Hubble Tension

Vladimir S. Netchitailo

netchitailov@gmail.com

Abstract

The results of measurements of the Hubble's constant H_0, which characterizes the expansion rate of the universe, shows that the values of H_0 vary significantly depending on Methodology. The disagreement in the values of H_0 obtained by the various teams far exceeds the standard uncertainties provided with the values. This discrepancy is called the Hubble Tension. In this paper, we discuss Macrostructures of the World (Superclusters and Galaxies); explain their Origin and Evolution in frames of the developed Hypersphere World-Universe Model (WUM), which is, in fact, the Paradigm Shift in Cosmology [1]; and provide the explanation of the Hubble Tension. The main difference between WUM and Big Bang Model (BBM) is: Instead of the Infinite Homogeneous and Isotropic Universe around the Initial Singularity in BBM, in WUM, the 3D Finite Boundless World (the Hypersphere) presents a Patchwork Quilt of different Luminous Superclusters ($\gtrsim 10^3$), which emerged in various places of the World at different Cosmological times. In WUM, the Medium of the World is Homogeneous and Isotropic. The distribution of Macroobjects in the World is spatially Inhomogeneous and Anisotropic and temporally Non-simultaneous.

1. Introduction

E. Conover in the paper "Debate over the universe's expansion rate may unravel physics. Is it a crisis?" outlined the following situation with the measurements of an expansion rate of the universe [2]:

- *Scientists with the Planck experiment have estimated that the universe is expanding at a rate of 67.4 km/s Mpc with an experimental error of 0.5 km/s Mpc;*
- *But supernova measurements have settled on a larger expansion rate of 74.0 km/s Mpc, with an error of 1.4 km/s Mpc. That leaves an inexplicable gap between the two estimates. Now "the community has started to take this [problem] extremely seriously," says cosmologist Daniel Scolnic of Duke University, who works on the supernova project led by Riess, called SH0ES;*
- *It is unlikely that an experimental error in the Planck measurement could explain the discrepancy. That prospect is "not a possible route out of our current crisis," said cosmologist Lloyd Knox of the University of California, Davis;*
- *So, worries have centered on the possibility that the supernova measurements contain unaccounted for systematic errors - biases that push the SH0ES estimate to larger value.*

L. Verde, T. Treu, and A. G. Riess gave a brief summary of the "Workshop at Kavli Institute for Theoretical Physics, July 2019" [3].

Table 1 summarizes the results of measurements of the Hubble's constant H_0 in 2019-2020 [4]. Observe that the values of H_0 vary significantly depending on Methodology. The disagreement in the values of H_0 obtained by the various teams far exceeds the standard uncertainties provided with the values. The average values of H_0 vary from 67.4 to 76.8 $km\, s^{-1} Mpc^{-1}$. This discrepancy is called the Hubble tension [5]. A. Mann gave a summary of the situation with the measurements of H_0 in "One Number Shows Something Is Fundamentally Wrong with Our Conception of the Universe"paper [6]. It is not clear whether the discrepancy in the observations is due to systematics, or indeed constitutes a major problem for the Standard model.

Table 1. Measurements of the Hubble constant H_0 . Adapted from [4].

