Implications of a 14.3 Gyr Universe for the Hubble Tension-V2

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Abstract

Firstly, notice how in the second version the Universe age goes down to 14.3 Gyr.

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 the section 3, it is calculated the current deceleration parameter in the ΛCDM model and the DMbQG theory being tested with some works published. Also it is studied the cosmological deceleration function depending on the z red-shift according to the two frameworks, yielding two quite different functions that could be tested by the recent results of the DESI project.

In the Section 4, 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 12.5% larger than that derived from ΛCDM. This difference allows for consistency with the Hubble constant measured by the SHOES or PANTHEON projects, based on Type Ia supernovae, with $H_0 = 73$ km s⁻¹ Mpc⁻¹, yielding an age of 14.3 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 or PANTHEON+ projects provide 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 the previous works 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 the section 2 are introduced the Friedmann equations using the DMbQG theory and the standard ΛCDM model. It is remarkable how in the DMbQG framework is demonstrated using the second Friedmann equation that the effective DM density is a half of the physical DM one. This theoretical finding has several successful consequences studied in the sections 3 and 4. Also in this section, it is calculated the transition between the decelerating-accelerating *eras*, by the two frameworks and the theoretical calculus are tested with other published results.

In the section 3, it is studied the current cosmologic deceleration parameter and his function associated depending on z red-shift according the two frameworks. The theoretical results are tested with other published results.

In the section 4, the age of the Universe is calculated within the DMbQG framework, yielding a value of 14.3 Gyr. This result is associated with the Hubble constant determined by the PANTHEON+ program, based on Type Ia supernovae ranging in red-shift from z = 0.001 to 2.26 , (H_0 = 73.5 km/s/Mpc). This method provides one of the most direct measurements of this cosmological parameter for the present-day Universe. See the paper [8] D.Brout. 2022. Additionally, in the frameworks of a flatΛCDM model and PANTHEON projects the authors find Ω_m= 0.33 and this new value regarding the Ω_m= 0.31 (the Plank project) has improved some results in the new version of this work, namely the Universe age.

However, within the standard ΛCDM model, the value H_0 = 73 km/s/Mpc 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 the paper [7] Plank collaboration. 2018.

Despite the fact that the Plank collaboration project has measured the CMB with an impressive precision, it is not the best method to calculate the current Hubble constant because it is needed a Universe evolution model, whereas the SHOES or PANTHEON+ projects are the most direct methods because the both ones use Type Ia supernovae. Precisely, the DMbQG theory calculates its best Universe age using the SHOES/PANTHEON+ Hubble constant.

The gap between the Hubble constant measured by the SHOES or PANTHEON + projects and the value calculated based on the Plank data of CMB generates an open problem in the current cosmology known as “Hubble tension” , which is one of the most significant over the past decade. See [9-10-11-12-13-14-15-16-17-18-19]. 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 it is a reasonable hypothesis and it 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, that by definition is: $H(a) = \frac{\dot{a}}{a}$, where 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 first Friedman equation may be rewritten like this:

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

Similarly to the equation (2.10), the first Friedmann equation into the ΛCDM paradigm will be

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

According to the paper [7] Plank Collaboration. 2018. The omega parameters are: $\Omega_{BA} = 0.05$, $\Omega_{DM} = 0.26$, $\Omega_\Lambda = 0.69$

According to the paper [8] PANTHEON+ project. 2022. In the framework of a flat-ΛCDM $\Omega_m = 0.334 \pm 0.018$ Then $\Omega_\Lambda = 0.67$ and supposing $\Omega_{BA} = 0.05$ it is obtained $\Omega_{DM} = 0.28$

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. The PANTHEON+ project [8] uses a more wide set of supernovae, with z ranging from 0.001 to 2,26. The Hubble constant obtained is H_0= 73.5±1.1 Km/s/Mpc

2.2 Second Friedmann equation

An expression quite compact for the equation is:

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

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 physical 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, P is the pressure 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 effective density as it will be shown in the following theorem.

