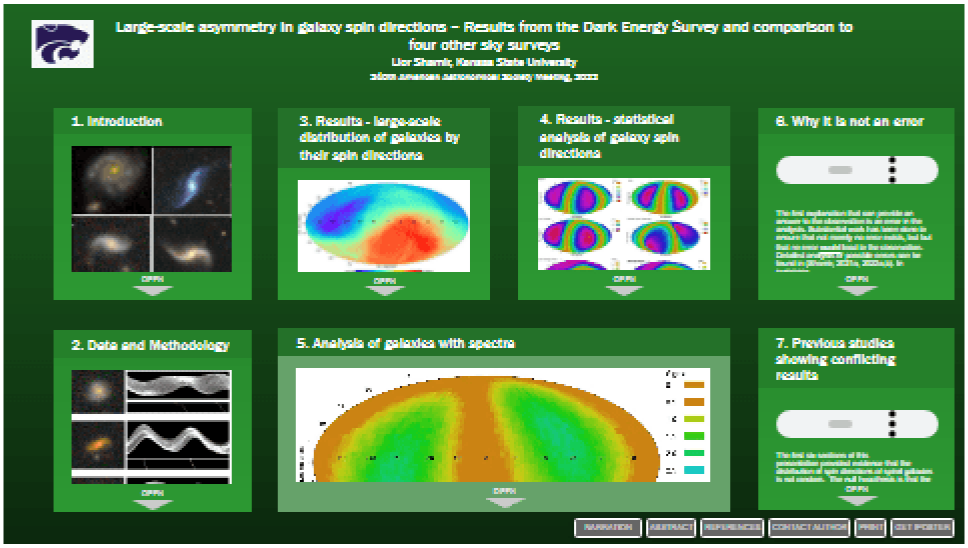
Large-scale asymmetry in galaxy spin directions – Results from the Dark Energy Survey and comparison to four other sky surveys



Lior Shamir, Kansas State University

240th American Astronomical Society Meeting, 2022

PRESENTED AT:

AAS 240 iPoster Sessions

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1. INTRODUCTION

The spin direction of a spiral galaxy depends on the location of the observer, and therefore the spin direction of a spiral galaxy is expected to be random for a given single galaxy.

In the past four decades, different studies showing conflicting results were reported. Early work includes manual counting of galaxies (MacGillivray & Dodd, 1985; Longo 2011), both argued for a higher number of galaxies spinning clockwise compared to the number of galaxies spinning counterclockwise.

This work tests that assumption using an automatic and fully symmetric annotation of almost two million galaxies imaged by five different sky surveys. The results show that all telescope show very similar patterns of non-random distribution. The distribution forms a cosmological-scale axis that agree between the different telescopes. The locations of the dipole axis observed with different telescopes are nearly identical.

While the cosmological homogeniety and isotropy assumptions are the common working assumptions of most cosmological theories, accumulating evidence show that the Universe is not necessarily isotropic. Several probes show cosmological-scale anisotropy. These probes include the cosmic microwave background radiation (Eriksen et al., 2004; Cline et al., 2003; Gordon & Hu,2004; Campanelli et al., 2007; Gruppuso, 2007; Zhe et al., 2015, Yeung et al., 2022), short gamma ray bursts (Meszaros, 2019), radio sources (Ghoshet al., 2016; Tiwari & Jain, 2015; Tiwari & Nusser, 2016), LX-T scaling (Migkas et al., 2020), Ia supernova (Javanmardi et al., 2015; Lin et al., 2016), distribution of galaxy morphological types (Javanmardi & Kroupa, 2017), dark energy (Adhav et al., 2011; Adhav, 2011; Perivolaropoulos, 2014; Colin et al., 2019), alignment of quasars (Hutsem´ekers et al., 2005; Secrest et al., 2021), and high-energy cosmic rays (Aab et al., 2017).

Possible explanations

The contention that the Universe is oriented around an axis has been proposed through theories related to different geometry of the Universe. An example is the theory of ellipsoidal universe (Campanelli et al., 2006, 2007; Gruppuso, 2007; Campanelli et al., 2011; Cea, 2014). Such Universe is expected to be anisotropic, exhibited in the form of cosmological-scale quadrupole (Rodrigues, 2008).

Another cosmological thoery that assumes the existence of a large-scale axis is the theory of rotating universe (Gamow, 1946; Godel, 1949; Ozsvath and Schucking, 2001; Su and Chu, 2009; Sivaram and Arun, 2012; Chechin, 2016, 2017; Campanelli, 2021).

Rotating universe is related to black hole cosmology (Pathria, 1972; Easson and Brandenberger, 2001; Seshavatharam, 2010; Poplawski, 2010; Chakrabarty et al., 2020). Because stars spin, a black hole created from a star also spins. If the Universe is the interior of a black hole, the Universe should has a preferred direction inherited from its host black hole (Poplawski, 2010; Seshavatharam, 2010). That observation is added to other observations that agree with the black hole cosmology thoery such as dark energy and the agreement between the Hubble radius and the cosmological Schwarzschild radius.

3. RESULTS - LARGE-SCALE DISTRIBUTION OF GALAXIES BY THEIR SPIN DIRECTIONS

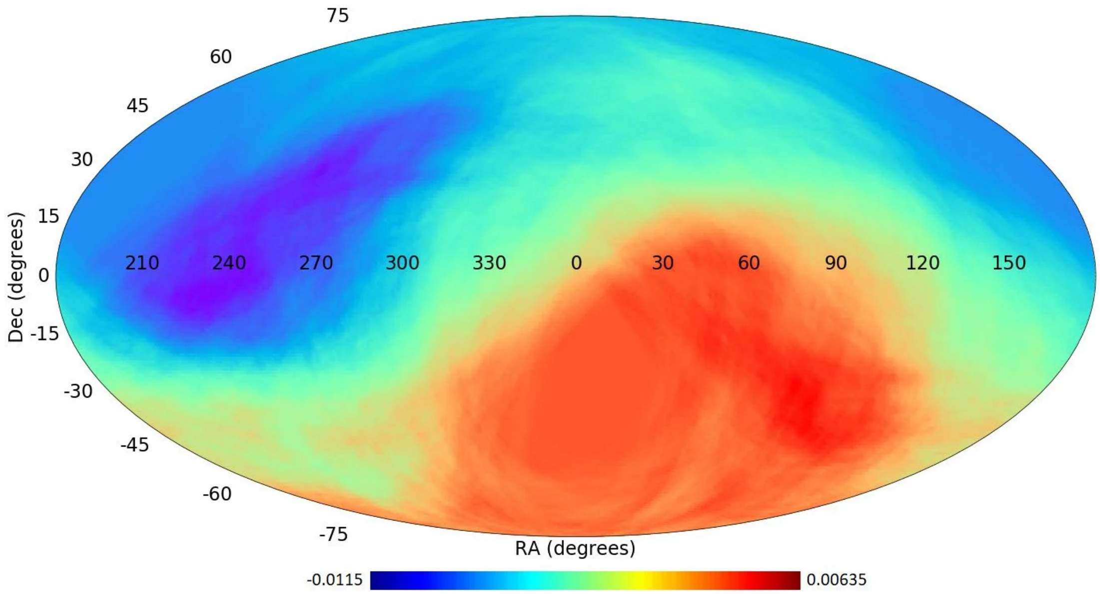


Figure 2. Distribution of spin directions of more than 10^6 spiral galaxies. This is direct a observation of galaxies in differet parts of the sky. The figure is therefore a direct observation, and not the result of a statistical analysis.

Figure 2 shows the distribution of the spin directions of over 1.3 million spiral galaxies. The analysis is not a statistical analysis, but a direct observation. The results show clearly that the sky can be separated into two hemispheres such that one hemisphere shows a higher number of galaxies spinning clockwise, and the other hemisphere has a higher number of galaxies spinning counterclockwise. The probability of the strength of asymmetry in one hemisphere to occur by chance is $P \ll 10^{-5}$.

Figure 2 is not a statistical analysis that attempts to fit the galaxy spin directions into an assumed model, but a direct observation. The figure show the distribution of the asymmetry in the sky, without any statistical analysis or an attempt to fit the distribution to a model. The large number of galaxies and the large footprint allows to observe the distribution directly, with no assumptions and no statistical analysis.

A simpler analysis just counts the galaxies with different spin directions in opposite hemispheres. The tables below show the distribution in opposite hemispheres in DECam (mostly the Southern hemisphere) and SDSS (mostly the Northern hemisphere), the Dark Energy Survey (DES), and a combination of several sky surveys. The P values are simple binomial distribution of the asymmetry to occur by chance when assuming that galaxies have 0.5 probability to spin in a certain direction.

