# Dark Matter and Dark Energy as Quantum Entities

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**Keywords**: dark matter, dark energy, recession velocity, redshift, coincidence problem, information relativity, quantum phenomena.

**Abstract**: In the present article, we propose a new model based on our recently proposed information relativity theory for explaining dark matter and dark energy and for inferring about the nature of their interactions. The model gives rise to a matter-wave duality, similar to the realistic de Broglie–Bohm model. We allude briefly to the model's applications in predicting and explaining quantum phenomena; then we utilize it to construct a simple quantum cosmology of the universe, according to which dark matter and dark energy are, respectively, quantum matter and dual-wave energy at cosmic scales. We use the model to explain, in physical terms, the dynamic interaction among matter, dark matter, and dark energy as functions of the recession velocities and redshifts of celestial objects, such galaxies, quasars, etc. Contrary to the standard cosmological model, the predicted distributions of matter and dark energy densities, as functions of redshift, are far from being uniform, with matter reaching its maximal energy density at a point of quantum phase transition equaling the golden ratio ($z \approx 1.618$). The predicted dynamics between matter and dark energy are shown to a function of the celestial's object recession velocity (or redshift). We derive general terms for predicting the amount of matter and dark energy in any redshift range and show that our predictions confirm with recent observations-based ΛCDM cosmologies. The model predicts that, for redshift $z \le \frac{1}{2}$, corresponding to recession velocity $\beta \le \frac{1}{3}$, the universe is dominated by matter, while for $z > \frac{1}{2}$ ($\beta > \frac{1}{3}$), it is dominated by dark energy. This prediction alleviates the so-called "coincidence problem," by providing a physical explanation as to why the density of the two components at the present time are equal.

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## 1 Introduction

Dark energy and dark matter constitute about 95% of the universe (e.g., Albrecht et al. 2006; Alam, Sahni, & Starobinsky 2004, Bahcall et al. 1999; Turner 1993). Nonetheless, not much is known about them. Existing theories fail to provide plausible definitions of the two entities or to predict their amounts in the universe. However, it is widely believed that dark energy is an unknown substance that has an enormous anti-gravitational force, driving the galaxies of our universe apart. One explanation for dark energy is founded on Einstein's cosmological constant (Λ). According to this explanation, the universe is permeated by a negative energy density, constant in time and uniform in space. The big problem with this explanation is that, for $\Lambda \neq 1$, it requires that the magnitude of $\Lambda$ be $\approx 10^{120}$ (!) times the measured ratio of pressure to energy density. An alternative explanation argues that dark energy is an unknown dynamical fluid, i.e., one with a state equation that is dynamic in time, $\Lambda = \Lambda(t)$. This type of explanation is represented by theories and models, which differ in their assumptions regarding the nature of the state equation dynamics (Linder 2004; Sandvik, Barrow, & Magueijo 2002; Easson, Framptona, & Smoota 2011). This explanation is no less problematic than the first one because it entails the prediction of new particles with masses 35 orders of magnitude smaller than the electron mass, which might imply the existence of yet unknown forces (Albrecht et al. 2006). At present, there is no persuasive theoretical explanation for the existence, dynamics, and magnitude of dark energy and its resulting acceleration of the universe.

Dark matter is no less an enigma than dark energy. Scientists are more certain about what dark matter is than what it is not. Some contend that it could be baryonic matter, tied up in brown dwarfs or in chunks of massive compact halo objects "or MACHOs" (Alcock 1998, 2001), but the common prejudice is that dark matter is not baryonic, and that it is comprised of particles that are not part of the "standard model" of particle physics. Candidates that were considered include light axioms and weakly interacting massive particles (WIMPs), which are believed to constitute a major fraction of the universe's dark matter (Steigman & Turner 1985; Sivertsson & Gondolo 2011; Aprile et al. 2011). Given the frustrating lack of knowledge about the nature of dark energy and dark matter, most experts contend that understanding the content of the universe and its cosmic acceleration requires nothing less than "discovering a new physics" (Aprile et al. 2011). For example, the Dark Energy Task Force (DETF) summarized its 2006 comprehensive report on dark energy by stating that there is consensus among most physicists that "nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration" (Albrecht et al. 2006, p. 6).