Theorem

Supposing that the formula for the density is $\rho = \rho_0 \cdot a^{-n}$, and adopting the formula for the pressure stated in the framework of G.R. The pressure is $P = w \cdot \rho \cdot c^2$, then by the cosmologic conservation equation may be demonstrated the following dependence:

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

Proof: The temporal derivative of density is written by a change of variable and using the Hubble function ($H(a) = \dot{a}/a$) like this:

$$\dot{\rho} = \frac{d\rho}{dt} = \frac{d\rho}{da} \cdot \frac{da}{dt} = \frac{-n}{a} \cdot \rho \cdot \dot{a} = -n \cdot \rho \cdot H(a) \quad (2.17)$$

Substituting the previous result for the derivative $\dot{\rho}$ into the equation (2.15) it is obtained:

$$-n \cdot \rho \cdot H + 3H \cdot (\rho + w\rho) = 0 \quad (2.18)$$

That is equivalent to: $H \cdot \rho \cdot \left(-n + 3 \cdot (1 + w)\right) = 0$ and from that equation it is obtained the thesis: n=3·(1+w)

In the table 1 is shown the factor w for the three types of substances:

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.

In the table 2 is shown the effective density for the three types of substances:

Table 2 Effective density for the baryonic mass, the 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	$P = -1 \cdot \rho \cdot c^2$	$\rho_{DE}^{EF} = -2\rho_\Lambda$

The effective density for the DM is the novelty arisen in the framework of DMbQG theory whereas the other two ones are known in the ΛCDM model.

2.2.2 Second Friedmann equation and the transition decelerating-accelerating eras in the ΛCDM paradigm

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

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3}(\rho_m - 2\rho_\Lambda) \quad (2.19)$$

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:

$$\rho_m - 2\rho_\Lambda = 0 \quad (2.20)$$

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 (2.20) becomes

$$\boldsymbol{\rho_M^0 a^{-3} - 2\rho_\Lambda} = 0 \quad (2.21)$$

that is equivalent to

$$\Omega_M a^{-3} - 2\Omega_\Lambda = 0 \quad (2.22)$$

Whose solution for a is: $a = \left(\frac{\Omega_M}{2\Omega_\Lambda}\right)^{1/3}$ (2.23)

By the formula z = 1/a -1 is calculated the red-shift associated to the factor scale *a*. In the table 3 are shown the values calculated for *a* and *z*. The subscript *Tda* means: Transition decelerating-accelerating.

Table 3 Transition decelerating-accelerating depending on Omega parameters - ΛCDM						
	Ω_{BA}	Ω_{DM}	Ω_M	Ω_Λ	a_{Tda}	z_{Tda}
Plank project [7]	0.05	0.26	0.31	0.69	0.608	0.645
PANTHEON+ [8]	0.05	0.28	0.33	0.67	0.627	0.595

If the parameter a is rounded to $a_{Tda} \approx 0.6$. that means that the Universe began to have a positive acceleration when he was a 60% of its current size.

2.2.3 Second Friedmann equation and the transition decelerating-accelerating eras in the DMbQG theory

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

$$\frac{\ddot{a}}{a} = \frac{-4\pi G}{3}\left(\rho_{BA} + \frac{\rho_{DM}}{2} - 2\rho_\Lambda\right) \quad (2.24)$$

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

$$\rho_{BA} + \frac{\rho_{DM}}{2} - 2\rho_\Lambda = 0 \quad (2.25)$$

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

$$\boldsymbol{\rho^0_{BA} a^{-3}} + \frac{\rho^0_{DM}}{2} \cdot \boldsymbol{a^{-2.5}} - 2\boldsymbol{\rho_\Lambda} = 0 \quad (2.26)$$

which is equivalent to

$$\Omega_{BA} a^{-3} + \frac{\Omega_{DM}}{2} a^{-2.5} - 2\Omega_\Lambda = 0 \quad (2.27)$$

In the table 4 are shown the values calculated for *a* and *z*, where z =1/a -1.The subscript Tda means: Transition decelerating-accelerating.