Decam

Hemisphere	# cw galaxies	# ccw galaxies	$\frac{cw-ccw}{cw+ccw}$	P
$(0^o - 180^o)$	252,478	250,555	0.0038	0.0033
$(180^o - 360^o)$	151,948	152,917	-0.0033	0.039

SDSS

Hemisphere	# cw galaxies	# ccw galaxies	$\frac{cw-ccw}{cw+ccw}$	P
$(0^o - 180^o)$	14,403	15,101	-0.024	0.00002
$(180^o - 360^o)$	17,263	16,926	0.01	0.035

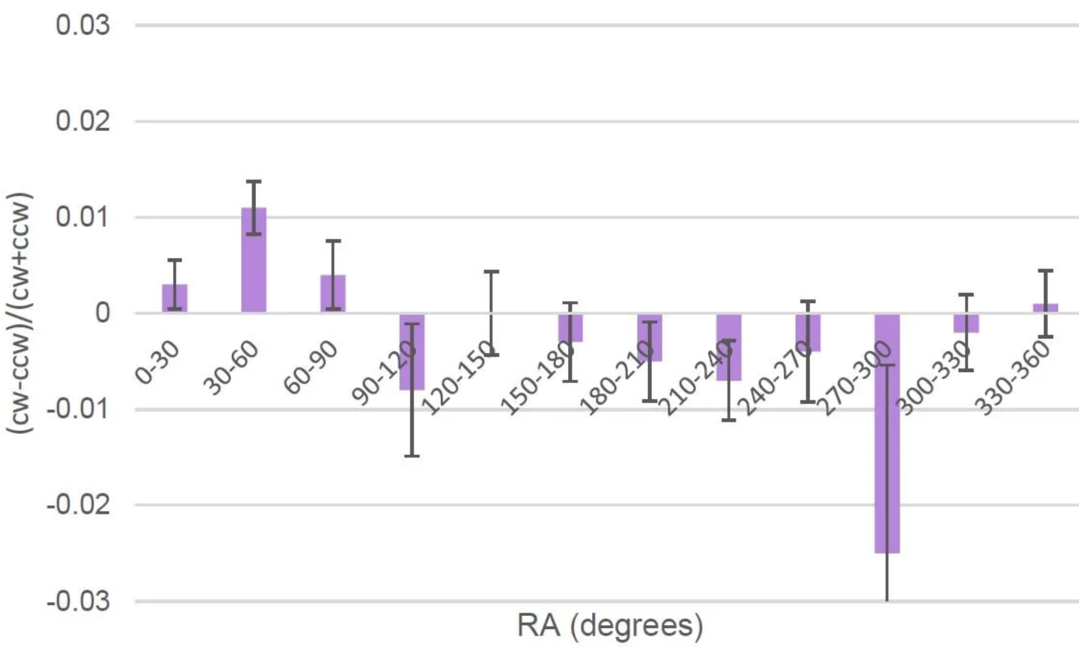
DES

Hemisphere	# cw galaxies	# ccw galaxies	$\frac{cw-ccw}{cw+ccw}$	P
$(0^o - 180^o)$	294,655	292,453	0.0038	0.002
$(180^o - 360^o)$	76,327	75,851	0.0031	0.11

All

RA	# cw galaxies	# ccw galaxies	$\frac{cw-ccw}{cw+ccw}$	P
$< 130^o, > 310^o$	299,898	298,252	0.0028	0.017
$130^o - 310^o$	179,765	180,926	-0.0032	0.026

All telescopes show inverse asymmetry in opposite hemispheres. DES shows asymmetry in the same directions in both hemispheres. That can be explained by the distribution of DES galaxies, covering just parts of the sky in which there is a higher number of galaxies spinning clockwise.



The graph above shows the difference between the number of clockwise and counterclockwise galaxies in different RA ranges (Shamir, 2021b). The analysis uses a relatively large dataset of 807K galaxies. The graph shows inverse agreement between RA ranges in opposite hemispheres.

4. RESULTS - STATISTICAL ANALYSIS OF GALAXY SPIN DIRECTIONS

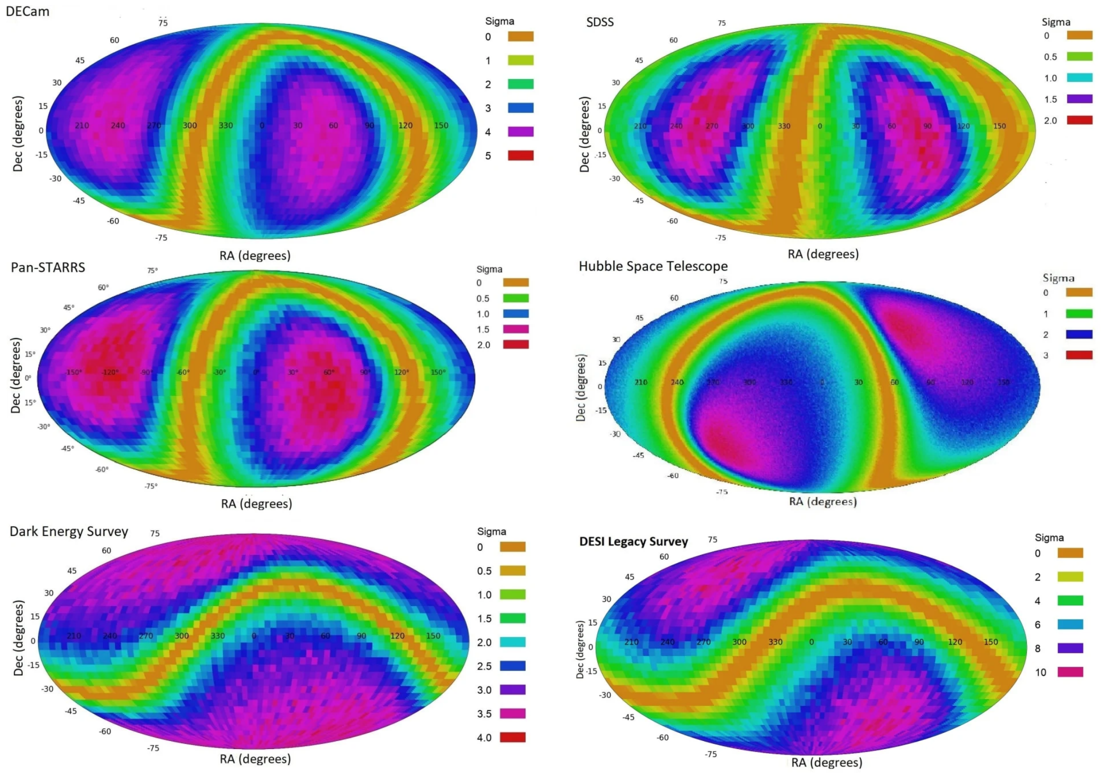


Figure 3. Statistical analysis of the statistical strength of a dipole axis formed by the distribution of galaxy spin directions. The analysis compares six different sky surveys, all showing very similar results.

If galaxy spin directions exhibit a cosmological-scale dipole axis, that axis can be identified by fitting the spin directions of the galaxies to the cosine between their location and the candidate location of the axis. That can be done by

$$\chi^2_{\alpha,\delta} = \Sigma_i \left| \frac{(d_i \cdot |cos(\theta_i)| - cos(\theta_i))^2}{cos(\theta_i)} \right|$$

where d_i is the spin direction of the galaxy i.

That can be done by first using the real spin directions of the galaxies, and then applying 2000 runs when the spin direction of the galaxies are random. The statistican strength of the axis can be determined by:

$$\sigma_{\alpha,\delta} = \frac{\chi^2_{\alpha,\delta} - \chi^{2\,random}_{\alpha,\delta}}{\sigma^{random}_{\alpha,\delta}}$$

Figure 3 shows the strength of the axis from all possible (ra, dec) combinations in the sky. It shows that all telescopes show similar profiles of the distribution of the spin direction asymmetry. All axes are statistically significant, except for Pan-STARRS, which is the smallest dataset of ~33K galaxies, and provides statistical strength of ~1.9 sigma. DESI Legacy Survey, which is also the largest dataset, shows statistical signal of over 8 sigma.

The same analysis can be used to identify quandrupole alignment (Shamir, 2020b, 2022b, 2021b). Quandrupole alignment also shows similar profile regardless of the telescope being used.

