Implications of a 14.7 Gyr Universe for the Hubble Tension

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Abstract

This work presents the first application of the Dark Matter by Quantum Gravitation (DMbQG) theory to the study of dark matter (DM) at cosmological scales. In Section 2.1, the first Friedmann equation is introduced within the DMbQG framework. A key feature of this approach is the explicit separation between baryonic matter density and dark matter density. It is shown that, in this theory, the dark matter density evolves with the cosmological scale factor following a power-law exponent of −2.5, in contrast to the ΛCDM model, where total matter density is not differentiated and scales as a^{-3}.

In Section 2.2, the second Friedmann equation and the cosmological conservation equation are presented. From the latter, the equation-of-state parameter *w* is derived for baryonic matter, dark matter, and dark energy. A novel result of this work is that, for dark matter, $w = -1/6$, which implies that its effective density is one-half of its physical density.

In Section 3, the age of the Universe is calculated first within the standard ΛCDM model and subsequently using the DMbQG framework. A central result is that the age integral obtained with DMbQG is approximately 11.5% larger than that derived from ΛCDM. This difference allows for consistency with the Hubble constant measured by the SHOES project, based on Type Ia supernovae in the local Universe, with $H_0 = 73$ km s^{-1} Mpc^{-1}, yielding an age of 14.7 Gyr. In contrast, applying this same value within ΛCDM leads to an age of 12.8 Gyr, in tension with the oldest known astrophysical objects. Consequently, ΛCDM relies on the Planck Collaboration value, $H_0 = 67.4$ km s^{-1} Mpc^{-1}, which gives an age of 13.85 Gyr.

Given that the SHOES method provides a more direct measurement of the present-day expansion rate, while the Planck value is inferred from early-Universe data (cosmic microwave background), the former may better represent the current Hubble parameter. The Hubble tension remains one of the major open problems in cosmology, and this work suggests that the DMbQG framework may offer a partial resolution by reconciling a higher H_0 value with a consistent estimate of the Universe's age.

1. Introduction

According to the Dark Matter by Quantum Gravitation theory (hereafter DMbQG), dark matter (DM) grows without spatial limit, and the total mass associated with a galaxy or a cluster is calculated using the so-called *direct mass* formula. The domain of this function is the halo, i.e., the region where the baryonic density is negligible compared to the DM density. This formula is derived in Section 8.8 of [1] Abarca (2024),

$M_{DIRECT}(<r) = \frac{a^2 \cdot \sqrt{r}}{G}$ where a^2 is the characteristic parameter of the galaxy or cluster.

Since baryonic matter is confined within galaxies, it is reasonable to assume that the halo region contains only DM. As a consequence of the direct mass formulation, the DM density function can be written as

$D_{DM} = L \cdot r^{-2.5}$ where $L = \frac{a^2}{8\pi G}$. Similarly to the *direct mass*, its domain is the halo region.

This radial dependence with exponent −2.5 is translated into the Hubble function because the DM density exhibits the same dependence on the cosmic scale factor (a), the variable associated with the Hubble expansion. The exponent −2.5 for the DM density constitutes the main novelty of this work and explains why the estimated age of the Universe is increased relative to the value obtained in the standard ΛCDM model.

The DMbQG theory was initially developed through the study of the rotation curves of the Milky Way (MW) and M31. In [1] Abarca (2024), the theory was formulated and successfully tested using several published datasets for the rotation curves of these galaxies. In [2] Abarca (2024), the theory was extended to galaxy clusters and tested using observational studies of the turnaround radius and its associated mass in the Virgo cluster.

In [3] Abarca (2025), it was shown that the Navarro–Frenk–White (NFW) profile for the virial mass is equivalent to the virial mass calculated within the DMbQG framework, using rotation curves of the MW and M31. In [4] Abarca (2026), it was demonstrated that the NFW profile for the total mass is compatible with the direct mass formulation, the characteristic expression of total mass in the DMbQG theory. Consequently, it is also consistent with the velocity decay law in the halo region of rotation curves, characterized by the exponent −0.25. In that work, in addition to the MW and M31, six galaxies outside the Local Group were analyzed to test the proposed framework.

