A New Cosmological Model of a Spatial and Time-Reversal Couple Universe of Symmetrical Relativity

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Abstract

This study investigates the possibility of applying a new four-dimensional and positively curved model of a spatial and time-reversal Couple Universe to predict the expansion rate and the speed of stars. The model assumes the universe as matter and antimatter dominated halves with opposite time arrow directions in agreement with the fundamental Charge, Parity, and Time-reversal symmetry (CPT). General Relativity was used to derive the model where gravity is considered as the only force governing the universe. The model was utilised to predict the spatial and temporal evolution of the universe over the conformal time. The results revealed that cosmic evolution might experience three distinct stages. Firstly, a decelerated spatial expansion stage of both halves away from the Big Bounce (non-singular Big Bang) in opposite directions until they reach their critical spatial radius. Secondly, an accelerated stage of a reverse spatial expansion, which might occur due to gravitation attraction between cosmic matter and antimatter at the critical radius of both halves. Finally, a time-reversal drifting stage of a spatial contraction, which might be precipitated as a result of a high concentration of the matter and antimatter in both halves that can produce a strong gravitational attraction around the Big Crunch. Regarding the speed of stars, the curved spacetime fabric of both halves may drive stars located at a lesser curved spacetime fabric to move faster than their counterparts that are located within a highly curved fabric. This reasoning was assessed by performing fluid simulation, which demonstrated the plausibility of this interpretation. This model predicts a possible flow of the whole observable matter universe towards the antimatter dominated half where both halves could be currently expanding under free-fall gravitational acceleration.

Keywords: cosmology: theory, accelerated expansion, star speed, time-reversal symmetry.

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INTRODUCTION

The matter and antimatter would have been created in the same quantities according to the standard Big Bang theory (Mavromatos 2017). In contrast, the matter-antimatter asymmetry, by the violation of the CPT in the early era, could have given rise to today’s matter-dominated universe (Sakharov 1967).
However, recent measurements of the fine structure of hydrogen and antihydrogen atoms were found to be consistent with the estimations of quantum electrodynamics theory (Erikssson 2018; Ahmadi et al. 2020). This could contradict the CPT violation assumption adopted in the Big Bang theory. As an alternative, the non-singular Big Bounce theory assumes the primordial substance was concentrated from a previous collapsed universe, and the universe experiences continuous expansions and contractions (Trautman 1973; Unger & Poplawski 2019). Besides, to comply with the fundamental CPT symmetry and the laws of thermodynamics, cosmology and mathematical scientists have proposed that the universe could consist of matter and antimatter dominated halves with opposite time arrow directions (Sakharov 1967; Petit 1977; Santilli 2006).

The first theory of a dual universe was proposed by Sakharov (1967), who proposed a baryonic asymmetry that may have violated the CP symmetry and created surplus matter. In addition, Petit (1977) developed a CPT preserved model by proposing an anti-universe with a reverse arrow of time while Santilli (2006) introduced a mathematical concept for the model. Ying (2013) anticipated the existence of anti-antimatter in an anti-universe of a ten-dimensional cosmos while Boyle et al. (2018) proposed pre- and post-bang periods encompassing the existence of a universe-anti-universe pair model. Although Sakharov (1967), Petit (1977) and Santilli (2006) have established the foundation of the dual universe theory, it appears that it still lacks the comprehensive dual geometry of the four-dimensional universe based on General Relativity. In addition, the dual universe theory is yet may provide physical explanations for the unsolved problems, namely: the accelerated expansion, the fast movement of stars and the contradictory Hubble parameter measurements from the early and present universe.

On the other hand, a few models adopting a single universe assumption were introduced prior to General Relativity. However, most of these models had a lot of uncertainty of how a finite Newtonian universe could survive the gravitational breakdown (O'Raifeartaigh 2019). Einstein (1917) proposed the first cosmological model of a static universe where he introduced the cosmological constant as the vacuum energy to balance gravity. Later, De Sitter (1917) introduced an expanding and almost empty universe dominated by the cosmological constant. However, these modes were reported to be unstable (O'Raifeartaigh 2019).

In 1922, Friedmann developed an expansion-contraction model of the universe. The model proposed that the universe began from a small size and then expands to the critical scale factor, and then contracts towards the Big Crunch (Friedmann 1922). However, his model was ignored for some time as the expansion of the universe was not established until Hubble’s discovery in 1929. In 1927, Lemaître developed a cosmological model compatible with the Friedmann model and introduced the early state of the universe as a hot and dense period (O'Raifeartaigh 2019). Nevertheless, after the discovery of the expansion of the universe, both De Sitter and Einstein (1932) jointly developed a simpler model of an expanding universe, where Einstein abandoned his cosmological constant (Sahni 2002).

