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A Quantum Multiverse approach to Dark Matter and Dark Energy

Richard D. Bateson

Oxford Alpha Limited UK
Email: richard@oxfordalpha.com

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Abstract

In this paper we discuss a Quantum Multiverse or “Many Worlds Interpretation” (MWI) of Dark Energy and Dark Matter. The universe is viewed cosmologically as a fermionic fluid with a hydrostatic pressure from “Zitterbewegung”, the quantum “zig-zagging” of Dirac particles. At each point in space–time the pressure from all possible velocity states existing in the Many Worlds sums to provide a dark energy. Visible matter is the matter observed or measured in a particular velocity state and dark matter is then considered as the unobserved fermion velocity contributions from different orthogonal spatial directions. The MWI model predicts the ratios of visible matter to be 5.1%, dark matter 25.4% and dark energy 69.5%, which are close to values observed experimentally.

1 Introduction

A current problem in cosmology and astrophysics in the nature of observed dark matter and dark energy which dominate the energy of the universe. Dark matter was first proposed by Fritz Zwicky in the 1930s [1] and is primarily supported by the rotation curves of galaxies, gravitational lensing and large scale structure of the universe including fluctuations in the Cosmic Background Radiation (CMB) [2,3,4,5]. Dark energy was observed by Saul Perlmutter's team in the late 1990s [6] from measurements on type 1a supernovae and evidence that the expansion of the universe is accelerating. Since then numerous additional experimental results have suggested the presence of dark energy [7,8,9]. Dark energy is thought to comprise around 70% of the universe total energy content with the reminder consisting of dark 25% and visible matter 5% [10]. Numerous theoretical explanations for this unseen dark universe have been proposed ranging from hypothetical dark matter particles and dark energy fields to extended gravity theories including $f(R)$ gravities [11,12]. However, currently the actual nature of the dark universe remains elusive.

In 1957 Everett proposed that the quantum wavefunction provided a full description of physical reality and that quantum mechanical phenomena could be described in terms of the existence of parallel histories rather than a traditional Bohmian collapse of the wavefunction interpretation. This led to the development of a Many Worlds Interpretation (MWI) of quantum mechanics popularised by DeWitt [13]. More recently, with the advent of quantum computing techniques there is renewed interest in the MWI and the structure of the possible Multiverse by David Deutsch [13]. The full set of Many Worlds constitutes the Multiverse. Whether the proposed MWI exists on macro-scale or simply a micro-scale, where quantum coherence can exist in isolated systems, is open to interpretation. Indeed, the existence of the MWI concept on a micro-scale can probably be traced back to the original theory of de Broglie where he postulated a kind of many worlds quantum state exists in the microscopic world but in the macroscopic world only one member of the ensemble is statistically realised when a particular measurement is obtained [15].

In this paper I apply the concept of the MWI and the simultaneous physical existence of the entire universal quantum wave function to the problem of dark matter and dark energy. The model universe is described as an ideal fluid comprised of fermions where each space–time point exhibits a local pressure due

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to the relativistic “Zitterbewegung” of the particles [16]. The local hydrostatic pressure summed over all possible quantum states in the MWI provides the dark energy. This approach leads to a ratio of dark energy to mass energy of a similar value to that observed experimentally.

2 “Zitterbewegung” in the Dirac Equation

Relativistic particles described by the Dirac equation [16] theoretically experience “Zitterbewegung” or velocity reversals as their velocity increases. The velocity reversals are related to the spinor components of the Dirac wavefunction. Indeed, Richard Feynman [17] presented a discrete space–time derivation of the 1+1 dimension Dirac equation for a free particle − the “Feynman chequerboard” − since a luminal velocity massive particle is viewed in the calculation as “zig-zagging” diagonally forwards through space–time in a similar manner to a bishop in chess. In this interpretation the spinor components can be viewed as providing branching probabilities at each space–time point.

The 3+1 dimension Dirac equation is conventionally written [18] as

$$\begin{pmatrix} mc^2 & c(\vec{\sigma}.\vec{p}) \\ c(\vec{\sigma}.\vec{p}) & -mc^2 \end{pmatrix} \Psi = E\Psi = i\hbar\frac{\partial\Psi}{\partial t}. \tag{1}$$

where Ψ is the 4 component spinor wavefunction for energy E. The Pauli spin vector $\vec{\sigma}$ and momentum operator $\vec{p}$ provide the relation $(\vec{\sigma}.\vec{p})\chi_\pm = |\vec{p}|\chi_\pm$ with two eigenvectors in polar coordinates

$$\chi_+ = (\cos\vartheta/2, e^{i\varphi}\sin\vartheta/2) \qquad \chi_- = (-e^{-i\varphi}\sin\vartheta/2, \cos\vartheta/2). \tag{2}$$