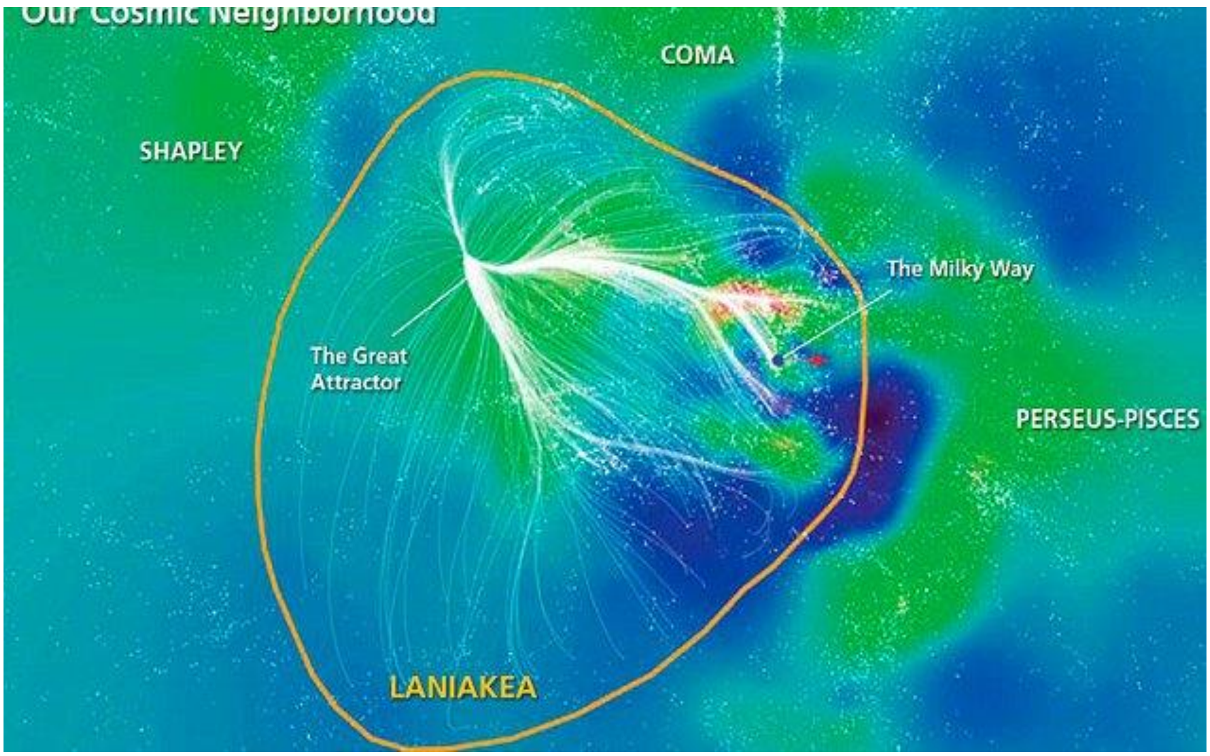
Date Published	H_0 $km\ s^{-1} Mpc^{-1}$	Observer	Remarks/Methodology
2020-12-16	72.1 ± 2.0	Hubble Space Telescope and Gaia EDR3	Combining earlier work on red giant stars, using the tip of the red-giant branch (TRGB) distance indicator, with parallax measurements of Omega Centauri from Gaia EDR3.
2020-12-15	73.2 ± 1.3	Hubble Space Telescope and Gaia EDR3	Combination of HST photometry and Gaia EDR3 parallaxes for Milky Way Cepheids, reducing the uncertainty in calibration of Cepheid luminosities to 1.0%. Overall uncertainty in the value for H_{0} is 1.8%, which is expected to be reduced to 1.3% with a larger sample of type Ia supernovae in galaxies that are known Cepheid hosts.
2020-12-04	73.5 ± 5.3	E. J. Baxter, B. D. Sherwin	Gravitational lensing in the CMB is used to estimate H_{0} without referring to the sound horizon scale, providing an alternative method to analyze the Planck data.
2020-11-25	$71.8^{+3.9}_{-3.3}$	P. Denzel ,*et al.*	Eight quadruply lensed galaxy systems are used to determine H_{0} to a precision of 5%, in agreement with both "early" and "late" universe estimates. Independent of distance ladders and the cosmic microwave background.
2020-11-07	67.4 ± 1.0	T. Sedgwick, *et al.*	Derived from 88 $0.02 < z < 0.05$ Type Ia supernovae used as standard candle distance indicators. The H_{0} estimate is corrected for the effects of peculiar velocities in the supernova environments, as estimated from the galaxy density field. The result assumes $\Omega m = 0.3$, $\Omega\Lambda = 0.7$ and a sound horizon of 149.3 Mpc, a value taken from Anderson et al. (2014).
2020-09-29	$67.6^{+4.3}_{-4.2}$	S. Mukherjee, *et al.*	Gravitational waves, assuming that the transient ZTF19abanrh found by the Zwicky Transient Facility is the optical counterpart to GW190521. Independent of distance ladders and the cosmic microwave background.
2020-06-18	$75.8^{+5.2}_{-4.9}$	T. de Jaeger, *et al.*	Use Type II supernovae as standardisable candles to obtain an independent measurement of H
2020-02-26	$73.9^{+3.0}_{-3.0}$	Megamaser Cosmology Project	Geometric distance measurements to Megamaser-hosting galaxies. Independent of distance ladders and the cosmic microwave background.
