SPEKTRA: Jurnal Fisika dan Aplikasinya
Volume 8, Issue 1, April 2023
Homepage: doi.org/10.21009/SPEKTRA

Check for updates

DOI: doi.org/10.21009/SPEKTRA.081.03

EXPLORING THE INTERCONNECTEDNESS OF COSMOLOGICAL PARAMETERS AND OBSERVATIONS: INSIGHTS INTO THE PROPERTIES AND EVOLUTION OF THE UNIVERSE

Budiman Nasution[1], Ruben Cornelius Siagian[1,*], Arip Nurahman[2], Lulut Alfaris[3]

[1]*Physics Departement, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, Medan, Indonesia*
[2]*Department of Physics Education, Faculty of Applied Science and Science, Indonesian Institute of Education, Garut, West Java, Indonesia,*
[3]*Department of marine technology, Pangandaran marine and fisheries Polytechnic, Pangandaran, Indonesia*

*Corresponding Author Email: Rubensiagian775@gmail.com

Received: 24 February 2023
Revised: 10 April 2023
Accepted: 12 April 2023
Online: 29 April 2023
Published: 30 April 2023

SPEKTRA: Jurnal Fisika dan Aplikasinya
p-ISSN: 2541-3384
e-ISSN: 2541-3392

ABSTRACT

This research aims to investigate the relationship between Confidence Interval, Hubble Parameter, Comoving Distance, and Distance-Volume Relationship, which are important equations in cosmology. The Confidence Interval equation is used to estimate the range of values for the difference between the mean redshift and Hubble parameter. The Hubble Parameter equation is used to measure the expansion rate of the universe, while the Comoving Distance equation is used to calculate the distance between two objects in the expanding universe, and the Distance-Volume Relationship equation is used to calculate the distance between an observer and a cosmic object based on the object's redshift. This study seeks to address several research questions, including the accuracy of estimating parameters using these equations and the potential for developing more precise equations. The study employs cosmological data analysis using the R program to analyze existing data and gain a better understanding of cosmological parameters. The results of this research contribute to our understanding of the nature and evolution of the universe, providing insights into the distribution of matter and the role of dark matter and dark energy in shaping the universe's evolution. By examining the relationship between cosmological parameters, this study enables us to make predictions about cosmic phenomena and improve the accuracy of future measurements. The findings of this research have implications for cosmological research and can aid in the development of more accurate models and theories in the field of cosmology. Overall, this study provides valuable insights into the fundamental equations in cosmology and their relationships, advancing our understanding of the universe's dynamics and evolution.

Keywords: cosmological data analysis, hubble parameter, comoving distance, distance-volume relationship, confidence interval

INTRODUCTION

The topic of this research is focused on three important equations in cosmology: Confidence Interval, Hubble Parameter, Comoving Distance, and Distance-Volume Relationship. The purpose of this study is to provide a better understanding of the relationship between these cosmological parameters and to provide new insights into the nature and evolution of the universe. The Confidence Interval equation is used to estimate the range of values within which a population parameter is likely to fall based on a sample statistic [1]. In cosmology, this equation is used to estimate the range of values for the difference between the mean redshift and Hubble parameter [2]. By understanding the Confidence Interval equation, researchers can better estimate the values of these important parameters and improve our understanding of the properties of the universe. The Hubble Parameter equation is used to measure the expansion rate of the universe, which is a key factor in determining the age of the universe [3]. By understanding this equation, researchers can gain insights into the history of the universe and the processes that have shaped its evolution. The Comoving Distance equation is used to calculate the distance between two objects in the expanding universe [4]. This equation takes into account the expansion of the universe and provides a more accurate estimate of the distance between objects than traditional methods. By understanding this equation, researchers can better measure the distances between cosmic objects and improve our understanding of the large-scale structure of the universe. The Distance-Volume Relationship equation is used to calculate the distance between an observer and a cosmic object based on the object's redshift [5]. This equation takes into account the expansion of the universe and provides a way to estimate the average density of matter in the universe. By understanding this equation, researchers can gain insights into the distribution of matter in the universe and the role of dark matter and dark energy in shaping the evolution of the universe.

The background for the author's interest in this topic stems from the need to further investigate and understand the relationships between these cosmological parameters. Previous studies have provided valuable insights into these equations individually, but there is still a need to explore their interrelationships and potential implications for our understanding of the universe [6]. Additionally, there may be limitations or discrepancies in previous studies that need to be addressed and improved upon. Therefore, this research aims to contribute to the existing body of knowledge by examining the relationships between these cosmological parameters in a comprehensive manner.

Previous related studies have been conducted on each of these cosmological parameters individually. However, there may be discrepancies or inconsistencies among these studies, and it is important to thoroughly review and analyze the existing literature to identify any gaps or limitations. By doing so, this research can build upon the findings of previous studies and potentially provide new insights or corrections to improve our understanding of these cosmological parameters.

Furthermore, this research will highlight the benefits of the method used in this study compared to previous studies. The approach taken in this research may offer advantages in terms of accuracy, precision, or comprehensiveness in analyzing the relationships between these cosmological parameters. By explaining the benefits of the method used in this study compared to previous studies, the author can provide a justification for the chosen approach and demonstrate the potential contributions of this research to the field of cosmology.

