

# An empirical consistent redshift bias: A possible direct reproducible observation of Zwicky's TL theory

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## Abstract

Recent advancements have shown tensions between observations and our current understanding of the Universe. Such observations may include the  $H_0$  tension and massive galaxies at high redshifts that are older than what traditional galaxy formation models predicted. Since these observations are based on the redshift as the primary distance indicator, a bias in the redshift may explain these tensions. While the redshift follows an established model, when applied to astronomy it is based on the assumption that the rotational velocity of the Milky Way galaxy relative to the observed galaxies has a negligible effect on the redshift. But given the mysterious nature of the physics of galaxy rotation, that assumption should be tested. The test is done by comparing the redshift of galaxies rotating in the same direction relative to the Milky Way to the redshift of galaxies rotating in the opposite direction relative to the Milky Way. The results show that the mean redshift of galaxies that rotate in the same direction relative to the Milky Way is higher than the mean redshift of galaxies that rotate in the opposite direction. Additionally, the redshift difference becomes larger as the redshift gets higher. The consistency of the analysis was verified by comparing data collected by three different telescopes, annotated using four different methods, released by three different research teams, and cover both the Northern and Southern ends of the galactic pole. All datasets are in excellent agreement with each other, showing consistency in the observed redshift bias. Given the “reproducibility crisis” in science, all datasets used in this study are publicly available, and the results can be easily reproduced. The observation could be a first direct empirical reproducible observation for the Zwicky’s “tired-light” model.

## 1 Introduction

The unprecedented imaging power of JWST has revealed new information about the Universe that is not aligned with some of the current fundamental cosmological assumptions. For instance, the presence of galaxies at redshifts higher than 13 (Curtis-Lake et al., 2023) or even as high as 15 (Whitler et al., 2023) was not expected according to previous assumptions (Cowley et al., 2018). Mature massive galaxies observed at redshift of  $\sim 11$  (Glazebrook et al., 2024) also challenge the cosmological model and the history of the Universe. The

existence of massive galaxies at high redshifts was reported also before JWST was launched (Neeleman et al., 2020), and JWST provided more and deeper instances of such galaxies, showing that mature galaxies were prevalent in the early Universe. Another example of a puzzling unexplained observation is the  $H_0$  tension, reflected by two different messengers that provide two different expansion rates and ages of the Universe (Wu and Huterer, 2017; Mörtzell and Dhawan, 2018; Bolejko, 2018; Davis et al., 2019; Pandey et al., 2020; Camarena and Marra, 2020; Di Valentino et al., 2021; Riess et al., 2022). Since both measure the same Universe, it can be assumed that one of these measurements is biased.

These puzzling observations introduce a challenge to cosmology: If the distance indicators are fully accurate, the standard cosmological theories are incomplete. If the current standard cosmological theories are complete, then the distance indicators might not be fully accurate. That is, either the standard cosmological theories need to be revised, or the redshift as a distance indicator needs to be revised, but the two might not be able to co-exist without modifications. While some solutions include alternative cosmological models, it has also been suggested that the tensions can be solved by changing the redshift model (Crawford, 1999; Pletcher, 2023; Gupta, 2023; Lee, 2023; Lovyagin et al., 2022).

The redshift of an astronomical object is expected to correspond to the linear velocity of the object relative to Earth. But in addition to the linear velocity, the measurement of the redshift can also be affected by the rotational velocity of the observed galaxy, or the rotational velocity of the Milky Way. The rotational velocity of a luminous object can affect the Doppler shift effect (Marrucci, 2013; Lavery et al., 2014; Liu et al., 2019), but since the rotational velocity of a galaxy is far smaller than its linear velocity, it is assumed that the effect of the rotational velocity is negligible. For that reason the rotational velocity of galaxies is ignored in common redshift models. However, it should be reminded that the physics of galaxy rotation, and namely its rotational velocity, is still one of the most mysterious and most provocative phenomena in nature.

While the puzzling nature of the physics of galaxy rotation was noted in the first half of the 20th century (Oort, 1940), only five decades later it became part of the mainstream science (Rubin, 1983; El-Neaj et al., 2020). Common explanations include dark matter (Rubin, 1983) or modified Newtonian dynamics (Milgrom, 1983), but numerous other explanations have also been proposed (Sanders, 1990; Capozziello

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and De Laurentis, 2012; Chadwick et al., 2013; Farnes, 2018; Rivera, 2020; Nagao, 2020; Blake, 2021; Gomel and Zimmerman, 2021; Skordis and Złośnik, 2021; Larin, 2022). But despite over a century of scientific research, there is still no proven explanation to the nature of galaxy rotation (Sanders, 1990; Mannheim, 2006; Kroupa, 2012; Kroupa et al., 2012; Kroupa, 2015; Arun et al., 2017; Akerib et al., 2017; Bertone and Tait, 2018; Aprile et al., 2018; Skordis and Złośnik, 2019; Sivaram et al., 2020; Hofmeister and Criss, 2020; Byrd and Howard, 2021; Haslbauer et al., 2022a,b).