2019-10-14	$74.2^{+2.7}_{-3.0}$	STRIDES	Modelling the mass distribution & time delay of the lensed quasar DES J0408-5354.
2019-09-12	$76.8^{+2.6}_{-2.6}$	SHARP H0LiCOW	Modelling three galactically lensed objects and their lenses using ground-based adaptive optics and the Hubble Space Telescope
2019-08-20	$70.3^{+1.36}_{-1.35}$	K. Dutta, *et al.*	This is obtained analyzing low-redshift cosmological data within ΛCDM model. The datasets used are Type-Ia Supernova, Baryon Acoustic Oscillations, Time-Delay measurements using Strong-Lensing, measurements using Cosmic Chronometers and growth measurements from large scale structure observations.
2019-08-15	$73.5^{+1.4}_{-1.4}$	M. J. Reid, D. W. Pesce, A. G. Riess	Measuring the distance to Messier 106 using its supermassive black hole, combined with measurements of eclipsing binaries in the Large Magellanic Cloud.
2019-07-16	$69.8^{+1.9}_{-1.9}$	Hubble Space Telescope	Distances to red giant stars are calculated using the tip of the red-giant branch (TRGB) distance indicator.
2019-07-10	$73.3^{+1.7}_{-1.7}$	H0LiCOW collaboration	Updated observations of multiply imaged quasars, now using six quasars, independent of the cosmic distance ladder and independent of the cosmic microwave background measurements.
2019-07-08	$70.3^{+5.3}_{-5.0}$	LIGO and Virgo detectors	Uses radio counterpart of GW170817, combined with earlier gravitational wave and electromagnetic data.
2019-03-28	$68.0^{+4.2}_{-4.1}$	Fermi-LAT	Gamma ray attenuation due to extragalactic light. Independent of the cosmic distance ladder and the cosmic microwave background.
2019-03-18	$74.03^{+1.42}_{-1.42}$	Hubble Space Telescope	Precision HST photometry of Cepheids in the Large Magellanic Cloud (LMC) reduce the uncertainty in the distance to the LMC from 2.5% to 1.3%. The revision increases the tension with CMB measurements to the 4.4σ level (P=99.999% for Gaussian errors), raising the discrepancy beyond a plausible level of chance. Continuation of a collaboration known as Supernovae, for the Equation of State of Dark Energy (SHoES).
2019-02-08	$67.78^{+0.91}_{-0.87}$	Joseph Ryan, *et al.*	Quasar angular size and baryon acoustic oscillations, assuming a flat LambdaCDM model. Alternative models result in different (generally lower) values for the Hubble constant.