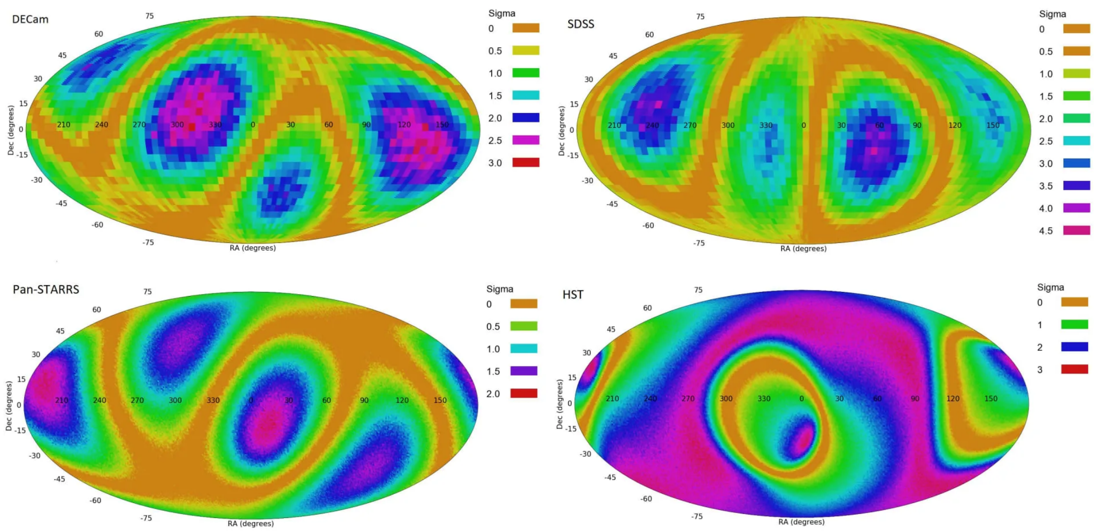
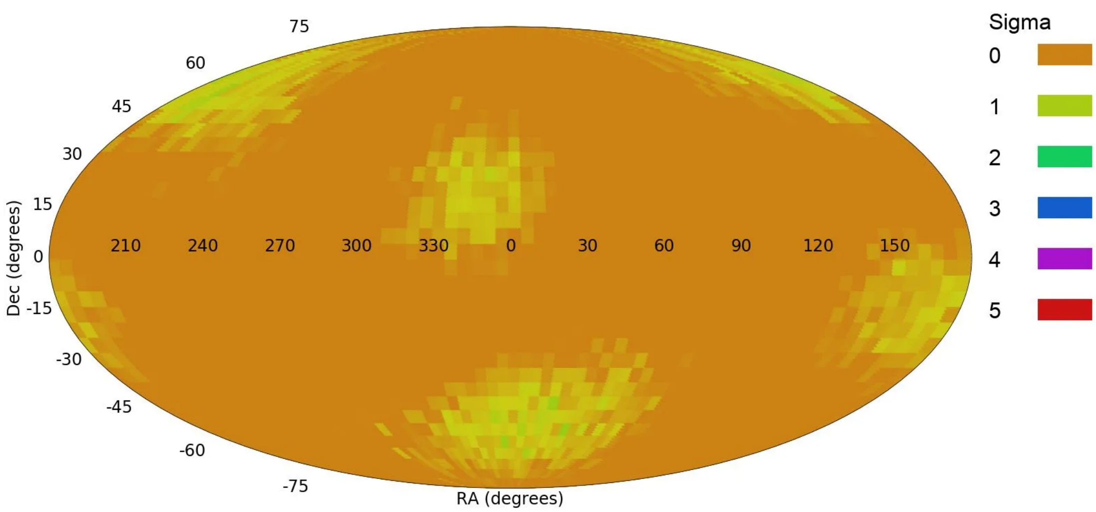


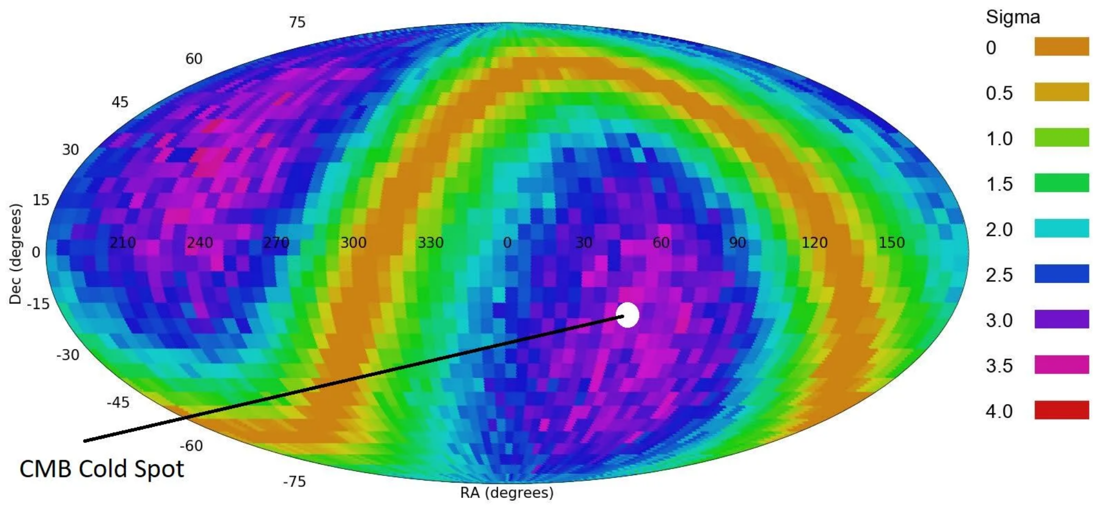
Figure 4. Quadrupole analysis in four different telescopes.

When assigning the galaxies with random spin directions, the asymmetry becomes statistically insignificant. That is also consistent in all telescopes. More information about "sanity checks" can be found in Section 6, as well as in previous papers (Shamir, 2021a,b, 2022a,b,c).



The quadrupole distribution when the galaxies are assigned with random spin directions.

When combining several telecopes into one dataset with ~10^6 galaxies, the llocation of the most likely axis is very close to the location of the CMB Cold Spot (Shamir, 2022d). Obviously, that can be a coincidence, but the agreement is interesting and should be investigated further.



6. WHY IT IS NOT AN ERROR

The first explanation that can provide an answer to the observation is an error in the analysis. Substantial work has been done to ensure that not merely no error exists, but but that no error **could** lead to the observation. Detailed analysis of possible errors can be found in (Shamir, 2021a, 2022a,b). In summary:

1. Error in the galaxy annotation algorithm

There are multiple indications showing that the galaxy annotation algorithm cannot lead to the observation. The algorithm is fully symmetric, based on defined model-driven rules. It is not based on any form of pattern recognition, machine learning, deep learning, or any other forms of complex data-driven rules that tend to be complex andnon-intuitive, and can lead to complex biases (Dhar & Shamir, 2022).

Mirroring of the galaxy images provides exactly inverse results to the results when using the original images. That is expected, as the algorithm of the galaxy annotation is fully symmetric. Because each galaxy is analyzed independently, even if the annotation algorithm was biased, a consistent error in the annotation would exhibit itself as consistent assymetry in all parts of the sky. Such error is not expected to "flip" in opposite hemispheres.

All galaxies were analyzed on the same system and the same processor to eliminate the possibility that the algorithm runs differently on different systems. When assigning the galaxies with random spin directions, the signal disappears immediately. The strength of the signal gets below 1 sigma.

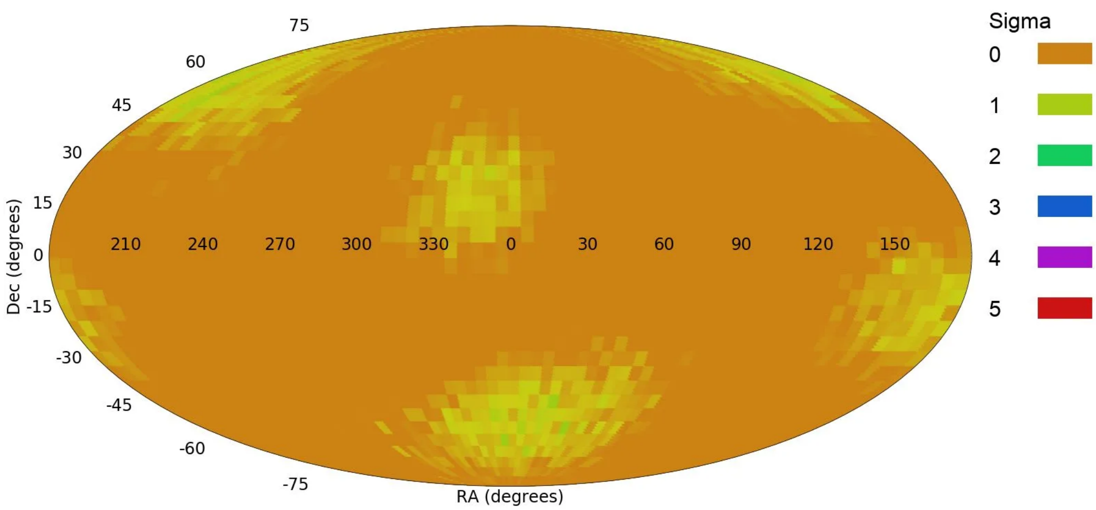


Figure 11. Quadrupole analysis when assigning the galaxies with random spin directions.

Because the algorithm is symmetric, error in the annotation is expected to make the signal weaker in a symmetric manner. As explained in (Shamit, 2022,a,b), such error can only make the signal weaker, but cannot make the signal stronger than the signal that comes from the real sky.