The purpose of this experiment is to examine the impact of the galaxy rotational velocity on the redshift. That can be done by observing galaxies located around the Galactic pole, and comparing the redshift of galaxies that rotate in the same direction relative to the Milky Way to the redshift of galaxies that rotate in the opposite direction relative to the Milky Way. An observed difference in the redshift can indicate that the redshift is affected by the rotational velocity, and therefore the way it is implemented in astronomy is incomplete.

## 2 A possible link between the galaxy rotational velocity and the redshift

A preliminary possible link between the redshift and the rotational velocity of galaxies have been proposed through empirical observations showing that galaxies that rotate in the same direction relative to the Milky Way have different redshift compared to galaxies that rotate in the opposite direction relative to the Milky Way (Shamir, 2024b). The analysis was based on several different datasets of galaxies acquired by two different telescopes, and annotated by their direction of rotation using several different annotation methods. Since galaxies with leading arms are extremely rare (Buta et al., 2003), the direction of rotation was determined by the arms of the galaxies. The analysis was based on galaxies at the  $10^\circ \times 10^\circ$  field centered at the Galactic pole, as well as the  $20^\circ \times 20^\circ$  field to increase the number of galaxies and consequently the statistical significance. The analysis was done for both the Northern and Southern ends of the Galactic pole (Shamir, 2024b).

The catalogs used in the experiment included galaxies annotated by the *Ganalyzer* algorithm (Shamir, 2011a,b), by the *SpArcFiRe* method (Davis and Hayes, 2014, 2021), and by the manual annotation of *Galaxy Zoo* such that the “super-clean” criteria of 95% agreement between the annotations (Lintott et al., 2008) was used. All of these methods determine the spin direction of the galaxies based on analysis if the shape of the galaxy arms. The datasets are all available publicly. SDSS and DESI galaxies annotated by the *Ganalyzer* algorithm are available at <https://people.cs.ksu.edu/~lshamir/data/zdifference/>. Galaxies annotated by *SpArcFiRe* are available at <https://people.cs.ksu.edu/~lshamir/data/sparcfire/>. The annotations of *Galaxy Zoo* can be accessed through SDSS CAS server at <http://casjobs.sdss.org/CasJobs/default.aspx>. Table 1 shows the mean redshift of galaxies that rotate in the same direction and in the opposite direction relative to the Milky Way.

As the table shows, all catalogs show lower redshift for

galaxies that rotate in opposite direction relative to the Milky Way. With the exception of the small Galaxy Zoo catalog, in all cases the difference is statistically significant. The observed  $\Delta z$  difference was higher when using the smaller  $10^\circ \times 10^\circ$  field centered at the Galactic pole compared to the larger  $20^\circ \times 20^\circ$  field. That can be explained by the difference in the relative rotational velocity that is expected to increase when the observed galaxies are closer to the Galactic pole. The *SpArcFiRe* algorithm was used with both the original images and with the mirrored images. That was done due to the reported bias of the *SpArcFiRe* method (Hayes et al., 2017). *SpArcFiRe* provided a higher number of galaxies, but on the expense of the accuracy of the annotation, leading to a smaller absolute  $\Delta z$  though stronger statistical signal due to the higher number of galaxies (Shamir, 2024b). The *Ganalyzer* algorithm has a simple “mechanical” symmetric nature (Shamir, 2011a, 2021, 2022a), and therefore mirroring the galaxies did not change the results (Shamir, 2024b). When using *SpArcFiRe* the results changed when the galaxy images were mirrored, but the change was not substantial, except for the expected inverse  $\Delta z$  observed when the galaxy images were mirrored.

The p-values shown in Table 1 are based on Student t-test, which assumes normal distribution of the redshift. Because the redshift distribution does not necessarily follow normal distribution, the Student t-test might not provide the real probability to have such distribution by chance. To verify the statistical significance, a simulation analysis was used such that the galaxies were separated randomly into two groups, and the difference between the mean redshift of each of the two groups of galaxies was computed. That was repeated 100,000 times with the dataset of 1,642 galaxies of the second row in Table 1. In 307 of the runs the difference between the first group of galaxies and the second group was larger than 0.0016, providing a probability of 0.0031 to occur by chance (Shamir, 2024b).

The DESI Legacy Survey data was collected around the Southern galactic pole, and therefore galaxies in that field that rotate in the same direction relative to the Milky Way would seem to rotate in the opposite direction compared to galaxies in the Northern galactic pole that rotate in the same direction relative to the Milky Way. That provides an additional verification that the difference is not a feature of some unknown behavior of the galaxy annotation methods, as such effect should have been consistent across the sky, rather than flip and provide inverse results in the two ends of the Galactic pole (Shamir, 2024b). An additional control experiment was performed by using SDSS galaxies from the same source that rotate in opposite directions in fields that are perpendicular to the Galactic pole. For instance, in the  $20 \times 20$  degree fields centered at  $(\alpha = 102^\circ, \delta = 0^\circ)$  the  $\Delta z$  was  $0.00022 \pm 0.004$ , which is statistically insignificant.