2. Macrostructures of the World

Laniakea Supercluster (LSC) is a galaxy supercluster that is home to Milky Way (MW) and approximately 100,000 other nearby galaxies (see **Figure 1**). It is known as one of the largest superclusters with estimated binding mass $10^{17}\ M_{\odot}$ [7]. The neighboring superclusters to LSC are the Shapley Supercluster, Hercules Supercluster, Coma Supercluster, and Perseus-Pisces Supercluster. Distance from the Earth to the Centre of LSC is $250\ Mly$, Redshift – 0.0708 (center).

The mass-to-light ratio of the Virgo Supercluster is about three hundred times larger than that of the Solar ratio. Similar ratios are obtained for other superclusters [8]. In 1933, F. Zwicky investigated the velocity dispersion of Coma cluster and found a surprisingly high mass-to-light ratio ($\sim$500). He concluded: "*If this would be confirmed, we would get the surprising result that dark matter is present in much greater amount than luminous matter*" [9]. These ratios are one of the **main arguments in favor of presence of substantial amounts of Dark Matter in the World**.

Figure 1. Laniakea Supercluster. Adapted from [10].



We emphasize that about 100,000 nearby galaxies are moving around Centre of Laniakea Supercluster. They belong to LSC. All these galaxies did not start their movement from the "Initial Singularity". The neighboring superclusters have the same structure (see **Figure 2** and **Figure 3**). It means that the World is, in fact, a Patchwork Quilt of different Luminous Superclusters ($\gtrsim 10^3$) [11].

According to R. B. Tully, *et al.*, "*Galaxies congregate in clusters and along filaments, and are missing from large regions referred to as voids. These structures are seen in maps derived from spectroscopic surveys that reveal networks of structure that are interconnected with no clear boundaries. Extended regions with a high concentration of galaxies are called 'superclusters', although this term is not precise*" [10].

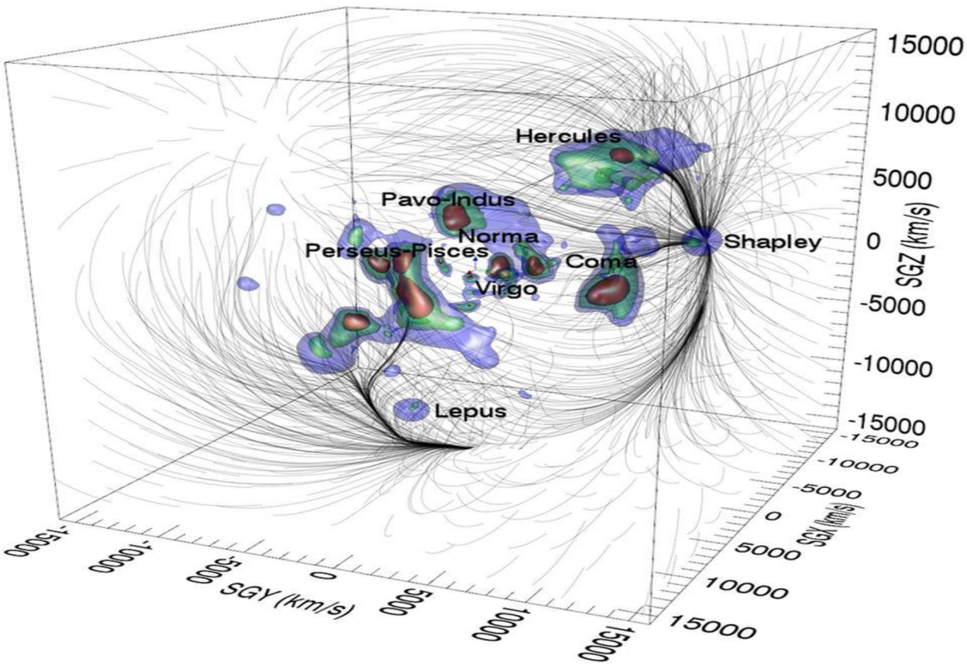


Fig. 2. Structure within a cube extending 16,000 km s−1 (~200 Mpc) on the cardinal axes from our position at the origin. Densities on a grid within the volume are determined from a Wiener Filter reconstruction based on the observed velocity field. Three isodensity contours are shown. The density map is detailed near the center of the box where observational constraints are dense and accurate but tapers to the mean density as constraints weaken. Nevertheless, velocity flows illustrated by the black threads are defined on large scales. Ultimately all flows appear to drain toward Shapley although flows through the Perseus-Pisces filament take a circuitous route through the poorly studied Lepus region. Adapted from [10].

