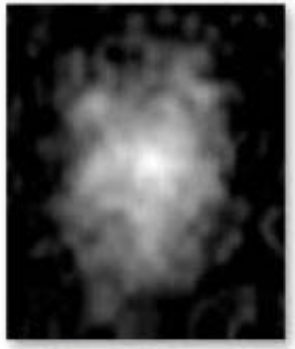


HSC

41135358515108699 (z=0.37)

PGC001922_DES.jpg

PGC001922_DES.png



PGC001922_DSS.png

PGC001922_PS1.jpg

Typical Examples

Yagi+2022 ADASS

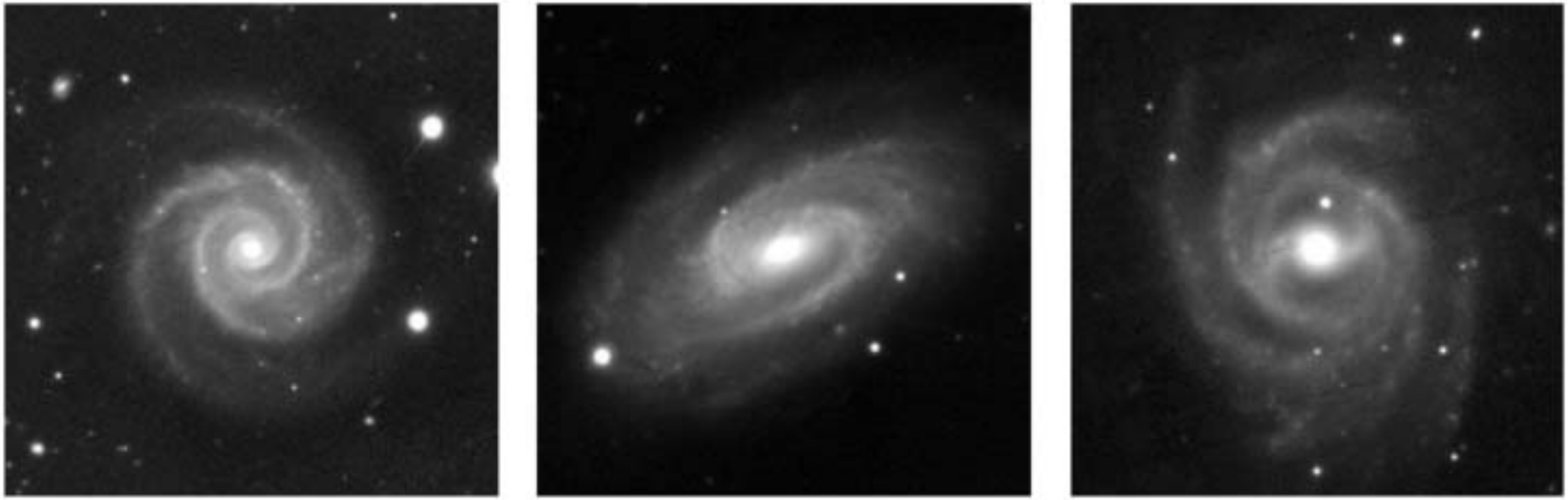
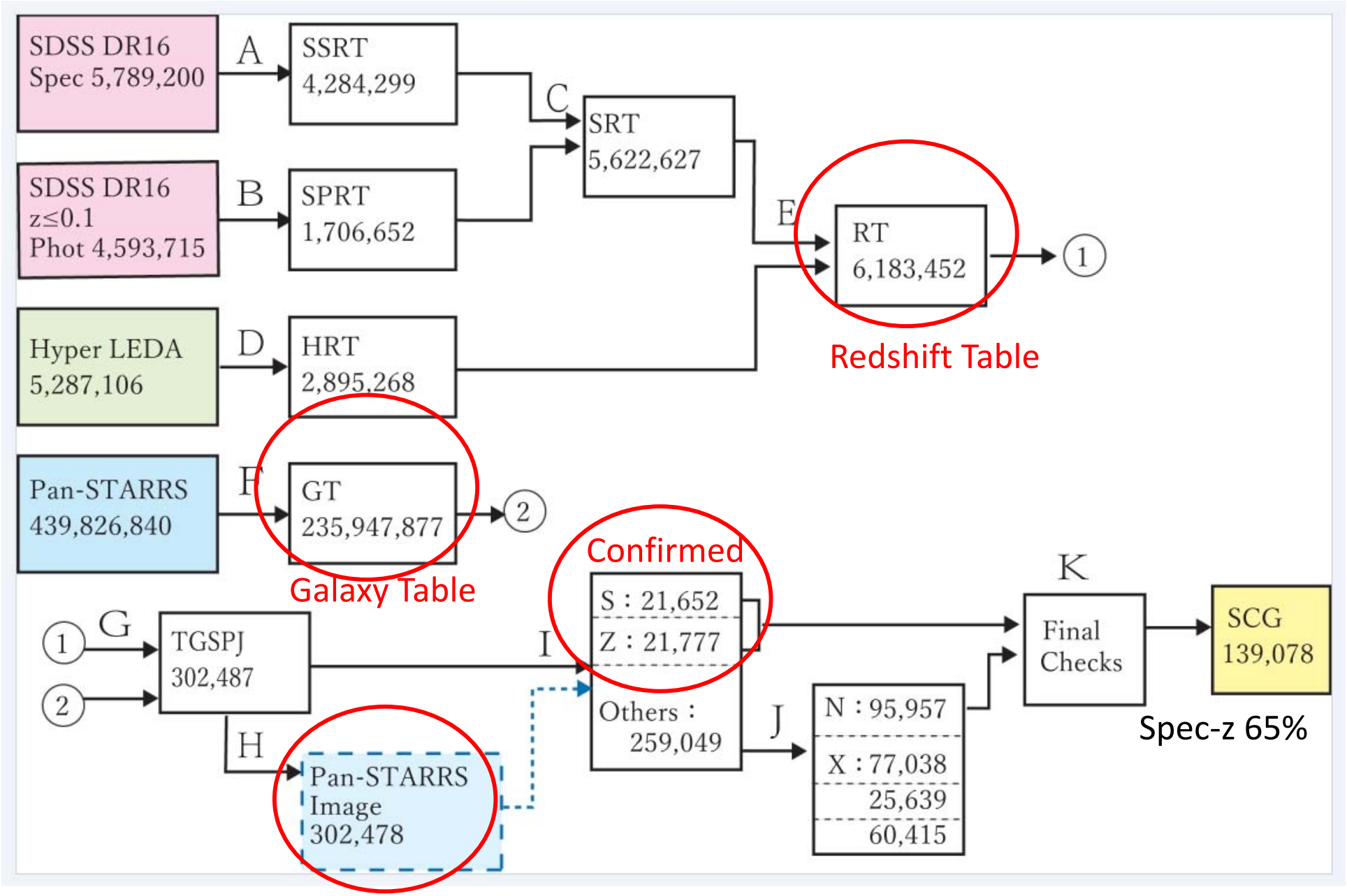
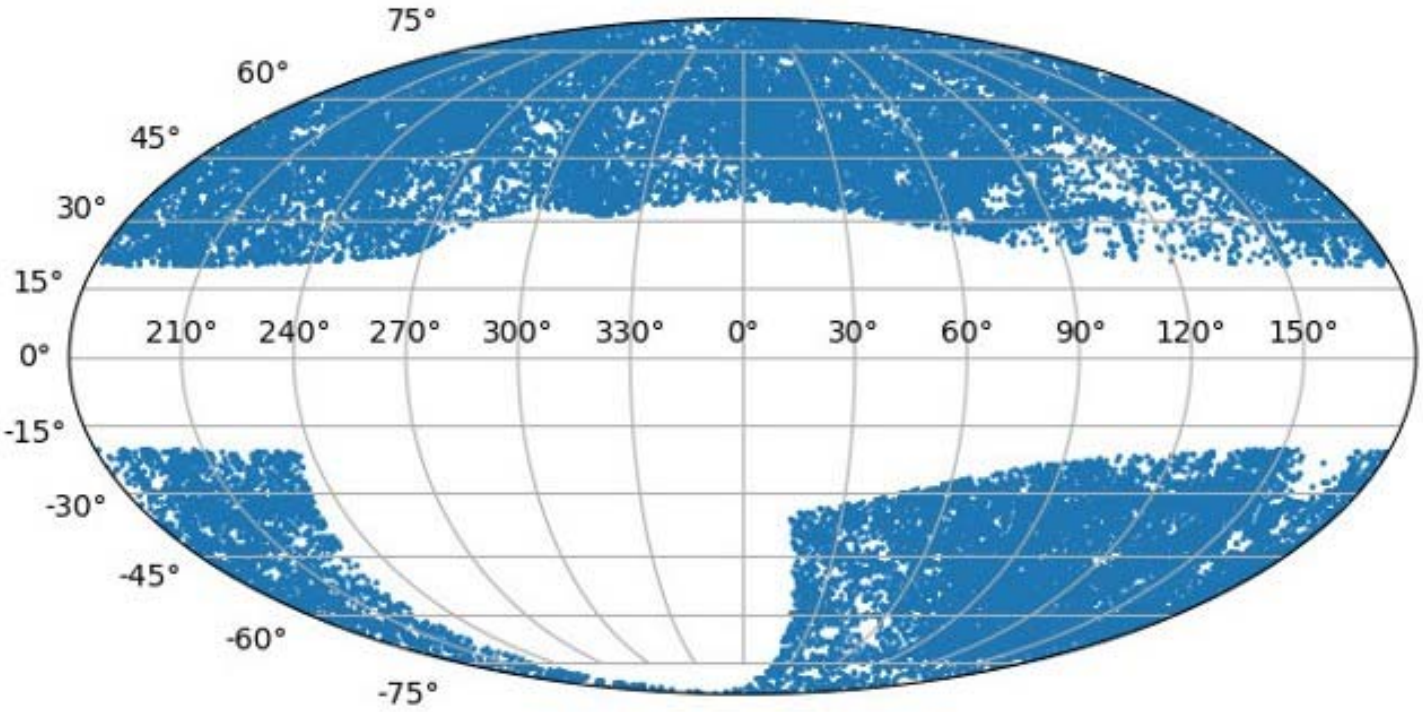