Furthermore, in 1998, the universe expansion was discovered to be accelerating (Riess et al. 1998; Perlmutter et al. 1999), which invalidated the reliability of the available cosmological models. To end this, the current standard Λ cold dark matter (ACDM) model was developed, which proposed a flat expanding universe with dark energy as the vacuum energy, quintessence or cosmological constant to explain the accelerated expansion (Peebles & Ratra 2003).
The ΛCDM model has provided appropriate alignments with astronomical observations (Lusso et al. 2019). However, the assumption of the dark energy continuous formation from vacuum to sustain the accelerated expansion is an obvious violation of the energy conservation law (Josset et al. 2017). Also, the predicted value of the ΛCDM cosmological constant contradicts with the quantum field theory where the discrepancy between estimations and the experiment is about 120 orders of magnitude (Adler 1995; Steinhardt & Turok 2006).

Similar to previous models, the ΛCDM model has recently faced inconsistency with the advancement of new astronomical observations and measurements (Valentino et al. 2020). The recent Planck Legacy 2018 (PL18) release indicated the existence of an enhanced lensing amplitude in the cosmic microwave background (CMB) that is higher than what is expected in the ΛCDM model (Aghanim et al. 2019a; Aghanim et al. 2019b). This endorses the existence of a positive curvature of the universe with a level of confidence greater than 99% (Valentino et al. 2019).

In addition, the precise Hubble parameter measurements from the early universe using the Planck datasets based on the CMB show a lower value of expansion rate in comparison with the value of Hubble parameter in the present universe using the type Ia supernovae distance-redshift method (Riess 2018), where the variation is about three standard deviations (Valentino et al. 2019). Further, the cosmic shear observed by the Kilo Degree Survey 450 is conflicting with Planck datasets at about two standard deviations (Hildebrandt et al. 2017; Valentino et al. 2019). Furthermore, Riess (2020) found that the expansion of the universe is faster than what ΛCDM estimates where the disagreement between several independent measurements taken from the early and present universe is at four to six-sigma and concluded this outcome cannot be ignored.

Accordingly, a profound adjustment of the ΛCDM model or new physics is now escalating due to this new evidence underlying the model assumptions (Lusso et al. 2019). The development of a new cosmological model is crucial to avoid a possible crisis for the cosmology (Valentino et al. 2019) where a new closed model of the universe could find a settlement to these problems as well as aid a large-scale cut-off in the primaeval density fluctuations and provide an agreement with the low CMB anisotropy quadrupole observations (Valentino et al. 2019; Valentino et al. 2020).

On the other hand, several alternative theories which encounter the assumptions of the ΛCDM model are under consideration, such as modified gravity, entropic gravity, bimetric gravity, modified Newtonian dynamics, scale invariance of empty-space, large-scale variations in the matter density of the universe and the decaying dark matter (Maeder 2017; Brouer 2017; Kroupa et al. 2010; Petit et al. 2018; Pandey 2019).

In contrast to the stated theories and traditional models that seem to be lacking the essential temporal parameter, this study presents a new four-dimensional and positively curved model of a spatial and time-reversal Couple Universe that is compatible with General Relativity, as a promising alternative to the ΛCDM model. The model was initiated based on the concept that everything in nature is basically symmetrical and balanced, and then the model was derived using General Relativity. The model consists of two halves of matter and antimatter with opposite time arrow directions, which preserves the vital CPT symmetry (Petit 1977). Both halves are assumed to be coexisting, symmetrical and gravitationally balancing each other in agreement with quantum electrodynamics theory (Ahmadi et al. 2020). The proposed model aligns with the energy-momentum conservation and quantum field theory as the dark
energy and dark matter hypotheses were not considered (Steinhardt & Turok 2006; Josset et al. 2017). The purpose of this model is to estimate the expansion rate and the speed of stars as well as to predict the possible fate of the universe.

This paper is organised as follows: Section 2 describes the mathematical derivation of the model. Section 3 discusses the model application, optimisation, calibration and outcomes. Section 4 presents the speed of star simulation, while Section 5 introduces model predictions. Finally, Sections 6 and 7 discuss the conclusions and future work.

2. The Mathematical Derivation of the Proposed Model

The relationship between the geometry of the spacetime and the distribution of energy density, which could include matter, antimatter and radiation, is described by General Relativity according to Einstein's field equations:

\[ R_{uv} - \frac{1}{2} R g_{uv} = \frac{8\pi G}{c^4} T_{uv} \]  

where \( R_{uv} \) is Ricci curvature tensor, \( R \) is the scalar curvature, \( g_{uv} \) is the metric tensor, \( G \) is Newton's gravitational constant, \( c \) is the speed of light in vacuum, and \( T_{uv} \) is the energy-momentum tensor (Einstein 1916).

The cosmological constant was omitted as this model does not consider the dark energy parameter. Here, gravity is considered as the only force governing the universe (Einstein 1916; Einstein 1932) while the geometrical configuration of the universe could influence the cosmic evolution directions. In addition, Einstein’s field equations could predict the evolution paths since the birth of the universe until probable fate as the scale factor of the universe must be greater than zero according to the Big Bounce theory (Trautman 1973; Unger & Poplawski 2019). New Einsteinian based coupled field equations for the matter and antimatter dominated halves, respectively, are proposed in this Couple Universe model as follows:

\[ R_{uv}^{(+) - \frac{1}{2} R g_{uv}^{(+)} = \frac{8\pi G}{c^4} T_{uv}^{(+)} } \]  

\[ R_{uv}^{(-)} - \frac{1}{2} R g_{uv}^{(-)} = - \frac{8\pi G}{c^4} T_{uv}^{(-)} \]  

The proposed coupled field equations in Equations 2 and 3 were founded based on the coupled field equations proposed by Petit et al. (2001). However, the extra negative energy-momentum tensors that were introduced by Petit et al. (2001) to account for their proposed negative masses were not considered in this model.