In [5] Abarca (2026), within the DMbQG framework, the mass associated with the turnaround radius of galaxy clusters was calculated, showing results approximately 5% lower than those obtained using the corresponding formula in the standard model.

This brief summary of previous work highlights that the DMbQG theory was initially developed to describe dark matter in galaxies and was subsequently extended successfully to galaxy clusters.

The present work represents the first test of the theory at cosmological scale. In Section 5, the age of the Universe is calculated within the DMbQG framework, yielding a value of 14.7 Gyr. This result is associated with the Hubble constant determined by A. Riess and the SHOES program, based on Type Ia supernovae in the local Universe, (H_0 = 73 km/s/Mpc). This method provides one of the most direct measurements of this cosmological parameter for the present-day Universe. See [6] SHOES project. 2022.

However, within the standard ΛCDM model, this value cannot be adopted because it would lead to an age of the Universe in tension with the oldest astrophysical objects. Consequently, the value obtained by the Planck collaboration is typically used instead, based on the most precise measurements of the cosmic microwave background (CMB), yielding (H_0 = 67.4 km/s/Mpc). See [7] Plank collaboration. 2018.

It is well known that the Hubble tension is one of the most significant open problems in cosmology over the past decade. See [8-9-10-11-12-13-14-15-16-17-18]. This work aims to partially address this issue within the framework of the DMbQG theory.

2. Friedmann equations

2.1 First Friedmann equation

In this work it will supposed flat Universe because at the present knowledge is allowed and will be neglected the radiation contribution as this work is focused on the *eras of matter and DE*.

With the previous hypothesis the first Friedman equation in the current ΛCDM paradigm is:

$$H^2(a) = \frac{8\pi G}{3}(\rho_m + \rho_\Lambda) \quad (2.1)$$

Where H(a) is the Hubble function, a is the cosmic scale factor, normalised to unity today, ρ_m is the density of the matter (baryonic plus DM) and ρ_Λ is the density of the Dark Energy which is defined through the cosmological constant:

$$\rho_\Lambda = \frac{\Lambda \cdot c^2}{8\pi G} \quad (2.2)$$

In the framework of ΛCDM it is not necessary to distinguish baryonic versus DM, but in DMbQG it is. So the Friedman equation in this novel theory becomes:

$$H^2(a) = \frac{8\pi G}{3}(\rho_{BA} + \rho_{DM} + \rho_\Lambda) \quad (2.3)$$

The baryonic density decreases with the exponent -3, and ρ_Λ is constant, like in the ΛCDM paradigm, but the DM density decreases with the exponent -2.5 by the reason explained in the introduction, so the densities may be written like these:

$$\rho_{BA} = \rho_{BA}^0 a^{-3} \quad (2.4)$$

where the superscript 0 means the density at the present Universe.

$$\rho_{DM} = \rho_{DM}^0 a^{-2.5} \quad (2.5)$$

As ρ_Λ is constant may be considered that the exponent for a is zero, $\rho_\Lambda = \rho_\Lambda \cdot a^0$.

So the Friedman equation becomes:

$$H^2(a) = \frac{8\pi G}{3}\left(\rho_{BA}^0 a^{-3} + \rho_{DM}^0 a^{-2.5} + \rho_\Lambda\right) \quad (2.6)$$

The omega cosmological parameters are defined by the formulas:

$$\Omega_{BA} = \frac{\rho_{BA}^0}{\rho_C} \quad (2.7)$$

where $\rho_c = \frac{3H_0^2}{8\pi G}$ is the critic density of the Universe, H_0 is the Hubble constant at the present and ρ_{BA}^0 is the baryonic density at the present Universe.

$$\Omega_{DM} = \frac{\rho_{DM}^0}{\rho_C} \quad (2.8)$$

where ρ_{DM}^0 is the DM density at the present Universe, and

$$\Omega_\Lambda = \frac{\rho_\Lambda}{\rho_C} \quad (2.9)$$

So using these parameters the Friedman equation may be rewritten like this:

$$H^2(a) = H_0^2 \cdot (\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda) \quad (2.10)$$

At the present knowledge the best values for these parameters are: $\Omega_{BA} = 0.05$, $\Omega_{DM} = 0.26$, $\Omega_\Lambda = 0.69$ See [7] Plank Collaboration. 2018.

