“Dark velocity”: Observed discrepancy between the rotational velocity of galaxies and their physical properties

Lior Shamir

Kansas State University

PRESENTED AT:

AAS 241 iPoster Sessions

Sponsored by AAS PUBLISHING

1. "DARK VELOCITY"

The physics of galaxy rotation is one of the most puzzling phenomena. Despite over a century of research, the physics of galaxy rotation is still not fully understood. The most common theories that explain the anomaly are dark matter and MOND.

The first observations of the galaxy rotation anomaly were made in the first half of the 20th century, but were ignored, possibly due to being conflict with existing theories (Rubin, 2000). Several decades later the contention that the physics of galaxy rotation violates the expected physics of galaxies became “mainstream” (Rubin, 1983).

The purpose of this study is to explore another indication of disagreement between the rotational velocity of galaxies and their other physical properties. The analysis is done by comparing the brightness of galaxies that spin in the same direction as the Milky Way to the brightness of galaxies that spin in the opposite direction of the Milky Way. While a certain subtle difference is expected due to Doppler shift, the difference is expected to be small, and barely detectable in Earth-based instruments. The analysis here shows a difference in brightness significantly larger than expected, and consistent in different telescopes and different sky surveys. That difference can be explained if the physics of galaxy rotation corresponds to a far higher rotational velocity than the rotational velocity of the Milky Way.

The same observation of "dark velocity" can explain several other anomalies. These include to parity violation in the distribution of galaxies, the Ho tension, the galaxy rotation curve anomaly, and the more recent observations of “late-type” galaxies in the very early Universe, before such galaxies could be formed according to the standard models.

5. HO TENSION

Another puzzling observation is the Hubble-Lemaitre constant (Ho) tension. Ho measured by using Ia supernovae is different from the Ho when using the CMB. Because both measure the same Universe, the statistically significant difference is unexpected.

“Dark velocity” can explain the tension. Since Ia are originated from stars, Ia supernovae are expected to inherit the rotational velocity of the star in its galaxy. If the brightness depends on the rotational velocity of the galaxy, the rotational velocity can lead to a slight change in the apparent brightness of the Ia supernova. Because the distance of an Ia supernova is determined by its apparent magnitude, such difference in brightness can change the measurement of the distance, and therefore slightly impact the Ho.

A simple experiment can be done by computing Ho when using galaxies that their spin direction is consistent. The same analysis of (Khetan et al., 2021) was repeated using the SH0ES collection of Ia supernovae. But in addition to using the entire collection, another analysis was done by using just Ia supernovae that are within 45 degrees from the galactic pole, and their host galaxies rotate in the same direction as the Milky Way. Unfortunately, only 21 supernovae in the SH0ES collection meet that criterion. But the Ho computed with them was 69.551 (and within statistical error to the Ho determined by the CMB). That is higher than the Ho computed with all supernovae, which was 69.071. The difference shows that wehn using galaxies that spin in the same direction as the Milky Way the Ho tension becomes smaller. Perhaps since a small number of supernovae was used, the difference is not statistically significant, and larger collections than SH0ES will be needed.

2. FOUR EMPIRICAL OBSERVATIONS OF "DARK VELOCITY"

There are four primary observation in support of discrepancy between the rotational velocity of galaxies and their physical properties.

1. **The galaxy rotation curve anomaly**:

The disagreement between the rotational velocity of stars and their distance from the center of the galaxy is a well known phenomenon. One of the most common explanations is that the amount and distribution of the galaxy mass is different than the observed mass (dark matter; Rubin, 1983). Another expanation is that galaxy rotation follows a different physics (MOND).

If the rotational velocity of galaxies does not correspond to their physical properties, that can immediately answer the question of the galaxy rotation curve anomaly. The disadvantage of that solution is that it is trivial. Observed discrepancy between the velocity of galaxies and their physical properties can very easily be dismissed by assuming that the velocity does not correspond to physics. On the other hand, the common explanations of dark matter and MOND are similarly trivial.