Table 2 shows the differences between the flux in different wavelengths. The flux differences between galaxies that rotate in opposite directions show a difference of  $\sim 10\%$  in the different filters, and the absolute difference is larger when the wavelength is shorter (Shamir, 2024b).

Table 1: The mean redshift of galaxies that rotate in the same direction relative to the Milky Way galaxy (MW) and the mean redshift of galaxies that rotate in the opposite direction relative to the Milky Way (OMW). The  $p$  values are the one-tailed  $p$  values determined by the Student t-test. All datasets are publicly available. The experiments are described in detail in (Shamir, 2024b).

Survey	Pole	Field size ( $^{\circ}$ )	Annotation	# MW	# OMW	$Z_{mw}$	$Z_{omw}$	$\Delta z$	t-test p
SDSS	North	10×10	Ganalyzer	204	202	$0.0996 \pm 0.0036$	$0.08774 \pm 0.0036$	$0.01185 \pm 0.005$	0.01
SDSS	North	20×20	Ganalyzer	817	825	$0.09545 \pm 0.0017$	$0.08895 \pm 0.0016$	$0.0065 \pm 0.0023$	0.0029
SDSS	North	20×20	Galaxy Zoo	154	135	$0.07384 \pm 0.004$	$0.06829 \pm 0.0035$	$0.0056 \pm 0.0053$	0.15
SDSS	North	10×10	SpArcFiRe	710	732	$0.07197 \pm 0.0015$	$0.06234 \pm 0.0014$	$0.00963 \pm 0.002$	<0.0001
SDSS	North	10×10	SpArcFiRe Mirrored	728	709	$0.06375 \pm 0.0014$	$0.07191 \pm 0.0014$	$-0.00816 \pm 0.002$	<0.0001
SDSS	North	20×20	SpArcFiRe	2903	2976	$0.07285 \pm 0.0007$	$0.07116 \pm 0.0007$	$0.00169 \pm 0.001$	0.04
SDSS	North	20×20	SpArcFiRe Mirrored	3003	2914	$0.07113 \pm 0.0007$	$0.07271 \pm 0.0007$	$-0.00158 \pm 0.001$	0.05
DESI	South	10×10	Ganalyzer	414	376	$0.1352 \pm 0.0027$	$0.1270 \pm 0.0025$	$0.0082 \pm 0.0036$	0.018
DESI	South	20×20	Ganalyzer	1702	1681	$0.1317 \pm 0.0013$	$0.1273 \pm 0.0014$	$0.0044 \pm 0.0018$	0.008

Table 2: Flux differences in different filters between galaxies that rotate in the same and in the opposite direction relative to the Milky Way. The data are the galaxies and the field shown in the first row of Table 1. The  $p$  values are the two-tailed Student t-test  $p$  value.

Band	MW	OMW	$\Delta$	t-test P
spectroFlux_g	$25.969 \pm 0.8669$	$28.554 \pm 1.0918$	-2.585	0.063
spectroFlux_r	$53.2433 \pm 1.765$	$58.6214 \pm 2.3422$	-5.378	0.066
spectroFlux_i	$77.4189 \pm 2.513$	$85.0868 \pm 3.407$	-7.667	0.067

### 3 Analysis of HSC DR3 galaxies

The analysis shown in Section 2 and in (Shamir, 2024b) shows a consistent but relatively small redshift bias. But these analyses are based on galaxies imaged mostly by SDSS, with one experiment with galaxies obtained through DESI Legacy Survey. Therefore, most galaxies used for the experiments included in Table 1 are of relatively low redshift. That makes it difficult to profile the change in  $\Delta z$  when the redshift changes. That is, if  $\Delta z$  increases at higher redshift, it can provide an indication that the redshift bias is higher for high-redshift galaxies.

To profile the dependence between the  $\Delta z$  and the redshift, an experiment was performed with the third data release (DR3) of the Hyper Suprime-Cam (HSC). Using the 8.2m Subaru telescope, HSC provides high details of galaxies with higher redshifts compared to galaxies imaged by SDSS or DESI Legacy Surveys. That allows to annotate galaxies with higher redshift by their direction of rotation, and test whether the redshift bias increases with the redshift.

The galaxies used in the experiment include all HSC DR3 galaxies that have redshifts in SDSS DR17. That included 101,415 galaxies with redshift of  $z < 0.3$ . The purpose of the redshift limit was to avoid galaxies that cannot be annotated accurately by their visible spin patterns. The galaxies were annotated by the *Ganalyzer* algorithm (Shamir, 2011a,b) as described in (Shamir, 2024b). That led to a clean dataset of 13,477 galaxies.