The current Hubble constant value is an important cosmologic challenge during the last decade.

Namely the value H_0= 67.4±0.5 Km/s/Mpc was obtained by [7] Plank collaboration.2018 and the value H_0= 73.04±1.04 Km/s/Mpc was calculated by [6] A. Riess, SHOES team, 2022. The first one was obtained through the CBM data provided by the satellite Plank and the second one was got studying the supernovas into the Local Universe, z < 0.011 that approximately is equivalent to 47 Mpc.

Similarly the first Friedmann equation into the ΛCDM paradigm will be

$$H^2(a) = H_0^2 \cdot (\Omega_M a^{-3} + \Omega_\Lambda) \quad (2.11)$$

where $\Omega_M = 0.05 + 0.26 = 0.31$ and $\Omega_\Lambda = 0.69$

2.2 Second Friedmann equation

An expression quite compact for the equation is:

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3} \cdot (\rho_{EFFECTIVE}) \quad (2.12)$$

where $\ddot{a}$ is the second time derivative of a and the effective density is referred to the baryonic matter, to DM and to DE.

The effective density ρ_{EF} , hereafter, is defined like this:

$$\rho_{EF} = \rho + \frac{3P}{c^2} \quad (2.13)$$

being ρ the usual density, P is the pressure and c is the speed of light.

2.2.1 The cosmologic conservation equation

In general relativity (GR) the pressure verifies the equation:

$$P = w \cdot \rho \cdot c^2 \quad (2.14)$$

where w is a factor that may be calculated by the cosmologic conservation equation on a specific condition.

The equation cosmologic conservation equation is:

$$\dot{\rho} + 3H\left(\rho + \frac{P}{c^2}\right) = 0 \quad (2.15)$$

where $\dot{\rho}$ is the time derivative and H is the Hubble function H(a).

This equation has important consequences for each type of matter or DE because each one has a different behaviour regarding the scale factor a.

Supposing in general that the formula for the density is: $\rho = \rho_0 \cdot a^{-n}$, by the cosmologic conservation equation is easy to demonstrate the following restriction:

3(1+w) = n or equivalently w = n/3 -1 (2.16)

Table 1	Factor w depending on exponent n	
Baryonic	n=3	W=0
DM	n= 2.5	W= -1/6
DE	n=0	W= -1

The factors w for the baryonic matter and for the DE are common in the ΛCDM paradigm but the factor w = -1/6 for the DM is exclusive in the DMbQG theory.

Table 2 Effective density for the baryonic, DM and DE		
	Pressure	Effective density
Baryonic matter	$P = 0 \cdot \rho \cdot c^2$	$\rho_{BA}^{EF} = \rho_{BA}$
DM	$P = -1/6 \cdot \rho \cdot c^2$	$\rho_{DM}^{EF} = \rho_{DM}/2$
DE	$P = -1 \cdot \rho \cdot c^2$	$\rho_{DE}^{EF} = -2\rho_{\Lambda}$

2.2.2 Second Friedmann equation in the ΛCDM paradigm

By substitution of the effective densities calculated in the previous section is obtained:

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3}(\rho_m - 2\rho_\Lambda) \quad (2.17)$$

This equation is useful to calculate the ratio a, when the acceleration was zero, i.e. the moment into the history of the Universe when the *era of the matter*, with acceleration negative changed to the *era of D.E.* with acceleration positive. So the acceleration zero verifies:

$$\rho_m - 2\rho_\Lambda = 0 \quad (2.18)$$

As in the ΛCDM model the matter decreases with the ratio a to the -3 power, like the baryonic matter, then $\boldsymbol{\rho_M = \rho_M^0 a^{-3}}$, the DE density is constant so the equation (2.18) becomes

$$\boldsymbol{\rho_M^0 a^{-3} - 2\rho_\Lambda} = 0 \quad (2.19)$$

that is equivalent to

$$\Omega_M a^{-3} - 2\Omega_\Lambda = 0 \quad (2.20)$$

and considering the cosmological parameters $\Omega_M = 0.31,\ \Omega_\Lambda = 0.69$ the solution for a is

$$a = \left(\frac{\Omega_M}{2\Omega_\Lambda}\right)^{1/3} \approx 0.6 \quad (2.21)$$

and using the equation z=1/a -1 to conversion to red shift is obtained $z \approx 0.67$. In other words the Universe began to have a positive acceleration when he was a 60% of the current size.

