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The Origin of Wave-Particle Duality

John A. T. Bye [a*]

[a] *School of Geography, Earth and Atmospheric Sciences, The University of Melbourne, Victoria-3010, Australia.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

We present a basic model for the formation of a stress-free universe, which shows that its formation gives rise to a wave and particle mass, which together characterize the universe. In this model a decaying exponential expansion rate is responsible for the particle mass (M_P) and a growing exponential expansion rate is responsible for the wave mass (M_W). The evolution of the universe is governed by the ratio ($\alpha = M_P/M_W$) in which $\alpha = K_o/c$ where K_o is the initial expansion rate and c is the velocity of light. In a stress-free expansion process, $0 \le \alpha \le ½$, the mass ratio, $M_P/M_W = \alpha$. The mass of the universe, $M = M_W + M_P$, in which it is found from the exponential model that $M_W = m_o\, c\, T/ \ln (1/\alpha)$ where T is the age of the universe and $m_o = c^2/G$ where G is the universal gravitational constant. Observations of the mass and age of the universe, yield, $\alpha = 0.235$, and hence $M_P / M = 0.19$. This ratio is very close to the ratio of ordinary matter to dark matter of 0.18 in [1]. Hence, the wave mass, M_W, can be interpreted as the dark matter remaining after the formation of the particle matter. The analysis also shows that on temporal scales (t_o) much less than the age of the universe (T), $M_P (t_o) / M_W(t_o) \rightarrow 1$, which is an exact wave-particle duality.

Keywords: Net-zero stress; evolution of the universe; wave-particle duality.

1. INTRODUCTION

The concept of wave-particle duality is a central topic in modern theoretical physics, and it arose from efforts to comprehend the properties of light [2]. In this research, we place the concept directly in a cosmological framework on the temporal scale of the universe, rather than the

**Corresponding author: E-mail: jbye@unimelb.edu.au;*

nanoscale of particle physics, and explain theoretically how duality lies at the heart of an understanding of the universe. The production of ordinary matter from dark matter is the governing process in the expansion of the universe. This process is not merely theoretical; it can be explicitly defined through an analysis based on Newtonian physics, which leads to theoretical predictions, which can be tested by observational data. The theoretical model, which uses observational data for the age and mass of the universe to forecast the radius of the cosmos, is based on an astrophysical stress-free dynamical model. The results build on previous research in four papers, [1,3-5] that focused on the features of the stress-free model.

Section 2 presents the theoretical results. In section 3 data on the age and mass of the universe are accessed, and it is demonstrated that the results of the model are consistent with a stress-free expansion process for the universe, as well as that the predicted radius of the universe is 4.7 10^{26} km, which is similar to observational estimates.

The main property of the study is wave-particle duality. The theoretical model predicts that the ratio of the particle mass to the wave mass in the universe is 0.235, and suggests that an exact wave-particle duality occurs on temporal scales much smaller than those of the cosmos. Section 4 is a conclusion that puts the findings of the study in a broader framework, specifically the ratio of ordinary matter to dark matter.

2. THE MASS OF THE EVOLVING UNIVERSE

2.1 The Growing Exponential Expansion Rate

In a stress-free model of the universe, the evolving universe expands at the homogeneous rate,

$$dR/dt_R = K(t_o),\ 0 \le t_o \le \infty \tag{1}$$

where $K(t_o)$ is the homogenous expansion rate [5] in which t_o is the absolute time, and t_R is the local time at the radius (R). We will investigate the solution of equation 1 for a growing exponential rate,

$$K(t_o) = K_o \exp(\lambda\, t_o) \tag{2}$$

where $\lambda > 0$, and K_o is the expansion rate at the origin of time ($t_o = 0$). On expressing the local time (t_R) which occurs in a universe of radius (R), in terms of the absolute time (t_o) using the fundamental time relation,

$$t_R = t_o + R/c \tag{3}$$

where c is the velocity of light, we obtain for a growing exponential rate, as in [5] for a decaying exponential rate,

$$dR/dt_o = K_o \exp(\lambda\, t_o) /(1 - \alpha) \tag{4}$$

where $\alpha = K_o/c$. Thus, on differentiating the defining relation for mass, $M_W = m_o R$ where M_W is the wave mass of the expanding universe, and $m_o = c^2/G$, in which G is the universal gravitational constant [1], and integrating equation 4 with respect to t_o assuming that R = 0 at $t_o = 0$, we obtain,

$$M_W(t_o) = m_o\, K_o\, (\exp \lambda\, t_o - 1) / [\lambda\, (1 - \alpha)],\quad 0 \le t_o \le t_1 \tag{5}$$

At the radius ($R_1 \equiv R(t_1)$), $t_o = t_1$ the ratio of the expansion rate ($K(t_1)$) to the velocity of light (c) is unity, from which on evaluating equation 5 at $t_o = t_1$, using equation 2, we have $\exp(\lambda\, t_1) - 1 = (1 - \alpha)/\alpha$, and hence,

$$R_1 = c/\lambda \tag{6}$$

and,

$$T = \lambda^{-1} \ln(1/\alpha) \tag{7}$$

in which $T \equiv t_1$ is the age of the universe, and from equation 7, the wave mass of the universe, is,

$$M_W = m_o\, c\, T/ \ln(1/\alpha) \tag{8}$$

where $M_W \equiv M_W(t_1)$, which is independent of λ.