Table 4 Transition decelerating-accelerating depending on Omega parameters - DMbQG						
	Ω_{BA}	Ω_{DM}	Ω_M	Ω_Λ	a_{Tda}	z_{Tda}
Plank project [7]	0.05	0.26	0.31	0.69	0.4649	1.15
PANTHEON+ [8]	0.05	0.28	0.33	0.67	0.4785	1.09

Discussion

The gap associated to z_{Tda} between ΛCDM vs DMbQG is virtually 0.5. This remarkable difference is originated especially by the fact that in the DMbQG theory the effective DM density is a half of physical density, although the exponent -2.5 instead -3 also has its importance.

2.2.4 Theoretical value of Z_{Tda} parameter in DMbQG theory versus published results

To study the transition decelerating-accelerating red-shift value is an impressive challenge that it has been possible thanks to the most sophisticated cosmologic experiments and the remarkable development of the theoretical cosmology in the last decades.

There are many others works, and the majority give a value for the parameter Z_{Tda} close to the one predicted by the ΛCDM model. However there are some others that gives a value closer to the one calculated by the DMbQG theory. See the three papers below [20],[21],[22]. Notice how the paper [21] also gives a value q_0 (the deceleration parameter that will be studied in the following chapter) compatible with the one calculated by the DMbQG theory.

[20]Verdugo.2026.

The authors present a generalized phenomenological parameterization of the deceleration parameter q(z). They constrained the free parameters of his model using late-time observational data from cosmic chronometers (CC), Pantheon+ Type Ia supernovae (SNIa),H II galaxies (HIIG), and intermediate-luminosity quasars (QSO). For the full data combination (CC+SNIa+HIIG+QSO), they obtain $q_0 = -0.25 \pm 0.04$ and a transition red shift $z_{Tda} \simeq 0.80$. Furthermore, they obtain a Hubble constant $H_0 = 72.9 \pm 0.6$ km/s/Mpc

[21] M. Koussour,.2026.

The authors, using 31 cosmic chronometer data points, 1701 Pantheon+ Type Ia supernovae, and 12 BAO measurements from DESI, they obtain the best-fit values $H_0 = 73.11 \pm 0.4$ km/s/Mpc, $q_0 = -0.524 \pm 0.06$ and $z_{Tda} \simeq 0.9$

[22] B. Santos.2011

Using the 557 type Ia supernovae from the Union2 Compilation set along with the current estimates involving the product of the CMB acoustic scale ℓ_A and the BAO peak at two different red shifts, and using a well-behaved parameterization for the deceleration parameter, the authors have estimated $z_{Tda} \approx 1$

3. The deceleration parameter

This parameter by definition is:

$q = -\frac{a \cdot \ddot{a}}{\dot{a}^2}$ or equivalently $q = -\frac{\ddot{a}}{a \cdot H^2}$ (3.1)

Notice that a negative deceleration parameter means an accelerating factor scale ***a***. i.e. if the Universe is accelerating the deceleration parameter is negative, as it happens at the present Universe.

3.1 Formula for the deceleration parameter

Before to obtain the formula it will be shown three identities used in the process:

1º As $H = \frac{\dot{a}}{a}$ then by the time derivative it is right to get $\frac{\ddot{a}}{a} = H^2 + \dot{H}$ (3.2)

2º The time derivative of the function Hubble may be changed like this:

$\dot{H} = \frac{dH}{da} \cdot \dot{a} = a \cdot H \cdot \frac{dH}{da}$ (3.3)

3º The Hubble function may be expressed by a dimensionless function like this:

In the framework of DMbQG theory, from the expression (2.10) $H^2(a) = H_0^2 \cdot (\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda)$ it is defined the dimensionless function

$$E^2 = (\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda) \quad (3.4)$$

In the framework of ΛCDM model, from the expression (2.11) $H^2(a) = H_0^2 \cdot (\Omega_M a^{-3} + \Omega_\Lambda)$

it is defined the dimensionless function

$$E^2 = (\Omega_m a^{-3} + \Omega_\Lambda) \quad (3.5)$$

So the Hubble function may be expressed like this:

$$H^2(a) = H_0^2 \cdot E^2(a) \text{ or } H(a) = H_0 \cdot \sqrt{E^2(a)} \quad (3.6)$$

And it is right to get the following identity

$$\frac{1}{H} \cdot \frac{dH}{da} = \frac{1}{2E^2} \cdot \frac{dE^2}{da} \quad (3.7)$$

Process to obtain the deceleration parameter formula

From the definition $q = -\frac{\ddot{a}}{a \cdot H^2}$ and by the identity (3.2) it is right to get

$$q = -1 - \frac{\dot{H}}{H^2} \quad (3.8)$$

And by substitution of identity (3.3) into (3.8) it is right to get:

$$q = -1 - \frac{a}{H}\frac{dH}{da} \quad (3.9)$$

And by substitution of identity (3.7) into (3.9) it is right to get:

$$q = -1 - \frac{a}{2 \cdot E^2}\frac{dE^2}{da} \quad (3.10)$$

Deceleration parameter formulas and the current value for the both theories

Finally it is possible to calculate the deceleration parameter using the function (3.4), for DMbQG theory or the function (3.5), for the ΛCDM model.

Below are written the formulas for the deceleration parameter as a compact expression for the two models:

$$q_{DMbQG} = \frac{0.5 \cdot \Omega_{BA} a^{-3} + 0.25 \cdot \Omega_{DM} a^{-2.5} - \Omega_\Lambda}{\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda} \quad (3.11)$$

Similarly for the ΛCDM model.

$$q_{\Lambda CDM} = \frac{0.5 \cdot \Omega_M a^{-3} - \Omega_\Lambda}{\Omega_M a^{-3} + \Omega_\Lambda} \quad (3.12)$$

In the table 5 are represented the current deceleration parameter (a=1) according the two models and depending on the set of Omega parameters selects.

Table 5 Current decelerating parameter ΛCDM versus DMbQG

	Ω_{BA}	Ω_{DM}	Ω_M	Ω_Λ	$q_{0\text{ - }\Lambda CDM}$	$q_{0\text{- }DMbQG}$
Plank project [7]	0.05	0.26	0.31	0.69	-0.535	-0.6
PANTHEON+ [8]	0.05	0.28	0.33	0.67	-0.505	-0.575

3.2 Theoretical results versus published results

In the paper [23], year 2022, the authors, assuming a spatially flat Universe and having tested 8 kinematic parameterized models with H(z) data from Cosmic Chronometers and SNe Ia from Pantheon compilation, they have obtained the value H_0 =68.8 ±3.7 km/s/Mpc and q_0 = -0.58 ±0.13

In the paper [24],year 2023, named: Constrained evolution of effective equation of state parameter in non-linear f (R, Lm) dark energy model: Insights from Bayesian analysis of cosmic chronometers and Pantheon samples, the authors have obtained the value q_0= -0.61 ± 0.01

In the paper [6], year 2022, named: *A comprehensive Measurement of the Local Value of the Hubble Constant with 1 km/s/ Mpc uncertainty from the Hubble Space Telescope and the SH0ES Team*. The authors have obtained the value H_0 =73.30 ±1.04 km/s/Mpc and q_0= -0.51 ±0.024

Discussion

Although there are many other works, these three publications show that it is possible to find published results compatibles with the ΛCDM model (q_0 = - 0.505) and others compatibles with DMbQG theory (q_0 = - 0.575). It is remarkable the fact that the papers [23] and [24] both using the PANTHEON samples give a results that virtually match with the value $q_{0\text{- DMbQG}}$.

This results show that according to DMbQG theory, currently the Universe has a rate acceleration bigger than in the ΛCDM model because the contribution of DM density is a half of the baryonic density as it is shown clearly in the formulas (3.11) and (3.12) .