The objective of this short article is to propose a new model for explaining dark matter and dark energy and for inferring about the dynamics of their interactions. The model is based on our recently proposed information relativity theory. Before describing the model, and its application to the cosmology of the universe, it is in order here to caution the reader that he or she will most probably find difficulty in the absence of the terminology he or she is used to in the literature. Primarily, we do not use the concept of space–time. Configuration of space and time is treated by us independently, just as Newton did. We refrain from using variables that are not completely like vacuum energy and arbitrary parameters like a cosmological constant. All terms used in constructing the theory are observable physical variables.

In the following section, we summarize the main tenets of the theory, describe its main transformations, and demonstrate that they give rise to a matter–wave duality model, similar to the realistic de Broglie–Bohm model. We allude briefly to the model's applications in predicting and explaining quantum phenomena. In Section 3, we utilize the proposed model for constructing a simple quantum cosmology of the universe, in which dark matter and dark energy are explained as quantum matter and dual-wave energy at cosmic scales. In Section, 4 we show that the proposed model provides a plausible physical explanation to the recently investigated interaction between dark matter and dark energy and solves the so-called "coincidence problem." In Section 5, we conclude with some remarks.

## 2 Information relativity theory: a brief description

A complete formulation of information relativity theory (IR) and its applications to various field in physics, including small particles physics, quantum mechanics, and cosmology, are detailed elsewhere (e.g., (Suleiman 2013, 2016a, 2016b, 2017a). In principle, information relativity theory is nothing more than "relativizing" Newtonian physics, which we accomplished by taking into account the time travel of information from one reference frame to another. The theory is also local-realistic, with no uncertainties. It is formulated only in terms of physical observables, with no axioms (e.g., constancy of $c$) nor hypothetical constructs (e.g., space–time, quantum states).

It is important to note that, in the framework of information relativity, the scale of the system is of no importance. The theory takes a unifying approach toward physics by using the same set of equations to explain and predict both quantum and cosmological phenomena. In several previous articles, we showed that, not only does the theory reproduce quantum theoretical results, it also explains them in simple mechanical terms.

Note that, unlike special relativity theory, in which the relativity of time is achieved by axiomatizing constancy of light velocity, relativizing time and other physical entities in information relativity theory is a force majeure of the fact that information does not pass between two points in configuration space instantaneously but rather suffers delay, which depends on the spatial distance between the two points and the velocity of the information carrier.

The rationale behind the theory is extremely simple and straightforward. It could be illustrated as follows: Consider the case where information from a "moving" body is transmitted to a "stationary" observer by light signals. Assume that the start and end of an event on the body's reference frame are indicated by two signals sent from the body's "moving" reference frame to the "stationary" observer. Because the light's velocity is finite, the two signals will arrive to the observer's reference frame in delays, which are determined by the distances between the body and the observer, at the time when each signal was transmitted. Suppose that the "moving" body is distancing from the observer; in this case, the termination signal will travel a longer distance than the start signal. Thus, the observer will measure a longer event duration than the event duration at the body's reference frame (time dilation). For approaching bodies, the termination signal will travel a shorter distance than the start signal. Thus, the observer will measure a shorter event duration than the event duration at the body's reference frame (time contraction). It is obvious from the above description that no synchronization of the clocks at the two reference frames is required.
For the simple case of transverse motion with constant velocity $v$, expressing the above-mentioned example in the language of mathematics detailed in [13-16] yields the following equation:

$$\frac{\Delta t}{\Delta t_0} = \frac{1}{1-\beta} \ , \tag{1}$$

where $\Delta t$ is the event's time duration as measured by the observer, $\Delta t_0$ is the event's time duration at the body's rest-frame, and $\beta$ is the relative velocity, $\beta = \frac{v}{c}$. Derivations of the transformations of length, mass, and energy, detailed elsewhere (Suleiman 2017a), are depicted in the second column in Table 1. Notice that, for $\beta \rightarrow 0$ (or $v << c$), the matter energy density reduces to $e_k = e_0\, \beta^2 = \frac{1}{2}\, \rho_0\, c^2 \beta^2 = \frac{1}{2}\, \rho_0\, v^2$, which is the classical Newtonian term, and the wave energy $e_w \rightarrow 0$.