2. **Differences between the brightness of galaxies spinning with the Milky Way and the brightness of galaxies spinning in the opposite direction.**

This is the main observation discussed here. Due to Doppler shift, it is expected that galaxies that spin in the same direction as the Milky Way should have a different brightness (to an Earth-based observer) than galaxies spinning in the opposite directions as the Milky Way.

The apparent flux F of a galaxy can be determined by

$$F = F_o(1 + 4 \cdot \frac{V_r}{c})$$

where Fo is the absolute flux, and Vr is the rotational velocity of the galaxy (Loeb & Gaudi, 2003). Therefore, a galaxy that spins in the same direction as the Milky Way should have different brightness than a galaxy spinning in the opposite direction.

Because it is not possible to measure Fo directly for a specific galaxy, the analysis can only be done statistically, by comparing a large number of galaxies that spin with the Milky Way or in the opposite direction of the Milky Way.

By analyzing a large number of galaxies, the brightness difference is indeed observed. The details of the experiments are provided in Section 3. The difference, however, is consistently far larger than expected, and corresponds to rotational velocity of at least 5-10 times faster than the rotational velocity of the Milky Way. The difference is consistent in both the Southern and Northern galactic poles, and in several different telescopes. These fidnings are shown in Section 3.

3. **Large-scale axis formed by galaxy spin directions.**

Multiple obervations in the past have shown a large-scale axis formed by galaxy spin directions. If the observation indeed reflects the local Universe, it challanges the standard cosmological theories. On the other hand, the observation can be explained by the differences in brightness. Brighter galaxies are easier to detect, and therefore can form an axis for an Earth-based observer. The porximity of the axis to the galactic pole strengthen the link between the axis and the differences in brightness. That is explained in Section 4.

4. **H_o tension**

The differences between H_o determined by Ia supernovae and H_o determined by the CMB is an unsolved question. "Dark velocity" provides a solution. Ia supernovae rotate with their hist galaxies. If the rotation can affect their brightness, it can also affect their estimated distance from Earth. A simple experiment shows that Ho tension becomes smaller (and within statistical error) when measuring using Ia supernovae when the spin directions of the host galaxies are aligned with the Milky Way. That is explained in Section 5.

3. DIFFERENCES IN BRIGHTNESS OF GALAXIES THAT SPIN WITH AND AGAINST THE MILKY WAY

The experiment is done by using a large number of galaxies around the galactic pole that spin in the same direction as the Milky Way. The magnitude of these galaxies is averaged, and compared to the average magnitude of galaxies in the same part of the sky, but spin in the opposite direction.

The galaxies were annotated by their spin directions by the Ganalyzer algorithm (Shamir, 2011), which is a fully symmetric model-driven algorithm that does not rely on any elements of pattern recognition or machine learning that can add some unknown bias.

The following table shows the number and average brightness of galaxies in the 60x60 degree window at around the Northern galactic pole. The table shows magnitude differences in all bands. The galaxies are taken from the DESI Legacy Survey.

Band	# cw galaxies	# ccw galaxies	Mag ccw	Mag cw	ΔMag	t-test P
G	20,918	21,253	20.06525±0.010	20.10073±0.010	-0.03548	0.01
R	20,917	21,251	18.98522±0.008	19.01481±0.008	-0.02958	0.01
Z	20,925	21,261	18.2934±0.007	18.31783±0.007	-0.02443	0.01

The g, r, and z magnitude and the number of clockwise and counterclockwise galaxies in the 60x60 degree field centered around the Northern galactic pole (Shamir & McAdam, 2022).

The following table shows the same analysis, but for the Southern galactic pole. The brightness difference is also statistically significant, but inversed.

Band	# cw galaxies	# ccw galaxies	Mean Mag ccw	Mean Mag cw	ΔMag	t-test P
G	87,640	89,534	20.13622±0.004	20.11937±0.004	0.01685	0.003
R	87,917	89,849	19.08793±0.003	19.07216±0.003	0.01574	0.0002
Z	88,228	90,142	18.38424±0.003	18.37225±0.003	0.01199	0.0047

The g, r, and z magnitudes of galaxies that spin with and against the direction of the Milky Way in the 60x60 degree field centered around the Southern galactic pole (Shamir & McAdam, 2022).