The smaller dataset of annotated galaxies compared to the initial dataset is expected since not all galaxies are spiral, and not all spiral galaxies have an identifiable direction of rotation. Manual inspection of randomly selected 100 galaxies showed that all galaxies are annotated accurately. The dataset can be accessed at [https://people.cs.ksu.edu/~lshamir/data/zdifference\\_hsc/](https://people.cs.ksu.edu/~lshamir/data/zdifference_hsc/). The redshift distribution of the galax-

ies is displayed in Figure 1. Although most galaxies have a relatively low redshift, the catalog still contains more than 1000 galaxies with  $z > 0.2$ .

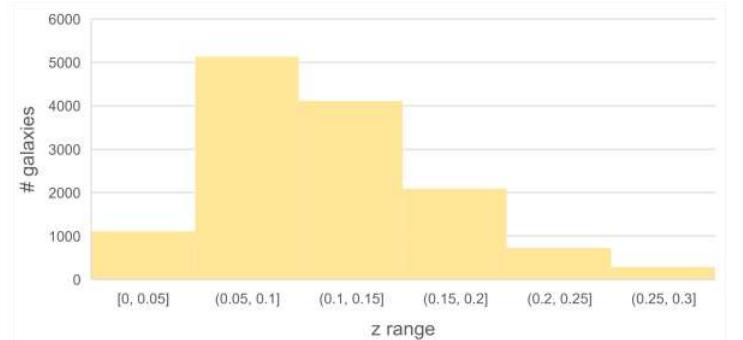


Figure 1: Distribution of the redshift of the HSC DR3 galaxies.

While providing better image quality and depth compared to the catalogs summarized in Section 2, the downside of the HSC catalog used here is that it does not cover neither the South nor North end of the Galactic pole. Therefore, the galaxies used for the analysis are galaxies that are closer to the South end of the Galactic pole, as well as galaxies that are close to the North end of the Galactic pole. The declination of the galaxies range between  $-6.58^{\circ}$  to  $53.18^{\circ}$ . The distribution of the right ascension is shown in Figure 2. The catalog contains 4,724 galaxies that are within  $60^{\circ}$  from the Southern Galactic pole, and 8,753 galaxies that are within  $60^{\circ}$  from the Northern Galactic pole.

Tables 3 and 4 show the mean redshift of galaxies that rotate in the same direction relative to the Milky Way and in the opposite direction relative to the Milky Way in the Southern and Northern Galactic poles, respectively. The tables show the difference between the mean  $z$  among all galaxies, but also the differences when the galaxy population is separated into 0.1 redshift ranges. As the table shows, in both ends of the Galactic pole there is a statistically significant difference between the redshift of galaxies that rotate in the same direction as the Galactic pole, and galaxies that rotate in the opposite direction relative to the Galactic pole.

The direction of rotation of the galaxies observed in the opposite sides of the Galactic pole are inverse, such that a galaxy located around the North end of the Galactic pole and rotates in the same direction relative to the Milky Way would

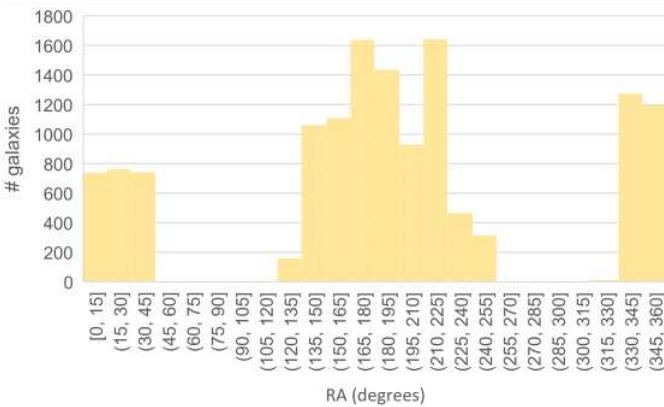


Figure 2: Distribution of the RA in the dataset of HSC DR3 galaxies.

seem to rotate in the opposite direction if it was located in the South end of the Galactic pole. That is naturally taken into account in the analysis, but the consistency between both ends of the Galactic pole shows that the differences are not driven by an unknown bias in the annotation, as such bias should have been consistent in both ends of the Galactic pole, and not expected to flip based on the locations of the galaxies in the sky.

As discussed in Section 2, the p-values are based on Student t-test, and therefore on the assumption that the redshifts are distributed normally. Since that assumption might not necessarily be correct, a simulation was performed such that the galaxies were separated into two groups randomly, and the mean redshift of one group was compared to the mean redshift of the galaxies of the other group (Shamir, 2024b). After 100,000 tests, the galaxies close to the Southern Galactic pole were separated into two random groups with mean redshift difference larger than 0.00363 in 518 runs. The same experiment when using the galaxies closer to the Northern Galactic pole showed a mean redshift difference larger than 0.002451 in 230 of the runs. These simulation experiments show that the probability to have such separation by mere chance is far below 1%.

The simple separation of the analysis into several redshift ranges shows that  $\Delta z$  increases as the redshift gets higher. That observation is consistent in both ends of the Galactic pole. Figure 3 shows the  $\Delta z$  in the different redshift ranges.