METHOD

The research method used in this discussion is cosmological data analysis using the R program. Cosmological data obtained from various observational techniques are used to calculate and estimate the values of cosmological parameters such as Confidence Intervals, Hubble Parameters, Komoving Distances, and Distance-Volume Relationships. First of all, statistical calculations are used to calculate the confidence interval of the difference between the z and h means. Then, a mathematical equation is used to calculate the value of the Hubble parameter in redshift z by entering the value of the mass fraction of matter in the universe Ω_m, fraction of dark energy in the universe Ω_λ, fraction of the empty pocket in the universe Ω_k, Hubble's current constant (H_0), and redshift (z). Next, an equation is used to calculate the moving distance between two objects in cosmic space by integrating the velocity equation. Finally, we use the distance-volume relationship to calculate the measured distance from the observer to the cosmic object at any given time located at a certain redshift by including the moving distance, the angle of the solid seen from the observer, and the effect of the redshift that occurs on the light received from the cosmic object. During data analysis, the R program was used to calculate the values of the cosmological parameters and visualize the calculation results. In the R program, integrated mathematical and statistical functions are used to facilitate calculations. In this discussion, the use of the R program makes it possible to perform data analysis quickly and accurately, making it possible to obtain more reliable and accurate results

This table is a data table that contains information about Redshift (z), Hubble Parameter (H(z)), and error a ± 1σ from a number of observations. Redshift is a measure of the spectral shift of an astronomical object caused by a shift in the object's light toward red due to movement away from Earth [7]. The Hubble Parameter is a cosmological parameter that describes the expansion rate of the universe [8]. Error a ± 1σ is the measurement error expressed in standard deviation units from the average value of observations. In this table, each row represents a different observation at a different redshift (z), with the corresponding H(z) value and error a ± 1σ.

TABLE 1. Redshift, Expansion Rate, and Error Measurements for Cosmological Models

Redshift (z)	H(z)	a ± 1σ error
0.07	69	±19.6
0.1	69	±12
0.12	68.6	±26.2
0.17	83	±8
0.1791	75	±5
0.1993	75	±5
0.2	72.9	±29.6
0.27	77	±14
0.28	88.8	±36.6
0.3519	83	±14
0.3802	83	±13.5
0.4	95	±17
0.4004	77	±10.2
0.4247	87.1	±11.2
0.4497	92.8	±12.9
0.47	89	±67
0.4783	80.9	±9
0.48	97	±62
0.5929	104	±13
0.6797	92	±8
0.7812	105	±12
0.8754	125	±17
0.88	90	±40
0.9	117	±23
1.037	154	±20
1.3	168	±17
1.363	160	±33.6
1.43	177	±18
1.53	140	±14
1.75	202	±40
1.965	186.5	±50.4

Source: J. Niu and T.-J. Zhang, 2023 [9]

Statistical Methods for Redshift (z), H(z), and a ± 1σ Error: The mean of Redshift (z) is 0.6565, H(z) is 101.1621, and a ± 1σ error is ±26.5435. The mean is calculated by summing all the values and dividing by the total number of values. It represents the central tendency or the average value of the data. The median of Redshift (z) is 0.47, H(z) is 89, and a ± 1σ error is ±17. The median is the middle value when the data is arranged in ascending or descending order. It is less affected by extreme values and represents the midpoint of the data distribution. The mode of Redshift (z) is 0.2, H(z) is 75, and a ± 1σ error is ±5. The mode is the value that appears most frequently in the data. It represents the most common value or the peak of the data distribution. The standard deviation of Redshift (z) is 0.5704, H(z) is 36.6026, and a ± 1σ error is ±20.7713. The standard deviation measures the amount of variation or dispersion in the data. A higher standard deviation indicates higher variability in the data points from the mean. The variance of Redshift (z) is 0.3258, H(z) is 1342.6632, and a ± 1σ error is ±432.6321. Variance is the square of the standard deviation and represents the average of the squared differences between each data point and the mean. It provides information about the spread or dispersion of the data. The range of Redshift (z) is 1.895, H(z) is 135.1, and a ± 1σ error is ±80.6. The range is the difference between the highest and lowest values in the data. It provides an indication of the spread of the data across the entire range. The coefficient of correlation between Redshift (z) and H(z) is 0.2761, between Redshift (z) and a ± 1σ error is -0.1505, and between H(z) and a ± 1σ error is 0.0798. The coefficient of correlation measures the strength and direction of the linear relationship between two variables. It ranges from -1 to 1, where 1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation. In this case, a positive correlation between Redshift (z) and H(z) indicates that as Redshift increases, H(z) also tends to increase, while a negative correlation between Redshift (z) and a ± 1σ error indicates an inverse relationship, where an increase in Redshift leads to a decrease in the error. The correlation between H(z) and a ± 1σ error is weak, as the coefficient is close to 0.

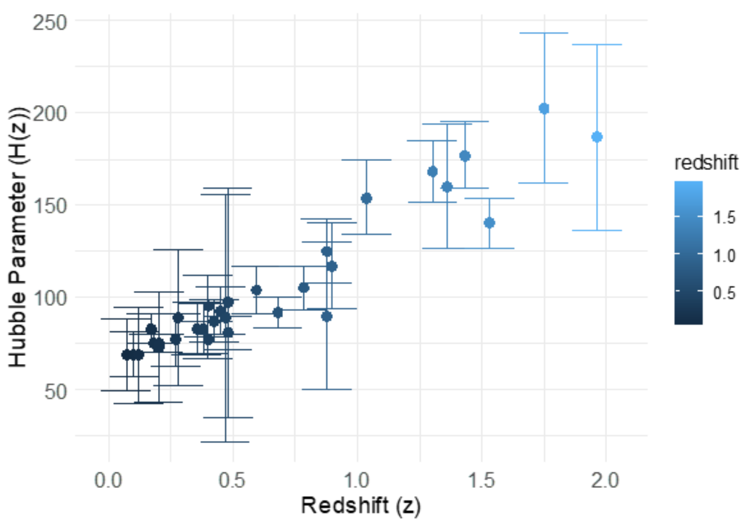

FIGURE 1. Hubble parameters (H) vs Redshift (z) based TABLE 1.