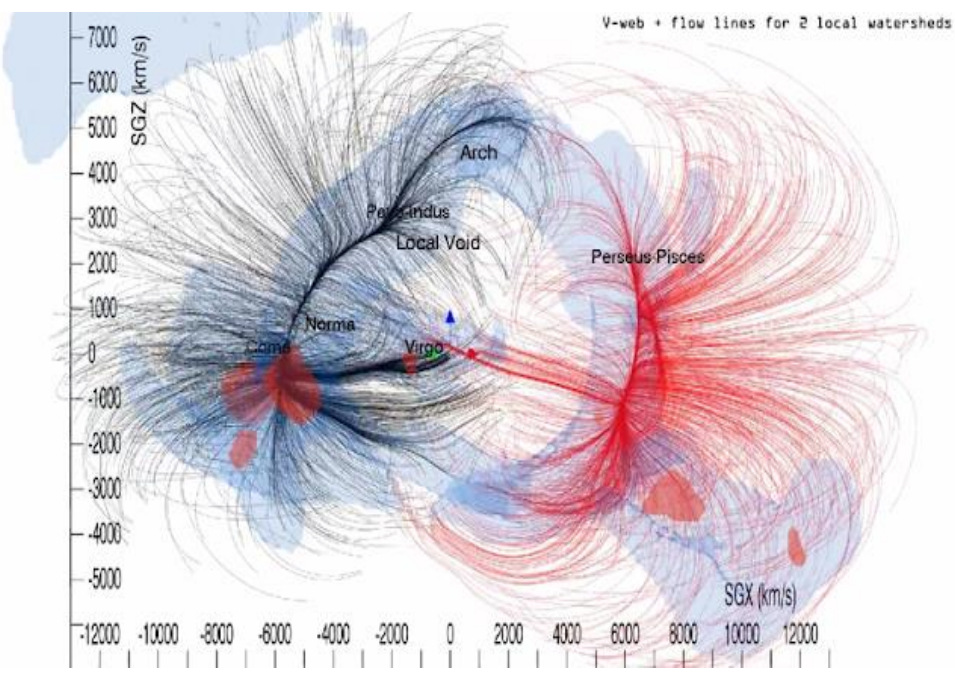


Fig. 3. A representation of structure and flows due to mass within 6,000 km s−1 (~80 Mpc). Surfaces of red and blue respectively represent outer contours of clusters and filaments as defined by the local eigenvalues of the velocity shear tensor determined from the Wiener Filter analysis. Flow threads originating in our basin of attraction that terminate near the Norma Cluster are in black and adjacent flow threads that terminate at the relative attractor near the Perseus Cluster are in red. The Arch and extended Antlia Wall structures bridge between the two attraction basins. Adapted from [10].

P. Wang, *et al.* made a great discovery: "*Most cosmological structures in the universe spin. Although structures in the universe form on a wide variety of scales from small dwarf galaxies to large super clusters, the **generation of angular momentum across these scales is poorly understood**. We have investigated the possibility that filaments of galaxies - cylindrical tendrils of matter hundreds of millions of light-years across, are themselves spinning. By stacking thousands of filaments together and examining the velocity of galaxies perpendicular to the filament's axis (via their red and blue shift), we have found that these objects too display motion consistent with rotation making them the largest objects known to have angular momentum. **These results signify that angular momentum can be generated on unprecedented scales***" [12].

In June 2021, at the "*Giant Arc at the 238th virtual meeting of the American Astronomical Society*", A. Lopez reported about the discovery of "*a giant, almost symmetrical arc of galaxies – the Giant Arc – spanning 3.3 billion light years at a distance of more than 9.2 billion light years away that is **difficult to explain in current models of the Universe**. The Giant Arc, which is approximately 1/15th the radius of the observable universe, is twice the size of the striking Sloan Great Wall of galaxies and clusters that is seen in the nearby Universe. This new discovery of the Giant Arc adds to an **accumulating set of (cautious) challenges to the Cosmological Principle**. The discovery of the Giant Arc adds to the number of structures on scales larger than those thought to be "smooth," and therefore pushes the boundary size for the Cosmological Principle. The growing number of large-scale structures over the size limit of what is considered theoretically viable is becoming harder to ignore. According to cosmologists, the current theoretical limit is calculated to be 1.2 billion light years, which makes the Giant Arc almost three times larger. **Can the standard model of cosmology account for these huge structures in the Universe as just rare flukes or is there more to it than that?"*** [13].