The general solutions for the wavefunction are four 4-component orthogonal vectors corresponding to up and down spin $S = \pm 1/2$ with positive and negative energies $\epsilon = \pm 1$. These can be written as

$$\Psi_{\substack{\epsilon=+1 \\ S=+1/2}} = \begin{pmatrix} \phi_1\chi_+ \\ \phi_2\chi_+ \end{pmatrix} \qquad \Psi_{\substack{\epsilon=+1 \\ S=-1/2}} = \begin{pmatrix} \phi_1\chi_- \\ -\phi_2\chi_- \end{pmatrix}, \tag{3}$$

and

$$\Psi_{\substack{\epsilon=-1 \\ S=+1/2}} = \begin{pmatrix} -\phi_2\chi_+ \\ \phi_1\chi_+ \end{pmatrix} \qquad \Psi_{\substack{\epsilon=-1 \\ S=-1/2}} = \begin{pmatrix} \phi_2\chi_- \\ \phi_1\chi_- \end{pmatrix}. \tag{4}$$

where spinor components are

$$\phi_j = \sqrt{P_j}e^{-imc^2\tau/\hbar} = \sqrt{P_j}e^{i(px-Et)/\hbar}, \tag{5}$$

formed from real branching probabilities $P_j = \phi_j.\phi_j^*$. The probabilities can be interpreted as a probability P_1 in the velocity direction and P_2 in the reverse direction. For equivalent proper time τ a hyperplane of simultaneity is defined for equivalent phase.

The branching probabilities are more clearly illustrated in the 1+1d Dirac equation [19] with one space direction

$$\begin{pmatrix} mc^2 & c\hat{p} \\ c\hat{p} & -mc^2 \end{pmatrix} \Psi = E\Psi = i\hbar\frac{\partial\Psi}{\partial t}. \tag{6}$$

The solutions of helicity $\lambda = \pm 1$ and positive energy $\epsilon = +1$ are given by

$$\Psi_{\substack{\epsilon=+1 \\ \lambda=+1}} = \begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix} \qquad \Psi_{\substack{\epsilon=+1 \\ \lambda=-1}} = \begin{pmatrix} \phi_1 \\ -\phi_2 \end{pmatrix}. \tag{7}$$

Thus in the 1+1d Dirac equation the spinor components are equivalent to the 3+1d case but with the function $\chi_\pm$ providing an orientation of the velocity direction in space. In the 1+1d case the spin is reduced to helicity.

Following Eq. (5) and Bateson [20] the normalised branching probabilities at each space–time point are then given by

$$\hat{P}_1 = \frac{E + mc^2}{2E} \qquad \hat{P}_2 = \frac{E - mc^2}{2E}. \tag{8}$$

where $\hat{P}_1 + \hat{P}_2 = 1$. For a velocity v we can see that in the low velocity limit $|v| \to 0$ then $\hat{P}_{11} \to 1$ and $\hat{P}_{21} \to 0$ and in the high velocity limit $|v| \to c$ then $\hat{P}_{11} \to \hat{P}_{21} \to 1/2$. At higher velocities the quantum path followed becomes more random and the trajectory exhibits “Zitterbewegung”. These probabilities can be written in the simple form

$$\hat{P}_1 = \cos^2(\theta/2) \qquad \hat{P}_2 = \sin^2(\theta/2). \tag{9}$$

where

$$\cos\theta = 1/\gamma \qquad \sin\theta = v/c. \tag{10}$$

Here $\gamma = 1/\sqrt{1 - v^2/c^2}$ is the Lorentz factor. These branching probabilities provide an expected velocity equal to the observed velocity v.

3 A Dirac Flux and Pressure

Using the branching probabilities we can introduce the concept of a quantum pressure produced by the “Zitterbewegung”. Consider a single free Dirac particle of mass m and a given energy E. The energy transfers at each space–time point can be decomposed into an expected energy “flux” F in the velocity direction of

$$F = E\hat{P}_1 - E\hat{P}_2 = mc^2, \tag{11}$$

and an internal “pressure” Π from the expected velocity reversal as

$$\Pi = 2E\hat{P}_2 = 2E\sin^2(\theta/2), \tag{12}$$

such that these equal the total energy E

$$F + \Pi = E. \tag{13}$$

The above relation is essentially a continuity equation or a conservation of energy condition. For a velocity or flux in any direction a hydrostatic-like pressure is observed. The pressure Π is thus similar as Bernoulli’s theorem to the kinetic energy or relativistically to the energy above that in the stationary local Lorentz frame mc^2 since

$$\Pi = 2E\hat{P}_2 = E - mc^2 = mc^2(\gamma - 1). \tag{14}$$

Under this interpretation any particle energy above the rest mass increases the internal pressure through “Zitterbewegung”.