Hubble Parameters (H)

The mathematical equation for calculating the value of Hubble parameters (H) is as follows [2]:

$$H(z) = H_0 \cdot \sqrt{\Omega_m \cdot (1+z)^3 + \Omega_k \cdot (1+z)^2 + \Omega_L} \quad (1)$$

Where H(z) is the value of the Hubble parameter on redshift z, H_0 is the current Hubble constant, Ω_m is the mass fraction of matter in the universe, Ω_k is the fraction of the empty pocket in the universe, Ω_L is the fraction of dark energy in the universe z is redshift, which is the shift in the spectrum of light produced by astronomical objects as it travels through space.

For the derivation of these equations, we can first start with the Friedmann equation which describe the evolution of the universe [10]. The Friedmann equation shows the relationship between the expansion rate of the universe and the density of matter and energy in it [11]. This equation can be written as:

$$H^2 = \left(\frac{8}{3}\pi G\right) \cdot \rho - \frac{k}{a^2} + \frac{\Lambda}{3} \tag{2}$$

Where H is the Hubble parameter G is Newton's gravitational constant ρ is the density of matter and energy in the universe k is the empty pocket constant a is the cosmological factor scale Λ is the cosmological constant (dark energy) [12]. If we plug in the equation for the cosmological factor scale, $a = \frac{1}{(1+z)}$, then we can write the Friedmann equation in a simpler form:

$$H^2 = H_0^2 \cdot (\Omega_m \cdot (1+z)^3 + \Omega_k \cdot (1+z)^2 + \Omega_L) \tag{3}$$

Where H_0 is the current Hubble constant ,Ω_m is the mass fraction of matter in the universe, Ω_k is the fraction of the empty pocket in the universe, Ω_L is the fraction of dark energy in the universe z is redshift.

Comoving distance r(z)

This equation is used in cosmology to calculate the comoving distance or the distance between two objects in cosmic space [13]. This formula is obtained through the integration of the velocity equation. First, we start by considering Hubble's law, which states that the speed of an object in cosmic space is proportional to its distance from the observer, as follows:

$$v = H(z) \cdot r \tag{4}$$

where v is the velocity of the object at a distance r from the observer and H(z) is the Hubble parameter, which is the expansion rate of the universe at a given time. We can turn this equation into a more useful form by multiplying both sides by the scale factor, a, so we get:

$$v = a \cdot \left(\frac{da}{dt}\right) \cdot r \tag{5}$$

with a as the scale factor and $\left(\frac{da}{dt}\right)$ as the rate of change of the scale factor. Next, we take advantage of the fact that the speed of an object at a certain distance can be expressed as the rate of change of distance in time. In this case, we can write:

$$v = \frac{dr}{dt} \tag{6}$$

We can then solve this equation for dr:

$$dr = v \cdot dt$$

$$= a \cdot \left(\frac{da}{dt}\right) \cdot r \cdot dt \tag{7}$$

We can divide both sides by r and perform integration on both sides from the initial time to the present time, with integration limits from 0 to z. The result is:

$$\int [0, z] \left(\frac{1}{r} dr\right) = c \cdot \int [0, z] \frac{dz'}{H(z')} \tag{8}$$

with c as the constant obtained from integrating the factor a / H(z) on both sides. In this equation, $\int[0, z]\left(\frac{1}{r} dr\right)$ is the comoving distance, which is the distance between any two objects in cosmic space that takes into account the expansion of the universe, where as $\int[0, z]\frac{dz'}{H(z')}$ a is the cosmological integral, which gives information about how fast the universe is expanding at any given time.

Distance-volume relation (Dv(z))

The distance-volume relation in cosmology is a mathematical relationship used to calculate the measured distance (expressed in units of volume) from an observer to a cosmic object at a specific redshift (z) during a given time in the universe [14]. The derivation of this equation involves several basic concepts in cosmology, such as the general theory of relativity, redshift, and the Hubble constant [15]. First, we need to know the definition of a measured distance in cosmology. In cosmology, measured distances are expressed in units of volume (usually megaparsec^3) and are defined as:

$$D_v(z) = \left(\frac{c}{H(z)}\right) \cdot (z \cdot r(z))^2 \tag{9}$$

where c is the speed of light, H(z) is the Hubble constant at redshift z, and r(z) is the moving distance from the observer to the cosmic object at redshift z. The moving distance is a fixed distance in cosmological space that expands with time. At the present time (z = 0), the moving distance is equal to the physical distance (which can be measured in meters). To get a simpler equation, we can manipulate the above equation by eliminating factors $(z \cdot r(z))^2$, so we get:

$$D_v(z) = \left(\frac{c}{H(z)}\right) \cdot \frac{(z \cdot r(z))^2}{((z \cdot r(z))^2)^{\frac{1}{3}}} \tag{10}$$

$$D_v(z) = \left(c \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}} \cdot r(z) \cdot \frac{1}{(z \cdot r(z))^{\frac{2}{3}}} \tag{11}$$