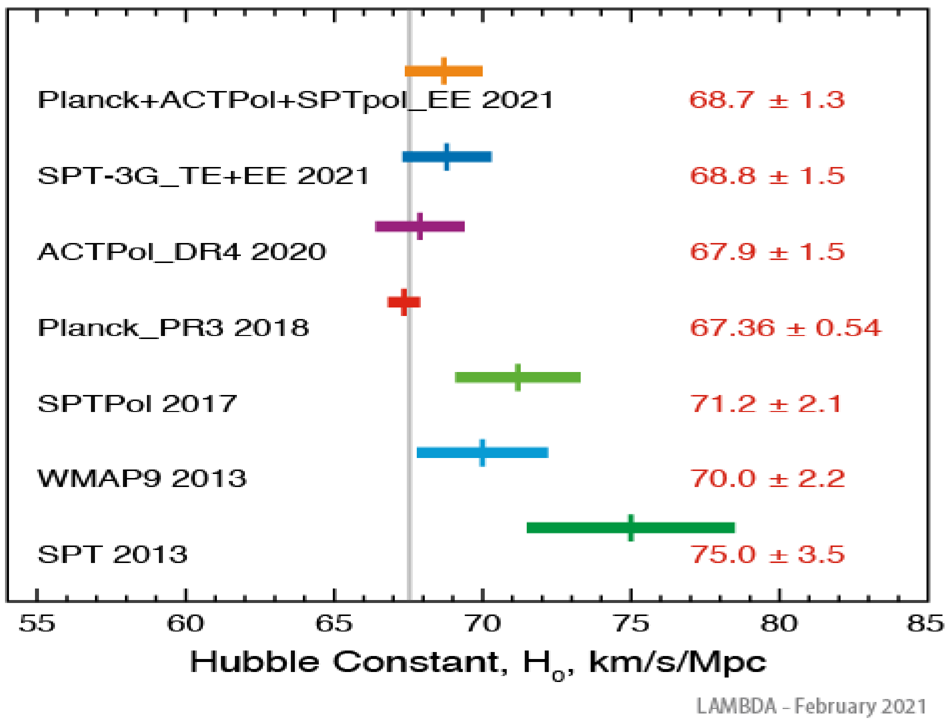
WUM. These latest observations of the World can be explained in frames of the developed WUM only [14];

- "*Galaxies **do not** congregate in clusters and along filaments."* On the contrary, Cosmic Web that is "*networks of structure that are interconnected with no clear boundaries"* is the result of the Explosive Volcanic Rotational Fission of Dark Matter (DM) Cores of neighboring Superclusters;
- *"Generation of angular momentum across these scales"* provide DM Cores of Superclusters through the Explosive Volcanic Rotational Fission;
- *"Spinning cylindrical tendrils of matter hundreds of millions of light-years across"* are the result of spiral jets of galaxies generated by DM Cores of Superclusters with internal rotation;
- The Giant Arc is the result of the intersection of the Galaxies' jets generated by the neighboring DM Cores of Superclusters;
- 13.77 *Gyr* ago, when the Laniakea Supercluster emerged, the estimated number of DM Supercluster Cores in the World was around $\sim 10^3$ [11]. It is unlikely that all of them gave birth to Luminous Superclusters at the same cosmological time being far away from each other. The 3D Finite Boundless World presents a Patchwork Quilt of different Luminous Superclusters, which emerged at different Cosmological times;
- The main conjecture of BBM: "*Projecting galaxy trajectories backwards in time means that they converge to the Initial Singularity at $t=0$ that is an infinite energy density state*" is wrong because all Galaxies are gravitationally bound with their Superclusters (**Figure 1**, **Figure 2**, **Figure 3**). Big Bang never happened.

3. Hubble Tension Explanation

The experimental observations of galaxies in the universe show that most of them are disk galaxies [15]. It is well-known that when observing spiral galaxies, the side spinning toward us have a slight blueshift relative to the side spinning away from us. Therefore, there is a meaning of a redshift of a Center of galaxy only. The redshift of the Centre of LSC is 0.0708. But it does not mean that LSC is moving away from MW. On the contrary, MW is moving away from the Centre of LSC. In LSC, some galaxies are moving toward MW, and the other are moving away (see **Figure 1**). Then redshift depends on the position and movement of a particular galaxy in LSC against MW. More complicated situation with redshift is when galaxies belong to neighboring superclusters, which emerged at different cosmological times.

