Gravitational redshift from the early Universe

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SUMMARY
A simple gravitational alternative to Hubble's Law is presented. Measured redshifts are attributed to gravitation rather than recessional velocity. The measured redshift-distance data fits a gravitational potential with constant mass. Redshift is then a measure of the gravitational potential and the space-time curvature of the early universe. The redshift-distance data is fitted to a constant mass of 3.35 x 10^{53} kg (1.67 x $10^{23}M_{sol}$) which is 2.23 times the estimated total mass of ordinary matter in the current universe. The expanding and accelerating universe are not predicted and the speculation of dark energy is no longer required.

Key Words: *Cosmology:* early Universe, large scale structure of Universe, gravitation.

1 INTRODUCTION

Hubble's Law has shaped our understanding of the universe for the past century (Hubble, 1929). Hubble was the first to report that the nebulosities observed in the sky were galaxies like our own Milky Way. Early large telescope observations combined with spectroscopy showed that more faint galaxies appeared to have greater redshifts. The observed redshifts were attributed to recessional velocities and the Hubble Law was created (Hubble, 1929, Bahcall, 2015). Hubble and Humason were in fact looking for curvature in space-time (Hoyle et al., 2000). It should be noted that Hubble was reticent to solely attribute the measured redshifts to a Doppler effect (Ratcliffe, 2010). Current consensus is that the redshift-distance curves, Hubble plots, are interpreted as an increasing velocity with distance in an expanding and accelerating universe (Hubble, 1929, Riess, 2020, Smith, 1982, Smith, 1990).

The "standard model" of big bang cosmology, the Lambda Cold Dark Matter (Λ-CDM) model (Deruelle and Uzan, 2018) is founded on the Hubble expansion of the universe (Hubble, 1929, Perlmutter et al., 1999, Schmidt et al., 1998, Shirokov et al., 2020, Perlmutter, 2003) and the interpretation using general relativity (Einstein, 1911, Einstein, 1917, Weinberg, 1972, Einstein, 1907, Friedmann, 1922, Friedmann, 1924). The accelerating universe has added experimental evidence in support of the existence of dark energy (Riess, 2020, Riess et al., 1998).

Several recent papers have questioned the "standard" Λ-CDM model of cosmology in view of the experimental data from the Planck Legacy 2018 measurements of the cosmic microwave background (Di Valentino, 2022, Di Valentino et al., 2020, Gaztañaga, 2023). There also exists an earlier body of data by Arp et al. that shows that the measured redshifts are not due to a Doppler effect alone (Ratcliffe, 2010, Arp, 1987, Arp, 1998, Arp, 2003). A number of interacting galaxies and their associated quasars have been shown to have significantly differing redshifts (Arp, 2003). In many cases the ejected objects have redshifts that differ significantly from their galaxy. The quasar redshifts are all larger that the ejecting galaxy and are not attributable to their ejection velocity as none are blue shifted. Essentially, a single astronomical object has components with redshifts that differ from each other and that of the host galaxy. Despite showing that the measured redshifts cannot be singularly attributed to recessional velocity, these results have been largely overlooked by the astrophysics community (Ratcliffe, 2010, Arp, 1987, Arp, 1998, Arp, 2003, Fulton and Kokus, 2017). A number of alternatives to recessional velocity have been suggested by Arp(Arp, 1987, Arp, 1998, Arp, 2003) and Radcliffe (Ratcliffe, 2010) who suggested that an "intrinsic" redshift of the quasars was responsible. Possibly the only effect that generates redshift that is consistent with all the observations and criteria outlined by Arp and Ratcliffe is that of gravitation. This would require that the estimated masses and/or radii of the quasars differ from the current estimates. Apparent quantisation of the redshifts is also potentially explained by gravitational effects where the mass of the objects generating the intrinsic redshifts have discrete values (Ratcliffe, 2010, Arp, 1998, Arp, 2003).

The current belief that redshifts are manifestations of the Doppler effect means that observed redshifts greater than 1 suggest velocities greater than that of light which are due to"stretched space" (Peebles, 1993). A gravitational interpretation of redshift data avoids this issue as redshifts greater than 1 do not imply a velocity exceeding that of light. Gravitational redshift also effectively removes the Hubble tension problem (Tully, 2024, Freedman, 2021, Hu and Wang, 2023).

2 THEORY AND ANALYSIS

The measured redshifts are composed of a Doppler and gravitational contribution:

$$z = z_D + z_G \qquad (1)$$

Where z is the measured redshift, z_D is the doppler redshift and z_G the gravitational contribution. In the early Universe, $z_D \ll 1$ and the measured value of z is equal to the gravitational redshift, z_G, as shown in Fig. 1. In the local region of the later universe, $z_G \sim 0$ and z tends to the Doppler value as is shown in Figure 1 below.