2.2.3 Second Friedmann equation in the DMbQG theory

By substitution of the effective densities, see the table 2, into the second Friedman equation is obtained

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3}\left(\rho_{BA} + \frac{\rho_{DM}}{2} - 2\rho_{\Lambda}\right) \quad (2.22)$$

In this new framework, the acceleration zero has to verify the equation:

$$\rho_{BA} + \frac{\rho_{DM}}{2} - 2\rho_{\Lambda} = 0 \quad (2.23)$$

Introducing the dependence of the densities with the ratio a, like in the previous section is obtained:

$$\boldsymbol{\rho^{0}_{BA} a^{-3}} + \frac{\rho^{0}_{DM}}{2} \cdot \boldsymbol{a^{-2.5}} - 2\boldsymbol{\rho_{\Lambda}} = 0 \quad (2.24)$$

which is equivalent to

$$\Omega_{BA} a^{-3} + \frac{\Omega_{DM}}{2} a^{-2.5} - 2\Omega_{\Lambda} = 0 \quad (2.25)$$

and considering the values:

$$\Omega_{BA} = 0.05\,, \qquad \Omega_{DM} = 0.26\,, \qquad \Omega_{\Lambda} = 0.69$$

it is obtained the equation:

$$\boldsymbol{0.05 a^{-3}} + 0.13 \cdot \boldsymbol{a^{-2.5}} - 1.38 = 0 \quad (2.26)$$

whose solution is a = 0.465 with a red shift z = 1/a -1= 1.15

i.e. in this new theory the Universe began to accelerate when he was a 46.5 % of the current size.

3. The age of the Universe

3.1 The lower bound for the age Universe from the oldest astrophysical objects

As the age of the Universe has to be bigger than the oldest astrophysical object it is important to determine the age of this objects in order to compare with the age obtained by the cosmological models.

Although there are several types of very ancient astrophysical objects, the globular clusters of stars placed in the galactic halos are one of the most reliable. By this method the best age range for the oldest stellar clusters is 13.0 Gyr to 13.5 Gyr.

3.2 The age of the Universe by the Hubble function

By definition $H(a) = \frac{\dot{a}}{a}$ (3.1) where a(t) is the scale factor depending on the time and $\dot{a}$ is its time derivative. So considering $\dot{a} = \frac{da}{dt}$ it is right to write

$$dt = \frac{da}{a \cdot H(a)} \quad (3.2)$$

and by integration it is possible to obtain the age of the Universe

$$t_0 = \int_0^1 \frac{da}{a \cdot H(a)} \quad (3.3)$$

3.3 The Hubble time

At the present time the Hubble tension is one of the most important cosmologic open problems and scientist community point to be necessary new physic to solve the conundrum.

There are several techniques to measure H_0 and the intrinsic errors are lower than the gap between the greater and the lower values of H_0. See the table 3.

Table 3 Hubble time with different methods		
Method	H_0 Km/s/Mpc	Hubble time $1/H_0$ Gyr
Plank (CMB) See [7]	67.4±0.5	14.5
Supernova (SHOES) See [6]	73±1	13.4
Intermediate value	70	14

3.4 The age of the Universe in the ΛCDM paradigm

As it was pointed in the section 2.1, the Hubble function in this cosmological model is:

$$H(a) = H_0 \cdot \sqrt{\Omega_M a^{-3} + \Omega_\Lambda} \quad (3.4)$$

So the integral becomes

$$t_0 = \frac{1}{H_0} \int_0^1 \frac{da}{a \cdot \sqrt{\Omega_M a^{-3} + \Omega_\Lambda}} \quad (3.5)$$

In the integral has been neglected the *radiation era*, because it has no significance as its duration time is estimated to be lower than a million years.