We can also use the definition of the commoving distance in cosmology, ie:

$$\int[0, z]\left(\frac{1}{r} dr\right) = c \cdot \int[0, z]\frac{dz'}{H(z')} \tag{12}$$

where the integral is calculated from redshift 0 (current time) to redshift z (earlier time in cosmological history). Substituting r(z) in the above equation, we get:

$$D_{V(z)} = \left(c \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}} \cdot \left(c \cdot \int[0, z]\frac{dz'}{H(z')}\right) \cdot \frac{1}{\left(z \cdot \left([0, z]\frac{dz'}{H(z')}\right)\right)^{\frac{2}{3}}} \tag{13}$$

$$D_{V(z)} = \left(c \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}} \cdot \left(c \cdot \int[0, z]\frac{dz'}{H(z')}\right) \cdot \frac{1}{\left(\left(\frac{c \cdot \left(\int[0, z]\frac{dz'}{H(z')}\right)}{z'}\right)\right)^{\frac{2}{3}}} \tag{14}$$

$$D_{V(z)} = \left(c \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}} \cdot \left(c \cdot \int[0, z]\frac{dz'}{H(z')}\right) \cdot \frac{1}{(1+z)^{\frac{2}{3}}} \tag{15}$$

$$D_{V(z)} = \left(r(z)^2 \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}} \quad (16)$$

Hence, the equation $D_{V(z)} = \left(r(z)^2 \cdot \frac{z}{H(z)}\right)^{\frac{1}{3}}$ obtained from manipulating the DV measured distance equation and substituting the moving distance equation (r).

Luminosity Distance Equation D_M(z)

In cosmology, the comoving distance r(z) is calculated from the integration of the cosmic scale factor a from the moment (a=1) to the redshift moment z, as follows:

$$\int[0,z]\left(\frac{1}{r}dr\right) = c \cdot \int[0,z]\frac{dz'}{H(z')} \quad (17)$$

where c is the speed of light, H(z) is the Hubble parameter at redshift z, and the integral is calculated from redshift 0 (current) to redshift z. Sound horizon rs is defined as the physical distance traveled by acoustic vibrations in the plasma during the last redshift before the photons escape from the plasma, which is expressed in Mpc units [16].

In cosmology, the comoving distance and the sound horizon are usually expressed in Mpc/h, where h is the current Hubble constant in km/s/Mpc [17]. By combining the definitions of comoving distance and sound horizon, the D_M(z) equation can be derived as follows:

$$a(t) = \left(\frac{1}{(1+z)}\right) \cdot \frac{1}{H_0 \cdot \sqrt{\Omega_r + \Omega_m \cdot (1+z)^3 + \Omega_k \cdot (1+z)^2 + \Omega_l}} \quad (18)$$

$$D_M(z) = c \cdot \int[0,z]\frac{\frac{dz'}{H(z)'}}{r_s} \quad (19)$$

$$D_M(z) = \frac{c}{r_s} \cdot \int[0,z]\frac{dz'}{H(z')} \quad (20)$$

In this last equation, the c/rs factor can be calculated using the sound horizon value given in Mpc/h units and the c factor expressed in km/s units. The D_M(z) equation is used to calculate the angular distance comoving diameter D_M at redshift z, which is the distance between two objects in Mpc/h units, where the positions of these objects are observed from the earth [18].

Angular Diameter Distance D_A(z)

The derivation of the equation starts from the definition of the angular distance θ in radian units as $\frac{r}{D_A}$, where r is the physical distance between the two objects and D_A is the angular diameter distance. The physical distance r can be expressed as $r = D_A \cdot (1+z)$, where D_M is the comoving distance which is the physical distance between two objects at the same time in moving coordinates [13]. Therefore, the angular distance θ can be expressed as:

$$\theta = \frac{r}{D_A} \quad (21)$$

$$\theta = \frac{D_M \cdot (1+z)}{D_A} \quad (22)$$

The above equation can be changed in such a way that D_A can be isolated. First of all, the ratio between these two distances is defined as the scale factor:

$$a = \frac{D_A}{D_M} \tag{23}$$

By using this definition, the equation can be produced:

$$\theta = (1+z) \cdot \frac{r}{D_M \cdot a} \tag{24}$$

$$a = \frac{D_A}{D_M} = \frac{r}{(\theta \cdot D_M \cdot (1+z))} \tag{25}$$

In this equation form, the scale factor a can be expressed in units of comoving distance D_M, so that D_A can be expressed as:

$$D_A = a \cdot D_M \tag{26}$$

$$D_A = \frac{r}{(\theta \cdot (1+z))} \tag{27}$$

This last equation is an equation $D_A(z) = \frac{D_M(z)}{(1+z)}$, which shows that the angular diameter distance $D_A(z)$ can be calculated from the comoving distance $D_M(z)$ which is known.

Luminosity Distance D_L(z)

In order to derive this equation, we must first understand the concepts of apparent magnitude and absolute magnitude [19]. Apparent magnitude refers to the brightness of a light source as we observe it on earth, while absolute magnitude refers to the brightness of a light source when placed at a specified standard distance [20]. We can use the equations for apparent magnitude and absolute magnitude to calculate the distance between the light source and the observer. This equation is known as the distance modulus equation, and is given by:

$$m - M = 5 \cdot log\left(\frac{d}{10}\right) \tag{28}$$

where m is the apparent magnitude, M is the absolute magnitude, and d is the distance between the light source and the observer in parsecs. We can solve this equation for d and get:

$$d = 10^{\left(\frac{m-M+5}{5}\right)} \tag{29}$$

To calculate the luminosity distance, we must take into account the redshift of the light source. Redshift refers to the phenomenon where the spectral lines of a light source are shifted towards longer wavelengths, appearing "redder," due to the expansion of the universe. The farther the light source is from us, the greater redshift. In cosmology, the distance that is often used is the comoving distance, which is the distance that follows the expansion of the universe [21]. The moving distance is expressed in units r_s, that is, the radius of the particle horizon at the beginning of the universe [22]. Therefore, we can calculate the luminosity distance in units r_s. In this equation, $D_M(z)$ has been calculated before. To count $D_L(z)$, we can use the luminosity distance equation:

$$D_L = \frac{r}{a} \cdot \frac{1}{z} \tag{30}$$

where r is the moving distance, a is the cosmological scale factor, and z is the redshift. The cosmological factor scale, a, is the ratio of the size of the universe at a given time to the size of the universe at another time [23]. The scale of this factor is time dependent and is usually expressed as a function of time, a(t). In cosmology, we work with the FLRW (Friedmann-Lemaître-Robertson-Walker) cosmological model, which assumes that the universe is homogeneous and isotropic [24]. In this model, the cosmological factor scale is expressed as:

$$a(t) = \left(\frac{1}{(1+z)}\right) \cdot \frac{1}{H_0 \cdot \sqrt{\Omega_r + \Omega_m \cdot (1+z)^3 + \Omega_k \cdot (1+z)^2 + \Omega_l}} \tag{31}$$

Where H_0 is the Hubble constant, Ω_r, Ω_m, Ω_k, and Ω_l. As for each is a cosmological parameter for radiation density, matter density (including dark matter)

Parameter cosmological universe calculation results

The calculation results will be made in the data table which contains information about several cosmological parameters calculated from observations and cosmological modeling at the time of observation. The parameters will include:

- z: redshift, namely the magnitude of the redshift of the observed object
- r: comoving distance, namely the physical distance between these objects in megaparsec units (Mpc) adjusted for the expansion of the universe
- D_V: sound size, namely the size of the volume at redshift z which is calculated from the combination of cosmological parameters
- H: Hubble parameter, namely the expansion rate of the universe at the time of observation in units of km/s/Mpc
- D_M: luminosity distance, namely the physical distance between these objects in megaparsec units (Mpc) which is calculated using the object's intrinsic luminosity
- D_A: angular distance, namely the physical distance between these objects in megaparsec units (Mpc) which is calculated using the observed angle of the object

D_L: redshift-adjusted luminosity distance, namely the physical distance between these objects in megaparsec units (Mpc) calculated using the object's intrinsic luminosity and z-adjusted redshift.

This data table is the result of this calculation and can be used for cosmological research, especially in testing and comparing cosmological models. By observing the values of these parameters at different redshifts, we can evaluate the fit between the existing cosmological model and the actual observations, as well as improve and enhance the cosmological model, shown by TABLE 2.

TABLE 2. Cosmology parameter calculation results from TABLE 1

No	z	r	D_V	H	D_M	D_A	D_L
1	0.07	291.6716	18140.04	73.15093	139.7371	130.5954	149.5187
2	0.1	413.7262	24412.75	74.23204	198.2123	180.193	218.0335
3	0.12	494.097	28176.43	74.97711	236.7172	211.3546	265.1233
4	0.17	691.4938	36315.88	76.92425	331.2881	283.1522	387.6071
5	0.1791	726.8744	37622.73	77.29151	348.2387	295.3428	410.6082
6	0.1993	804.8089	40351.75	78.12078	385.5764	321.5012	462.4217
7	0.2	807.4947	40442.25	78.14986	386.8631	322.3859	464.2357
8	0.27	1071.021	48268.54	81.17383	513.1161	404.0284	651.6574
9	0.28	1107.851	49208.96	81.62431	530.7611	414.6571	679.3742
10	0.3519	1366.679	54898.15	84.99638	654.763	484.328	885.1741
11	0.3802	1465.692	56688.44	86.38657	702.1994	508.7664	969.1756
12	0.4	1534.015	57811.68	87.37994	734.9319	524.9513	1028.905
13	0.4004	1535.387	57833.34	87.40018	735.5893	525.2708	1030.119
14	0.4247	1618.154	59076.56	88.64273	775.2421	544.1441	1104.487
15	0.4497	1702.09	60215.26	89.94721	815.4554	562.4994	1182.166
16	0.47	1769.349	61043.73	91.0257	847.6781	576.6518	1246.087
17	0.4783	1796.618	61359.21	91.47158	860.7426	582.2516	1272.436
18	0.48	1802.187	61422.22	91.56325	863.4106	583.3855	1277.848
19	0.5929	2159.747	64547.06	97.91192	1034.714	649.5789	1648.196
20	0.6797	2418.739	65822.98	103.1284	1158.795	689.8821	1946.428
21	0.7812	2705.023	66441.07	109.5766	1295.951	727.5717	2308.347
22	0.8754	2955.662	66405.35	115.8788	1416.03	755.0548	2655.622
23	0.88	2967.547	66391.75	116.194	1421.724	756.2359	2672.84
24	0.9	3018.846	66321.47	117.5728	1446.3	761.2107	2747.971
25	1.037	3354.534	65433.4	127.355	1607.125	788.9668	3273.714
26	1.3	3929.63	62488.63	147.6668	1882.647	818.5422	4330.088
27	1.363	4055.36	61652.26	152.8089	1942.885	822.211	4591.036
28	1.43	4184.47	60733.47	158.3876	2004.74	824.996	4871.519
29	1.53	4368.85	59325.78	166.9182	2093.075	827.3023	5295.479
30	1.75	4742.66	56176.99	186.5021	2272.164	826.2413	6248.45
31	1.965	5070.97	53150.04	206.6559	2429.453	819.377	7203.327

RESULT AND DISCUSSION

The data provided above TABLE 2 represents statistical values and correlations for a set of variables. The variables include No (number), z (z-score), r (correlation coefficient), DV (dependent variable), H (mean), DM (median), DA (mode), and DL (standard deviation). The dataset consists of 31 data points, numbered from 1 to 31. The z-score values range from 0.07 to 1.965, with corresponding values for r ranging from 291.6716 to 5070.97. The DV values range from 18140.04 to 53150.04. The mean (H) values range from 73.15093 to 206.6559, while the median (DM) values range from 139.7371 to 2429.453. The mode (DA) values range from 130.5954 to 827.3023. The standard deviation (DL) values range from 149.5187 to 7203.327.