According to WUM, the value of the Hubble parameter H depends on the cosmological time: $H = \tau^{-1}$. It means that the value of H should be measured based on Cosmic Microwave Background (CMB) radiation only. **Figure 4** illustrates recent H_0 determinations using only CMB data. Adapted from [16].



The calculated value of Hubble's constant in 2013 [17]: $H_0 = 68.733\, km/s\ Mpc$ is in excellent agreement with the most recent measured value in 2021: $H_0 = 68.7 \pm 1.3\ \ km/s\ Mpc$ using only CMB data [16].

In frames of WUM, the Hubble Tension can be explained the following way:

- All measurements of Hubble's constant are model-dependent;
- Statistics of these measurements is not sufficient to yield reliable conclusions;
- Hubble's law in Standard Cosmology is valid for the Big Bang model only when all galaxies start their movement from a single point named "Initial Singularity" that is not the case in WUM;
- There are observations of Galaxies, which belong to different Superclusters;
- The value of H depends on the cosmological time $H = \tau^{-1}$ and is higher for the earlier Epoch of the World. It means that the value of H should be measured for each Galaxy separately depending on a distance to it and corresponding cosmological time. We must not calculate average values of H depending on Methodology as it is done in **Table 1**;
- The value of H should be measured based on Cosmic Microwave Background Radiation only.

Acknowledgement

Special thanks to my son Ilya Netchitailo who helped me refine the Model and improve its understanding.

References

[1] Netchitailo V. S. (2021) Paradigm Shift in Cosmology. https://vixra.org/pdf/2107.0020v2.pdf.
[2] Conover, E. (2019) Debate over the universe's expansion rate may unravel physics. Is it a crisis? ScienceNews. https://www.sciencenews.org/article/debate-universe-expansion-rate-hubble-constant-physics-crisis .
[3] Verde, L., Treu, T., and Riess, A. G. (2019) Tensions between the Early and the Late Universe. arXiv:1907.10625.
[4] Wikipedia (2021) Hubble's Law. https://en.wikipedia.org/wiki/Hubble%27s_law
[5] Poulin, V., *et al.* (2019) Early Dark Energy Can Resolve The Hubble Tension. arXiv:1811.04083v2.
[6] Mann A. (2019) One Number Shows Something Is Fundamentally Wrong with Our Conception of the Universe. https://www.livescience.com/hubble-constant-discrepancy-explained.html.
[7] Bliss, L. (2014) The Milky Way's 'City' Just Got a New Name. https://www.bloomberg.com/news/articles/2014-09-03/the-milky-way-s-city-just-got-a-new-name.
[8] Heymans, C., *et al.* (2008) The dark matter environment of the Abell 901/902 supercluster: a weak lensing analysis of the HST STAGES survey. arXiv:0801.1156.
[9] Zwicky, F. (1933) Die Rotverschiebung von extragalaktischen Nebeln. Helvetica Physica Acta, **6**, 110.
[10] Tully, R. B., *et al.* (2014) The Laniakea supercluster of galaxies. Nature, **513**, 71. arXiv:1409.0880.
[11] Netchitailo, V. (2021) From the Beginning of the World to the Beginning of Life on Earth. *Journal of High Energy Physics, Gravitation and Cosmology*, **7**, 1503-1523. Doi: 10.4236/jhepgc.2021.74092.
[12] Wang, P., *et al.* (2021) Possible observational evidence that cosmic filaments spin. arXiv:2106.05989.
[13] Boardman, L. (2021) Discovery of a Giant Arc in distant space adds to challenges to basic assumptions about the Universe. https://www.star.uclan.ac.uk/~alopez/aas238_press_release.pdf .
[14] Netchitailo V. S. (2021) Decisive Role of Dark Matter in Cosmology. https://vixra.org/pdf/2110.0166v1.pdf.
[15] What are galaxies? (2021) Cool Cosmos. https://coolcosmos.ipac.caltech.edu/ask/216-What-are-galaxies-.
[16] NASA Education/Graphics (2021) Hubble Constant H_0 . https://lambda.gsfc.nasa.gov/education/graphic_history/hubb_const.cfm
[17] Netchitailo V. S. (2013) Word-Universe Model. viXra:1303.0077v7. https://vixra.org/pdf/1303.0077v7.pdf.