Figure 1. Examples of Z(left), S(center), and inside Z outside S(right)

Spin Parity Catalog of Disk Galaxies

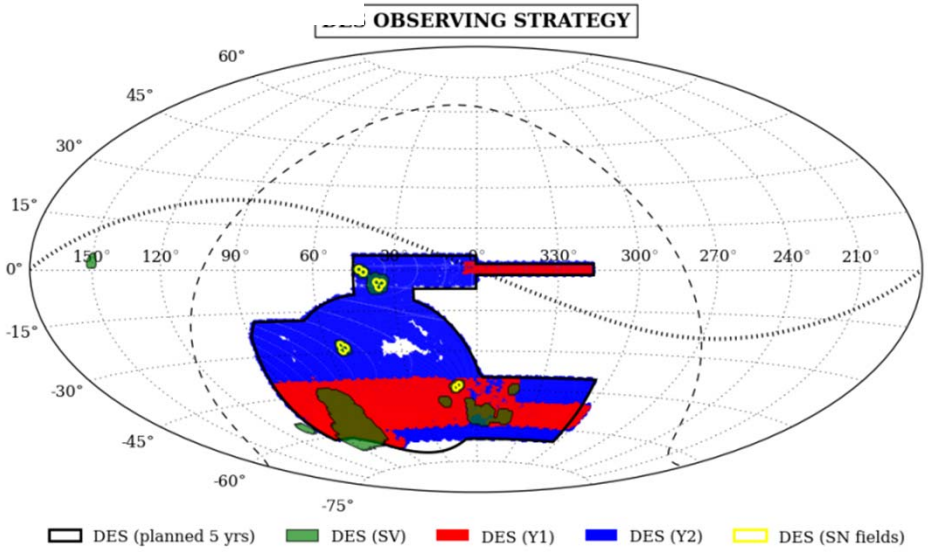


2) Spin Catalog of galaxies



Fukumoto+2023
PanSTARRS Survey samples studied

Dark Energy Survey
samples to be added



Objects with misassigned redshift at z ∼0

Yagi+2022 ADASS

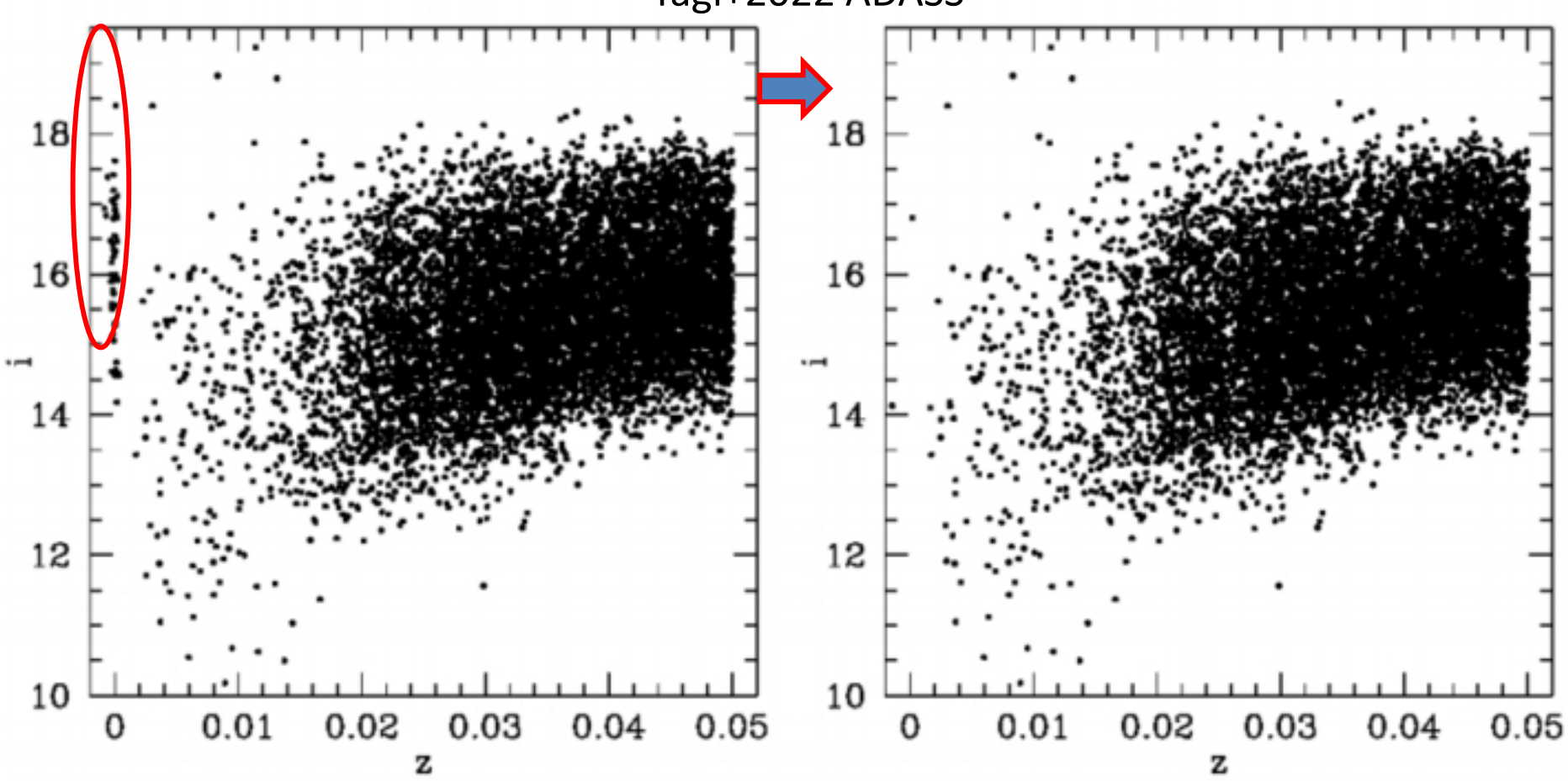


Figure 2. Redshift vs magnitude diagram of galaxies whose helicity is identified. Those with SDSS spectroscopic redshift are plotted. The y-axis is PanSTARRS i-band Kron magnitude. Before(left) and after(right) cleaning inappropriate redshift.

Objects with misassigned redshift

Yagi+2022 ADASS XXXII

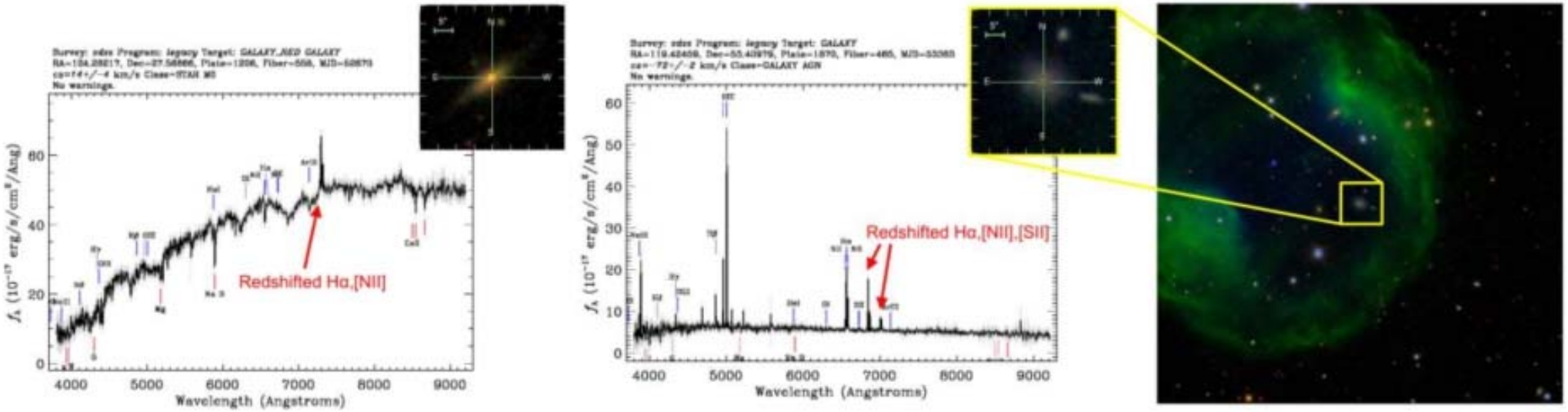


Figure 3. Examples of overlapping spectrum. Left: A foreground star located in front of a background galaxy. The SDSS spectrum shows redshifted Hα, [NII], and [SII] (z=0.1112). Center: A galaxy behind a Galactic planetary nebula. It is not obvious in the default size postage stamp image that the galaxy is covered with an foreground object. The spectrum shows emissions at z=0 and z=0.0429. Right: Zooming out the field around shows the signs of an extended planetary nebula.