Because our objective is to apply the theory to the cosmology of the universe, it is in place to describe the set of transformations in the table above as functions of redshift $z$, instead of the recession velocity $\beta$. For this end, consider an observer on Earth who receives redshifted waves emitted from a receding celestial object (e.g., a star, galaxy center, etc.). Assume that the recession velocity of the celestial object at the time the light wave was emitted was equal to $v$. Using Doppler's formula, we can write

$$z = \frac{\lambda_{ob} - \lambda_{em}}{\lambda_{em}} = \frac{f_{em} - f_{ob}}{f_{ob}}, \tag{6}$$

where $\lambda_{em}$ ($f_{em}$) is the wavelength (frequency) of the wave emitted by the galaxy and $\lambda_{ob}$ ($f_{ob}$) is the wavelength (frequency) measured by the observer. We also have $f_{em} = \frac{1}{\Delta t_{em}}$ and $f_{ob} = \frac{1}{\Delta t_{ob}}$, where $\Delta t_{em}$ *and* $\Delta t_{ob}$ are the time intervals corresponding to $f_{em}$ and $f_{ob}$, respectively. Substitution in Eq. (6) gives

$$z = \frac{\frac{1}{t_{em}} - \frac{1}{t_{ob}}}{\frac{1}{t_{ob}}} = \frac{\Delta t_{ob}}{\Delta t_{em}} - 1. \tag{7}$$

**Table 1**

**Information relativity main transformations for inertial transverse motion**

| Variable | Transformation in terms of velocity | Transformation in terms of redshift |
|---|---|---|
| Time interval $\frac{\Delta t}{\Delta t_0}$ | $\frac{1}{1-\beta}$ | $z+1$ (1') |
| Length $\frac{l}{l_0}$ | $\frac{1+\beta}{1-\beta}$ (2) | $2z+1$ (2') |
| Mass density $\frac{\rho}{\rho_0}$ | $\frac{1-\beta}{1+\beta}$ (3) | $\frac{1}{2z+1}$ (3') |
| Kinetic energy density $\frac{e_m}{e_0}$ | $\frac{1-\beta}{1+\beta}\,\beta^2$ (4) | $\frac{z^2}{(z+1)^2(2z+1)}$ (4') |
| Wave energy density $\frac{e_w}{e_0}$ | $\frac{2\,\beta^3}{1+\beta}$ (5) | $\frac{2z^3}{(z+1)^2(2z+1)}$ (5') |

where $e_0 = \frac{1}{2}\rho_0 c^2$.

From Eq. (1), we have $\frac{\Delta t_{ob}}{\Delta t_{em}} = \frac{1}{1-\beta}$, where $\beta = \frac{v}{c}$. Substitution in Eq. (7) yields

$$z = \frac{1}{1-\beta} - 1 = \frac{\beta}{1-\beta}. \tag{8}$$

And the recession velocity in terms of redshift is

$$\beta = \frac{z}{z+1}. \tag{9}$$

Substituting Eq. (5) in the transformations depicted in the second column in Table 1 yields the transformation as functions of the redshift $z$ depicted in the right-side column of the table. Figures 1a and 1b depict the matter and wave energies as functions of β and $z$, respectively.