The asymmetry A can be dfined by:

$$A = \frac{(N_{cw}+E_{cw})-(N_{ccw}+E_{ccw})}{N_{cw}+E_{cw}+N_{ccw}+E_{ccw}},$$

where Ecw is the number of galaxies spinning clockwise incorrectly annotated as counterclockwise, and E_ccw is the number of galaxies spinning counterclockwise incorrectly annotated as spinning clockwise. Because the algorithm is symmetric, the number of counterclockwise galaxies incorrectly annotated as clockwise is expected to be roughly the same as the number of clockwise galaxies missclassified as counterclockwise, and therefore Ecw =~ Eccw (Shamir, 2021a, 2022a,b). Therefore, the asymmetry A can be defined by

$$A = \frac{N_{cw}-N_{ccw}}{N_{cw}+E_{cw}+N_{ccw}+E_{ccw}}$$

Since Ecw and Eccw cannot be negative, a higher rate of incorrectly annotated galaxies is expected to make the asymmetry A lower. Therefore, incorrect annotation of galaxies is not expected to lead to asymmetry, and can only make the asymmetry weaker rather than stronger.

2. Bias in the sky survey hardware or photometric pipeline

Autonomous digital sky surveys are complex research instruments. It is difficult to think of an error in the hardware or software that can lead to asymmetry between the number of clockwise and counterclockwise galaxies, but due to the complexity of these systems it is also difficult to prove that such error does not exist. While it is difficult to think of such error in one telescope, it is clearly difficult to think of such error that happen consistently in four telescopes.

3. Cosmic variance / Milky Way obstruction

The asymmetry is determined by the difference between two measurements made in the same field. Therefore, the asymmetry between the number of clockwise and counterclockwise galaxies observed from Earth is a relative measurement. That measurement is not expected to be affected by cosmic variance. Any effect that impacts the number ofclockwise galaxies observed from Earth is expected to have a similar effect on the number of counterclockwisegalaxies in the same field.

4. Multiple photometric objects in the same galaxy

In some cases, digital sky survey can identify several photometric objects as independent galaxies, even in casethey are part of one large extended object. In the datasets used here all photometric objects that are part of the same galaxy were removed by removing all objects that had another object within angular distance of 0.01^{o}. Even if such objects existed in the dataset, they are expected to be evenly distributed between galaxies that spinclockwise and galaxies that spin counterclockwise. Experiments by using datasets of galaxies assigned withrandom spin directions and adding artificial objects to the galaxies showed that adding objects at exactly the sameposition of the original galaxies does not lead to signal of asymmetry (Shamir 2021a,2022a,b).

5. Atmospheric effect

There is no known atmospheric effect that can make a galaxy that spin clockwise appear as if it spins counterclockwise. Also, because the asymmetry is always measured with galaxies imaged in the same field, any kind of atmospheric effect that affects galaxies that spin clockwise will also affect galaxies that spin counterclockwise. Therefore, it is unlikely that a certain atmospheric effect would impact the number of clockwisegalaxies at a certain field, but would have a different impact on galaxies spinning counterclockwise. In any case,one of the datasets used here is made of galaxies imaged by the space-based Hubble Space Telescope, and aretherefore not subjected to any kind of atmospheric effect.

6. Spiral galaxies with leading arms

WHile most galaxies have trailing arms, some galaxies can have leading arms. Spiral galaxies with leading arms are relatively rare, and expected to be distributed equally between galaxies with differentspin directions. Therefore, there is no reason to assume that the observations shown here are driven by backwardspiral galaxies.

2. DATA AND METHODOLOGY

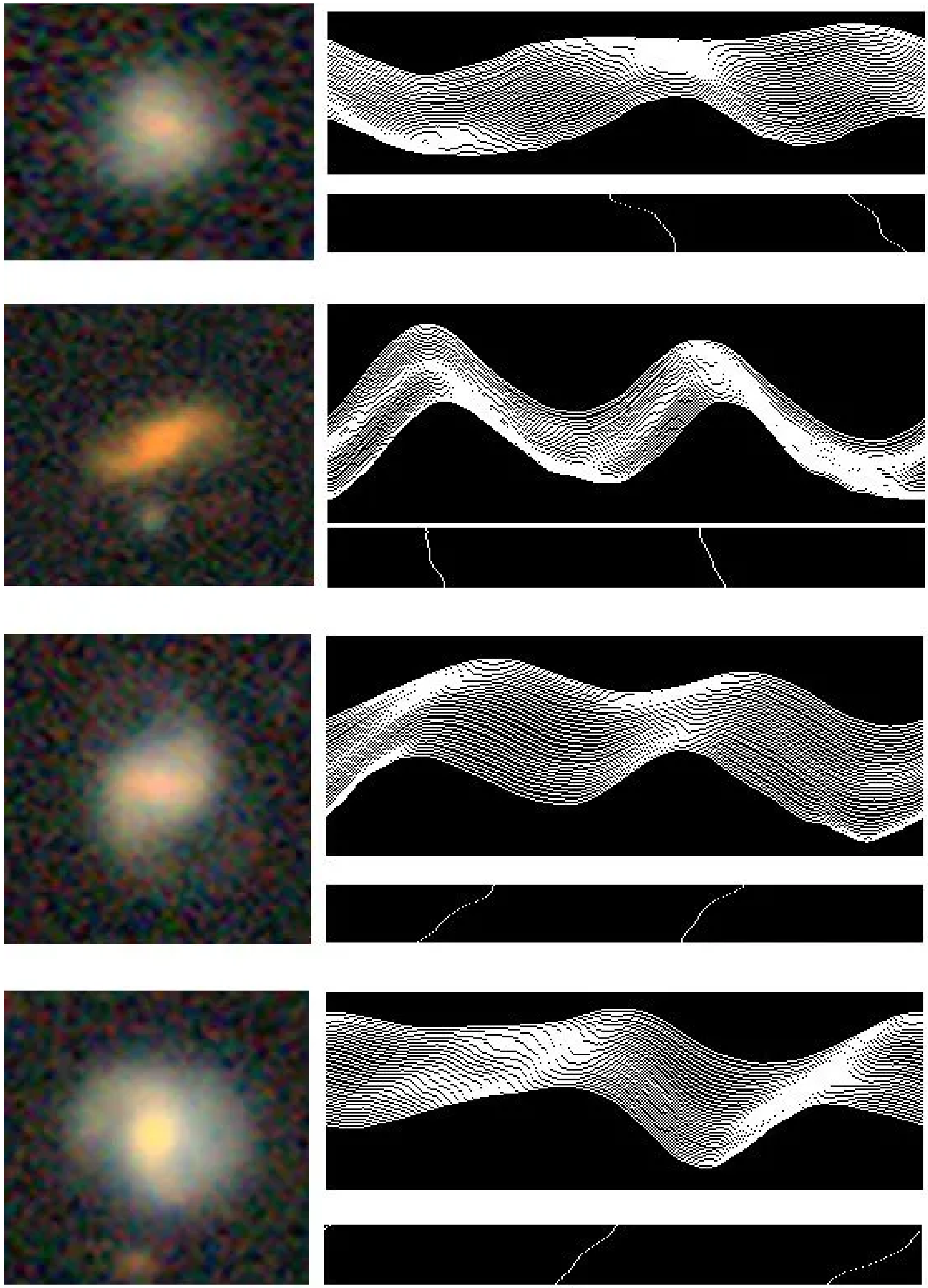


Figure 1. DES galaxies analyzed by radial intensity plots to identify their spin direction. The main advantages of the algorithm is that it is model-driven and follws clear rules, and the algorithm is fully symmetric.

The analysis requires a large set of spiral galaxies annotated by their spin direction. Since most galaxy arms are trailing, the spin directions can be determined automatically by the shape of the arms.

Figure 1 shows examples of several galaxies from DES, and their analysis using the radial intensity plots. The Ganalyzer algorithm (Shamir, 2011) turns the galaxy image into its radial intensity plot, applies a peak detection to detect peaks in the plots, and then applies a linear regression on the peaks. The sign of the linear regression can determine the curves of the arms, and assuming that the arms are trailing it can determine the spin direction of the galaxy.

The automatic annotation allows to handle the analysis of a very high number of galaxies, while also avoiding a possible human bias in the annotation. The algorithm works by clear, defined, and fully symmetric rules. It can identify the spin direction of the galaxies, and can also identify when a galaxy does not have clear spin patterns (e.g., elliptical galaxies). Only galaxies with at list 30 peaks identified in their radial intensity plots (as shown in Figure 1) are used.

By using model-driven clear algorithm, the analysis completely avoids any kind of analysis that is based on machine learning, and especially deep learning. These algorithms are biased in many ways, and the bias can be unintuitive and difficult to notice and profile (Dhar & Shamir, 2022). Machine learning, deep learning, and any other form of pattern recognition cannot be used to annotate data for studying subtle anisotropies in the large-scale structure.

Some of the datasets were annotated manually, to compare the different results when using different annotation methods. The analysis was done by mirroring the galaxies randomly to correct for the human perceptual bias.

The datasets from the different sky surveys are:

773K DES galaxies.