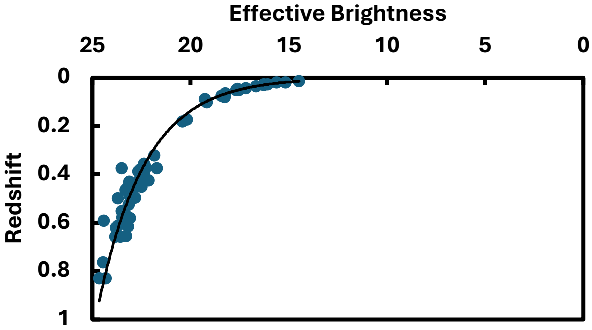

Figure 1. Measured redshift versus effective brightness data taken from Perlmutter et al.(Perlmutter et al., 1999) showing the nature of the gravitational potential (equation 4) and space-time curvature. Note the solar system is at the origin with the data between zero and brightness 14 (not shown) being along the horizontal axis. The data presented by Rout and Karachentsev shows that there is significant scatter in the redshift distance data in the local universe (between effective brightness 14 and 0) (Ratcliffe, 2010).

Figure 1 reveals that there is a rapid decrease in redshift at an effective brightness of 15-25. In the local region of the Universe the redshift values are relatively small. It is worth noting that the curvature seen in the gravitational potential of the early universe is precisely the space-time curvature that Hubble and Humason were looking for in their early measurements (Hoyle et al., 2000).

The data of Perlmutter et al. (Perlmutter et al., 1999, Perlmutter, 2003, Perlmutter et al., 1998, Perlmutter et al., 1997) Schmidt et al.(Schmidt et al., 1998, Hicken et al., 2009) and the compiled data presented by Shirokov et al. (Shirokov et al., 2020) are consistent with a power law relating the redshift and distance:

$z \sim R^n$ (2)

Where z is the redshift and R the distance from the gravitational mass evident in the logarithmic plot in Fig 2. The extended data set that includes high redshift long gamma-ray burst (LGRB) data presented by Shirokov et al. (Shirokov et al., 2020) extends the observed range of redshift values to ten. All three data sets reveal similar behaviour.

The data of Perlmutter et al.(Perlmutter et al., 1999) yields n = -0.90 +/- 0.1 while that of Schmidt et al. (Schmidt et al., 1998) yield a value of n = -1 +/-0.1 (data not shown) for the R vs z^n while the higher redshift data presented by Shirokov et al. (Shirokov et al., 2020) yields a slightly lower number of n = -0.8 +/-0.1 (data not shown)

Uncertainty in the distance measurements has recently been discussed(Mörtsell et al., 2022). Measurement of SN 1a brightness as used by Perlmutter et al.(Perlmutter et al., 1999) and Schmidt et al. (Schmidt et al., 1998) appears to be a relatively robust measure of distance. General Relativity shows that both length and time change in high field strengths giving rise to a gravitational redshift without modifying the measured intensities (Einstein, 1911, Einstein, 1914-1917, Einstein, 1953).

Gravitational redshift was first proposed by Einstein theoretically and has been observationally verified (Einstein, 1911, Misner et al., 1970, Einstein, 1914-1917, Einstein, 1953). The gravitational redshift has been measured for a number of nearby astronomical objects including the sun (Brault, 1962) and a number of local cosmological objects outside the solar system at low redshift (Capozziello et al., 2019). Indeed, the measured gravitational redshift has been considered to be a confirmation of the theory of General Relativity (Weinberg, 1972). The calculated intrinsic gravitational redshifts from various cosmological objects, galaxies, quasars and AGN's are of order 10^{-7} to 10^{-5}.

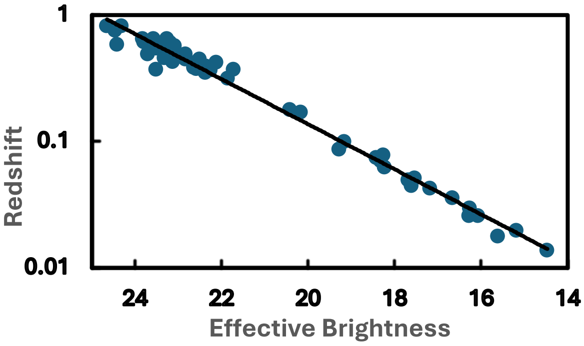

Figure 2. The data of Fig. 1 presented on a logarithmic plot giving an exponent of n = -0.90 +/-0.1 (Eq. 1). Effective brightness is related to distance by: $M_{eff} = 5 \log D_L + M_B$ where M_{eff} is the effective brightness, D_L is the distance and M_B the measured brightness as detailed in Perlmutter et al. (Perlmutter et al., 1999)

Calculation of the general relativistic gravitational redshift for a spherically symmetric gravitating body has been shown to be of the form (Einstein, 1911, Misner et al., 1970, Einstein, 1907, Einstein, 1914-1917, Einstein, 1953):

$1 + z = (1 - 2GM/c^2R)^{-1/2}$ (3)

Where M is the gravitational mass and R the distance from the source, G is the gravitational constant and c the speed of light.