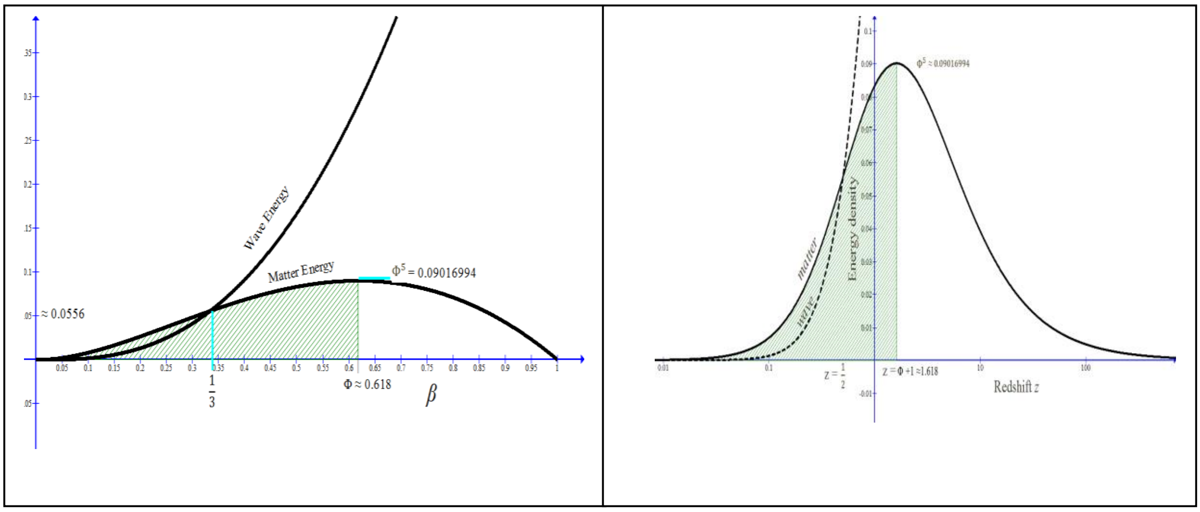


**Figure 1.** Matter and dual-wave energy density distributions as functions of recession velocity (left panel) and redshift (right panel).

Strikingly, the maximal kinetic energy density reaches its maximal value at velocity $\beta$ equaling the famous golden ratio (Olsen 2006; Livio 2002), see Fig. 1a. This could be verified by deriving Eq. (4) with respect to $\beta$ and equating the result to zero, yielding

$$\beta^2 + \beta - 1 = 0, \tag{10}$$

which solves for

$$\beta_{cr} = \frac{\sqrt{5}-1}{2} = \varphi \approx 0.618. \tag{11}$$

Substituting $\beta_{cr}$ in the energy expression yields

$$\left(\frac{e_m}{e_0}\right)_{max} = \frac{1-\varphi}{1+\varphi}\ \varphi^2 \quad . \tag{12}$$

From Eq. (10), we can write $\varphi^2 + \varphi - 1 = 0$, which implies $1 - \varphi = \varphi^2$ and $1 + \varphi = \frac{1}{\varphi}$. Substitution in Eq. (12) gives

$$\left(\frac{e_m}{e_0}\right)_{max} = \varphi^5 \approx 0.09016994. \tag{13}$$

The amount of the wave energy density at this critical point is equal to:

$$\frac{e_w}{e_0} = \frac{2\,\varphi^3}{1+\varphi} = 2\,\varphi^4 \approx 0.29179607. \tag{14}$$

And the redshift at which the matter energy density reaches its maximum is

$$z_{cr}=\frac{\beta_{cr}}{1-\beta_{cr}}=\frac{\varphi}{1-\varphi}=\frac{\varphi}{\varphi^2}=\frac{1}{\varphi}=1+\varphi\approx 1.618. \tag{15}$$

The results above are astonishing in more than one aspect:
1. Mathematically, they are beautiful with fascinating golden ratio symmetries.

2. They suggest a relativistic interpretation of the phase transition of matter from normal (baryonic) matter to quantum matter. According to the suggested explanation, in the type of motion analyzed above, for $\beta \leq \varphi$ the relativistic matter energy displays a semi-classical behavior, in the sense that an increase in the recession velocity results in increase in kinetic energy, although considerably less than what would be predicted by Newton's quadratic relationship. A dramatic transition is predicted for recession velocities $\beta > \varphi$, at which an increase in velocity results in decrease in kinetic energy. We propose that the point of transition discovered by our relativistic approach is the point of quantum transition. A strong support for our conjecture comes from a recent *Science* article (Coldea et al. 2010), which reported that applying a magnetic field at right angles to an aligned chain of cobalt niobate atoms makes the cobalt enter a quantum critical state, in which the ratio between the frequencies of the first two notes of the resonance equals the golden ratio. Another support for our conjecture is the fact that the maximal kinetic energy at the point of phase transition is proportional to $\Phi^5 \approx 0.09016994$, which equals to the eighth decimal digit (!) to Hardy's maximum probability of obtaining an event which contradicts local realism (Hardy 1994).