The same analysis in parts of the sky that are perpendicular to the galactic pole shows no statistically significant difference in brightness. That indicates that either the spin direction of galaxies is related to the brightness differences, or that some unknown large-scale structure is aligned with the galactic pole.

The same observation is consistent in data from SDSS. The following table shows the brightness differences around the Northern galactic pole when using SDSS galaxies.

Band	Mag cw	Mag ccw	ΔMag	P t-test
G	17.7095±0.005	17.6948±0.005	0.0147	0.0376
R	16.9893±0.004	16.9745±0.004	0.0148	0.0089
Z	16.4564±0.004	16.4393±0.004	0.0171	0.0025

The g, r, z brightness of galaxies that spin in the same direction as the Milky way and in the opposite direction in SDSS around the Northern galactic pole.

A simple analysis was done with SDSS galaxies around the Northern galactic pole annotated by Galaxy Zoo. The table below shows the same analysis by using "clean" Galaxy Zoo annotations. The results are consistent with the results of the automatic annotations. Galaxy Zoo is known to be heavily biased by the human perception, so the agreement can also be a coincidence. In any case, it does not disagree with the other experiments.

Band	$\overline{Mag}$ cw	$\overline{Mag}$ ccw	ΔMag	P t-test
G	16.9765±0.01	16.9579±0.01	0.0186	0.09
R	16.4129±0.01	16.3723±0.01	0.0406	0.002
Z	15.9817±0.01	15.9539±0.01	0.0278	0.025

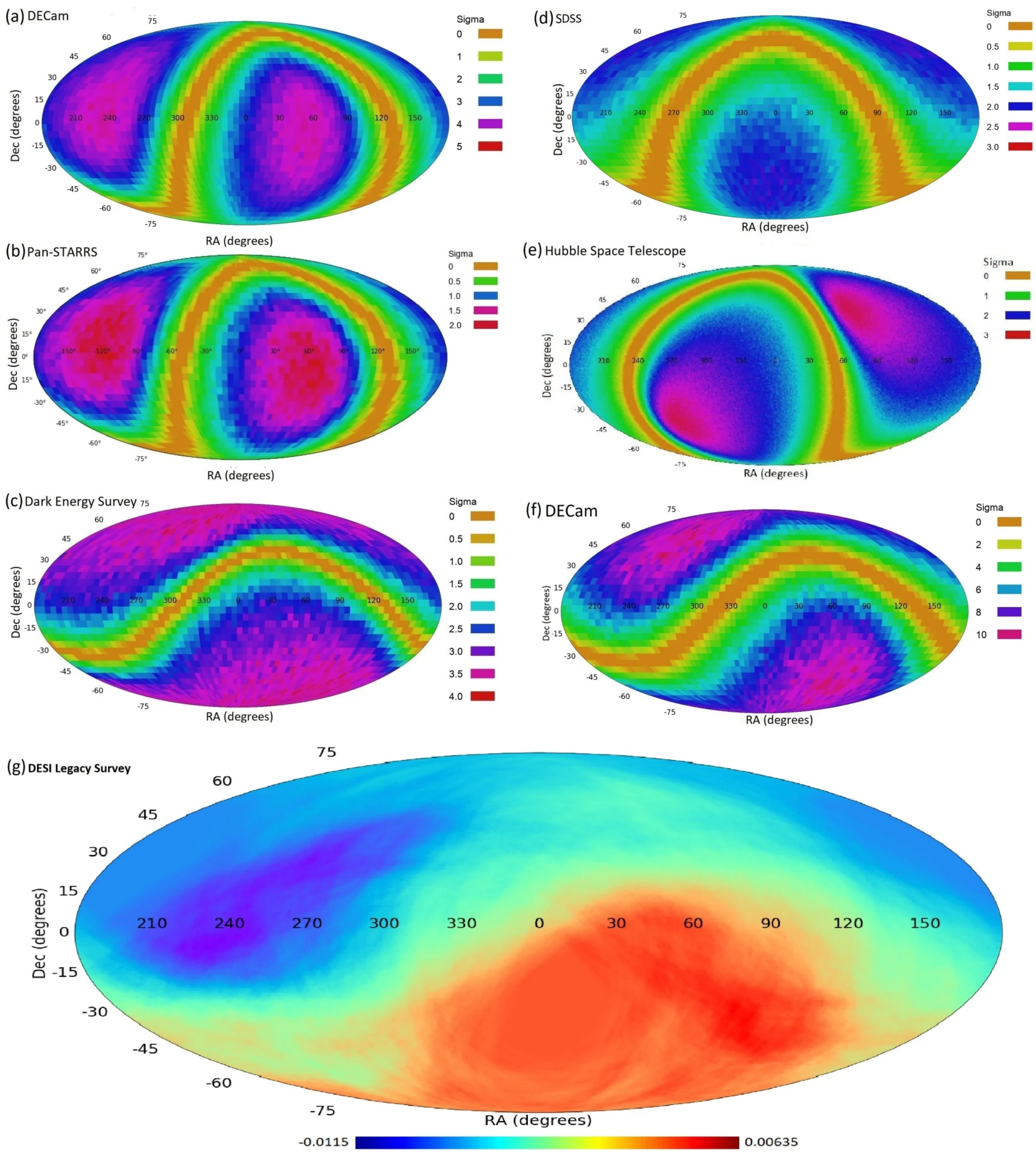
To account for atmospheric effect, another experiments was done with HST COSMOS galaxies. COSMOS is not exactly on the galactic pole, but it is closer to the Northern galactic pole than to the Southern galactic pole. The results are similar to the results observed by the Earth-based surveys around the Northern galactic pole.