The deceleration parameter value obtained by DMbQG theory is consistent with the fact that current Hubble constant, measured by the project SHOES or PANTHEON+, is bigger than the one calculated by CMB in the framework of ΛCDM model, because according to the former model the Universe has a bigger rate of acceleration than in the last model.

The following natural step in the theoretical development will be to calculate the current Hubble value using the CMB Plank data in the framework of DMbQG theory. If the value obtained were close to the current H_0 measured by the projects SHOES and PANTHEON+ then the tension Hubble problem would be solved and as the reader knows, the tension Hubble is one of the most important open problems for the current cosmology.

3.3 Deceleration parameter as a function depending on z

The function depending on a, is given by the expression (3.9) $q(a) = -1 - \frac{a}{H}\frac{dH}{da}$ (3.9). The factor scale a depending on z is $a = {}^{1}\!/_{(1+z)}$ and conversely $z = \frac{1}{a} - 1$.

Using the change of variable it is right to get the deceleration parameter depending on z:

$q(z) = -1 + (1+z)\frac{1}{H}\frac{dH}{dz}$ (3.13)

Where H(z) =H_0·E(z) being:

Case DMBQG theory $E^2(z) = \Omega_{BA}(1+z)^3 + \Omega_{DM}(1+z)^{2.5} + \Omega_\Lambda$ (3.14)

Case ΛCDM model $E^2(z) = \Omega_m(1+z)^3 + \Omega_\Lambda$ (3.15)

By the expressions (3.13), (3.14) and (3.15) it is quite right to get the cosmologic deceleration function for the both theories:

$$q_{DMbQG}(z) = \frac{\Omega_{BA}(1+z)^3+0.5\Omega_{DM}(1+z)^{2.5}-2\Omega_{\Lambda}}{2\cdot E^2(z)} \quad (3.16)$$

Where $E^2(z)$ is the equation (3.14)

Notice how the numerator of expression (3.16) is modulated by the coefficients (1, 0.5, -2) associated to the effectives densities in the framework of DMbQG theory.

Below is represented the cosmologic deceleration function for the ΛCDM model.

$$q_{\Lambda\mathrm{CDM}}(z) = \frac{\Omega_m(1+z)^3-2\Omega_{\Lambda}}{2\cdot E^2(z)} \quad (3.17)$$

Where $E^2(z)$ is the equation (3.15)

Notice how the numerator of expression (3.17) is modulated by the coefficients (1, -2) associated to the effectives densities in the framework ΛCDM model.

3.3.1 Deceleration function using data Plank for the Omega cosmologic parameters

According to the paper [7] Plank Collaboration. 2018. The omega parameters are: $\Omega_{BA} = 0.05$, $\Omega_{DM} = 0.26$, $\Omega_{\Lambda} = 0.69$