3. The model offers a physical interpretation for the dynamics of matter–wave duality. As shown in Figure 1a, at relatively low velocities, the bulk of the receding body's energy is carried by its matter. For higher velocities, the matter density becomes diluted [see Eq. (2)], and the accompanying wave becomes the primary carrier of the total energy.

4. Strikingly, at velocity $\beta_{cr}$ = φ ≈ 0.618, the energy carried by matter reaches a maximum equaling $\varphi^5$ *e0*, which amounts to ≈ 0.09016994 *e0*. The amount of the wave energy density at this critical point is equal to 2 $\varphi^4$ ≈ 0.29179607. These results are striking given the role played by this type of symmetry, in nature, science, technology, and the arts, including in the structure of plants (Douady & Couder 1992; Klar 2002; Zeng & Wang 2009), physics (Coldea et al. 2010; Affleck 2010; Stoudenmire et al. 2015; Linder et al. 2015), structure of the human brain (Kopell 2008), music (Hammel & Vaughan 1995; Putz 1995), aesthetics (Pittard, Ewing, & Jevons 2007), social sciences van den Bos 2007; Suleiman 2017b; Schuster 2017), and much more.

5. Most importantly, the proposed model applies to all moving bodies, regardless of the scale of the system, which renders it a unifying model. In previous articles, we demonstrated its success in predicting and explaining in mechanical terms several quantum phenomena, including solution of the hydrogen problem (Suleiman 2017a), quantum phase transition and quantum criticality (Suleiman 2017a, Suleiman, in press], single particle's diffraction in the double-slit experiment [2016b], quantum entanglement (Suleiman 2017a, Suleiman, in press), the strong force, quantum confinement, asymptotic freedom (Suleiman 2017a), and more. In cosmology, we demonstrated that the theory predicts and explains the pattern of recession velocity and expansion of the universe (Suleiman, 2015; 2017a), the Schwarzschild's radius of black holes (without

the troubling singularity) (Suleiman 2014, 2017a), and the deflection angle of starlight by the Sun, measured during totality (Suleiman 2017c).

## 3 A simple relativistic quantum cosmology

Our unifying model enables the construction of a simple quantum cosmology, according to which dark matter is quantum matter at cosmic scales, whereas what is believed to be a negative dark energy is the energy associated with de Broglie pilot waves, which are associated with receding celestial bodies (e.g., galaxies). This explanation abolishes the mystery of the source and nature of dark energy.

As shown in the right panel of Fig.1 our theory prescribes that matter's energy and dark energy densities in the universe are far from not homogeneous and isotropic. In fact, the anisotropy of the universe, even within the "GZK horizon", has been established empirically with more than 99% confidence level in the arrival directions of events with energy above ~ 60 EeV detected by the Pierre Auger Observatory (Abraham, et al., 2008).

Our model predicts that the energy carried by matter increases with redshift, in a bell-shaped pattern, up to a maximum of $(\frac{e_m}{e_0})_{max} = \varphi^5 \approx 0.09016994$, at redshift z = 1+ φ ≈ 1.618, and then decreases (symmetrically) with redshift to almost zero. In contrast, the density of dark energy increases sharply with redshift. The predicted decline in kinetic energy density, after reaching a maximal value at redshift $z \approx 1.618$ is in agreement with the well-known GZK cutoff limit to the cosmic-ray energy spectrum (Greisen 1966; Zatsepin & Kuz'min 1966). In the framework of our model, the GZK cutoff point is the point of cosmic quantum criticality (see Fig. 1b). This conjecture is in good agreement with the HiRes experiment, which shows a break in the luminosity densities QSOs and AGNs at about $z = 1.6$ as well as with numerous discoveries of quasars, galaxies, and AGNs, indicating a break in luminosity densities at about $z = 1.6$ (e.g., Bergman et al. 2006; Thomson 2006), including a recent discovery of galaxies at redshift equaling exactly 1.618 (Gilli et al. 2003).