Call for simulation studies on spin parity distributions identifying the **spin vectors** not just from the shape but from the vortex motion.

This is a complementary approach to the shape analyses and disentangles the 4 fold or 2 fold degeneracy associated in the shape analysis.

3) Anisotropy Analysis in the Local Universe

Dipole vector:

$$\vec{d} = \left[\sum_N h_i f_i \vec{g}_i \right] / N$$

h_i : helicity

f_i : flip probability from viewer

$\vec{g}_i$: directional unit vector

Dipole Error for data set with void regions.

$$\|\vec{d}\| = \frac{2\sqrt{2(1+\sin\theta_{\min}+\sin^2\theta_{\min})}}{\sqrt{3\pi N}}.$$

Paper III: Iye+ (2021)

Dipole formulation and with error evaluation and application to SDSS sample. ApJ, 907,123

h^i = +1(Z-wise), -1(S-wise)

$$D(l_P, b_P) = \sum_{i=1}^{N} h^i \Omega^i \mathbf{P}/N = \sum_{i=1}^{N} h^i \cos\theta^i/N \quad (2)$$

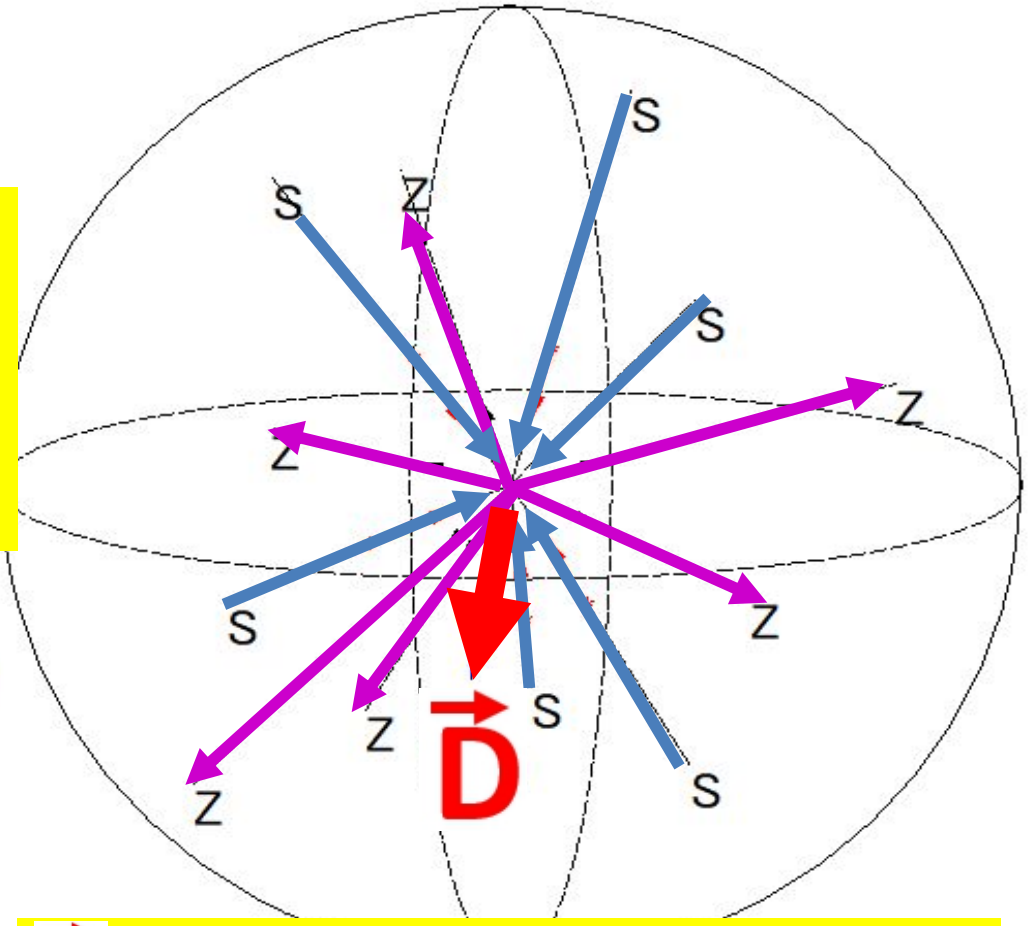
If random

3D random flight : $\vec{D}$ is Gaussian distribution (Chandrasekhar 1943) and D^2 follows chi-squared distribution with 3 dof.

$$W(\mathbf{R}) = \frac{1}{(2\pi N\langle r^2\rangle_{Av}/3)^{\frac{3}{2}}} exp(-3|\mathbf{R}|^2/2N\langle r^2\rangle_{Av}) \quad (3)$$

$$\overline{D}_{max} = \frac{\sqrt{2}\Gamma(2)}{\sqrt{3N}\Gamma(3/2)} = \frac{2\sqrt{2}}{\sqrt{3\pi N}} \sim \frac{0.921}{\sqrt{N}}. \quad (4)$$

$$\sigma_D \sim (D_{max}\sqrt{N} - 0.921)/0.389. \quad (6)$$



$\vec{D}$: N step 3D random flight

Dipole anisotropy in the Local Super Cluster (?) Shamir (2017), Iye+(2021)

Confirmed 4 σ dipole for Shamir's data.

But found data flaw. 160k =>75k sample.

Cleaned data do not show dipole anisotropy.