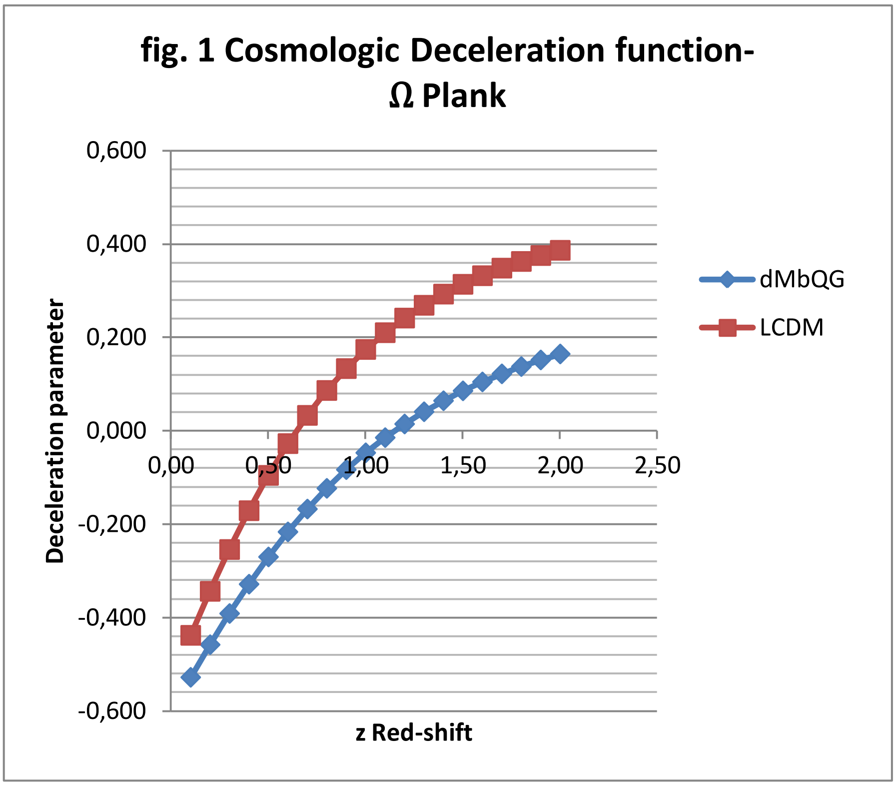
In this section are tabulated and plotted the functions (3.16) and (3.17) using the above omega parameters. The first column represents the factor scale *a*, given by a =1/(1+z). The value z = 0 corresponds to the present time.

Table 6 Cosmologic deceleration function – Ω Plank

a	z	q(z) DMbQG	q(z) ΛCDM
1,000	0	-0,600	-0,535
0,909	0,10	-0,529	-0,439
0,833	0,20	-0,459	-0,344
0,769	0,30	-0,392	-0,255
0,714	0,40	-0,329	-0,172
0,667	0,50	-0,271	-0,096
0,625	0,60	-0,217	-0,028
0,588	0,70	-0,168	0,032
0,556	0,80	-0,124	0,086
0,526	0,90	-0,084	0,132
0,500	1,00	-0,048	0,174
0,476	1,10	-0,015	0,209
0,455	1,20	0,014	0,241
0,435	1,30	0,040	0,268
0,417	1,40	0,064	0,292
0,400	1,50	0,085	0,313
0,385	1,60	0,104	0,331
0,370	1,70	0,121	0,348

0,357	1,80	0,137	0,362
0,345	1,90	0,151	0,375
0,333	2,00	0,164	0,386

In the figure 1 is plotted the table 6 and it is seen how the gap between the both theories goes decreasing toward the current time.