Strikingly the densities of matter and dark energy are predicted to be equal precisely at a critical redshift z = 0.5, which could be sought as the point of transition in the universe from one dominated by dark energy (at z > 0.5), to one dominated by matter (at z ≤ 0.5). This prediction, provides a true physical explanation of the dynamics behind the so-called "coincidence problem", which we shall say more about in section 4.

The proportions of matter and dark energy at any redshift $z$ could be easily calculated from Eqs. (4') and (5') in Table 1, yielding:

$$\frac{e_m}{e_m + e_{DE}} = \frac{\frac{z^2}{(z+1)^2(2z+1)}}{\frac{z^2}{(z+1)^2(2z+1)} + \frac{2z^3}{(z+1)^2(2z+1)}} = \frac{1}{1+2z} \qquad (16)$$

and

$$\frac{e_{DE}}{e_m + e_{DE}} = \frac{\frac{2z^3}{(z+1)^2(2z+1)}}{\frac{z^2}{(z+1)^2(2z+1)} + \frac{2z^3}{(z+1)^2(2z+1)}} = \frac{2z}{1+2z} \quad . \qquad (17)$$

Figure 2 depicts the relative amounts of matter kinetic energy and dark energy densities, out of the total energy, as functions of the redshift $z$.

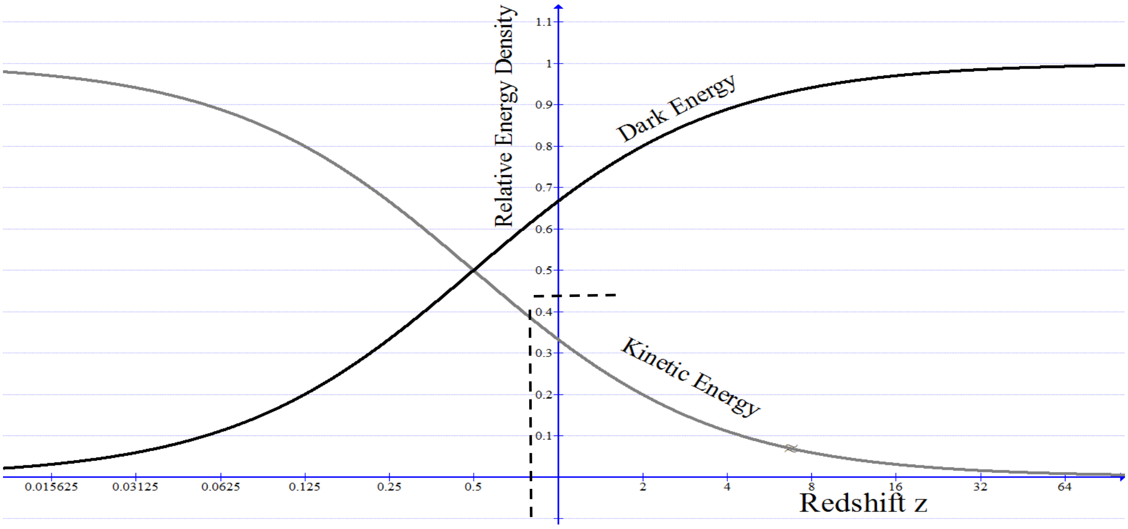


**Figure 2. Ratios of kinetic and dark energy densities as functions of redshift**

For any redshift range ($z_{1,}$ $z_2$), $z_2 > z_1$, the amounts of matter and dark energy could be calculated by integrating over the functions in Eqs. (4') and (5'), yielding (see Suleiman 2017a)

$$\frac{e_k(z_1 - z_2)}{e_0} = = \frac{1}{2}\, ln\left(\frac{2z_2+1}{2z_1+1}\right) - \frac{z_2 - z_1}{(z_2+1)(z_1+1)} \tag{18}$$

and

$$\frac{e_d(z_1 - z_2)}{e_0} = (z_2 - z_1) + 2\,\frac{(z_2 - z_1)}{(z_2+1)\,(z_1+1)} - 2\, ln\left(\frac{z_2+1}{z_1+1}\right) - \frac{1}{2}\ln\left(\frac{2z_2+1}{2z_1+1}\right). \tag{19}$$