The statistical significance of the increase in  $\Delta z$  can also be determined by using a simple Pearson correlation after assigning the galaxies that rotate in the same direction relative to the Milky Way with the value 1, and galaxies that rotate in the opposite direction relative to the Milky Way as -1. When using galaxies closer to the Northern Galactic pole the Pearson correlation is 0.0296, and the probability to have such correlation by chance is  $p=0.02$ . When using galaxies closer to the Southern Galactic pole, the Pearson correlation is 0.02669, and the  $p$  is 0.0064.

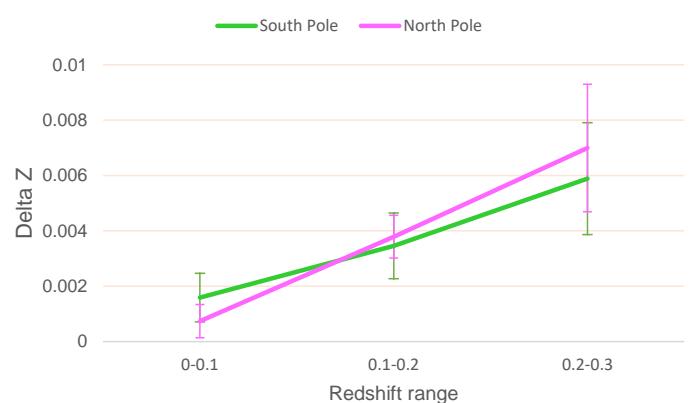


Figure 3:  $\Delta z$  in different redshift ranges in the South and North end of the Galactic pole. Both ends of the Galactic pole show a very similar  $\Delta z$  increase.

## 4 Verification using a third-party dataset

To further test the consistency of the bias, the observation described in Sections 2 and 3 was compared to a third party catalog (Longo, 2011). That catalog was prepared by five undergraduate students who manually annotated SDSS galaxies, and the galaxy images were also mirrored to offset for a possible human bias (Longo, 2011). While the purpose of that dataset was not to compare redshifts or test the impact of the rotational velocity of the Milky Way, 14,462 of the galaxies in that dataset has redshift, and therefore can be used for the analysis. The dataset can be accessed at <https://ars.els-cdn.com/content/image/1-s2.0-S0370269311003947-mmcl1.txt>. The redshift of all galaxies that have spectra is smaller than 0.1, and the redshift distribution is displayed by Figure 4. The distribution of the RA is displayed in Figure 5. As the figure shows, the majority of the galaxies are in relatively close proximity to the Northern Galactic pole.

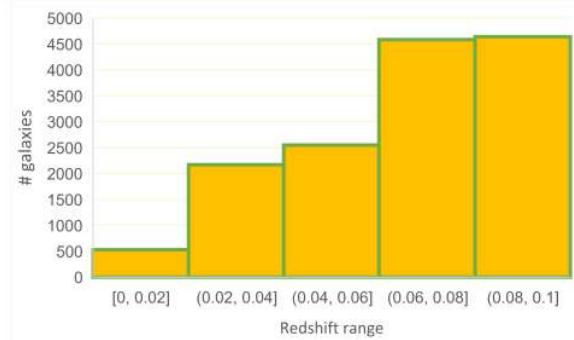


Figure 4: Distribution of the reshift of the galaxies in the catalog of (Longo, 2011). The redshift of all galaxies is smaller than 0.1.

A very simple analysis of the data shows that the mean redshift of the galaxies that rotate clockwise in that catalog is  $0.06586 \pm 0.00029$ , while the mean redshift of galaxies rotating

Table 3: Redshift of the galaxies around the Southern galactic pole that rotate in the same direction relative to the Milky Way and in the opposite direction relative to the Milky Way. The p values are the Student t-test probabilities to have such difference are stronger by chance.

z range	# MW	# OMW	$Z_{mw}$	$Z_{omw}$	$\Delta z$	t-test P
0-0.1	871	917	$0.072788 \pm 0.0006$	$0.071198 \pm 0.0006$	$0.001589 \pm 0.0009$	0.03
0.1-0.2	1,100	1,144	$0.149292 \pm 0.0008$	$0.145834 \pm 0.0008$	$0.003458 \pm 0.001$	0.001
0.2-0.3	342	350	$0.242174 \pm 0.0015$	$0.236287 \pm 0.001$	$0.005886 \pm 0.002$	0.0006
All	2,313	2,411	$0.13421 \pm 0.001$	$0.13058 \pm 0.001$	$0.00363 \pm 0.0014$	0.005

Table 4: Redshift of the galaxies around the Northern galactic pole that rotate in the same direction relative to the Milky Way and in the opposite direction relative to the Milky Way.