3.3.2 Deceleration function using the data PANTHEON for the Omega cosmologic parameters

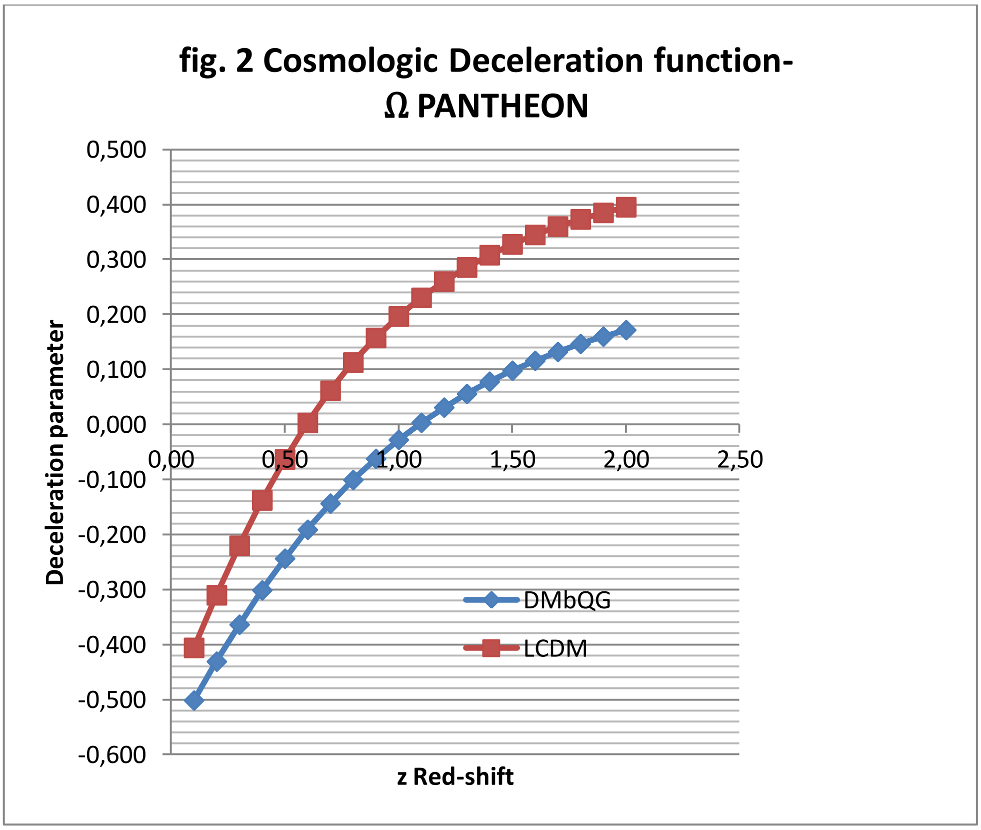
According to the paper [8] PANTHEON+ project. 2022.In the framework of a flat-ΛCDM model $\Omega_m = 0.334 \pm 0.018$ Then $\Omega_\Lambda = 0.67$ and supposing $\Omega_{BA} = 0.05$ it is obtained $\Omega_{DM} = 0.28$

In this section are tabulated and plotted the functions (3.16) and (3.17) using the above omega parameters.

Table 7 Cosmologic deceleration function - Ω PANTHEON		
	DMbQG	ΛCDM
z	q(z)	q(z)
0	-0.575	-0.505
0,10	-0,502	-0,406
0,20	-0,431	-0,310
0,30	-0,364	-0,220
0,40	-0,301	-0,138
0,50	-0,244	-0,063

0,60	-0,191	0,003
0,70	-0,144	0,061
0,80	-0,101	0,113
0,90	-0,062	0,157
1,00	-0,028	0,196
1,10	0,003	0,230
1,20	0,031	0,260
1,30	0,056	0,285
1,40	0,078	0,308
1,50	0,098	0,328
1,60	0,116	0,345
1,70	0,132	0,360
1,80	0,147	0,373
1,90	0,160	0,385
2,00	0,172	0,395

In the figure 2 is plotted the table 7. It is clear how towards the ancient time Universe, the gap between the both theories is enormous and goes decreasing toward the current time.



These theoretical functions may be tested with recent results published of the DESI project. As the gap between the both functions is remarkable, this test may be crucial in order to validate or reject the DMbQG theory for the cosmological scales.

4. The age of the Universe

4.1 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 the 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. See [25-26-27-28-29].

4.2 The age of the Universe by the Hubble function

By definition $H(a) = \frac{\dot{a}}{a}$ (4.1)

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

$$dt = \frac{da}{a \cdot H(a)} \quad (4.2)$$

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

$$t_0 = \int_0^1 \frac{da}{a \cdot H(a)} \quad (4.3)$$

4.3 The Hubble time

The inverse of Hubble constant is called Hubble time. $t_H = \frac{1}{H_0}$

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 in the table 8 the different Hubble time associated to each Hubble constant.