807K DECam galaxies

64K SDSS galaxies (with spectra)

33K Pan-STARRS galaxies

9K HST galaxies

1.3M DESI Legacy Survey galaxies

5. ANALYSIS OF GALAXIES WITH SPECTRA

[VIDEO] https://res.cloudinary.com/amuze-interactive/image/upload/f_auto,q_auto/v1652201927/aas/15-4e-ae-d0-4f-8a-ec-eb-86-42-61-f1-23-9f-4c-b8/image/all_loq1uy.mp4

Figure 5. Changes in the location of the most likely axis with the redshift (Shamir, 2022d).

The profiles of asymmetry in galaxy spin directions become nearly identical when the distribution of the redshift is normalized. That shows that the location of the most likely axis changes with the redshift. The asymmetry also becomes stronger with the redshift. The observation that the location of the most likely axis changes with the redshift, and that the asymmetry becomes stronger with the redshift might indicate that if such axis indeed exists, it does not go directly through Earth (Shamir, 2022a,b,c).

Figure 6 shows the distribution of SDSS galaxies with redshift higher than 0.15 (Shamir, 2020a). That is comapred to the analysis of HST galaxies. The two profiles are very similar. HST galaxies have redshift much higher than 0.15, but the profiles are very similar. That shows, as also shown in Figure 5, that the axis changes at low redshift, but at the higher redshift ranges the change with the redshift is small.

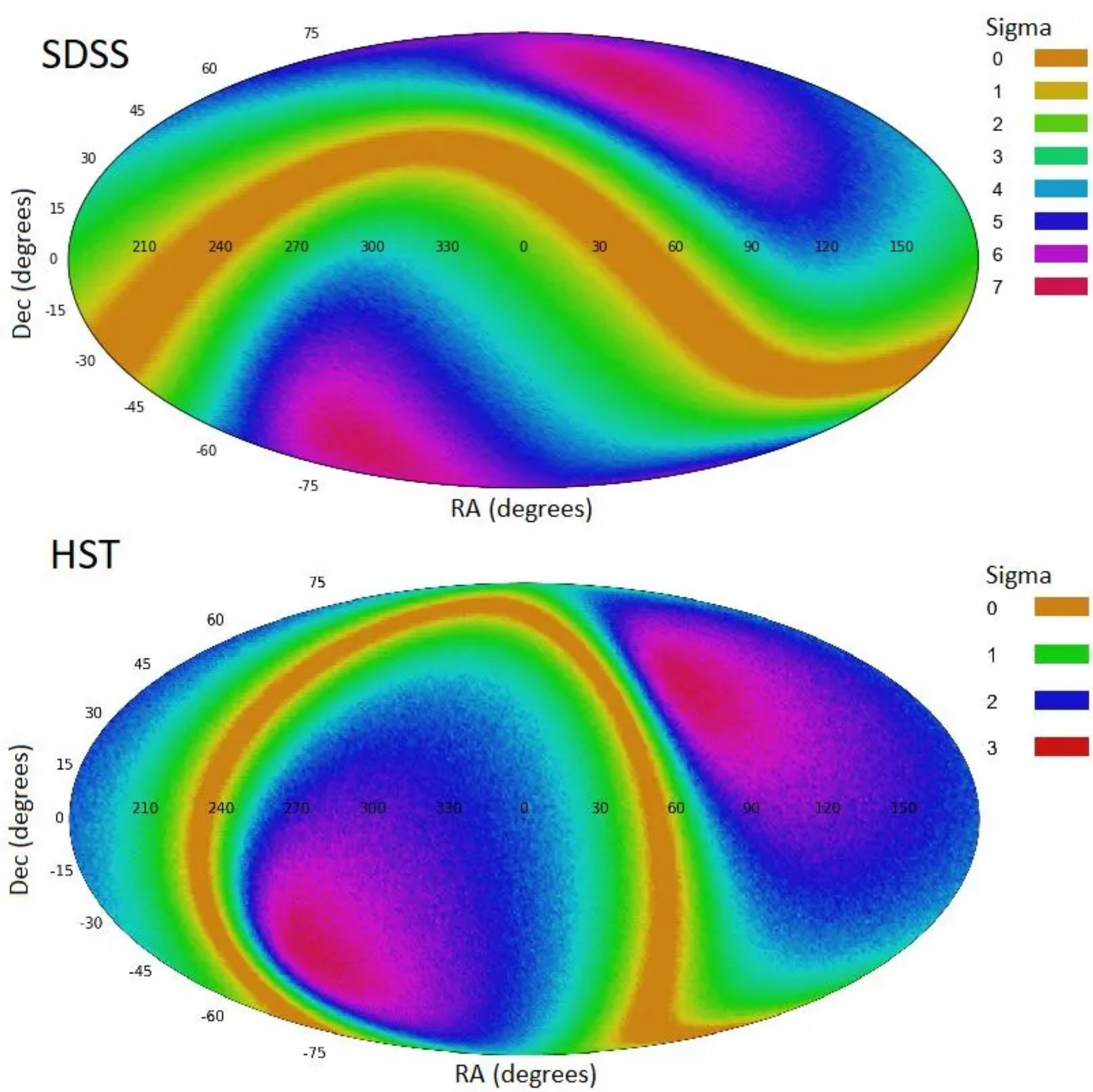


Figure 6. Comparison of the most likely axis observed in HST galaxies and in SDSS galaxies with redshift higher than 0.15 (Shamir, 2020a).

That can also be explained by an axis that does not go directly through Earth, as shown in Figure 7. The differences in the location become smaller when the redshift is higher. Therefore, if the galaxies form an axis that does not go directly through Earth, the location of the axis is expected to change with the redshift when the redshift is lower, and the change is expected to be much less as the redshift gets higher.

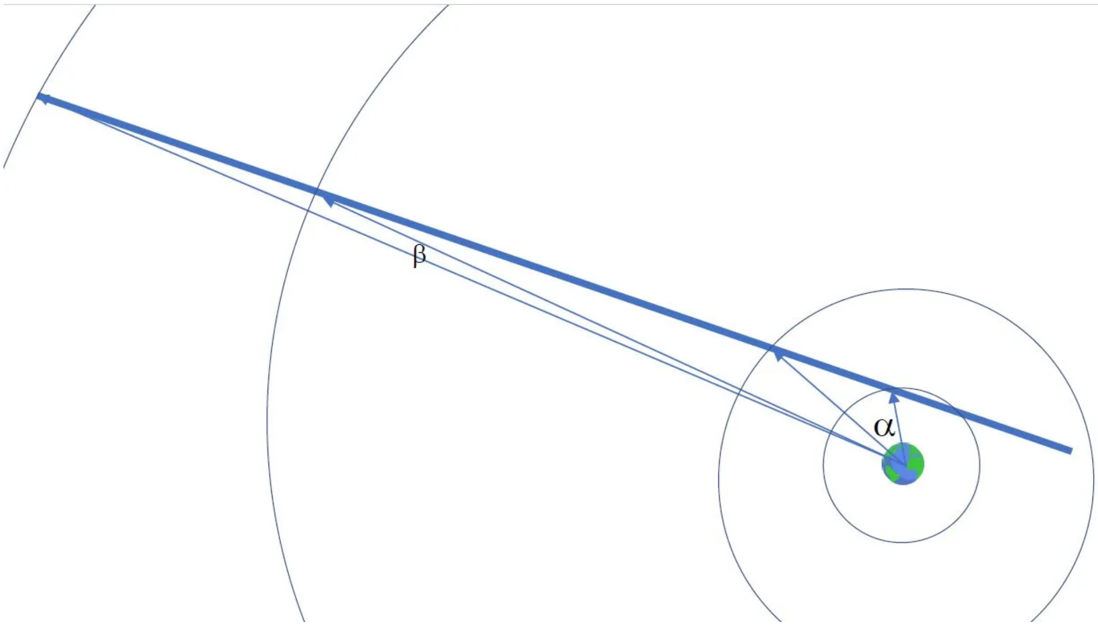


Figure 7. The changes in the angle become smaller when the redshift is higher (Shamir 2022b).

The axis can be analyzed by limiting the analysis to different redshift ranges. Each 3D point is the location of the most likely axis when the redshift range is different. Figure 8 and 9 shows how the location of the most likely axis changes with the redshift when using dipole and quadrupole analysis. Figure 10 shows the full quadrupole profile when the redshift changes. That analysis was also done with ~90K galaxies with spectra.