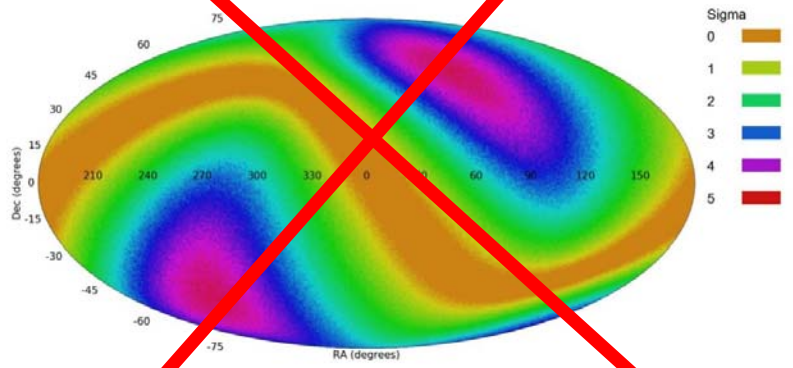
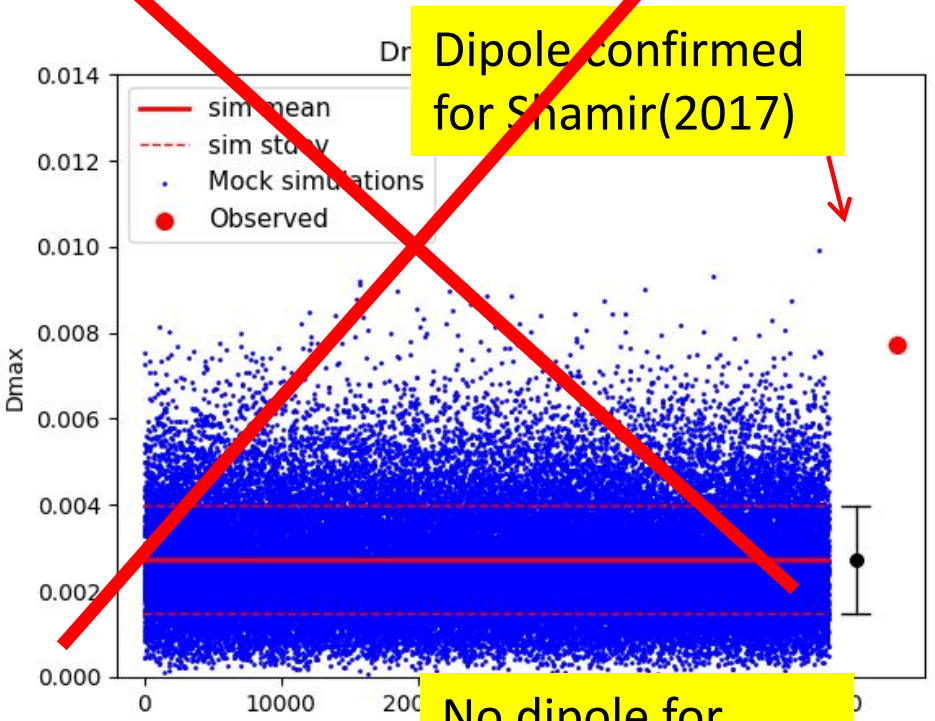
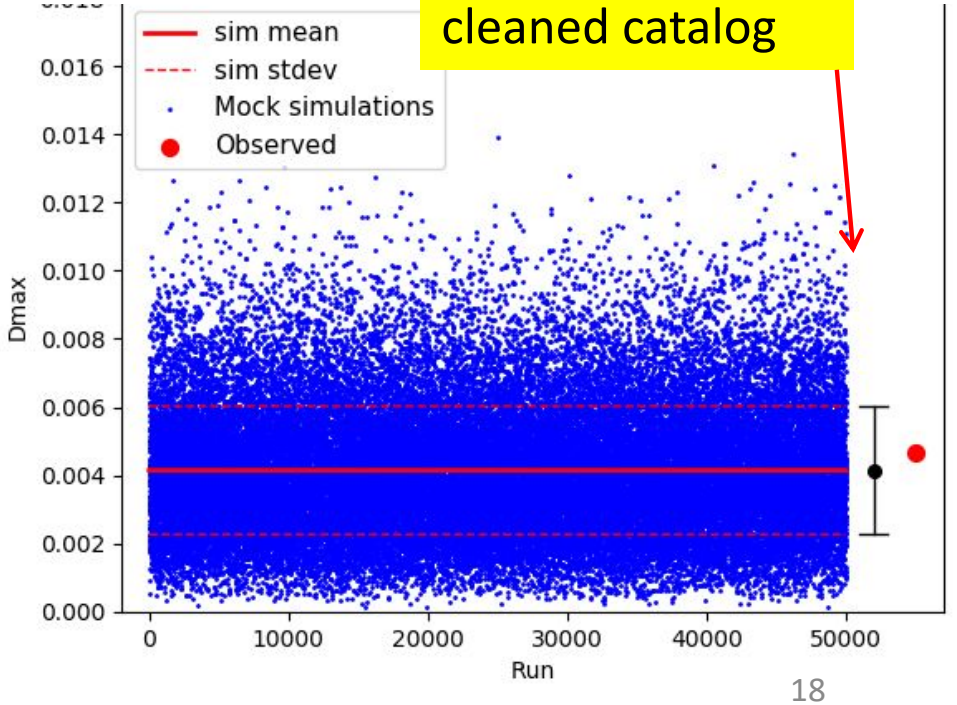


Fig. 5 The σ of the likelihood of a dipole axis of SDSS galaxies in different (α, δ) combinations





4) Comments on PA/Axis ratio studies

- Galaxy axis ratio distribution
- Galaxy position angle distribution

(MacGillivray et al 1982, Helou 1984,
Trujillo et al 2006, Lee & Erdogdu 2006)

Error ambiguity

- Spiral winding sense S/Z

＝＞ 1 bit info but robust

（Thompson 1973,
Borchkhadze&Kogoshvili 1976,
Yamagata et al 1981,
Iye ＆ Sugai1991, Sugai & Iye 1995)