Band	Mag cw	Mag ccw	ΔMag	P (t-test)
G	23.131±0.019	23.077±0.019	0.054	0.023
R	22.266±0.019	22.218±0.02	0.048	0.045
Z	21.358±0.017	21.323±0.018	0.035	0.087

Brightness of clockwise and counterclockwise galaxies in the COSMOS field of HST (Shamir, 2020).

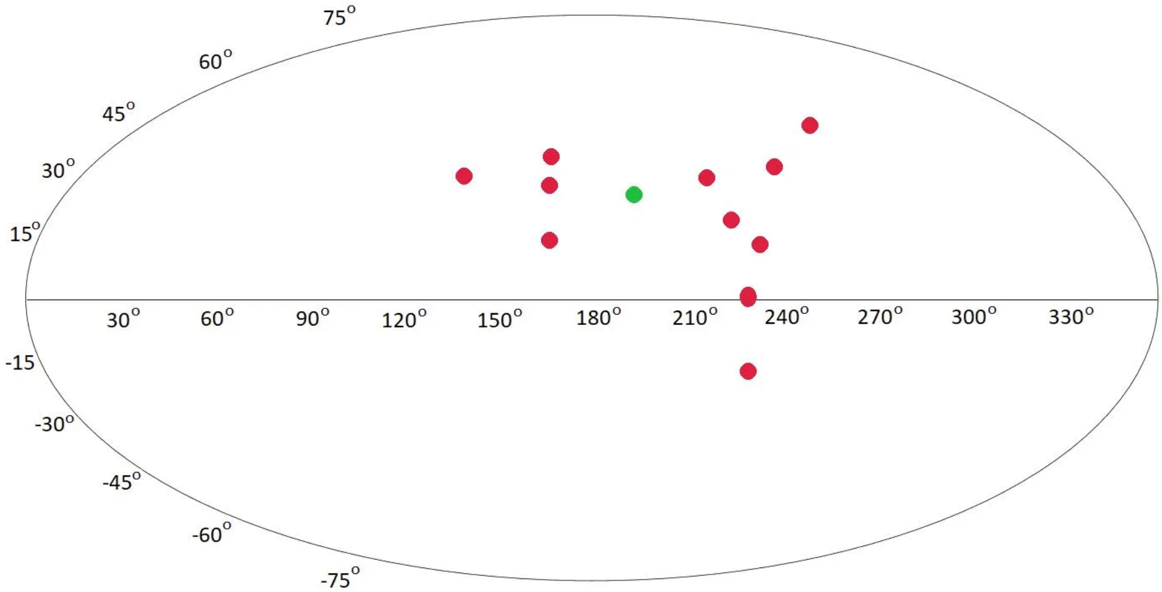
4. OBSERVED AXIS FORMED BY GALAXY SPIN DIRECTIONS