Calculations based on the above expressions are in good agreement with observational-based $\Lambda$CDM cosmologies. As an example, for the redshift ranging 0.6–1, tested by Wittman et al. (2000), it was concluded that dark matter is distributed in a manner consistent with either an open universe, with $\Omega_b = 0.045$, $\Omega_{matter}$ - $\Omega_b = 0.405$, $\Omega_\Lambda = 0$, or with a $\Lambda$CDM with $\Omega_b = 0.039$, $\Omega_{matter}$ - $\Omega_b = 0.291$, $\Omega_\Lambda = 0.67$, where $\Omega_b$ is the fraction of critical density in ordinary (baryonic) matter, $\Omega_{matter}$ is the fraction of all matter, and $\Omega_\Lambda$ is the fraction of dark energy. In the open universe model, we have $\Omega_{matter} = 0.045 + 0.405 = 0.45$, and $\Omega_\Lambda = 0$, whereas in the $\Lambda$CDM, we have $\Omega_{matter} = 0.039 + 0.291 = 0.33$, and $\Omega_\Lambda = 0.67$. Calculating the ratios of kinetic and wave energies from Eqs. (18) and (19) for the same redshift range gives:

$$\frac{e_k}{e_{tot}} = \frac{e_k}{e_k + e_w} = \frac{0.0300775}{0.0300775 + 0.0486354} \approx 0.382\ (\approx 38.2\%) \tag{20}$$

and

$$\frac{e_w}{e_{tot}} = \frac{e_w}{e_m + e_{DE}} = \frac{0.0486354}{0.0300775+0.0486354} \approx 0.618 \ (\approx 61.8\%), \tag{21}$$

which is in agreement with the observation-based ΛCDM model with ($\Omega_m = \frac{1}{3}$, $\Omega_\Lambda = \frac{2}{3}$). For the entire range of semi-classical matter ($0 \leq z < 1.618$), we obtain $\frac{e_k(0\ -1.618)}{e_0} \approx 0.1038$, and $\frac{e_w(0\ -\varphi)}{e_0} \approx 0.3420$, yielding

$$\frac{e_k}{e_k + e_w} = \frac{0.138}{0.138+0.3420} \approx 0.233 \text{ (or 23\%)} \tag{22}$$

and

$$\frac{e_w}{e_k + e_w} = \frac{0.3420}{0.138+0.3420} \approx 0.767 \text{ (or 76.7\%)}, \tag{23}$$

which is in excellent agreement with the ΛCDM cosmology with $\Omega_{matter} = 0.23$, $\Omega_\Lambda = 0.77$ (see, e.g., Kunz & Bassett 2004; Samushia & Ratra 2009; Farooq 2013), and quite close to the $\Omega_{matter} = 0.26$, $\Omega_\Lambda = 0.74$ cosmology (see, e.g., Haehnelt, & Springel 2004; Furlanetto 2006; Oguri et al. 2008; Viel).