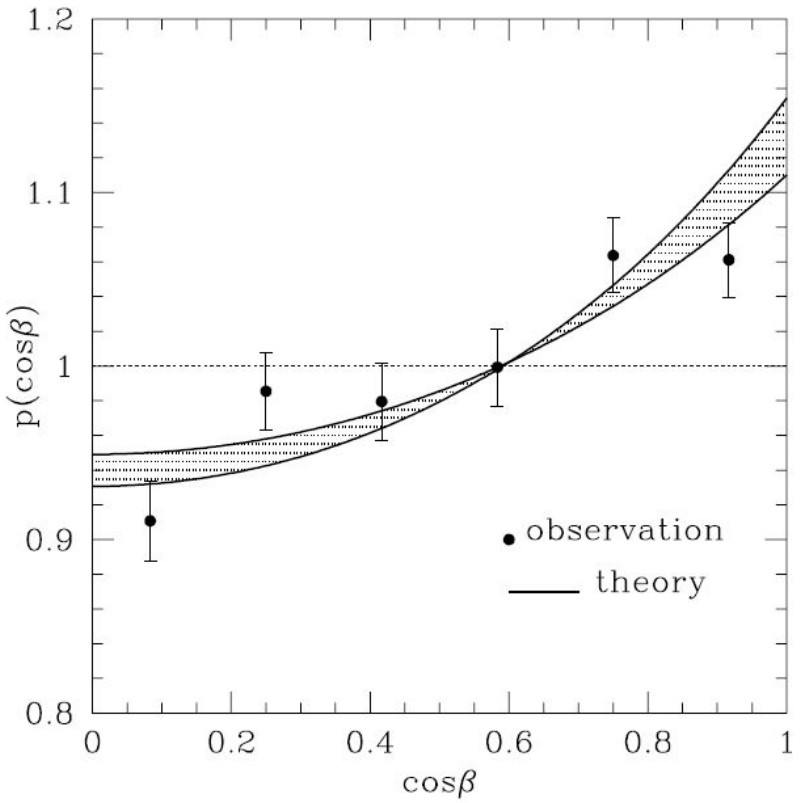
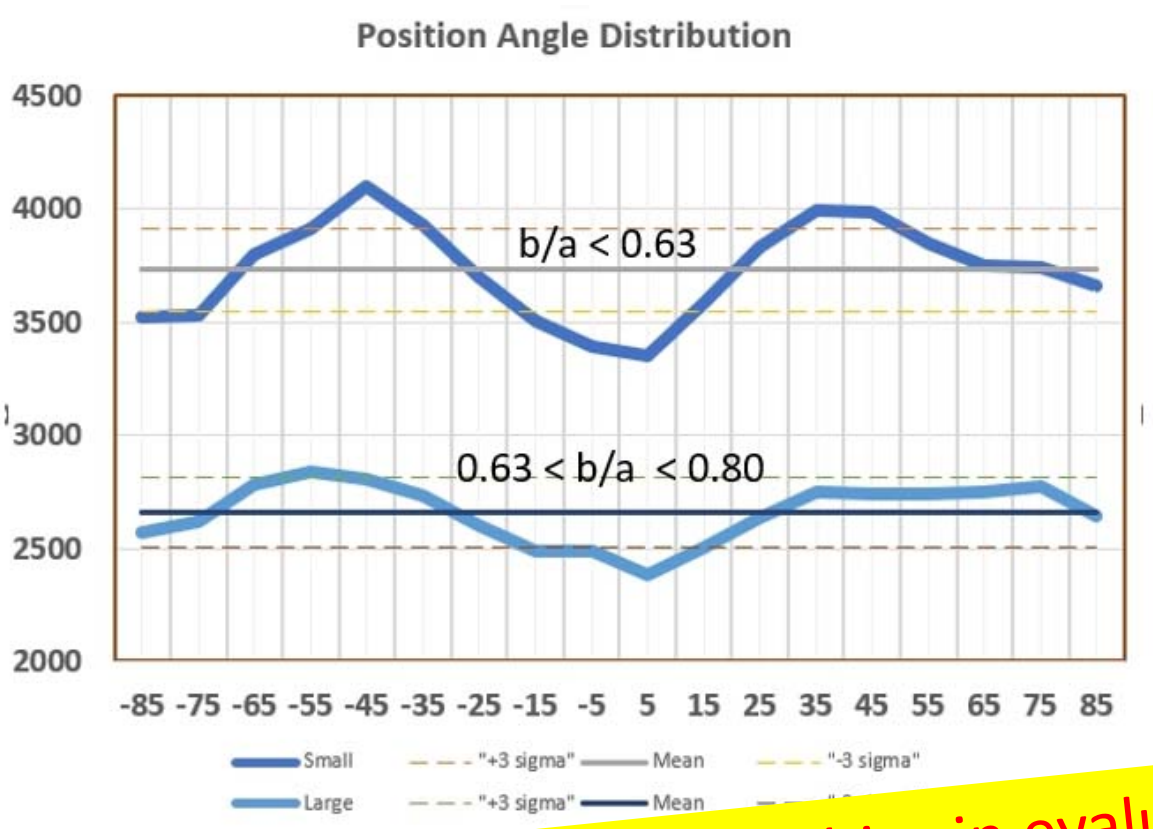


FIG. 3.—Probability density distribution of the cosines of the angles between the spiral galaxy's spin axes and the intermediate principal axes of the local tidal tensors. The dots with Poisson errors represent the observational results, the solid lines correspond to the analytic predictions, and the dotted line represents the case of no correlation. The shaded area represents 1 σ of the correlation parameter. A total of 12,347 spiral galaxies with all morphological types are used.

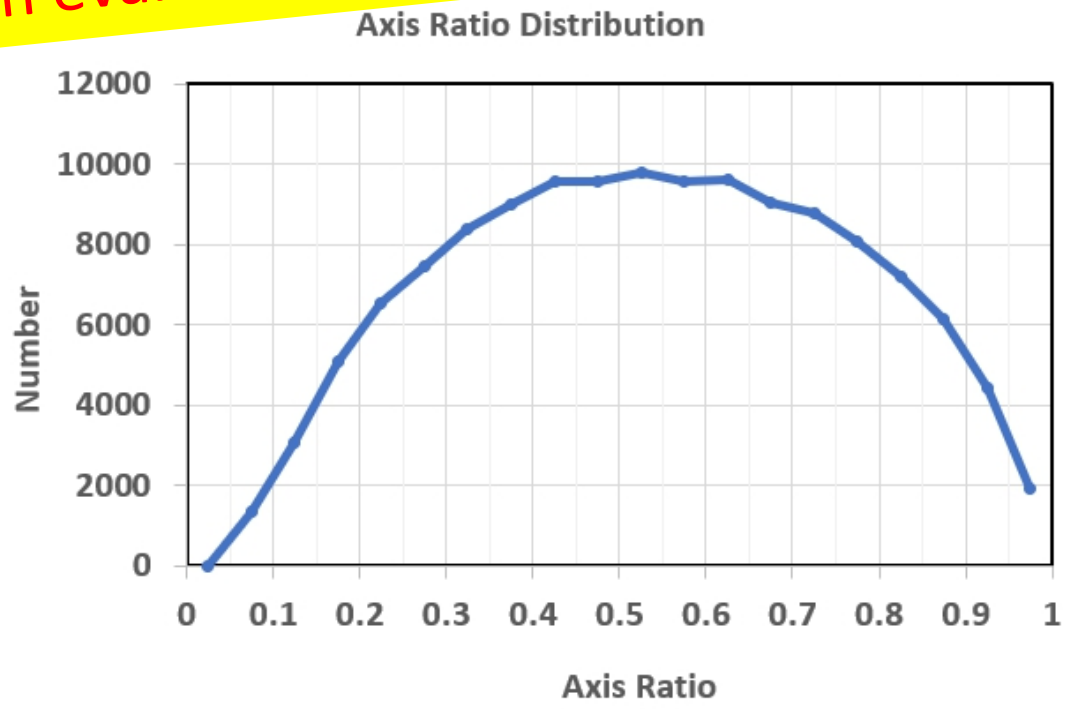
Spin-filament axis correlation



Position Angle distribution of PanSTARRS disk galaxies shows excess at diagonal directions in equatorial coordinates.