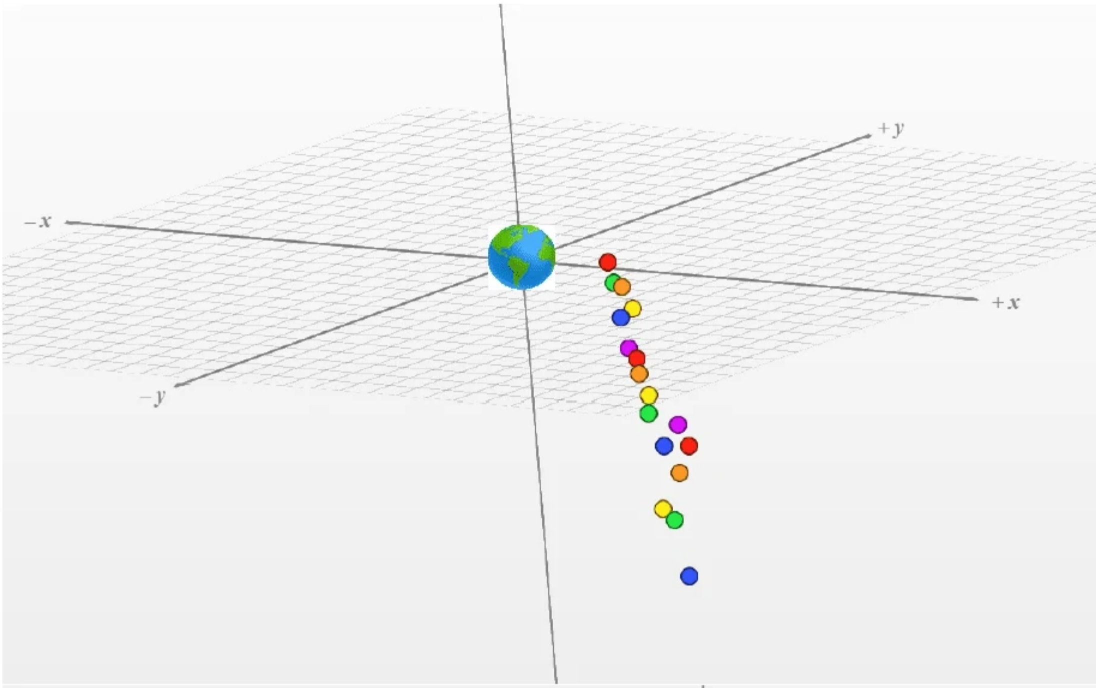


Figure 8. Analysis of the most likely axis when using different redshift ranges (Shamir, 2022a).

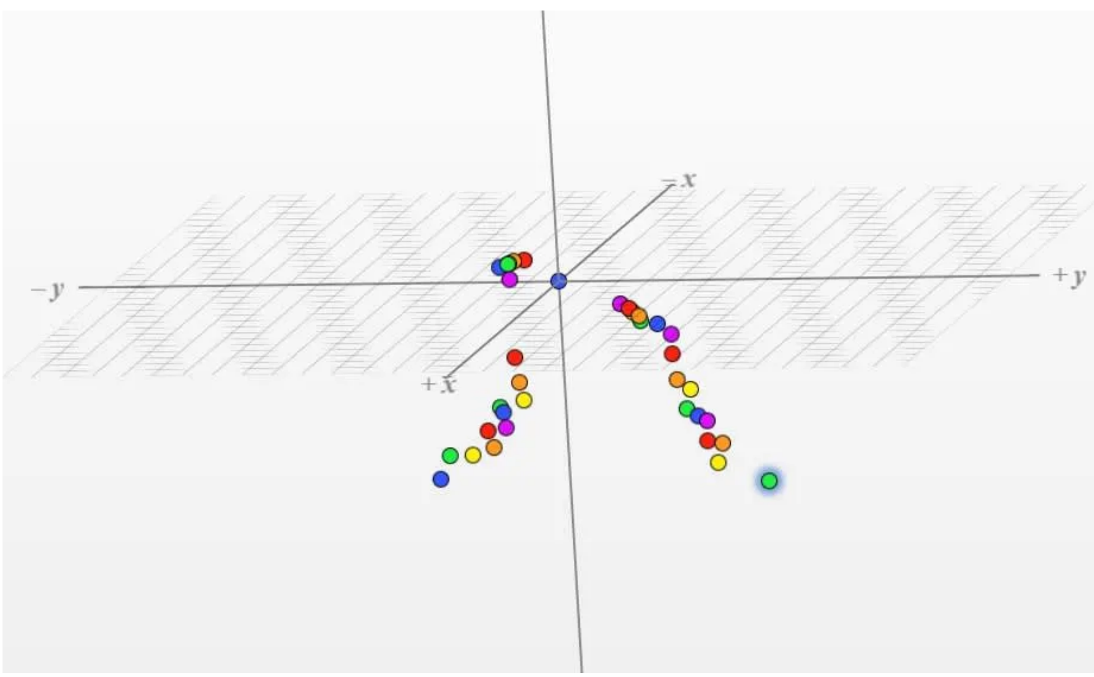


Figure 9. Anaysis of quandrupole axis when using different redshift ranges (Shamir, 2022a).

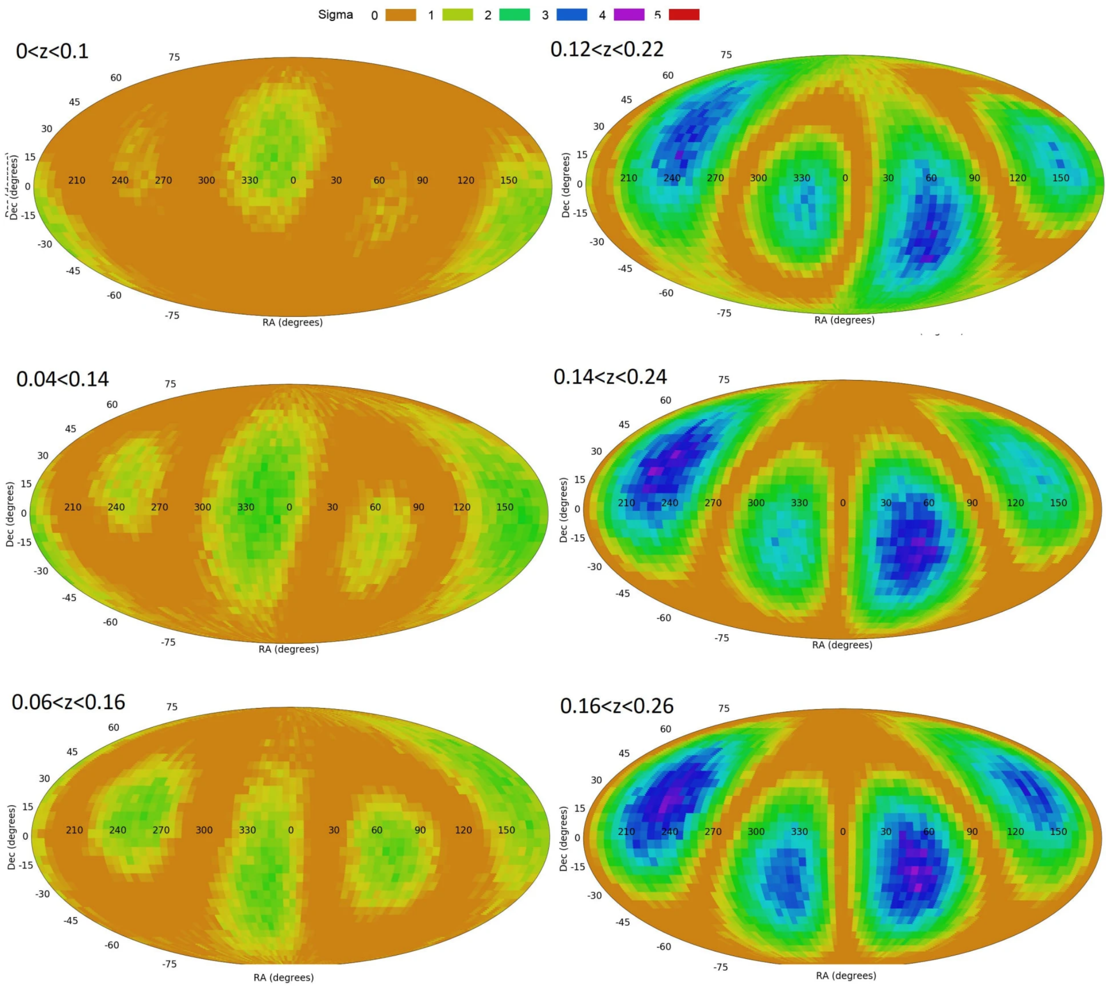


Figure 10. Changes in quadrupole analysis when using different redshift ranges. The analysis is based on ~$9*10^5$ galaxies with spectra from SDSS, DECam, and DES (Shamir, 2022a).

7. PREVIOUS STUDIES SHOWING CONFLICTING RESULTS

The first six sections of this presentation provided evidence that the distribution of spin directions of spiral galaxies is not random. The null hypothesis is that the distribution of galaxy spin directions is random, and therefore could lead to the common bias known in science as "confirmation bias (Hart et al., 2009).

An early attempt that showed random distribution was made by Iye and Sugai (1991). In the absence of autonomous digital sky surveys, the analysis was based on a relatively small dataset of about $6.5*10^3$ galaxies. When assuming asymmetry of 1%, at least 27,000 galaxies are needed to provide a one-tailed P value of ~0.05. Even when assuming 2% asymmetry, 7,000 galaxies are needed to provide one-tailed binomial distribution probability of ~0.048. Therefore, a dataset of several thousands galaxies is not sufficiently large to provide dtrong statistical signal.