2.2 The Decaying Exponential Expansion Rate

The model in section 2.1 is only half the story. The other half of the story was originally investigated in [5], in which instead of a growing exponential rate at $t_o \ge 0$, the decaying exponential rate,

$$K(t_o) = K_o \exp(-\lambda\, t_o) \tag{9}$$

where $\lambda > 0$ was assumed. The two relations (2) and (9) can be used to model the production and dispersal of material in the universe. On making use of the results in section 2.1, the solution of equation 1 for the decaying exponential rate in equation 9 is easily obtained.

On substituting equation 9 in equation 1, and integrating with respect to t_o, assuming that $R = 0$ at $t_o = 0$, and using equation 6, we obtain,

$$M_P(t_o) = m_o K_o (1 - \exp(-\lambda t_o)) / [\lambda(1 - \alpha)], \quad 0 \le t_o \le t_1 \qquad (10)$$

and on evaluating equation 10 at $t_o = T$, using equation 7, we find that the particle mass of the universe ,

$$M_P = m_o \alpha c T / \ln(1/\alpha) \qquad (11)$$

where $M_P \equiv M_P(t_1)$. Hence, from equation 8,

$$M_P / M_W = \alpha \qquad (12)$$

in which, from equation 7,

$$\alpha = \exp(-\lambda T) \qquad (13)$$

and also by conservation of mass, the mass (M) of the universe is the sum of the wave mass (M_W) and the particle mass (M_P),

$$M = M_P + M_W \qquad (14)$$

which, from equations 8 and 11, is,

$$M = (1 + \alpha) m_o cT / \ln(1/\alpha) \qquad (15)$$

Hence, from equations 6 and 8,

$$M = (1 + \alpha) m_o R_1 \qquad (16)$$

An alternative expression, in terms of the particle mass, is,

$$M = \alpha m_o R_2 \qquad (17)$$

where R_2 is the radius of the universe. On equating the two expressions for mass, equations 16 and 17, we obtain,

$$R_2/R_1 = (1 + \alpha) / \alpha \qquad (18)$$

and hence from equation 18, the radius of the universe becomes,

$$R_2 = F(\alpha) c T \qquad (19)$$

where $F(\alpha) = (1 + \alpha)/(\alpha \ln 1/\alpha)$.

3. DUALITY

Observations indicate that the mass of the universe, $M = 1.5\ 10^{53}$ kg [6] and the age of the Universe, $T = 13.8\ 10^9$ yr [7]; and $c = 3\ 10^8$ m s^{-1} and $G = 6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}, from which $m_o = 1.35\ 10^{27}$ kg m^{-1} [1], and hence $M/(m_o c T) = 0.85$. On substituting this ratio in equation 8 using equation 12, we obtain $\alpha = 0.235$ which is well within the allowable range ($0 \le \alpha \le ½$) for a stress-free expansion mechanism for the universe [5].

For $\alpha = 0.235$, equation 6 predicts that $R_1 = 0.9\ 10^{26}$ km. Thus from equation 18, the radius of the universe, $R_2 = 4.7\ 10^{26}$ km, which is similar to observational estimates of $4.4\ 10^{26}$ km [6] and also from equation 12, $M_P / M_W = 0.235$ which indicates that on the temporal scale of the universe the wave mass is about four times greater than the particle mass.

On the temporal scale (t_o) much less than that of the universe (T), equations 5 and 10 show respectively that, $M_W(t_o) = M_P(t_o) = m_o c t_o \alpha/(1-\alpha)$, and hence,

$$M_P(t_o) / M_W(t_o) = 1, \; t_o/T \rightarrow 0. \qquad (20)$$

which is an exact wave-particle duality.

4. CONCLUSION

The particle mass (M_P) and the mass (M), arguably can be equated respectively with the ordinary matter mass (M_P) and the dark matter mass (M_D) in [1]. In this study, the mass ratio, $M_P / M = 0.19$, which is very close to the mass ratio of ordinary matter to dark matter, $M_P/M_D = 0.18$ in [1]. This concurrence indicates that the wave mass (M_W) is the dark matter remaining after the formation of the particle mass (M_P). In particular, equation 20 shows that the masses of ordinary matter and wave matter (which is dark matter) are equal in light.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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