Aren't there any similar bias in evaluating simulated galaxies?

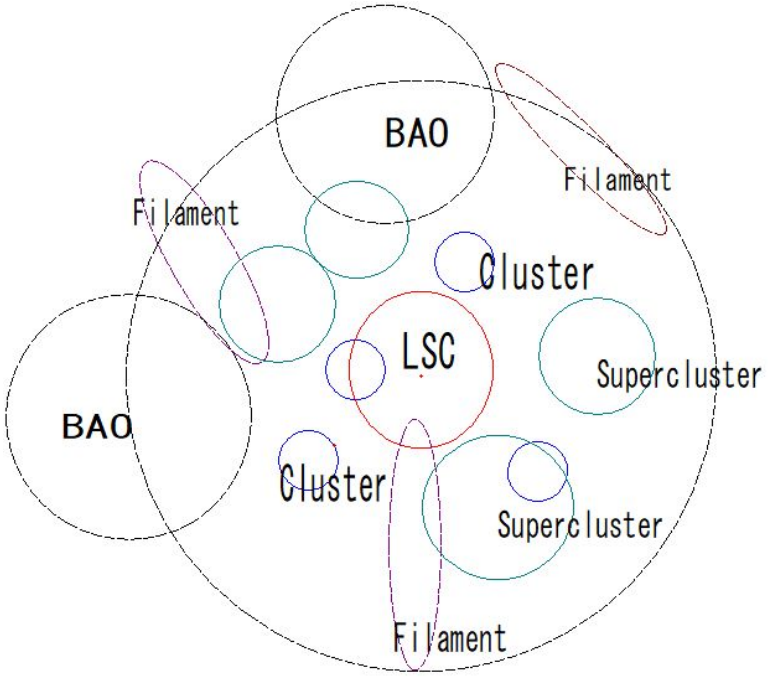
Axis ratio distribution of PanSTARRS disk galaxies



5) Cluster/Filament Analyses

Dipole analysis in the Local universe

Dipole analysis for any sub-volume around an arbitrary center

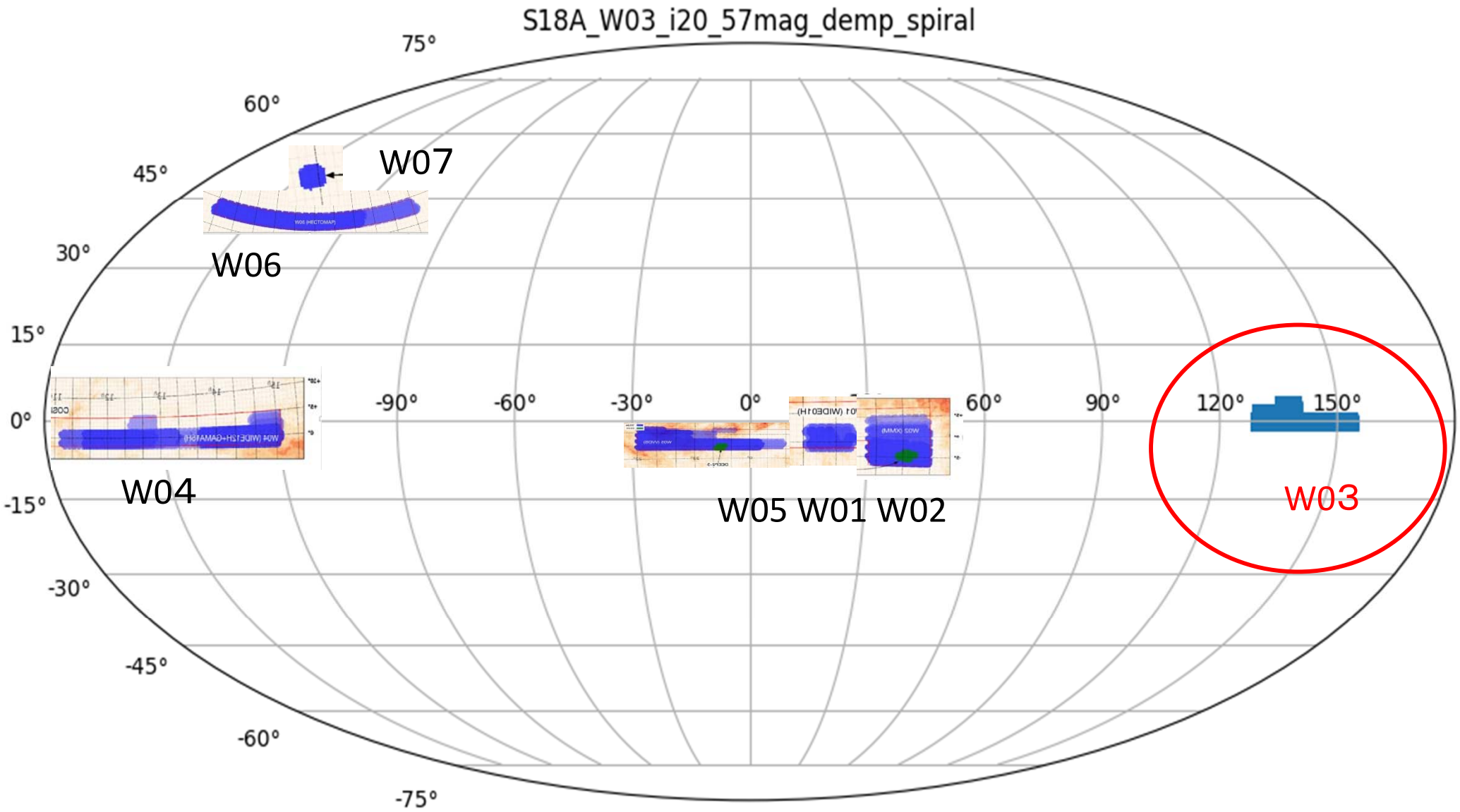


SDSS
PS2
DES
ESO DSS
(z<0.1)