The dataset also includes information on the correlations between the variables. The correlation coefficient (r) measures the strength and direction of the linear relationship between two variables. Positive values indicate a positive correlation, while negative values indicate a negative correlation. The correlation coefficients in the dataset range from 0.07 to 1.965, suggesting varying degrees of correlation between the variables. the dataset provides statistical values and correlations for a set of variables, indicating their relationship and variability. These values can be used to analyze and interpret the data for further analysis or decision-making purposes.

The TABLE 2 given is cosmological observational data used to measure cosmological parameters, namely parameters that describe the nature and evolution of the universe. Each row in the table represents an observable cosmic object, and each object has several associated parameters. In cosmology, these parameters are interrelated and provide information about properties of the universe such as age, density and composition. For example, the Hubble parameter (H) is used to measure the age of the universe, while the D_V parameter is used to measure the average density of the universe [25]. In addition, changes in these parameters can provide clues about the cause and effect of cosmological phenomena such as the accelerating expansion of the universe and dark energy [26].

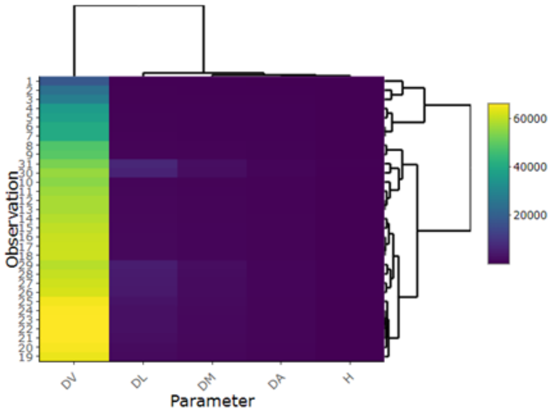

FIGURE 2. Heatmap visualitation of cosmological parameters.

A cosmology parameter heatmap is a visualization that displays the intensity or values of cosmology parameters in a matrix form based on the level of observation or measurement [27]. This heatmap is used to identify patterns or trends in data and visualize the relative differences between the values of cosmology parameters in the analyzed dataset [28]. From a physics perspective, this heatmap can depict the relationship or correlation between cosmology parameters present in the data. For example, if there is a positive correlation between two parameters, then brighter areas on the heatmap will indicate higher values for those two parameters at a particular observation [29]. Conversely, if there is a negative correlation, then darker areas on the heatmap will indicate lower values for those two parameters at a particular observation.

Theoretical support can be added to the parameter heatmap by incorporating a theoretical framework or theoretical values of cosmology parameters as references. This can be displayed in the form of horizontal or vertical lines with different line styles or colors, such as dashed lines or red color. This can help in comparing observational values with expected theoretical values. Theoretical support can aid in identifying differences between observational and theoretical values in the cosmology parameter heatmap. By incorporating theoretical values or frameworks, the heatmap can provide insights into the agreement or discrepancy between observational data and theoretical predictions in cosmology research. This can help researchers validate or refine existing cosmological models and theories based on the observed data, and further our understanding of the Universe's fundamental properties and evolution.