Another case of using manual annotation of was based on crowdsourcing through Galaxy Zoo (Land et al., 2008). The approach had the advantage of using a large number of volunteers to increase the bandwidth of the annotation. That interesting approach was still limited by the number of galaxies that could be annotated, and especially by the human bias of the annotators.

The human bias led to inaccuracy of the annotations. More importantly, the bias was systematic, and led to very strong asymmetry that is not necessarily driven by the real sky. That required a correction.

The correction was applied by re-annotating a small subset of the galaxies by mirroring the images. By mirroring the images, the bias based on the image is expected to offset.

The results using the mirrored and original galaxy images showed an asymmetry of 1%-2%, That can be seen in Table 2 in (Land et al., 2008). The table shows that when mirroring the galaxy images the number of counterclockwise galaxies is reduced by ~1.5%. The number of clockwise galaxies, on the other hand, increases by ~2%. The asymmetry of 1%-2% is very similar in both direction and magnitude to the asymmetry observed in (Shamir, 2020b). The comparison to (Shamir, 2020b) is the relevant comparison because it also used SDSS galaxies with spectra, and therefore the footprint and distribution of the galaxies inside the footprint are expected to be similar. The number of galaxies used by Galaxy Zoo was too small to provide statistical significance, but the results definitely do not conflict with the results shown here, and actually agree with it.

Clockwise: 5,044

Counterclockwise mirrored: 5155

Counterclockwise: 5507

Clockwise mirrored: 5425

An attempt that used automatic annotation of the spin directions of spiral galaxies was by Hayes et al. (2017). That work used computer annotation of the galaxies, allowing to annotate a relatively large number of galaxies. When annotating spiral galaxies from Galaxy Zoo, the analysis showed a higher number of counterclockwise galaxies, and the difference was statistically significant. That asymmetry also agrees with (Shamir, 2020b), which also analyzed SDSS galaxies with spectra. That led to the assumption that the selection of Galaxy Zoo spirals is biased, and therefore a machine learning algorithm was used to select the galaxies, which also led to asymmetry. To observe no asymmetry, the machine learning algorithm was modified to ignore specifically all features that correlate with the asymmetry in spin directions. That indeed provided a dataset with no asymmetry, but it was observed only after specifically ignoring all features that can identify the asymmetry, which naturally weakened the ability of the annotation to identify the asymmetry.

Perhaps an interesting attempt to show that the distribution of the spin direction of spiral galaxies is random is by (Iye et al., 2021), who argued that the asymmetry in spin directions is due to "duplicate objects" in the dataset. As the abstract says:

https://iopscience.iop.org/article/10.3847/1538-4357/abb3bb

Spin Parity of Spiral Galaxies. III. Dipole Analysis of the Distribution of SDSS Spirals with 3D Random Walk Simulations

Masanori Iye[1], Masafumi Yagi[1], and Hideya Fukumoto[2]

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The Astrophysical Journal, Volume 907, Number 2

Citation Masanori Iye *et al* 2021 *ApJ* **907** 123

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Abstract

Abstract

Observation has not yet determined whether the distribution of spin vectors of galaxies is truly random. It is unclear whether is there any large-scale symmetry-breaking in the distribution of the vorticity field in the universe. Here, we present a formulation to evaluate the dipole component D_{max} of the observed spin distribution, whose statistical significance σ_D can be calibrated by the expected amplitude for 3D random walk (random flight) simulations. We apply this formulation to evaluate the dipole component in the distribution of Sloan Digital Sky Survey (SDSS) spirals. Shamir published a catalog of spiral galaxies from the SDSS DR8, classifying them with his pattern recognition tool into clockwise and counterclockwise (Z-spiral and S-spiral, respectively). He found significant photometric asymmetry in their distribution. We have confirmed that this sample provides dipole asymmetry up to a level of $\sigma_D = 4.00$. However, we also found that the catalog contains a significant number of multiple entries of the same galaxies. After removing the duplicated entries, the number of samples shrunk considerably to 45%. The actual dipole asymmetry observed for the "cleaned" catalog is quite modest, $\sigma_D = 0.29$. We conclude that SDSS data alone do not support the presence of a large-scale symmetry-breaking in the spin vector distribution of galaxies in the local universe. The data are compatible with a random distribution.

Back to top

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According to that abstract, the authors used the same data I used in the past to show a dipole axis in galaxy spin directions, but found "duplicate objects" in the data. After removing the duplicate objects and creating a "clean" dataset, the statistical signal of the dipole axis dropped to 0.29 sigma. While that is the only way to understand the abstract, that did not happen.

First of all, the data used by Iye et al (2021) was taken form (Shamir, 2017a). The (Shamir, 2017a) paper is focused on photometric analysis. No claim for the presence or absence of any kind of axis was made in (Shamit, 2017a), and no such claim about that dataset was made in any other paper.

When using the (Shamir 2017a) dataset for identifying a dipole axis in the popualtion of galaxies with opposite spin directions, photometric objects that are part of the same galaxies such as satelite galaxies, merging systems, detached segments, large star clusters, etc, become "duplicate objects". But as mentioned above, the (Shamir, 2017a) paper does not use that dataset for that purpose, and no claim for any kind of axis in that dataset was made in any other paper.

One might wonder how such error can get through a peer-review process without being noticed. The way the paper is written, one can assume that Iye et al (2021) used the same data that I used to show a dipole axis. Moreover, the paper specifically states that I used the dataset of (Shamir, 2017a) with 33,028 Pan-STARRS galaxies to show a dipole axis.

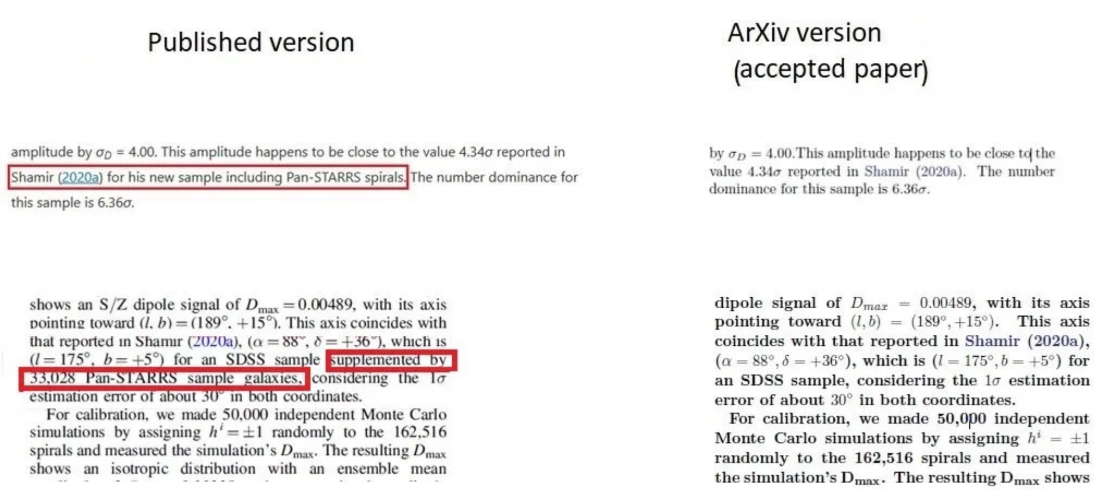

Figure 11. The claims marked in red did not happen. Both instances of the claim are present in the journal version, but not in the arXiv version of the "accepted" paper.

That obviously never happened. Not in the reference cited in the paper (Shamir, 2020a), and not in any other paper. I never combined any number of SDSS galaxies with any number of Pan-STARRS galaxies to create a single dataset from the two telescopes. Certainly, I did not use such dataset to show any kind of dipole axis.

But the more interesting question is why the distribution of galaxies spin directions in the "clean" dataset is random. The answer is that it is not random. Even a very simple analysis of the exact same data used by Iye et al (2021) shows that the dataset is not random.

For instance, a simple binomial distribution analysis using the exact same "clean" dataset used by Iye et al (2021) shows that the distribution is not random.

Hemisphere (RA)	# Z-wise	# S-wise	#Z/#S	P (one-tailed)	P (two-tailed)
70-250	23,037	22,442	1.0265	0.0026	0.0052
>250 U <70	13,660	13,749	0.9935	0.29	0.58

That shows that the sky can be separated into two hemispheres such that one hemisphere has a higher number of clockwise galaxies, and the opposite hemisphere has a higher number of counterclockwise galaxies. Even when assuming that the distribution in the less populated hemisphere is fully random, a Bonferroni correction still provides probability of ~0.01 of the asymmetry to happen by chance. The data can be accessed at https://people.cs.ksu.edu/~lshamir/data/assym_72k (https://people.cs.ksu.edu/~lshamir/data/assym_72k) , and the results shown here can be easily reproduced.