The metric tensors for both matter \( g_{uv}^{(+)} \) and antimatter \( g_{uv}^{(-)} \) dominated halves can be characterised using the Friedmann – Lemaître – Robertson – Walker metric (FLRW) model. FLRW model is an exact solution of Einstein’s field equations, which designates an isotropic, homogeneous, expanding or contracting, and simply or non-simply path-connected universe (Lachieze-Rey & Luminet 1995; Ellis & Elst 1999).

The isotropic spherical coordinates of the FLRW are (Landau & Lifshitz 1975):

\[ ds^2 = c^2 dt^2 - a^2(t) \left( \frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \right) \]  

where \( ds \) is the four-dimension spacetime interval in polar coordinates, \( a \) is the spatial factor of the universe and \( k \) is a constant representing the curvature of the space. The tensor signatures for both matter and antimatter metrics will be utilised throughout this study as \( (+, -, -, -) \) and \( (-, +, +, +) \) respectively.
Regarding the matter-dominated half of the universe, Einstein’s field equations in Equation 2 can be solved for perfect fluid. By using the notation \( c = 1 \) and rising one index of Equation 2, the field equations can be expressed in term of mixed component tensors:

\[
R^u_v - \frac{1}{2} R \delta^u_v = 8\pi G T^u_v
\]

(5)

where \( \delta^u_v \) is the Kronecker delta (Carmeli 1982; Carmeli 2001). The energy-momentum tensor \( T_{uv} \) for a perfect fluid is given by:

\[
T_{uv} = (\rho + P) u_u u_v + P g_{uv}
\]

(6)

where the four-dimensional velocity of the celestial object fluid is \( \vec{u} = (1, 0, 0, 0) \). \( u_u = u^u = 0 \) and \( u_t = -u^t = c = 1 \), as well as \( \rho \) is the energy density and \( P \) is the isotropic pressure (Norbert 2013). Rising one index of Equation 6, thus, it can be expressed in term of mixed component tensors as follows:

\[
T^u_v = (\rho + P) u^u u_v + P \delta^u_v
\]

(7)

The trace tensor \( T^u_u \) of the energy-momentum tensor \( T^u_v \) can be obtained by contracting through indices \( u \) and \( v \) in Equation 5:

\[
R = -8\pi GT^u_u
\]

(8)

where \( R \) is the scalar curvature. The trace tensor for a perfect fluid is equivalent to (Norbert 2013):

\[
T^u_u \equiv (-\rho + 3P)
\]

(9)

Submitting Equation 8 to Equation 5 gives:

\[
R^u_v = 8\pi G \left( T^u_v - \frac{1}{2} \delta^u_v T^u_u \right)
\]

(10)

Submitting Equations 7 and 9 to Equation 10:

\[
R^u_v = 8\pi G \left( (\rho + P) u^u u_v + \frac{1}{2} (\rho - P) \delta^u_v \right)
\]

(11)

The Ricci tensor \( R^u_v \) can be solved for the matter half using the matter metric tensor as follows (Friedmann 1922; Romeu 2014):

\[
R^i_i = \frac{1}{a^2} (a\ddot{a} + 2\dot{a}^2 + 2k) \delta^i_i
\]

(12)

\[
R^0_0 = 0
\]

(13)

\[
R^i_i = 3\frac{\dot{a}}{a}
\]

(14)

Submitting Equations 12, 13 and 14 to Equation 11 while solving it along the \( i - i \) and \( t - t \) components gives Equations 15 and 16 respectively:

\[
\frac{1}{a^2} (a\ddot{a} + 2\dot{a}^2 + 2k) = 4\pi G (\rho - P)
\]

(15)

\[
3\frac{\dot{a}}{a} = 8\pi G (-\rho + P) + \frac{1}{2} (\rho - P)
\]

(16)

By combining Equations 15 and 16, Equation 17 is obtained:

\[
\dot{a}^2 - \frac{8\pi G \rho}{3} a^2 + k = 0
\]

(17)

Equation 17 can be solved for the positively curved matter half of the universe as follows:

\[
\dot{a}^{(+)} = \left( \frac{8\pi G \rho_e}{3} a^2 \left( \frac{a_e}{a} \right)^3 - k \right)^{1/2}
\]

(18)

\[
da^{(+)} = \left( \frac{8\pi G \rho_e a_e^3}{3a} - 1 \right)^{1/2} dt
\]