Table 8 The 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
PANTHEON+/SHOES See [8],[30]	73.5±1	13.3

4.4 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:

$$H(a) = H_0 . \sqrt{\Omega_M a^{-3} + \Omega_\Lambda} \quad (4.4)$$

So the integral becomes

$$t_0 = \frac{1}{H_0} \int_0^1 \frac{da}{a \cdot \sqrt{\Omega_M a^{-3} + \Omega_\Lambda}} \quad (4.5)$$

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 the Plank project parameters [7] $\Omega_M = 0.05 + 0.26 = 0.31$ and $\Omega_\Lambda = 0.69$ the integral value is:

$$I_{Plank} \approx 0.9553 \quad (4.6)$$

According to the paper [8] PANTHEON+ project. 2022. In the framework of a flat-ΛCDM model $\Omega_m = 0.334 \pm 0.018$ and $\Omega_\Lambda = 0.67$ so the integral value is:

$$I_{PANTHEON} \approx 0.9386 \quad (4.7)$$

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 9 are shown the different result for the age of the Universe depending on the different values of H_0 and depending on the Ω parameters selected (Plank or PANTHEON).

Table 9 Universe age in the ΛCDM model

H_0 Km/s/Mpc	Hubble time Gyr.	Universe age Gyr. Ω- Plank par. $I_{Plank} \approx 0.9553$	Universe age Gyr. Ω-PANTHEON par. $I_{PANTHEON} \approx 0.9386$
Plank- 67.4±0.5	Plank 14.5	13.85	13.61
SHOES 73±1	SHOES 13.4	12.80	12.58
PANTHEON 73.5±1	PANTHEON 13.3	12.70	12.48

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.

4.5 The age of the Universe in the DMbQG theory

In this new theory the Hubble function is:

$$H(a) = H_0 \cdot \sqrt{\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda} \quad (4.8)$$

So the integral becomes

$$t_0 = \frac{1}{H_0} \int_0^1 \frac{da}{a \cdot \sqrt{\Omega_{BA} a^{-3} + \Omega_{DM} a^{-2.5} + \Omega_\Lambda}} \quad (4.9)$$

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

So considering the Plank project parameters [7] $\Omega_{BA} = 0.05$ $\Omega_{DM} = 0.26$ and $\Omega_\Lambda = 0.69$ the integral value is

$$I_{Plank} \approx 1.0948 \quad (4.10)$$

According to the paper [8] PANTHEON+ project. 2022.In the framework of a flat-ΛCDM model $\Omega_m = 0.334 \pm 0.018$ the $\Omega_\Lambda = 0.67$ and supposing $\Omega_{BA} = 0.05$ it is obtained $\Omega_{DM} = 0.28$ so the integral value is:

$$I_{PANTHEON} \approx 1.0783 \quad (4.11)$$

In the table 10 are shown the different result for the age of the Universe depending on the different values of H_0 and depending on the Ω parameters selected (Plank or PANTHEON).

Table 10 Universe age in the DMbQG theory			
H_0 Km/s/Mpc	Hubble time Gyr	Age Universe Gyr. Ω-Plank par. $I_{Plank} \approx 1.0948$	Age Universe Gyr. Ω-PANTHEON par. $I_{PANTHEON} \approx 1.0783$
Plank 67.4±0.5	Plank 14.5	15.87	15.63
SHOES 73±1	SHOES 13.4	14.67	14.45
PANTHEON 73.5±1	PANTHEON 13.3	14.56	14.34

The DMbQG theory gives values bigger than the oldest astrophysical objects for any one of the H_0 values, although the preferable would be 14.34 Gyr because is the nearest upper bound to the estimations of the oldest astrophysical objects.

Additionally its Hubble value associated is got by the Supernovae type Ia placed into the Local Universe, 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.

5. Concluding remarks

One of the most significant results obtained in this work is that the integral determining the age of the Universe is about 12.5% 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 the SHOES or PANTHEON+ programs.

The SHOES/PANTHEON+ programs provide two 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/PANTHEON values 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 ($z = 1.1$) within the DMbQG framework.

In the section 3 is studied the cosmologic deceleration parameter and its associated function according to the two frameworks, yielding two quite different function that could be tested by the recent results of the project DESI.

In light of these results, a natural next step is to compute the Hubble constant within the DMbQG framework using the Planck Collaboration 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 and the tension Hubble problem would be solved definitively.

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