When reproducing the method described in (Iye et al., 2021), the results are substantiqally different from the results shown in (Iye et al., 2021). The following link provides the data, code, and the results observed when applying the code to the data.

https://people.cs.ksu.edu/~lshamir/data/iye_et_al (https://people.cs.ksu.edu/~lshamir/data/iye_et_al)

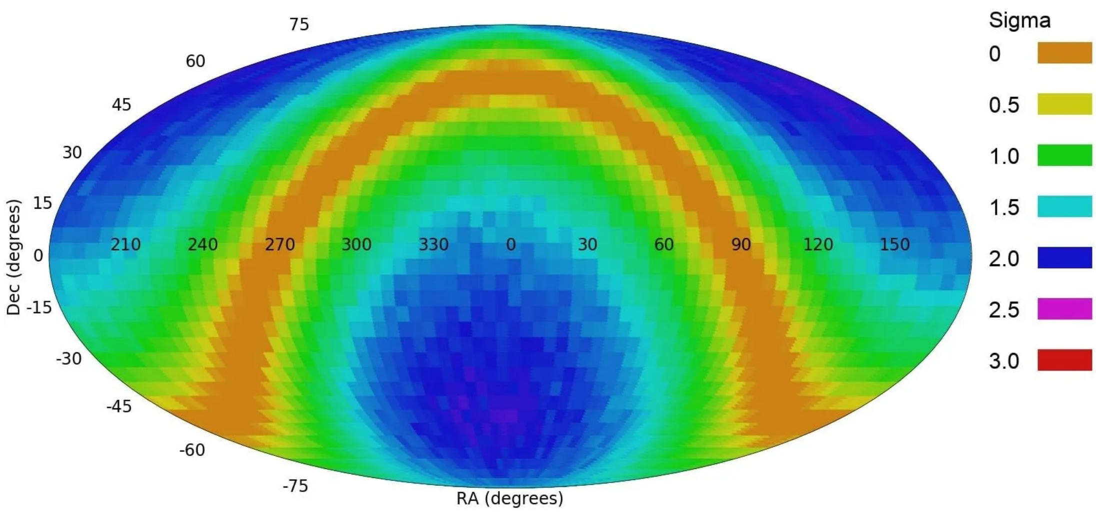

Figure 12, Results of applying the method described in (Iye et al., 2021) to the same "clean" dataset used in (Iye et al., 2021). The results show a statistically significant dipole axis.

Figure 12 shows that when applying the same method described in (Iye et al, 2021) to the same "clean" dataset, the results are substantially different from the results reported in (Iye et al., 2021).

The dipole axis with 2.14 sigma is weaker than the dipole axis reported with other datasets, and that can be attributed to the fact that the dataset was limited to bright galaxies (i<18), and therefore galaxies with lower redshift. It has been shown here and in other papers (e.g., Shamir 2020b) that when limiting the redshoft, the asymmetry becomes weaker. But in any case, 2.14 sigma is still statistically significant.

It is difficult to fully understand why the results reported in (Iye et al., 2021) are so different from the results observed when reproducing their analysis.

One reason can be that (Iye et al., 2021) observed the 0.29 sigma reported in the abstract when using a subset of the data, limited to photometric redshift of less than 0.1. That redshift range has been shown in the past to have random distribution (Shamir, 2020b), and therefore these results are in full agreement with previous work described in (Shamir, 2020b).

But Iye et al (2021) also report on 1.29 sigma when not limiting the galaxies by their redshift. That 1.29 sigma is in direct disagreement with the 2.14 sigma observed when reproducing the analysis.

One of the possible explanations is that Iye et al (2021) used the photometric redshift not just to select a subset of the data, but also for the analysis. The photometric redshift is highly inaccurate and systematically biased, and its inaccuracy is about 20%. Obviously, looking for ~1% signal in data that has ~20% error is essentially a random number generator, and the use of the photometric redshift is completely expected to reduce the strength of the signal.

One might wonder how such a crude scientific error was not noticed in a peer-review process. According the AAS EiC, neither the reviewer nor the editors knew that the analysis of the dipole was based on the photometric redshift. Indeed, the photometric redshift is not discussed or mentioned anywhere in the paper. The only link to the photometric redshift is the reference to (Paul et al., 2018), which is a catalog of photometric redshift with error of ~18.5%. However, the reference is not present in the accepted version of the paper, which means that the reviewer did not have a chance to know that the photometric redshift was used.

Accepted version

The second sample we studied is a volume-limited sample retaining 111,867 spirals with measured redshift in the range $0.01 \leq z \leq 0.1$. To avoid any possible effect of local peculiar motions, 162 nearby spirals at $z \leq 0.01$ were removed from this volume-limited sample. This sample shows a stronger S/Z dipole signal $D_{max} = 0.00773$ with its axis pointing toward $(l, b) = (138°, -38°)$.

Published version

The second sample we studied is a volume-limited sample retaining 111,867 spirals with measured redshift (Paul et al. 2018) in the range $0.01 \leqslant z \leqslant 0.1$. To avoid any possible effect of local peculiar motions, 162 nearby spirals at $z \leqslant 0.01$ were removed from this volume-limited sample. This sample shows a stronger S/Z dipole signal $D_{\max} = 0.00773$ with its axis pointing toward $(l, b) = (138°, -38°)$.

"Accepted" ArXiv version

The second sample we studied is a volume-limited sample retaining 111,867 spirals with measured redshift in the range $0.01 \leq z \leq 0.1$. To avoid any possible effect of local peculiar motions, 162 nearby spirals at $z \leq 0.01$ were removed from this volume-limited sample. This sample shows a stronger S/Z dipole signal $D_{max} = 0.00773$ with its axis pointing toward $(l, b) = (138°, -38°)$.

Figure 13. The reference to the photometric redshift catalog is present in the published version of the paper, but not in the accepted version.

The accepted version of the paper does not mention anywhere that the photometric redshift was used. Instead, it uses the term "measured redshift", which is a term that is never used as a synonym to photometric redshift. Given the way the paper is worded, and given that "measured redshift" is never used as a synonym to photometric redshift, a reader cannot know that the analysis made use of the photometric redshift.

While it is not entirely clear why the Iye et al (2021) paper cannot be reproduced, the AAS agrees that the paper may not be reproducible, and also contains a large number of errors. As the AAS argues:

“Dr. Iye’s paper has aspects that are sloppily explained/written. It may also be the case that their analysis is not reproducible from the info they provide, or is plain wrong. Many of the nefarious motives that Dr. Shamir ascribes can be interpreted as sloppiness, errors, or poor language/phrasing. If there are

substantive differences between the arXiv version not matching the accepted version, this isn’t great, but even if there’s a bad-faith reason for this, I think it’s outside our purview. People can post whatever they want on arXiv and claim that it is or isn’t the same as a published paper, and are beyond our purview or control.”

Chris Sneden (2021, on behalf of the AAS).

One might also notice the acknowledgement in the end of the paper.

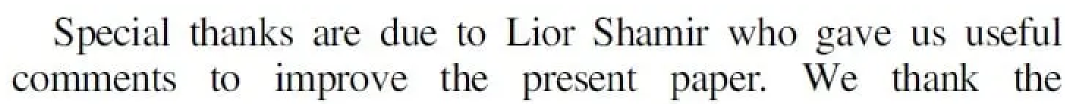
Special thanks are due to Lior Shamir who gave us useful comments to improve the present paper. We thank the

Figure 14. A weird "acknolwdgement". Nobody asked for my comments, and I did not even know the paper was being written. None of the statements made in the paper came from me.

I state that these authors never asked for my comments, never asked me any other question, and at no point of time I even knew that the paper was being written. The first time I saw the paper was after it was already accepted for publication. The authors of the paper refused to take comments from me, and 0.0% of the claims or statements made in the paper came from me. I therefore claim no responsibility of any kind to its content. Naturally, such an acknolwdgement can mislead the reviewer or reader to believe that I agree with the paper or that the paper was corrected based on comments from me. As stated above, that is not the case.

ABSTRACT

Observations using large datasets of galaxies imaged by DECam, SDSS, HST, and Pan-STARRS have shown substantial evidence of non-random cosmological-scale patterns in the spin directions of spiral galaxies. Here a dataset of nearly 800K galaxies imaged by the Dark Energy Survey are annotated by their spin directions. The results show patterns of non-random distribution of spiral galaxies. A chi^2 cosine dependence analysis shows a Hubble-scale dipole axis with statistical significance of 3.7 sigma. The profile of the spin directions of spiral galaxies and the location of the dipole axis is in very close agreement with the profiles observed by Pan-STARRS, DECam, and SDSS, and is well within one sigma from the dipole axis observed using HST data. All sky surveys show very similar patterns of non-random distribution of galaxy spin directions, and exhibit a Hubble-scale axis at the same location. That axis agrees across eight additional datasets of galaxies annotated by their spin directions. Some of the smaller datasets were annotated manually, while the larger datasets were annotated automatically by applying a fully symmetric model-based algorithm that follows clear symmetric rules. In all cases the results are nearly identical, further demonstrating the consistency of the patterns. The change in the strength and location of the most likely axis when the redshift of the galaxies gets higher suggests that if such axis indeed exists, it might not go directly through Earth. Possible errors that can lead to the observation are discussed, and previous studies showing opposite results are analyzed to understand the experimental design that led to the observations.

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