(19)

where \( \rho_e \) is the energy density and \( a_e \) is the corresponding spatial scale factor; both are functions of time and \( \rho_e a_e^3 \) equal to overall mass of the half. \( k = 1 \) for the positively curved matter-dominated half (Ryden 2003).
By integrating with regards to the conformal time in the parametric form $d\eta \equiv \frac{da}{a}$, which is represented in the range of $(0 < \eta < 2\pi)$ as follows:

$$
\int d\eta = \int_0^{2\pi} \frac{da}{(2\Omega_e a - a^2)^2} \quad (20)
$$

$$
\eta = \sin^{-1} \left( \frac{a - \bar{\Omega}_e}{\Omega_e} \right) + \frac{\pi}{2} \quad (21)
$$

$$
\frac{a - \bar{\Omega}_e}{\Omega_e} = \sin(\eta - \frac{\pi}{2}) \quad (22)
$$

Hence, the spatial factor of the matter half is:

$$
a(\eta)^{(+)} = \frac{\bar{\Omega}_e}{2} (1 - \cos \eta) \quad (23)
$$

where $\bar{\Omega}_e = \frac{4}{3}\pi G \rho_e a_e^3 \equiv \frac{\Omega_e}{(\Omega_e - 1)}$, $\Omega_e$ is the energy density parameter, which is equal to the energy density $\rho_e$ over the critical density $\rho_c$ (Ryden 2003).

In addition, the temporal factor $t(\eta)$ can be obtained by rewritten Equation 18 in term of Hubble parameter for positively curved matter-dominated half where the Hubble parameter $H = \frac{\dot{a}}{a}^2$ (Ryden 2003):

$$
\dot{a}^{(+)} = H \left( \frac{\Omega_e}{a} + (\Omega_e - 1) \right)^{1/2} \quad (24)
$$

The $t(\eta)$ in relative to the current age of the universe $t_0$ can be obtained by integrating Equation 24:

$$
\int dt = \int_0^{2\pi} \frac{da}{Ht_0 \left( \frac{\Omega_e}{a} + (\Omega_e - 1) \right)^{1/2}} \quad (25)
$$

Hence, the temporal factor of matter half is:

$$
t(\eta)^{(+)} = \frac{\bar{\Omega}_e}{2H t_0 (\Omega_e - 1)^{1/3}} (\eta - \sin \eta) \quad (26)
$$

Regarding the antimatter half, Einstein’s field equations in Equation 3 can be solved for a perfect fluid. By rising one index of Equation 3, the field equations become in term of mixed component tensors as follows:

$$
R_{\nu}^u - \frac{1}{2} R \delta_{\nu}^u = -8\pi G T_{\nu}^u \quad (27)
$$

Contracting through indices $u$ and $v$ in Equation 27 and submitting the resulting scalar curvature as well as Equations 7 and 9 of the perfect fluid to Equation 27 lead:

$$
R_{\nu}^u = 8\pi G (\rho + P) u^u u_v + \frac{1}{2} \rho (\rho - P) \delta_{\nu}^u \quad (28)
$$

The Ricci tensor $R_{\nu}^u$ can be solved for the antimatter half using the antimatter metric tensor as follows:

$$
R_{\nu}^t = \frac{1}{a^2} (-a \ddot{a} + 2\dot{a}^2 + 2k) \delta_{\nu}^t \quad (29)
$$

$$
R_{\nu}^0 = 0 \quad (30)
$$

$$
R_{\nu}^i = -\frac{3}{a} \delta_{\nu}^i \quad (31)
$$

Submitting Equations 29, 30 and 31 to Equation 28 while solving it along the $i - i$ and $t - t$ components gives Equations 32 and 33 respectively:

$$
\frac{1}{a^2} (-a \ddot{a} + 2\dot{a}^2 + 2k) = -4\pi G (\rho - P) \quad (32)
$$

$$
-3 \frac{\dot{a}}{a} = 8\pi G (\rho + P) - \frac{1}{2} (\rho - P) \quad (33)
$$

By combining Equations 32 and 33:

$$
\dot{a}^2 + \frac{8\pi G \rho}{3} - 1 = 0 \quad (34)
$$

$$
da \, (-) = \left( \frac{-8\pi G \rho_e a_e^3}{3a} - 1 \right)^{1/2} \, dt \quad (35)
$$
By integration over the conformal time:

$$\int d\eta = \int_0^{2\pi} \frac{da}{(-2\Omega_e a - a^3)^{1/2}}$$  \hspace{1cm} (36)

Hence, the spatial factor of the antimatter half:

$$a(\eta) = \frac{\Omega_e}{2} (\cos \eta - 1)$$  \hspace{1cm} (37)

where \( k = 1 \) for the positively curved antimatter-dominated half of the universe. Also, the temporal factor \( t(\eta) \) with regards to \( t_0 \) can be obtained by rewriting Equation 35 in term of Hubble parameter for positively curved antimatter-dominated half and then integrating of both sides as follows:

$$t(\eta) = -\frac{\Omega_e(\Omega_e - 1)^{1/3}}{2H_0} (\sin \eta - \eta)$$  \hspace{1cm} (38)