The Newtonian limit for the relativistic field is then (Misner et al., 1970):

$z = GMR^{-1} c^{-2}$ (4)

The redshift data of Perlmutter et al. (Perlmutter et al., 1999) and Schmidt et al. (Schmidt et al., 1998) is consistent with Equation 4 to within 10% assuming a constant mass M. The measured redshift data in the higher redshift region presented by Shirokov et al. (Shirokov et al., 2020) shows behaviour more consistent with equation 3 where the value of n = -0.80 shows deviation from the Newtonian limit as expected at ever increasing field strengths. In short, the observed redshift distance behaviour fits a constant-mass gravitational potential.

Assuming that the current age of the Universe is 13.787 Gyr (Gaztañaga, 2023) and it's effective radius is 46.5 Gyr (Lineweaver and Davis, 2005) enables an estimate of R = 0 to be made. The data is taken from Shirokov where the effective brightness is 44 at z = 1 corresponding to a distance from earth of 1.9 x 10^{26}m. This number is subtracted from the radius of the universe to give the number for the radius at which the potential is causing the redshift. Using equation 4 the calculated gravitational mass giving rise to the redshifts is then 1.67 x 10^{23} M_{sol}. This value is 2.23 times the estimated value for the mass of the Universe at 6 x 10^{22} solar masses (Gaztañaga, 2023). The value obtained here is the new estimate of the total mass of the early universe. Alternatively, fitting the data using the current estimate of the gravitational mass of the universe (7.5 x 10^{22} M_{sol}) requires a distance correction of 11 Gyr to fit the data. This is a significant correction to the distance scale that does not appear to be realistic.

Data plotted over the complete range of redshifts shows that z is relatively small in the later universe, our local region as shown in Fig. 1 (Perlmutter, 2003). From Fig. 1 it is readily seen that the universe is effectively flat after approximately one quarter of the total time of the universe has elapsed. A review of the blue and redshift data in the local region shows distinctly random behaviour that is scattered around zero redshift (Ratcliffe, 2010, Karachentsev and Nasonova, 2010). The data presented by Rout^{11} and Karechentsev^{42} shows that there is significant scatter in the redshift distance data in the local universe and that the Hubble Law is not obeyed (Ratcliffe, 2010). It is posited here that the local universe is in a state of diffusional Brownian motion of the galaxies in the local region as is consistent with the random nature of the observed red and blue shifts (Ratcliffe, 2010, Karachentsev and Nasonova, 2010, Karachentsev et al., 2009). The significant body of blueshift data is also not consistent with Hubble's Law.

A physical interpretation is that photons are ejected from their source, SN 1a and LGRBs, that are associated with galaxies. The galaxies are in the gravitational potential of the early universe and the photons are redshifted due to the gravitational potential. The observed gravitational redshifts arise from photons escaping from the gravitational field of the primal universe that has a gravitational mass that is roughly twice that calculated for the current universe. The difference between the effective mass calculated here and the mass of the universe estimated in the current epoch may be due to the conversion of matter into energy (radiation) as the universe evolves. This value is in accord with estimates of the baryonic matter being slightly less than one half of the total baryonic energy.

The gravitational interpretation suggests that the mass of the universe is being fed from a constant mass of approximately twice that of the estimated mass of the current universe. Galaxies initially evolve and reach a mature state over the distance of the gravitational potential. We postulate that the steady state universe is then in a state of dynamic equilibrium where the entropy of the galaxy distribution is opposed to the gravitational attraction in a manner similar to that posed by Hoyle (Hoyle, 1948). We note that Einstein also originally considered the universe to be static and similar to the motions of molecules in a gas. He reluctantly changed his view when Hubble's interpretation became known (Einstein, 1917, Einstein, 1953, Einstein, 1915). Entropy and gravitation are then postulated as the driving forces for the evolution of the universe that is tending to an equilibrium state in the limit of time. The cosmological constant, Λ, is then a measure of the entropy of the universe (Einstein, 1917, Einstein, 1915).

3 CONCLUSIONS

We have shown that attribution of the measured redshifts to gravitation, assuming a constant mass of $1.67 \times 10^{23} M_{sol}$ fits the data. This value is 2.23 times current estimates of the mass of the universe. The gravitational interpretation implies space-time curvature of the early universe that extends for approximately one quarter of the radius of the current universe. Hubble's Law and the expanding universe is replaced by a gravitational model. Interpreting the measured redshifts as gravitational redshifts also negates the requirement of dark energy to understand the accelerating universe. The cosmological constant Λ, is a measure of the entropy of the universe.

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DATA AVAILABILITY

The data used in this article are available in the public version of SNANA in the Pantheon+ directory, at https://pantheonplussh0es.github.io/. Tables of the data are also available in the references: Perlmutter et al. 1999, Schmidt et al. 1998 and Shirokov et al. 2020.

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