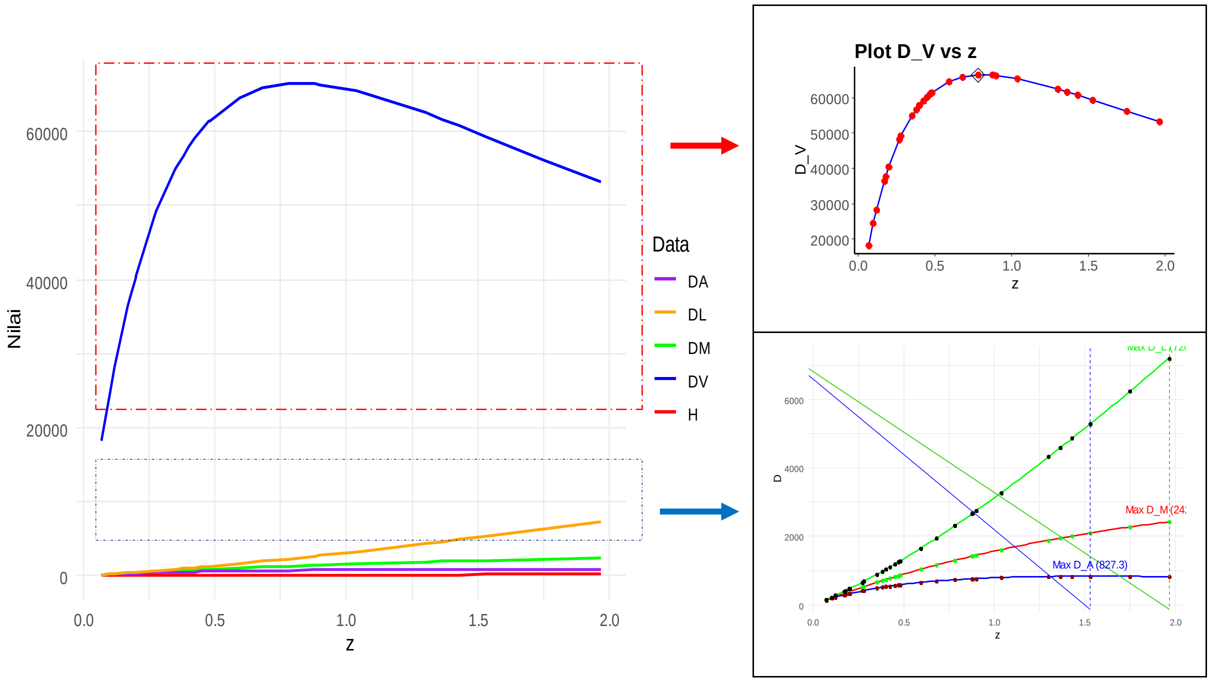

FIGURE 3. Visualization of the cosmology parameter relationship DV, DA, DL DM vs Z.

In this discussion, we will discuss three important equations in cosmology: Confidence Interval, Hubble Parameter, Komoving Distance and Distance-Volume Relationship. First, we'll cover Confidence Intervals. The calculation results show that the difference between the mean z and h is estimated to be between -105.8591 and -105.0449 with a 95% confidence interval. This shows that the greater the z value, the greater the h value.

Next, we'll cover Hubble Parameters. The mathematical equation for calculating the value of the Hubble parameter at redshift z is based on EQUATION 1. Where H_0 is the Hubble current constant, Ω_m is the mass fraction of matter in the universe, Ω_λ is the fraction of dark energy in the universe, Ω_k is the fraction of the empty pocket in the universe, and z is the redshift. Then, we will discuss the Komoving Distance. This equation is used in cosmology to calculate the comoving distance or the distance between two objects in cosmic space. This equation is obtained by integration of the velocity equation and can be written as r(z) = c * integral from

0 to z in a/H(a) da. In this equation, c is the constant of the speed of light, r(z) is the moving distance, which is the distance between two objects in cosmic space that takes into account the expansion of the universe, and the cosmological integral gives information about how fast the universe is expanding at any given time. Next we will discuss the Distance-Volume Relationship. This relationship in cosmology is used to calculate the measured distance (measured in units of volume) from an observer to a cosmic object at any given time that lies at a certain redshift (z). Distance measured in cosmology is expressed in units of volume and is defined as $D_v(z) = \frac{((1+z)^2 \cdot r^2(z) \cdot \Delta\Omega)}{c}$. Where c is the speed of light, r(z) is the moving distance from the observer to the cosmic object at redshift z, deltaOmega is the solid angle as seen by the observer, and the factor $(1+z)^2$ takes into account the redshift effect that occurs on the incident light. received from the cosmic object.

Next discussion in The TABLE 2 provided contains cosmological observation data that is used to measure cosmological parameters, which describe the nature and evolution of the universe. Each row in the table represents a cosmic object that has been observed, and each object has several related parameters. In cosmology, these parameters are interconnected and provide information about the properties of the universe, such as its age, density, and composition. For example, the Hubble parameter (H) is used to measure the age of the universe, while the D_V parameter is used to measure the average density of the universe. In addition, changes in these parameters can provide clues about the causes and effects of cosmological phenomena such as the acceleration of the universe's expansion and dark energy. Cosmological observations are made using various techniques, including telescopes, satellites, and ground-based experiments. The data collected from these observations is then used to build models and theories about the universe. By comparing these models with observational data, cosmologists can test the validity of their theories and gain new insights into the workings of the universe.

One of the key challenges in cosmology is the measurement of cosmological parameters with high precision. This requires the use of advanced technologies and techniques, such as gravitational lensing, which can distort the light from distant objects to reveal information about the distribution of matter in the universe. Another challenge is understanding the relationship between the various cosmological parameters and how they affect each other. This requires the development of mathematical models and simulations that can accurately capture the complex interactions between these parameters. In conclusion, the table provided contains valuable information about the properties of the universe and the interconnectedness of cosmological parameters. By analyzing this data, cosmologists can gain new insights into the workings of the universe and improve our understanding of its origins and evolution.

CONCLUSION

This research paper provides statistical values and correlations for a set of variables used to measure cosmological parameters, such as the age, density, and composition of the universe. The paper presents a cosmological parameter heatmap that visualizes the intensity or values of cosmology parameters in a matrix form, which helps to identify patterns or trends in data and to visualize the relative differences between the values of cosmology parameters in the analyzed dataset. Theoretical support can be added to the parameter heatmap by incorporating a theoretical framework or theoretical values of cosmology parameters as references. The paper also discusses three important equations in cosmology, namely the Confidence Interval, Hubble Parameter, Komoving Distance, and Distance-Volume Relationship. These equations are used to calculate the value of the Hubble parameter at redshift z, the comoving distance, and the measured distance from an observer to a cosmic object at any given time that lies at a certain redshift (z). The research paper aims to validate or refine existing cosmological models and theories based on observed data and to further our understanding of the Universe's fundamental properties and evolution.

ACKNOWLEDGEMENT

Thank you to colleagues and collaborators for funding this research.

REFERENCES

[1] J. R. Fieberg, K. Vitense and D. H. Johnson, “Resampling-based methods for biologists,” *PeerJ*, vol. 8, p. e9089, 2020.