A related observation is the asymmetry in the number of clockwise and counterclockwise galaxies as seen from Earth. That asymmetry was first mentioned as early as the 1980's (MacGillivray & Dodd, 1985). The following figure shows the analysis of the asymmetry in galaxy spin directions in several different telescopes, all show very similar patterns of asymmetry.



The statistical significance of a dipole axis in galaxy spin directions in different sky surveys. The analyses are taken from previous experiments (Shamir, 2020; Shamir 2022a,b,c,d,e,f). Panels (a) through (f) show statistical analysis. Panel (g) shows direct measurements of the asymmetry in different parts of the sky using 1.3M galaxies from the DESI Legacy Survey (Shamir, 2022b).

The graphs, and especially Panel (g), show asymmetry that peaks close to the galactic pole. The following figure shows the peaks of several experiments. The figure shows that the peaks are close to the galactic pole.



Peaks of the dipole axes in galaxy spin directions in different studies. The studies include also results of Galaxy Zoo and (Longo, 2011). The galactic pole is marked in green.

The agreement of the axes with the galactic pole can be a coincidence, but can also indicate that the two are related. If in the galactic pole the magnitude between clockwise and counterclockwise galaxies is different, that can change the population of clockwise and counterclockwise galaxies as observed from Earth, and lead to a dipole axis that peaks around the galactic pole.

Several studies showed that galaxy spin directions are distributed randomly. Thorough analysis of these studies is available in (Shamir, 2022f).

6. DISCUSSION AND CONCLUSIONS

After several decades of research, the nature of galaxy rotation is still not fully understood, and does not follow any known physics. The most common explanations are dark matter and MOND, but no theory has been proven.

This study shows that galaxies that spin in the same direction as the Milky Way have different brightness compared to galaxies that spin in the opposite direction. The difference is much higher than the expected difference due to Doppler shift, and fits rotational velocity of at least 5 to 10 times the rotational velocity of the Milky Way. A possible explanation is that like with its mass, the physics of galaxy rotation corresponds to a far higher rotational velocity than the observed velocity. That can also explain other mysteries such as the Ho tension.

Indications of brightness differences between galaxies with opposite spin directions were observed in the past (Shamir, 2017, 2020). Analysis also showed that the difference peaks at the galactic pole (Shamir, 2017, 2020). The alignment with the galactic pole suggests that it could be related to the spin direction of the Milky Way comapred to the observed galaxies.

The disagreement between galaxy rotational velocity and its physical properties is one of many other possible explanations to the observation of different brightness for galaxies spinning in opposite directions. Another explanation is a possible anomaly in the large-scale structure. In that case, the difference in brightness is not driven by the perspective of an Earth-based observer, but reflects the real structure of the Universe. In that case, the observation suggests that the Universe has large-scale parity violation in the galaxy spin directions, and the magnitude of that parity violation was stronger in the early Universe. Evidence of such preferred direction to the Universe exhibited through the distribution of galaxies have been noted in (Longo 2011, Shamir, 2012, 2019, 2021, 2022a-f; Philcox, 2022; Hou et al., 2022). If these are correct, it means that the standard cosmological models are incomplete, while "Dark velocity" explains the parity violation without the need to change the standard models.

ABSTRACT

Despite over a century of research, the disagreement between the observed galaxy rotation curve and the expected rotational velocity of galaxies is still an unsolved scientific question. The two most common explanations suggest that the physics of galaxy rotation is different from the physics of other rotating objects (MOND), or that the majority of the galaxy mass is dark matter that its distribution in the galaxy is different from the distribution of stars. This study proposes the possibility that the physical properties of galaxies fit a far greater rotational velocity. The observation is made by comparing the brightness of galaxies that spin in the same direction as the Milky Way, to the brightness of galaxies that spin in the opposite direction. While certain differences in brightness are expected, these differences are expected to be negligible. The observed differences in brightness are far greater than the expected differences, and correspond to five to 10 times greater rotational velocity, assuming these galaxies have similar rotational velocity as the Milky Way. These observations are consistent across several telescopes, as well as both the Northern and Southern galactic poles. If the physics of objects that rotate inside a galaxy indeed correspond to a far higher velocity, that can explain the galaxy rotation curve anomaly, as well as other anomalies such as the Ho tension.