Accordingly, the Couple Universe model can be expressed for the matter and antimatter halves as follows respectively:

$$a, t(\eta)^+ = \frac{\Omega_e}{2} (1 - \cos \eta)$$

$$+ i \left( \frac{\Omega_e(\Omega_e - 1)^{1/3}}{2H_0} \right) \times (\eta - \sin \eta)$$  \hspace{1cm} (39)

$$a, t(\eta)^- = \frac{\Omega_e}{2} (\cos \eta - 1)$$

$$- i \left( \frac{\Omega_e(\Omega_e - 1)^{1/3}}{2H_0} \right) \times (\sin \eta - \eta)$$  \hspace{1cm} (40)

where the real part represents the three-dimensional spatial factor and the imaginary part represents the temporal factor over the conformal time. The deceleration/acceleration of the spatial factor of both halves is obtained using Equation 16 or 33 (Friedmann 1922):

$$\frac{d^2a}{dt^2} = -\frac{4\pi G}{3} a (\rho + 3p)$$  \hspace{1cm} (41)

3. Model Application, Optimisation, Calibration and Outcomes

3.1 Model Application

The derived model was applied to evaluate the evolution of the universe over the conformal time. Equations 39 and 40 were utilised to predict the evolution paths of the matter and antimatter halves, respectively. The Hubble parameter was assumed to be 70 km/s/Mpc as an average of the early and today’s universe expansion rates, the current age of the universe was assumed to be 13.8 billion years, and the density parameter \( \Omega_e \) was assumed to be 8.

By implementing these values, Figure 1 was obtained; this Figure presents the predicted spatial and temporal evolution of the universe over the conformal time. The model predicts that both halves of the universe were expanding in opposite directions away from the Big Bounce during the first 9.6 billion years (0.7 of the temporal factor or the current age of the universe). It also predicts that the rate of expansion was slowing down, which could be due to the gravity between the two halves. The expansion then reached a critical radius where both halves reversed their direction (Friedmann 1922).

The reverse direction after passing 0.7 of the temporal factor could be due to the gravitational attraction between the cosmic matter and antimatter at the critical radius of both halves towards each other, which could lead both of them to free-fall towards each other over large-scale spacetime of the universe. At the reverse stage of expansion, the three-dimensional spatial factor of both halves is predicted to continue to enlarge over the increase in the temporal factor.
8

Figure 1: Evolution of the four-dimensional Coupled Universe. Firstly, a spatial expansion stage of both halves away from the Big Bounce (0, 0) until they reach their critical spatial radius. Secondly, a reverse spatial expansion stage where the spatial radius of both halves continues to expand as both halves move towards each other.

Metaphorically, the two halves of the universe could be thought as two jet fountains that start from the same source and in opposite directions. The radius of fountains increases as they head away from the source; then, they reverse their directions and free-fall towards each other under their gravity while their radiiuses continue to increase.

Nevertheless, the model should be optimised to account for the effect of the coexistence of the two halves on the energy density distribution and then calibrated using available astronomical observations.

3.2 Model Optimisation

As mentioned earlier, the universe is predicted to pass through two spatial stages. In the first stage, both halves spatially expand away from the Big Bounce until they reach their critical spatial radius. If we consider the symbolic picture that the two halves are similar to two jet fountains, it is expected both halves are simply path connected at the first stage.

On the other hand, it is expected that both halves at the second stage could develop hollow spacetimes and both could be not simply path connected. Therefore, \( \rho_e a_e^3 \) could be no longer equal to the overall mass as spacetime-holes might be existed and accordingly, \( \tilde{\Omega}_e = \frac{4}{3} \pi G \rho_e a_e^3 \) can be variable. The energy density at the second stage is expected to increase as the cosmic matter and antimatter are moving towards each other over large-scale spacetime of the universe. Mathematically, \( \rho_e \) at the second stage can be considered as a function of the conformal time:

\[
\rho_e \propto \eta \quad \pi > \eta > 2\pi \quad (42)
\]

Accordingly, the energy density parameter can be express as function of the conformal time:

\[
\Omega_{e,2} = \Omega_c (1 + \sigma_{\Omega_e,2}) \quad \pi > \eta > 2\pi \quad (43)
\]

where \( \Omega_c \) is the critical energy density parameter at the critical radius and \( \sigma_{\Omega_e,2} \) is the energy density growth factor. Similarly, to account for the variable expansion rates, the Hubble parameter can be considered as a function of the conformal time for both stages as follows:

\[
H_1 \propto \eta \quad 0 > \eta > \pi \quad (44)
\]

\[
H_1 = H_i (1 - \sigma_{H_1}) \quad 0 > \eta > \pi \quad (45)
\]

\[
H_2 \propto \eta \quad \pi > \eta > 2\pi \quad (46)
\]

\[
H_2 = H_c (1 + \sigma_{H_2}) \quad \pi > \eta > 2\pi \quad (47)
\]

where \( H_i, H_1, H_c, H_2 \) represent the Hubble parameter at the initial, first, critical, and second stages respectively; \( \sigma_{H_1} \) is Hubble decrease factor at the first stage and \( \sigma_{H_2} \) is the Hubble increase factor at the second stage.
Accordingly, the optimised model of the matter half of the universe is:

\[
a_t(\eta)^{(+) = \frac{\Omega_m}{2} (1 - \cos \eta) + i \left( \frac{\Omega_m(\Omega_m - 1)^{1/3}}{2H_0 t_0} \right) * (\eta - \sin \eta)) \quad 0 > \eta > \pi \quad (48)
\]

\[
a_t(\eta)^{(+) = \frac{\Omega_m}{2} (1 - \cos \eta) + i \left( \frac{\Omega_m(\Omega_m - 1)^{1/3}}{2H_0 t_0} \right) * (\eta - \sin \eta)) \quad \pi > \eta > 2\pi \quad (49)
\]