## 4 Dark matter and dark energy's interaction and the coincidence problem

Recent models, supported by observational data, have suggested that, contrary to the standard cosmological model, matter and dark energy in the universe interact with each other (Padmanabhan & Choudhury 2002; Farrar & Peebles 2004; Salvatelli et al. 2014; Wang et al. 2016). The previous section suggests the following simple physical explanations to such an interaction, which alleviates the "coincidence problem" altogether. By treating the dark energy interacting with the matter of receding celestial objects in the same manner as Louis de Broglie and David Bohm(de Broglie 1923, 1970; Bohm 1952a, 1952b), who treated a small particle piloted by its dual wave, a new light is cast on the physical dynamics of matter/dark energy interaction, being nothing else than the well-studied matter–wave interaction within the de Broglie–Bohm perspective of quantum mechanics. As Figure 1 (a & b) clearly shows, our model predicts that, at sufficiently high recession velocities ($\beta > 0.618$ ($z > 1.618$) of a celestial object with respect to an observer on Earth or near it, when matter becomes quantum, dark energy "swallows" matter, as has been recently conjectured.

Moreover, our simple model provides a simple explanation to the "coincidence problem," namely, why "now"? At a redshift $z \approx 0.55$, the densities of matter and dark energy are equal (e.g., Zlatev, Wang, & Steinhardt 1999; Poitra 2014; Velten, vom Marttens, & Zimdahl 2014). The inspection of Eqs. (4') and (5') in Table 1 shows that we can write

$$\frac{e_m}{e_{DE}} \left(= \frac{e_m}{e_w}\right) = \frac{1}{2z}, \tag{24}$$

which implies that the densities of matter and dark energy are predicted to be equal at $z = \frac{1}{2}$, corresponding to a recession velocity of $\beta = \frac{1}{3}$. As can be seen in Figures 1a and 1b, our model marks this moment in the history of the universe as a major transition from a universe dominated by dark energy at redshifts $z > \frac{1}{2}$, corresponding to $\beta > \frac{1}{3}$, to a universe dominated by matter at redshifts $z \leq \frac{1}{2}$, corresponding to $\beta < \frac{1}{3}$.

## 5 Concluding remarks

In this paper, we took a completely different approach than all contemporary physics to construct a simple quantum cosmology of the universe. Admittedly, our approach is highly unorthodox relative to current cosmology. It abandons general relativity's concepts of space–time, vacuum energy, and cosmological constant. However, it could be thought of as a highly conservative approach, in that it brings back to central stage Newton's physics, with only one factual modification, dictated by the fact that a signal of information requires time to travel between two points in configuration space. As shown in Section 2, the importance of this modification is crucial, when a physical event's rest frame and an observer's rest frame are in a state of motion with respect to each other.

We note by passing that our simple model presumes that, at large cosmological scales, gravity plays a negligible role or no role at all. This assumption is justified by the immense distances between two galaxies or galaxy's clusters, rendering the gravitational forces between them negligible and continually decaying with ratio of $\frac{1}{v_{i,j}(t)^{2}}$, where $v_{i,j}(t)$ is the velocity in which the galaxies, or galaxies' clusters are distancing from each other.

Our main theoretical proposition in this paper, one which gains support from empirical data, advocates that the interaction between matter and dark energy at cosmic scales, could be accounted for using exactly the same model used in realistic quantum theory to describe the interaction between a small corpuscle matter and its dual piloting wave. We demonstrated that, despite being highly unorthodox, our proposed model is exceptionally successful in drawing a simple and plausible model of the dynamical interaction between matter and dark energy. We demonstrated that the model's predictions for the ratios of matter kinetic energy and dark energy in different segments of redshift confirm with recent observationally based ΛCDM cosmologies. No less importantly, we provided a dynamical explanation to why the densities of matter and dark energy at "present times" are equal, thus alleviating the so-called "coincidence problem."

We hold hopes that the reader will recognize several advantages of our unorthodox approach, which include, not necessarily in order of their practical importance, (1) that our model is mathematically simple and beautiful; two properties that several founding fathers of modern physics, including Isaac Newton, Albert Einstein, Paul Dirac, and others, believed to essential properties of good theories about the world, which they believed to be harmonious and simple; (2) it has no axioms and no free parameters; (3) it is articulated only in terms of physical observables; [4] it applies to all bodies, regardless of their mass, from elementary particles to cosmological structures, thus opening the door for a simple unification of all physics, including Newtonian mechanics; (5) its simple formulation renders its generalization to accounting for gravitation and other forces quite straightforward and mathematically tractable.

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