z range	# MW	# OMW	$Z_{mw}$	$Z_{omw}$	$\Delta z$	t-test P
0-0.1	2,202	2,255	$0.070232 \pm 0.0004$	$0.069493 \pm 0.0004$	$0.000739 \pm 0.0006$	0.095
0.1-0.2	1,949	2,021	$0.138494 \pm 0.0006$	$0.134705 \pm 0.0005$	$0.003789 \pm 0.0008$	0.00005
0.2-0.3	166	160	$0.228586 \pm 0.0018$	$0.221593 \pm 0.0014$	$0.006993 \pm 0.0023$	0.0012
All	4,317	4,436	$0.10714 \pm 0.0006$	$0.104689 \pm 0.0006$	$0.002451 \pm 0.0008$	0.0019

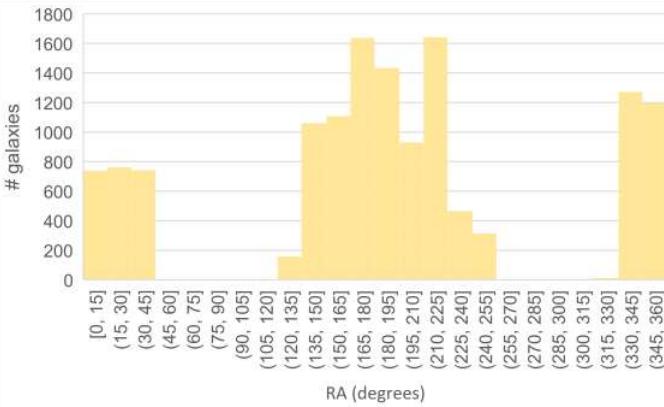


Figure 5: Distribution of the RA in the catalog of (Longo, 2011). Most galaxies are closer to the North end of the Galactic pole.

counterclockwise is  $0.065 \pm 0.00029$ . The probability to have such difference by chance is 0.018. While the statistically significant redshift difference might seem unexpected, most of the galaxies are located near the Northern Galactic pole, and therefore the lower redshift for galaxies that rotate counterclockwise is in agreement with the results shown in Table 4 using the HSC data taken from the Northern galactic pole, as well as the other datasets show in Table 1. Table 5 shows the mean  $z$  of galaxies that rotate in the same direction relative to the Milky Way in the catalog (Longo, 2011) and the mean  $z$  of galaxies that rotate in the opposite direction relative to the Milky Way in the Southern and Northern Galactic poles.

As the table shows, the  $\Delta z$  around the Northern Galactic pole agrees well with the  $\Delta z$  observed by HSC around the Northern Galactic pole at the same redshift range of 0-0.1, as shown in Table 4. The opposite end of the Galactic pole also shows that galaxies that rotate in the opposite direction relative to the Milky Way have lower redshift compared to galaxies that rotate in the opposite direction, but in the case of the (Longo, 2011) catalog the difference is not statistically significant, possible due to the low number of galaxies in that part of the sky.

Since the redshift of the galaxies in that catalog is limited to  $z < 0.1$ , a direct comparison to the redshift ranges used in Table 4 is not possible. However, when using the galaxies

around the Northern Galactic pole, the Pearson correlation coefficient between the direction of rotation and the redshift is 0.02033, and the probability to have this coefficient by chance is  $\sim 0.01$ . That provides an indication that the bias increases with the redshift, as was also observed with the data from HSC DR3. The third-party dataset therefore shows the same observation as the dataset of HSC DR3 galaxies and in fact data from all other premier sky surveys.

## 5 Possible link to Zwicky’s “tired-light” model

The early Universe as imaged by JWST is different than the early Universe predicted by the standard model. Among other explanations, that tension was proposed to have a link to Fritz Zwicky’s “tired-light” (TL) theory (Zwicky, 1929; Yourgrau and Woodward, 1971; Vigier, 1977; Shao, 2013; Kragh, 2017; Shao et al., 2018; Sato, 2019; LaViolette, 2021; Lovyagin et al., 2022; Lopez-Corredoira, 2023; Gupta, 2023, 2024).

According to TL, photons lose their energy along their traveling path through the Universe. That can lead to differences in the redshift as observed from Earth, and therefore different galaxies that are more distant from Earth can have different redshift than galaxies that are closer to Earth. If that theory is correct, it can explain the early mature galaxies observed by JWST, as their true age is not the same age that their redshift indicates. In its extreme form, TL can argue that the Big Bang is merely an artifact created by TL, and the Universe is in fact in steady state. One of the downsides of the model is that there is no empirical observation that can show that photons indeed lose their energy as they travel through the Cosmos.

An empirical experiment that shows a redshift bias that grows as the redshift gets higher is difficult to perform at cosmological-scale distance, since the only information that can be obtained is the redshift as observed from Earth. While the distances of the galaxies can be estimated through other candles such as Ia supernovae, it is difficult to prove whether the redshift of a galaxy is higher because the galaxy indeed moves faster away from Earth in accordance to the Big Bang theory, because of TL, or a combination of the two. Ia supernovae are also limited in the distance range compared to the redshift, and therefore a redshift bias in the very high

Table 5: Redshift of the galaxies annotated by (Longo, 2011) around the Southern and Northern galactic poles that rotate in the same direction relative to the Milky Way and in the opposite direction relative to the Milky Way. The older third-party dataset is used to confirm the results observed with the other datasets.