Similarly, the optimised antimatter model half of the universe is:

\[
a_t(\eta)^{(-) = \frac{\Omega_m}{2} (\cos \eta - 1) - i \left( \frac{\Omega_m(\Omega_m - 1)^{1/3}}{2H_0 t_0} \right) * (\sin \eta - \eta)) \quad 0 > \eta > \pi \quad (50)
\]

\[
a_t(\eta)^{(-) = \frac{\Omega_m}{2} (\cos \eta - 1) - i \left( \frac{\Omega_m(\Omega_m - 1)^{1/3}}{2H_0 t_0} \right) * (\sin \eta - \eta)) \quad \pi > \eta > 2\pi \quad (51)
\]

### 3.3 Optimised Model Calibration and Outcomes

Both Hubble parameter measurements at the early universe of 67.4 km/s/Mpc and at the current universe of 73.5 km/s/Mpc at approximate universe ages of 0.37 and 13.8 billion years respectively as well as the approximate age of 9.9 billion years when the accelerated expansion started were used in calibrating the optimised model. In addition, the reduction rate of the Hubble parameter at the first stage of expansion was assumed to be \(\sigma_{H_1} = 0.001\%\) and the initial density parameter at the Big Bounce was assumed to be \(\Omega_m = 8\). The increase in the density parameter at the second stage was calibrated as \(\sigma_{\Omega_m} = 0.001\%\) as both halves are moving towards each other over large scale spacetime. Similarly, the increase in the Hubble parameter at the second stage was calibrated as \(\sigma_{H_2} = 0.1\%\) as both halves are approaching each other under free-fall gravitational acceleration.

Due to the symmetry of both halves, the optimised model of the matter half was utilised, and the result is shown in Figure 2. The model predicts that cosmic evolution might experience three distinct stages. Firstly, the matter-dominated half of the universe was expanding away from the Big Bounce during the first 9.9 billion years (from 0 to 0.72 temporal factor) with a decelerated spatial expansion, which could be due to gravity between the two halves, until it reaches its critical radius.

![Figure 2: Evolution path of the matter half. Firstly, a decelerated stage of spatial expansion of the half away from the Big Bounce until it reaches its critical spatial radius. Secondly, an accelerated stage of a reverse spatial expansion. Finally, a time-reversal drifting stage of a spatial contraction, which could lead to the Big Crunch.](image-url)
Secondly, after passing 0.72 temporal factor or 9.9 billion years, an accelerated stage of a reverse spatial expansion of the universe started, which could be due to the gravitational attraction between the matter and antimatter at the critical radius of both halves. The cosmic matter and antimatter could be under free-fall towards each other at gravitational acceleration, causing the current accelerated expansion of the universe.

Interestingly, the model predicts a third drifting stage of spatial contraction with reversal-time direction at 1.15 temporal factor afterwards. This stage could be a result of a high concentration of the matter and antimatter in both halves, which could produce a strong gravitational attraction that leads to the Big Crunch.

The schematic representation of the model is shown in Figures 3 & 4. The evolution of the universe at the first stage of expansion (Figure 3) shows that both halves were expanding away from the Big Bounce in opposite directions along the CPT preserved and opposite frontward time arrows and through the upward future time arrow. The spatial expansion in opposite directions of matter and antimatter halves away from the Big Bounce seems to fit the interpretation of Stueckelberg (1941), where he proposed that the matter and antimatter travel at opposite time arrow directions. The blue circles represent a three-dimensional slice of the universe at an instant of time.

On the other hand, at the second stage of expansion (Figure 4), the matter and antimatter halves are expanding along the CPT preserved and opposite backward time arrows and through the upward future time arrow. The reverse direction could be a result of the gravitational attraction between the matter and antimatter at the critical radius of both halves, which can lead them to free fall towards each other under gravitational acceleration.

Figure 3: Schematic representation of the matter and antimatter halves of the Couple Universe at the first stage of expansion. Both halves are expanding away from the Big Bounce along the CPT preserved and opposite frontward time arrows and the upward future time arrow. Blue circles represent a 3-dimensional slice of the universe at an instant of time.

Figure 4: Schematic representation of the matter and antimatter halves at the second and third stages. At the second stage, both halves are expanding along the backward time arrows and through the upward future time arrow. In the third stage, both halves are shrinking along the backward time arrows and through the downward past time arrow. Blue circles represent a 3-dimensional slice that is not necessarily to be a simply path connected.
Finally, in the third stage of spatial contraction (Figure 4), both halves would be shrunken as a result of a high concentration of the matter and antimatter in both halves. The drifting in the direction of the evolution paths at this stage could prevent the direct collision between the matter and antimatter halves and lead them towards the Big Crunch.

