

# Holographic Origin of Matter Dominance and Weak CP Violation: A Unified Theory beyond the Standard Model

Rulin Xiu<sup>1,2</sup> 

<sup>1</sup>Tao Academy, Richmond Hill, Canada

<sup>2</sup>Hawaii Theoretical Physics Research Center, Kapoho, HI, USA

Email: rulin@htprc.org

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## Abstract

The observed matter-antimatter asymmetry in the universe and the origin of charge-parity (CP) violation remain among the most profound unresolved questions in modern physics. While the Standard Model has achieved remarkable success, it fails to adequately account for the observed imbalance. This paper introduces a novel theoretical framework grounded in the holographic principle, proposing that the universe emerges as a projection from a two-dimensional elementary information (EI) spacetime. Within this model, matter and antimatter occupy distinct domains—termed the holomorphic and anti-holomorphic sectors, respectively. This intrinsic separation offers a natural explanation for the predominance of matter in our universe. The theory posits that interactions mediated by background fields—corresponding to gravity and gauge forces—permit the generation of antimatter within the matter-dominated holomorphic sector, aligning with empirical observations. It further elucidates why all elementary particles carry SU(2) weak charge and why violations of C, P, and CP symmetries are confined to the weak interaction. Notably, the model accounts for the SU(2) doublet nature of matter particles and the singlet nature of their antimatter counterparts. This unified holographic approach provides a fresh perspective on fundamental symmetries and the architecture of the universe, potentially resolving long-standing puzzles in cosmology and particle physics. The model also predicts the existence of a distinct, parallel mirror antimatter universe—largely decoupled from ours but interacting through gravitational and gauge fields. The theoretical implications and experimental prospects of this prediction merit further investigation.

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## Keywords

Grand Unified Theory, Matter-Antimatter Asymmetry, CP Violation, Beyond Standard Model, Holographic Principle, Electroweak Symmetry Breaking, Generation of Large Hierarchy, Holographic Quantum Theory

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## 1. Introduction

The matter-antimatter asymmetry problem, also known as baryon asymmetry problem or the matter asymmetry problem, refers to the observed imbalance between matter and antimatter in the universe, both on the macroscopic and microscopic scale (up to 1 GeV or higher) [1]-[3]. Observations of the universe, including the cosmic microwave background (CMB) and the large-scale structure of the cosmos, indicate that the universe is composed almost entirely of matter. Antimatter is extremely rare and is only observed in high-energy processes, such as those occurring in particle accelerators.

According to our current understanding of particle physics, such as Standard Model [4] [5], the Big Bang should have produced equal amounts of matter and antimatter. When matter and antimatter come into contact, they annihilate each other, producing energy. If there had been perfect symmetry, all matter and antimatter should have annihilated, leaving behind a universe filled only with radiation. So far, CP violation is utilized in the Standard Model to explain the matter-antimatter asymmetry [6] [7]. CP violation implies that the laws of physics are not the same for matter and antimatter, which could lead to an asymmetry in their production and decay rates. The Standard Model does include some CP-violating processes, but the amount of CP violation observed so far is insufficient to account for the observed matter-antimatter asymmetry.

Another intriguing finding is that every elementary particle has SU(2) weak charge, but not every elementary particle has U(1) electromagnetic charge or SU(3) strong force charge. Only SU(2) weak force breaks C, P and CP symmetry, so far electromagnetic force and strong force do not break C, P, or CP symmetry. In particular, all particles are SU(2) doublet, but their anti-particles are SU(2) singlets.

Standard Model of particle physics is so far the accepted theory describing the observed elementary particles and gauge forces. However, it leaves many phenomena unexplained. For instant, Standard Model cannot include gravity forces; it cannot account for dark matter and dark energy; it cannot predict the small cosmological constant; it cannot account for the source of matter-antimatter asymmetry and CP violation; it cannot explain why the charge violation, parity violation, and charge-parity violation occur in weak interaction but not in electromagnetic and strong interaction and why very elementary particles have SU(2) charge but not U(1) or SU(3) charge, and why anti-particles are SU(2) singlet. It is desirable to develop a unified fundamental physics theory to explain all these phenom-

ena and derive the Standard Model from it.