Hemisphere	# MW	# OMW	$Z_{mw}$	$Z_{omw}$	$\Delta z$	t-test P values
North	6450	6573	$0.06598 \pm 0.0003$	$0.06498 \pm 0.0003$	$0.001 \pm 0.0004$	0.01
South	722	717	$0.06516 \pm 0.0008$	$0.06469 \pm 0.0009$	$0.00047 \pm 0.0012$	0.34

redshifts will be difficult to profile using Ia supernovae.

But when using the rotational velocity of the Earth within the Milky Way galaxy, a small redshift bias is expected due to the rotational velocity of the Earth. That bias is expected to affect galaxies that rotate in the same direction relative to the Milky Way differently than it affect galaxies that rotate in the opposite direction relative to the Milky Way. That bias is expected to be small, but according to several datasets as shown here it is statistically significant. More importantly, the bias grows with the redshift, suggesting that it is not the velocity alone that leads to the bias. The rotational velocity of the Earth within the Milky Way galaxy is obviously a constant that does not change, and the radial velocity of galaxies that rotate in the same direction relative to the Milky Way is expected to be, on average, the same as the radial velocity of galaxies that rotate in the opposite direction relative to the Milky Way. The idea that the redshift can change with the distance, and not necessarily the velocity, might be an indication supporting Fritz Zwicky’s century-old theory.

That observation can also be related to the far higher number of galaxies that rotate in the opposite direction relative to the Milky Way as imaged by JWST (Shamir, 2024a). The JWST deep field images show a 140% more galaxies that rotate in the opposite direction relative to the Milky Way (Shamir, 2024a). A possible explanation is that galaxies that rotate in the opposite direction relative to the Milky Way are brighter due to the Doppler shift effect. Due to TL, the brightness difference gets more significant when the galaxies are more distant from Earth, and therefore much more galaxies that rotate in the opposite direction relative to the Milky Way are observed. Earlier observation made before JWST saw first light also showed such asymmetry that grows with the redshift (Shamir, 2020, 2022b), although at the lower redshift ranged the asymmetry was far milder than the asymmetry observed in the early Universe image by JWST.

## 6 Conclusion

Unexpected observations such as the  $H_0$  tension and galaxies that according to the current theories are expected to be older than what traditional galaxy formation models predicted are challenging the standard cosmological model. If the cosmological model is complete and fully accurate, the distance measurements, and primarily the redshift, are biased. If the redshift is fully accurate then the standard cosmological model and basic theories regarding galaxy formation and the history of the Universe are incomplete. In any case, the redshift as used currently and the existing basic cosmological theories cannot co-exist without modifications.

This paper presents empirical observations that show that the redshift model might be biased, and the bias might be

driven by the rotational velocity of the Milky Way relative to the rotational velocity of the observed galaxies. The observed bias is consistent across different telescopes, different annotation methods, and shows very similar bias in both ends of the Galactic pole. It is also consistent in catalogs that were collected for other purposes by different research teams.

The empirical observations described in this paper are provided with the data to ensure that the results can be reproduced. It had been shown that the vast majority of the scientific results cannot be reproduced (Stodden et al., 2018), introducing the challenge known as the “reproducibility crisis” in science (Baker, 2016; Miyakawa, 2020; Sayre and Riegelman, 2018; Ball, 2023). The ability to access the data and reproduce the results allows to advance science in a transparent manner, and avoid errors that might not be noticeable to a reader unless they have access to the data.

In the current astrophysics and cosmology practices, the redshift is used in most cases by ignoring the rotational velocity of the Milky Way, as the rotational velocity is far lower than the linear velocity and can therefore be considered negligible. But it should be reminded that the physics of galaxy rotation, and in particular the rotational velocity of galaxies, is still not fully understood (Opik, 1922; Babcock, 1939; Oort, 1940; Rubin and Ford Jr, 1970; Rubin et al., 1978, 1980, 1985; Sanders, 1990; Sofue and Rubin, 2001; Mannheim, 2006; Kroupa, 2012; Kroupa et al., 2012; Kroupa, 2015; Arun et al., 2017; Akerib et al., 2017; Bertone and Tait, 2018; Aprile et al., 2018; Skordis and Zlošnik, 2019; Sivaram et al., 2020; Hofmeister and Criss, 2020; Byrd and Howard, 2021; Gomel and Zimmerman, 2021; Haslbauer et al., 2022b). . Theories such as dark matter (Rubin, 1983) or MOND (Milgrom, 1983) have been proposed to explain the anomaly of the rotational velocity of galaxies, but several decades of research still have not led to a proven explanation to the provocative nature of the rotational velocity of galaxies.

It is difficult to identify an immediate explanation to the link between the rotational velocity and the redshift as observed from Earth. A possible explanation is the tired-light theory. But as mentioned above, the physics of galaxy rotation in general is difficult to explain without making unproven assumptions. Since the redshift is the most common distance indicator in cosmological scales, a bias in the redshift can impact a large number of other studies that make use of the redshift.