In this model, the three stages of the universe evolution might reveal that each half of the universe has extra two-time directions: frontward time arrow away from the Big Bounce and backward time arrow towards the Big Crunch. These time directions in addition to the known time directions: future and past time arrows, which are shared between both halves. Thus, this Couple Universe model of symmetrical relativity could define the extra two-time arrows of frontward and backward directions for each half, which are perpendicular to the future and past time arrows. The frontward and backward time arrow directions are related to the charge of the matter and antimatter in agreement with the CPT symmetry (Stueckelberg 1941; Petit 1977). Further, the third stage of contraction shows the time-reversal direction where the evolution paths of the matter and antimatter halves are predicted to reverse the time arrow direction and evolve along the past time arrow.

4. Speed of Star Simulation

The consistent patterns of galactic rotation curves using precise and independent galactic redshift data confirmed that the hydrogen clouds and outer stars are orbiting galaxies at speeds faster than that calculated using Newtonian laws. Accordingly, the dark matter hypothesis was introduced to account for the apparently missing galactic mass and to explain the fast-orbital velocity (Mannheim & Kazanas 1989; Sofue & Rubin 2000).

However, no evidence of the existence of the dark matter, which supposed to account for the majority galactic mass, was observed since its introduction as well as this hypothesis is doubted to be correct by some mainstream scientists. The failure to find dark matter led to the introduction of new theories such as modified gravity and modified Newtonian dynamics theories (Edmund et al. 2013; Meter 2018; Milgrom 2019).

On the other hand, several recent studies found that many galaxies do not contain dark matter (Dodelson 2006; Guo et al. 2019a; Guo et al. 2019b). This conclusion was considered in some studies where the galaxy formation was simulated using modified Newtonian dynamics without considering the dark matter hypothesis (Wittenburg 2020). It seems that there is no evidence or agreement on the existence or nature of the dark matter as well as it is not an essential element in some galaxies.

As an alternative, a new hypothesis in this model is introduced based on the variation of the curvature of each half of the universe. The current universe is predicted at the second stage of reverse spatial expansion. The schematic representation of the model in Figure 4 and further schematic representation of the model in Appendix 1, Figure A show that the curvature of the spacetime of both halves varies at each three-dimensional slice of the universe at different instants of time. Accordingly, it is assumed that the observed fast movement may occur as a result of the variation of the universe curvature, where the gravitational attraction between both halves is assumed to highly bend the spacetime of both halves.

To evaluate this hypothesis, a fluid simulation experiment based on Newtonian dynamics was performed using the Fluid - Pressure and Flow software (Reid 2013). In this simulation, a perfect fluid of mass density $\rho$ and isotropic pressure $p$ was assumed to represent the matter of the universe while the fluid particles were assumed to represent the stars.
The fluid was considered as a perfect fluid because it is frictionless with no heat conductivity (Nemiroff & Patla 2008).

Using these conditions, the fluid model was built to simulate the star movement speed between highly and barely bent curvatures, as shown in Figure 5. This Figure illustrates the movement of fluid particles at the various curves where the particles located in the lesser curved paths were found to move faster than the ones that were passing in the highly curved paths. Therefore, it could be concluded that the curvature of the spacetime fabric of both halves can influence the speed of star movement as they are located through different curvatures of the universe.

![Figure 5: Simulation of fluid-particle movement. The particles located at lesser curved paths move faster than their counterparts that are located within highly paths.](image)

5. Model Predictions

In contrast to the ΛCDM model which assumes that the expansion rate of the universe is almost constant, this model predicts that the rate varies over time. Firstly, the spatial expansion rate was decreasing during the early universe era until approximately 9.9 billion years after the Big Bounce.

The model then predicts that the spatial expansion rate started to accelerate during the last four billion years and will continue until the universe reaches a high concentration of the matter and antimatter in both halves that would precipitate the contraction stage of reverse time arrow towards the Big Crunch.

The first stage of expansion is predicted to be decelerating while the second stage of expansion is predicted to be accelerating according to Equation 41. It was utilised to predict a relative deceleration and acceleration of the spatial factor over the conformal time, as shown in Figure 6.

![Figure 6: The deceleration and acceleration of the spatial factor over the conformal time.](image)

The expansion rate was decreasing at the first stage, and this conforms with the lower value of the Hubble parameter obtained by the Planck datasets of the early universe (Valentino et al. 2019; Valentino et al. 2020). However, at the second stage, the expansion was increasing, and this aligns the higher value of the Hubble parameter obtained using the supernovae type Ia distance-redshift method at the current universe (Riess et al. 1998; Riess et al. 2018; Riess et al. 2020). Therefore, the first and second stages of expansion align with the Hubble parameter contradictory measurements.
In contrast to the current models which assume an isotropic universe (Lachieze-Rey & Luminet 1995; Ellis & Elst 1999), this model predicts a possible flow of the whole observable universe due to the gravitational attraction by the antimatter half. The flow of the matter half of the universe can be predicted using Equation 49 and according to the evolution path in Figure 2. In addition, the flow rates or possible flow directions could be estimated using the derivative of the optimised matter model with regards to the conformal time as in Equations 52 and 53:

\[
a(t, \eta)^+ = \frac{\Omega_e}{2} (\sin \eta) + \left( \frac{\Omega_{e,1} - 1}{2H_t r_0} \right)^{1/3} \times (1 - \cos \eta) \quad 0 > \eta > \pi \quad (52)
\]

\[
a(t, \eta)^+ = \frac{\Omega_{e,2}}{2} (\sin \eta) + \left( \frac{\Omega_{e,2} - 1}{2H_2 r_0} \right)^{1/3} \times (1 - \cos \eta) \quad \pi > \eta > 2\pi \quad (53)
\]