So considering $\Omega_M = 0.05 + 0.26 = 0.31$ and $\Omega_\Lambda = 0.69$ the integral value is

$$I \approx 0.9553 \quad (3.6)$$

From the formula of the age of the Universe it is clear that it depend on two factors: the Hubble time $1/H_0$ and the integral. In the table 4 are shown the different result for the age of the Universe.

Table 4 The universe age according the ΛCDM model			
Method	H_0 Km/s/Mpc	Hubble time Gyr	Age Universe Gyr
Plank (CMB)	67.4	14.5	13.85
Supernova (SHOES)	73	13.4	12.80
Intermediate value	70	14	13.37

Currently the scientific community accept as the preferably age 13.85 Gyr by the H_0 (Plank) because the other values of H_0 give an Universe age a bit low if it is considered the age of the oldest astrophysical objects.

3.5 The age of the Universe in the DMbQG theory

In this new theory the Hubble function is:

$$H(a) = H_0 \cdot \sqrt{\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda} \quad (3.7)$$

So the integral becomes

$$t_0 = \frac{1}{H_0} \int_0^1 \frac{da}{a \cdot \sqrt{\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda}} \quad (3.8)$$

As in the previous section the *radiation era* has been neglected as well.

So considering $\Omega_{BA} = 0.05$ $\Omega_{DM} = 0.26$ and $\Omega_\Lambda = 0.69$ the integral value is

$$I \approx 1.0948 \quad (3.9)$$

In the table 5 are shown the different result for the age of the Universe depending on the different values of H_0.

Table 5 The universe age according the DMbQG theory			
Method	H_0 Km/s/Mpc	Hubble time Gy	Age Universe Gyr
Plank (CMB)	67.4	14.5	15.87
Supernova (SHOES)	73	13.4	14.67
Intermediate value	70	14	15.33

The DMbQG theory gives values bigger than the oldest astrophysical objects for any one of the H_0 values, although the preferable would be 14.67 Gyr because is the nearest upper bound to the estimations of the oldest astrophysical objects.

Additionally its Hubble value associated is got by the Supernovas placed into the Local Universe, with $z < 0.011$, so it is right to consider this technique as the most direct method to measure the current H_0.

By the contrary into the ΛCDM paradigm it is not possible to accept this Hubble value because its age of the Universe would be lower than the oldest astrophysical objects.

Concluding remarks

The most significant result obtained in this work is that the integral determining the age of the Universe is 11.5% larger when computed within the DMbQG framework than in the standard ΛCDM model. This difference makes it possible to adopt the Hubble constant measured by A. Riess and the SHOES program, which is based on Type Ia supernovae in the local Universe.

The SHOES program provides one of the most direct methods for measuring H_0, whereas the Planck program relies on observations of the cosmic microwave background (CMB), which reflects the state of the Universe at the onset of the matter-dominated era. Therefore, if the calculation of the age of the Universe requires the present-day value of the Hubble constant, it is more consistent to use the value obtained from direct measurements.

Within the ΛCDM model, however, it is not possible to adopt the SHOES value of H_0, since this would lead to an age of the Universe in tension with the oldest astrophysical objects. Consequently, the ΛCDM framework must rely on the value of H_0 inferred from Planck data.

By contrast, the DMbQG theory allows the age of the Universe to be computed consistently using the Hubble constant derived from local supernova observations. This is possible because the theory introduces a modification to the Hubble function.

Another important result is that, within the DMbQG framework, and using the cosmological conservation equation, the dark matter density is characterized by an equation-of-state parameter ($w = -1/6$). This implies that the effective density associated with dark matter is equal to one half of its physical density.

A direct consequence of these findings is that the transition from the matter-dominated era to the dark energy-dominated era shifts from ($z = 0.6$), as predicted by the ΛCDM model, to ($z = 0.465$) within the DMbQG framework.

In light of these results, a natural next step is to compute the Hubble constant within the DMbQG framework using Planck data. If this approach yields a value of H_0 close to 73 km/s/Mpc it would provide strong support for the validity of the DMbQG theory.

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