4 A MWI Ideal Cosmic Fluid

Assume the universe is behaves as an ideal fluid with an energy density ρ and local hydrostatic pressure Π. The stress energy tensor is [10,21,22]

$$T_{\mu\nu} = (\rho + \Pi/c^2)u_\mu u_\nu + (\Pi/c^2)g_{\mu\nu}. \tag{15}$$

where u_μ is the fluid 4-velocity. Assume the average universal 4-velocity is zero and the frame of a comoving observer. The energy density is a number density N multiplied by the fermion mass $\rho = Nm$. Consider the trace of the ideal fluid stress energy tensor

$$Tr(T) = -\rho c^2 + 3\Pi = -E + 4\Pi. \tag{16}$$

The ratio of pressure energy to matter energy for one velocity state then is

$$\frac{4\Pi}{E} = 8P_2 = 8\sin^2(\theta/2). \tag{17}$$

For a given mass the plane wave state of the Dirac equation is characterised by the velocity v. In a full quantum MWI there are 6 possible orthogonal velocity basis spatial directions $\hat{e}_i$ and an infinite number of velocity magnitudes $|v|$ from 0 to c. The full Hilbert space of wavefunctions is given by the total wavefunction tensor product $\psi_{\hat{e}} \otimes \psi_{|v|}$ and all these states must be considered in our model MWI universe [23]. In the local Lorentz frame at each space–time point under the MWI the trace can be approximated as

$$Tr(T_{MWI}) = -\sum_{i=1}^{6} \rho_i c^2 + 8\sum_{i=1}^{6} \rho_i c^2 \int_0^{\pi/2} \sin^2(\theta/2)\, d\theta. \tag{18}$$

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where we can integrate over the pressure terms for all velocities or angles at each space–time point. This is analogous to a multi-fluid [24] tensor where all the pressure components are summed. Assuming homogeneity amongst velocity directions, the total effective mass energy $\rho_{tot}c^2 = 6\rho_L c^2$ where $\rho_L = \rho_i$ is the density in the local Lorentz frame.

5 Dark Matter and Dark Energy

The ratio of matter energy Ω_M to dark energy Ω_Λ can be considered as the ratio of energy to pressure. Using the MWI trace above gives as an estimate for the observed matter energy to dark energy ratio

$$\frac{\Omega_M}{\Omega_\Lambda} = \frac{1}{8\int\limits_0^{\pi/2} \sin^2(\theta/2)d\theta} = \frac{1}{4(\frac{\pi}{2}-1)} \approx 0.438. \tag{19}$$

Current experimental estimates [10] for dark energy are approximately 0.7, dark matter 0.25 and normal matter 0.05. These values would provide an estimate of the ratio $\Omega_M/\Omega_\Lambda \approx (0.25+0.05)/0.7 = 0.428$. This value is close to the value derived from the simple MWI fluid approach, based on plane wave Dirac states.

The ratio of the hydrostatic pressure energy to the observed energy is consistent with all possible paths existing prior to a measurement under the MWI and contributing to a quantum dark energy. If an event or particle is measured, the quantum possibilities prior to the measurement manifest as a pressure or dark energy produced by the quantum "Zitterbewegung" of the different causal trajectories in space–time.

Since there are 6 possible orthogonal velocity basis directions the total mass energy is $\rho_{tot}c^2$ is approximately 6 times that of the contribution of a single direction $\rho_L c^2$. Only one velocity direction can constitute an observed or measured trajectory whilst the other 5 basis directions will remain unobserved. If these unseen quantum trajectories constitute equally dark matter then the ratio of observed matter to dark matter would be approximately 1:5.

Although experimental estimates vary slightly, the theoretical dark matter and dark energy proportions are in broad agreement with experimental observation as shown in Table 1 [10].

Table 1: Theoretical and Experimental Ratios of Visible Matter, Dark Matter and Dark Energy.

	Visible Matter %	**Dark Matter %**	**Dark Energy %**
Theoretical	5.1	25.4	69.5
Experimental [10]	5	25	70

The dark matter then possibly originates from the hidden quantum states, which contribute to the overall density of possible events in space–time. The gravitation of quantum objects would thus appear different from that of classical matter. If visible, classical matter is composed of measurable, well-defined trajectories in space–time, then dark matter is perhaps ephemeral relativistic quantum paths.