Figure 7 shows the flow rate using Equations 52 and 53:

As opposed to the ΛCDM model which assumed a flat expanding universe, this model predicts a positive curvature of the universe with a variable lensing amplitude based on the direction and location of the universe curvature. It also predicts a variable speed of stars depending on the curvature of the spacetime fabric in which they are situated.

In this Couple Universe model, it seems that each half is not a mirror image of the other half, but each is a separate identity where galaxies can evolve and spread in different locations and shapes. A new ‘Cosmic Conservation’ term can be suggested to illustrate that this positively curved symmetrical Couple Universe model has a finite amount of energy (Friedmann 1922; Trautman 1973; Unger & Poplawski 2019). Therefore, the Cosmic Conservation can explain the instantaneous quantum entanglement where the finite universe conserves the total spin of a pair of particles regardless of their locations. Therefore, this Couple Universe model predicts that the locations of quantumly entangled particles have no effect on their entanglement while their total spin is conserved.

There is a possibility that the black holes in the matter denominated half are tunnelled to antimatter white holes in the other half of the universe through Einstein–Rosen bridge or wormhole (Weyl 1921); where physical information can be quantumly tunnelled to antimatter white holes and never lost. The information would change its charge as it passes to the antimatter half of opposite time arrow in agreement with CPT symmetry and according to the interpretation of Stueckelberg (1941) that the antimatter travels backwards.
6. Conclusions

In this study, a new cosmological model of a closed Couple Universe was proposed to predict the expansion rate of the universe and the speed of stars. This model was developed to overcome the shortcomings within the available cosmological models such as the violation of CPT symmetry and violation of the energy conversation laws as well as to reflect the nature where everything seems to be symmetrical and balanced. The model assumes the universe consists of two halves of matter and antimatter that are symmetrical in geometry but have opposite time directions. This assumption conforms with CPT symmetry and quantum electrodynamics theory as well as the energy conversation law since dark energy hypothesis was not considered in the model. This four-dimensional model was derived using General Relativity and it accounts for the spatial and temporal factors of the universe. The model was optimised and calibrated based on available astronomical observations and measurements.

The model was then applied to simulate the evolution of the universe. The results predicted that the expansion rate is variable. The rate during the early universe was decreasing while the rate at the current universe is increasing. These results aligned with Hubble measurements from the early and current universe observations. The results also indicated that the universe would experience a third stage of accelerated contraction towards the Big Crunch in a reverse time arrow. The model also predicts a possible flow of the whole observable matter universe towards the antimatter dominated half where both halves could be currently expanding under free-fall gravitational acceleration.

Regarding the movement of the star, the fluid simulation can provide a plausible explanation where the highly curved spacetime fabric of both matter and antimatter halves could drive stars located at a lesser curved spacetime to move faster than their counterparts that are located within a highly curved fabric.

The abandonment of the cosmological constant in this model could fit the quantum field theory as it distinguishes the quantum vacuum energy from the energy of space and attributes the accelerated expansion to the gravitational attraction between both halves. However, the literature on dark matter/energy can be utilised to accurately estimate the energy density distribution and the energy growth factor. Finally, the suggested Cosmic Conservation of this closed and finite universe model could explain the instantaneous quantum entanglement where the finite universe would conserve the total spin of a pair regardless of their locations.

7. Future Work

The assumed value of the initial energy density parameter at the Big Bounce, the energy growth factor at the second stage of expansion as well as the Hubble parameter change factors at both stages have acted a vital role in the estimation of the universe expansion rates. Therefore, accurate values can provide a better estimation of the evolution paths of the universe.

The hypothesis that the black holes at the matter half maybe are tunnelled to antimatter white holes in the other half could be investigated, and it might solve the black hole information paradox.

Finally, the accurate age of the universe can be estimated based on the non-linear Hubble parameter and its change factors at both stages of expansion.
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Appendix 1

The schematic representation of the Couple Universe of matter and antimatter dominated halves according to the evolution paths

Figure A: A schematic representation of the Couple Universe of matter and antimatter dominated halves according to the evolution paths. While circles represent the evolution of galaxies, clusters and superclusters. Each half of the universe started from the Big Bounce and expanded at a decelerated rate due to gravity until the critical radius. Then, the gravitational attraction between matter and antimatter at the critical radius of both halves could cause the current accelerated expansion. Finally, a high concentration of the matter and antimatter in both halves can produce a strong gravitational attraction around the Big Crunch.