[2] A. G. Riess *et al*., “A comprehensive measurement of the local value of the Hubble constant with 1 km s− 1 mpc− 1 uncertainty from the Hubble space telescope and the sh0es team,” *The Astrophysical Journal Letters*, vol. 934, no. 1, p. L7, 2022.

[3] S. S. Mohammedamin and A. M. Rasool, “Expansion of the universe and Hubble’s law,”.

[4] H. J. Macpherson and A. Heinesen, “Luminosity distance and anisotropic sky-sampling at low redshifts: A numerical relativity study,” *Physical Review D*, vol. 104, no. 2, p. 023525, 2021.

[5] T. A. Dimitrova, N. R. Butler and S. Ravi, “Predicting Short-duration GRB Rates in the Advanced LIGO Volume,” *ArXiv Preprint ArXiv*, vol. 2303, p. 06598, 2023.

[6] Y. K. Dwivedi *et al*., “So what if ChatGPT wrote it? Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy,” *International Journal of Information Management*, vol. 71, p. 102642, 2023.

[7] F. Meza Obando, “Estimating the redshift of galaxies from their photometric colors using machine learning methods,” *A first approach to Acoustic Characterization of Costa Rican Children’s Speech*, 2020.

[8] M. Moresco *et al*., “New constraints on cosmological parameters and neutrino properties using the expansion rate of the Universe to z∼ 1.75,” *Journal of Cosmology and Astroparticle Physics*, vol. 2012, no. 07, p. 053, 2012.

[9] J. Niu and T. J. Zhang, “Cosmological joint analysis with cosmic growth and expansion rate,” *Physics of the Dark Universe*, vol. 39, p. 101147, 2023.

[10] A. Sheykhi, “Barrow entropy corrections to Friedmann equations,” *Physical Review D*, vol. 103, no. 12, p. 123503, 2021.

[11] K. Freese, “Cardassian expansion: Dark energy density from modified Friedmann equations,” *New Astronomy Reviews*, vol. 49, no. 2-6, pp. 103-109, 2005.

[12] J. S. Farnes, “A unifying theory of dark energy and dark matter: Negative masses and matter creation within a modified ΛCDM framework,” *Astronomy & Astrophysics*, vol. 620, p. A92, 2018.

[13] D. W. Hogg, “Distance measures in cosmology,” *ArXiv Preprint Astro-Ph9905116*, 1999.

[14] M. Lachièze-Rey, “Cosmology: a first course,” Cambridge University Press, 1995.

[15] E. Harrison, “The redshift-distance and velocity-distance laws,” *The Astrophysical Journal*, vol. 403, pp. 28-31, 1993.

[16] V. F. Cardone *et al*., “Testing the distance duality relation with present and future data,” *Physical Review D*, vol. 85, no. 12, p. 123510, 2012.

[17] A. Gómez Valent, “Measuring the sound horizon and absolute magnitude of SNIa by maximizing the consistency between low-redshift data sets,” *Physical Review* D, vol. 105, no. 4, p. 043528, 2022.

[18] E. Gaztanaga, “The black hole universe (BHU) from a FLRW cloud,” *Submitted to Physics of the Dark Universe*, 2021, online: https://hal. archives-ouvertes, fr/hal-03344159.

[19] J. H. Oort, “The force exerted by the stellar system in the direction perpendicular to the galactic plane and some related problems,” *Bulletin of the Astronomical Institutes of the Netherlands*, vol. 6, p. 249, 1932.

[20] E. Hubble and M. L. Humason, “The velocity-distance relation among extra-galactic nebulae,” *Astrophysical Journal*, vol. 74, p. 43, 1931.

[21] A. Clocchiatti *et al*., “Hubble space telescope and ground-based observations of type Ia supernovae at redshift 0.5: cosmological implications,” *Astrophysical Journal*, vol. 642, no. 1, p. 1, 2006.

[22] W. Rindler, “Visual horizons in world models,” *Monthly Notices of the Royal Astronomical Society*, vol. 116, no. 6, pp. 662-677, 1956.

[23] J. Ambjørn, J. Jurkiewicz and R. Loll, “The spectral dimension of the universe is scale dependent,” *Physical review letters*, vol. 95, no. 17, p. 171301, 2005.

[24] S. Räsänen, K. Bolejko and A. Finoguenov, “New test of the Friedmann-Lemaître-Robertson-Walker metric using the distance sum rule,” *Physical review letters*, vol. 115, no. 10, p. 101301, 2015.

[25] N. Borghi, M. Moresco and A. Cimatti, “Toward a Better Understanding of Cosmic Chronometers: A New Measurement of H (z) at z∼ 0.7,” *The Astrophysical Journal Letters*, vol. 928, no. 1, p. L4, 2022.

[26] D. Farrah *et al*., “Observational evidence for cosmological coupling of black holes and its implications for an astrophysical source of dark energy,” *The Astrophysical Journal Letters*, vol. 944, no. 2, p. L31, 2023.

[27] S. Yuan *et al*., “Stringent σ8 constraints from small-scale galaxy clustering using a hybrid MCMC+ emulator framework,” *Monthly Notices of the Royal Astronomical Society*, vol. 515, no. 1, pp. 871-896, 2022.

[28] S. Heydenreich, B. Brück and J. Harnois Déraps, "Persistent homology in cosmic shear: constraining parameters with topological data analysis," *Astronomy & Astrophysics*, vol. 648, p. A74, 2021.

[29] C. Montzka *et al.*, "Sensitivity of LiDAR Parameters to Aboveground Biomass in Winter Spelt," Drones, vol. 7, no. 2, p. 121, 2023.