6 Conclusion

In the MWI approach, dark energy is provided by a quantum pressure produced by all the possible quantum paths existing prior to a measurement. The effective pressure from each path is a result of "Zitterbewegung" and proportional to the reversal probability at each point in space. For a cosmological fluid model the equilibrium ratio of matter energy to hydrostatic pressure energy is similar to that observed experimentally for the ratio of matter energy to dark energy. Dark matter potentially results from the combined density of unobserved paths in the MWI existing in different orthogonal spatial directions. Under the MWI the gravitation of quantum objects would differ from classical matter in exhibiting both dark matter and dark energy.

In practice only one quantum state from the Multiverse is measured. This "measurement" could be provided by an observation, interaction or decoherence. Perhaps the pressure from "Zitterbewegung" could be a microscopic effect existing in quantum coherent regions as a local effect. The combined local effect across the cosmos might provide the macroscopic dark universe that we observe and this would allow a deBroglie style microscopic MWI [15] rather than a full DeWitt macroscopic multiverse MWI [13]. However, the MWI approach is also compatible with the latter, currently unfashionable, view that there exists a universal quantum wavefunction.

Many theoretical alternatives have been proposed to explain the presence of the dark universe ranging from new particles and fields to modifications of Einstein's general relativity [11,12]. However, the advantage of the theory proposed in this paper is than no new physics or phenomena are required, simply an interpretation that all quantum states contribute to physical reality and not just as a artificial computational or mathematical device used in quantum calculations. This Everettian view of reality is that favoured by Deutsche to explain quantum computation [14].

The MWI approach presented here is derived from the plane wave solutions of the Dirac equation. Interestingly, this provides a universe that historically possesses approximately the same ratio of matter energy to dark energy and that is always "flat" from a cosmological perspective [10]. There is no "cosmic coincidence" issue and the model is compatible with observational CMB measurements where the total energy density balances the critical density.

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References

[1] Zwicky, F. 1937 *Proceedings of the National Academy of Sciences* **23(4)** 250

[2] Rubin, V C & Ford, W K 1970 *The Astrophysical Journal* **159** 1

[3] Peebles P J E 1980 *Physics Reports* **64(4)** 191

[4] Penzias A A & Wilson R B 1964 *The Astrophysical Journal* **139** 1

[5] Turners M S 1981 *Annual Review of Astronomy and Astrophysics* **19** 1

[6] Perlmutter S, Riess A G, & Macri L M 1999 *The Astrophysical Journal Supplement Series* **126** 61

[7] Eisenstein, D J, Seaborn, T, & Cuccio-Fletcher E 2005 *The Astronomical Journal* **130**, 1

[8] Komatsu, E, Dunkley, J, Nolta, M R, O'Brien, K, Spergel, D N & WMAP Collaboration 2009 *The Astrophysical Journal Supplement Series* **180** 288

[9] Planck Collaboration 2015 *Astronomy & Astrophysics*, 57

[10] Carroll S M 2019 *Spacetime and Geometry* (Cambridge)

[11] Copeland, E J, Sami M, & Tsujikawa S 2006 *Int. Journal of Modern Physics D* **15** 11 1753

[12] Corda C 2009 *Int. Journal of Modern Physics D* **18** 14 2275

[13] DeWitt B S & Graham N 1973 *The Many Worlds Interpretation of Quantum Mechanics* (Princeton)

[14] Deutsch D 1985 *Int. J Theor. Phys.* **24** 1

[15] De Broglie L 1956 *Tentative d'Interprétation Causal et Non-linéaire de la Méchanique Ondulatoire* (Gautier-Villars)

[16] Dirac P A M 1928 *Proc. Royal Soc.* A 117

[17] Feynman R P and Hibbs A R 1965 *Quantum Mechanics and Path Integrals* (McGraw-Hill)

[18] Davydov A S 1965 *Quantum Mechanics* (Pergamon Press)

[19] Coulter B and Adler C 1971 *AJP* **39** 305

[20] Bateson R D 2012 *J. Phys.: Conf. Ser.* **361** 012009

[21] Misner C W, Thorne K S and Wheeler J A 2017 *Gravitation* (Princeton)

[22] Mukhanov V 2005 *Physical Foundations of Cosmology* (Cambridge)

[23] Aguire A & Tegmark M (2011) *Phys. Rev. D* **84** 105002

[24] Faghri A & Zhang Y 2006 *Transport Phenomena in Multiphase Systems* (Elsevier)