HSC
(z<0.8)

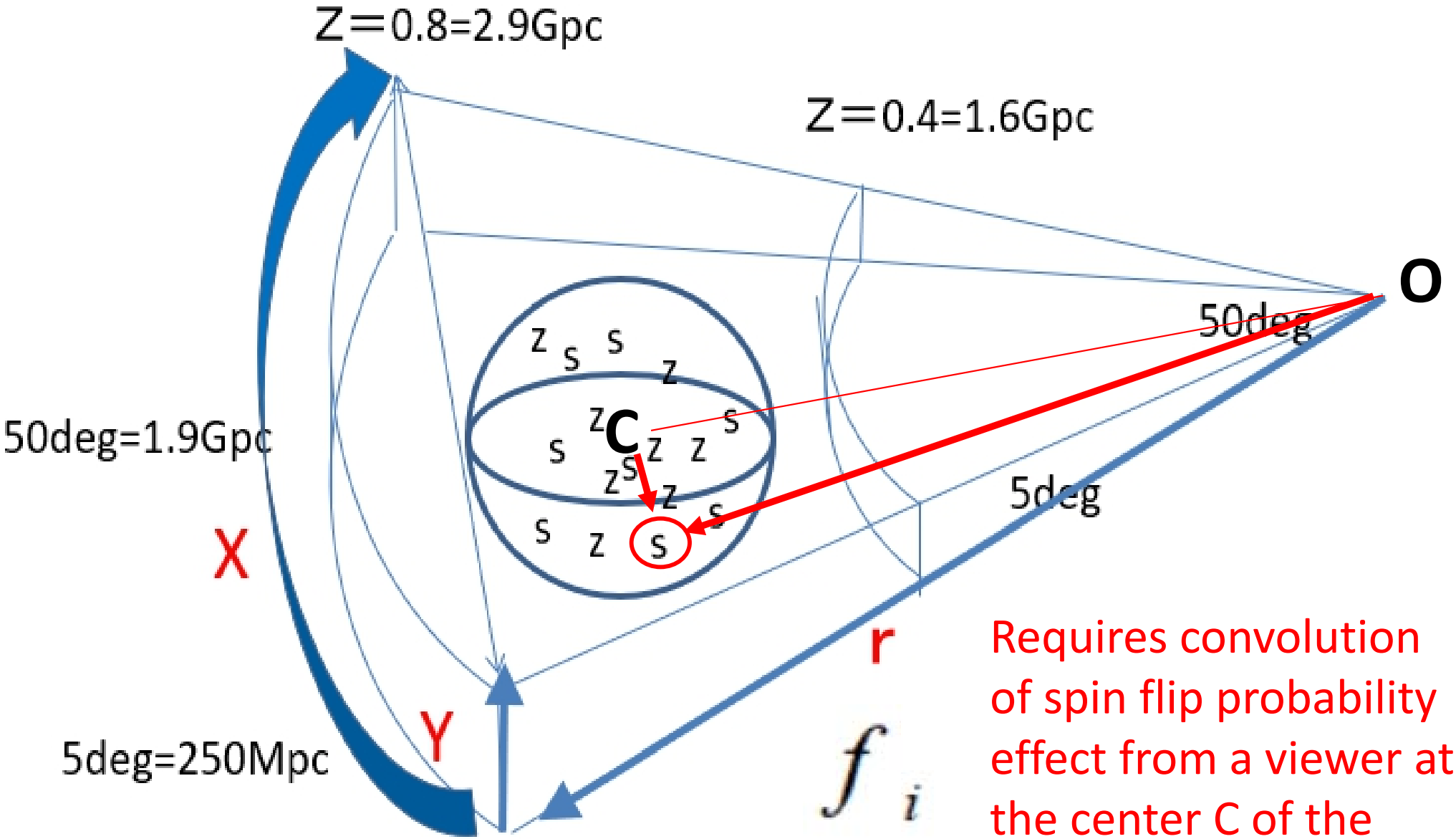
Clusters	RA	DEC	z	Visibility
A1367	176.152083	19.758889	0.022	○
A2151	241.3125	17.748611	0.0366	○
A1689	197.8925	-1.3655555	0.1832	○
A520	73.515833	2.8925	0.199	△
A2163	243.891667	-6.123888	0.203	△
A1758	203.18	50.5404722	0.279	△
J0916+2951	139.045417	29.81222	0.53	△

Selected Deep survey regions with Hyper SuprimeCam



Spin Distribution of Spirals : Masanori Iye (NAOJ) 20221206

Spin Anisotropy Analysis of 1Gpc HSC Survey Volume



Requires convolution of spin flip probability effect from a viewer at the center C of the studied volume.

Dipole vector:

$$\vec{d} = \left[\sum_{N} h_i f_i \vec{g}_i \right] / N$$

h_i : helicity

f_i : flip probability from viewer

$\vec{g}_i$: directional unit vector

Dipole Error for data set with void regions.

$$\|\vec{d}\| = \frac{2\sqrt{2(1+\sin\theta_{\min}+\sin^2\theta_{\min})}}{\sqrt{3\pi N}}.$$

Spin Parity Paper Series

Question: ***Any asymmetry in the galaxy spin vector distribution?***

- Classic (Sugai+:1995) Concept of S/Z analysis and application to 9k spirals.
- SDSS (Shamir:2017) S/Z catalog of 160k spirals. Claimed to find a strong anisotropy.
- Paper I (Iye+:2019) Spirals are all "trailing". Can use spiral S/Z parity to judge the sign of the line-of-sight component of galaxy spin vector to look for any anisotropy in their distribution.
- Paper II (Tadaki+:2020) Classified S/Z of 80k HSC spirals ($z<0.8$) with deep learning.
- **Paper III (Iye+:2021) Dipole analysis calibrated with Monte Carlo simulations and application to 70k SDSS spirals to disprove Shamir's claim to find a significant S/Z asymmetry in the π str of the local universe.**
- **Paper IV (Fukumoto+:2023) Compilation of reliable spin catalog of 45k PanStarrs spirals at $z<0.05$ in 3π str and its dipole analysis.**