REFERENCES

Hou, J., Slepian, Z. , Cahn, R. N., Measurement of parity-odd modes in the large-scale 4-point correlation function of sdss boss dr12 cmass and lowz galaxies, arXiv:2206.03625 (2022).

Khetan, N., Izzo, L., Branchesi, M., Wojtak, R., Cantiello, M., Murugeshan, C., Agnello, A., Cappellaro, E., Della Valle, M., Gall, C., Hjorth, J., Benetti, S., Brocato, E., Burke, J., Hiramatsu, D., Howell, D. A., Tomasella, L., and Valenti, S. (2021). A new measurement of the hubble constant using type ia supernovae calibrated with surface brightness uctuations. Astronomy & Astrophysics, 647:A72.

Longo, M. J. (2011). Detection of a dipole in the handedness of spiral galaxies with redshifts z 0.04. Physics Letters B, 699(4):224{229.

MacGillivray, H. and Dodd, R. (1985). The anisotropy of the spatial orientations of galaxies in the local supercluster. *Astronomy & Astrophysics*, 145:269{274.

Philcox, O. H. (2022), Probing parity-violation with the four-point correlation function of boss galaxies, arXiv:2206.04227.

Rubin, V. C. (1983). The rotation of spiral galaxies. Science, 220(4604):1339{1344.

Rubin, V. C. (2000). One hundred years of rotating galaxies, PASP, 112(772):747.

Shamir, L. (2011). Ganalyzer: A tool for automatic, galaxy image analysis. Astrophysical Journal, 736(2):141.

Shamir, L. (2017). Large-scale photometric asymmetry in galaxy spin patterns. Publications of the Astronomical Society of Australia, 34:e44.

Shamir, L. (2019). Large-scale patterns of galaxy spin rotation show cosmological-scale parity violation and multipoles. arXiv, 1912.05429.

Shamir, L. (2020). Asymmetry between galaxies with different spin patterns: A comparison between cosmos, sdss, and pan-starrs. Open Astronomy, 29(1):15{27.

Shamir, L. (2021a). Analysis of the alignment of nonrandom patterns of spin directions in populations of spiral galaxies. Particles, 4(1):11{28.

Shamir, L. (2021b). Large-scale asymmetry in galaxy spin directions: evidence from the southern hemisphere. Publications of the Astronomical Society of Australia, 38, e037.

Shamir, L. (2022a). Analysis of ~10^6 spiral galaxies from four telescopes shows large-scale patterns of asymmetry in galaxy spin directions. Advances in Astronomy, 2022: 8462363.

Shamir, L. (2022b). Analysis of spin directions of galaxies in the desi legacy survey. Monthly Notices of the Royal Astronomical Society, 516(2):2281-2291.

Shamir, L. (2022c). Asymmetry in galaxy spin directions-analysis of data from des and comparison to four other sky surveys. Universe, 8:8.

Shamir, L. (2022d). Large-scale asymmetry in galaxy spin directions: analysis of galaxies with spectra in des, sdss, and desi legacy survey. Astronomical Notes, 343(6-7):e20220010.

Shamir, L. (2022e). A possible large-scale alignment of galaxy spin directions - analysis of 10 datasets from sdss, pan-starrs, and hst. New Astronomy, 95:101819.

Shamir, L. (2022f). Using 3d and 2d analysis for analyzing large-scale asymmetry in galaxy spin directions. PASJ, 74(5):1114{1130.

Shamir, L., McAdam, D., (2022), A possible tension between galaxy rotational velocity and observed physical properties, https://arxiv.org/abs/2212.04044