Because the bias tends to becomes larger when the redshift gets higher, it is possible that such bias can explain anomalies such as galaxies that according to the existing theories are expected to be older than what traditional galaxy formation models predicted. The experiments described here were based on relatively low redshift ranges, and therefore it is still unclear whether higher redshifts will have significant redshift bias. Studying the bias in higher redshifts will require to use a

large number of galaxies with redshift imaged by space-based instruments such as JWST at around the galactic pole.

Because  $H_0$  is determined by using the redshift, a redshift bias can also explain the observed  $H_0$  tension. For instance, when using the *SH0ES* catalog (Khetan et al., 2021) of Ia supernovae by just selecting the galaxies that rotate in the same direction as the Milky Way,  $H_0$  drops from  $\sim 73.7$  to  $\sim 69.05 \text{ km/sMpc}^{-1}$  (McAdam and Shamir, 2023), which is within statistical error from the  $H_0$  as observed by the CMB. When using just *SH0ES* galaxies that rotate in the opposite direction relative to the Milky Way, the  $H_0$  increases to  $\sim 74.2 \text{ km/sMpc}^{-1}$  (McAdam and Shamir, 2023). Although *SH0ES* contains a relatively small number of Ia supernovae with their host galaxies, it suggests that the redshift as a distance indicator might depend on the rotational velocity relative to the rotational velocity of the Milky Way. This observation is also aligned with the contention the  $H_0$  tension might require new physics that applies to the entire Universe, rather than certain changes in the physics of the early Universe (Vagnozzi, 2023). Because the  $H_0$  is determined by using the redshift, redshift bias can also be related to the observed  $H_0$  anisotropy (Javamardi et al., 2015; Krishnan et al., 2022a; Cowell et al., 2022; McConville and Colgain, 2023; Aluri et al., 2023), which is another puzzling observation that does not have an immediate explanation.

It is also possible that the redshift difference is not a bias, and galaxies that rotate in the opposite direction relative to the Milky Way are indeed closer to Earth compared to galaxies that rotate in the same direction relative to the Milky Way. In that case the alignment with both ends of the Galactic pole is merely a coincidence. Such large-scale alignment is far larger than any known cluster, super-cluster, or filament in the cosmic web. That might be in agreement with numerous other observations that suggest that the cosmological principle is violated (Aluri et al., 2023).

Although alignment in galaxy spin directions is expected (d'Assignies D et al., 2022; Kraljic et al., 2020), it does not expect to form a cosmological-scale axis. If such axis indeed exists and it is not driven by the impact of the rotational velocity on the redshift measurements, it can be linked with theories such as dipole cosmology (Ebrahimanian et al., 2023; Krishnan et al., 2022b; Allahyari et al., 2023; Krishnan et al., 2023b,a), or rotating universe (Gödel, 1949; Ozsváth and Schücking, 1962; Gödel, 2000; Chechin, 2016; Campanelli, 2021). Theories that assume a universe rotating around a cosmological-scale axis include Black Hole Cosmology (Pathria, 1972; Stuckey, 1994; Easson and Brandenberger, 2001; Poplawski, 2010; Christillin, 2014; Dymnikova, 2019; Chakrabarty et al., 2020; Poplawski, 2021; Gaztanaga, 2022a,b) and ellipsoidal universe (Campanelli et al., 2006, 2007; Gruppuso, 2007; Campanelli et al., 2011; Cea, 2014).

Tensions between the expected age of some galaxies and the age of the Universe, as well as other cosmological-scale anisotropies and observations such as the  $H_0$  tension, challenge our understanding of the Universe. It is clear that the current theories cannot co-exist with the redshift model as it is used currently, and therefore if the current theories are complete, it means that the redshift as a distance indicator is incomplete. This paper showed consistent evidence that the redshift depends on the rotational velocity of the Milky Way

relative to the observed objects. The bias is small, but if it increases in the redshift ranges of the JWST deep fields it can potentially explain the existence of mature galaxies in the early Universe.

## Data availability

All datasets used in this paper are publicly available. HSC DR3 galaxy data are available at [https://people.cs.ksu.edu/~lshamir/data/zdifference\\_hsc/](https://people.cs.ksu.edu/~lshamir/data/zdifference_hsc/). Annotated SDSS and DESI galaxies from the Northern and Southern Galactic poles are available at <https://people.cs.ksu.edu/~lshamir/data/zdifference/>. The data used by Michael Longo can be accessed at <https://ars.els-cdn.com/content/image/1-s2.0-S0370269311003947-mmcl1.txt>. SDSS galaxies annotated by *SPARCFIRE* are available at <https://people.cs.ksu.edu/~lshamir/data/sparcfire/>. *Galaxy Zoo* data are available through SDSS CAS at <http://casjobs.sdss.org/CasJobs/default.aspx>.

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