String theory and supersymmetry are introduced to create a unified theory for all fundamental forces and elementary particles [8] [9]. However, string theory in current status is limited in its ability to make predictions. In our previous work [10], we derive a unified theory from the holographic principle [11]-[18] that can integrate all fundamental forces, elementary particles, dark matter, and dark energy into one mathematic formula. It predicts cosmological constant in agreement with the experimental observation. It can derive the entropy of black hole and study the internal dynamics of black hole.

In this paper, we will build a simple model from this holographic unified theory that can naturally deduce the matter-antimatter asymmetry and can also explain why only weak interaction has charge and parity violation, while other gauge forces and gravity do not have charge and parity violation. It can also explain why very elementary particles have SU(2) charge but not U(1) or SU(3) charge. In the following, we will first review our holographic unified theory and then we will present the model which naturally contains matter-antimatter asymmetry and weak interaction charge and parity violation and in which every elementary particles have SU(2) charge but not U(1) or SU(3) charge, with particles being SU(2) doublet and anti-particles SU(2) singlet.

## 2. Theory: A Holographic Unified Framework

### Review of Derivation of a unified theory based on Holographic Principle

We start with presuming the holographic principle as the fundamental principle. Here, the holographic principle is stated as:

**All physical phenomena emerge from a hologram that encodes the information of a system.**

The holographic principle implies that information is the basic ingredient determining everything. We call the basic and universal information underlying all physics the elementary information (EI). We propose that elementary information is encoded by spacetime and call the spacetime that encodes the elementary information the elementary information spacetime (EI spacetime).

Based on the general consideration from quantum physics and general relativity, we find that the minimum elementary information space  $\Delta\sigma$  and time  $\Delta\tau$  needed to encode a bit of information is (detailed derivation can be found in reference [10]):

$$\Delta\sigma\Delta\tau \geq l_p t_p, \quad (1)$$

here,  $l_p$  is the Planck length,  $t_p$  is the Planck time, and  $l_p = ct_p = (\hbar G/c^3)^{1/2}$ . Formula (1) indicates that EI space and time always appear together in pairs. The dimension of the EI spacetime is  $2^n$ , here  $n$  is the number of independent space and time pairs of EI spacetime. In this paper, we will only discuss the simplest case that  $n = 1$ .

From the uncertainty relationship (1), we propose that the holographic action  $A_h$ , calculating the maximum amount of observable information that can be en-

coded in EI spacetime,  $(\tau, \sigma)$  is in the form:

$$A_h = \alpha \int \Delta \sigma \Delta \tau . \tag{2}$$

Here, the integral symbol  $\int$  represents the summation over EI space and time  $(\tau, \sigma)$ , and  $\alpha$  is a constant:

$$\alpha = \frac{1}{l_p t_p} .$$

To derive the observable physical phenomena from the holographic action (2), it is necessary to see the physical spacetime  $X^\mu$  as a projection from the EI spacetime  $(\tau, \sigma)$ ,

$$X^\mu : (\tau, \sigma) \rightarrow X^\mu (\tau, \sigma) .$$

In the physical spacetime, the holographic action is:

$$A_h = A'_j = \alpha \int_0^T d\tau \int_0^L d\sigma \partial_\tau X^\mu \partial_\sigma X_\mu . \tag{3}$$

One can define the holographic function  $\Psi_h$ :

$$\Psi_h (T, L) = \exp(iA_h) . \tag{4}$$

The holographic function  $\Psi_h$  is related to the amount of elementary information in a system,  $Ei$ , through the formula:

$$Ei = A_h = -i \ln \Psi_h , \tag{5}$$

$$\Psi_h (T, L) = \exp(iA_h) = \sum_{\text{sum over possible } X^\mu} \exp(iA'_h) . \tag{6}$$

Compared to the wave function in quantum physics [19]:

$$\Psi (T) = \int \mathcal{D}X \exp(iS) \Psi_0 ,$$

here,  $S = \int_0^T dt \mathcal{L}(x(t), \dot{x}(t))$ .

One can notice that the holographic function  $\Psi_h$  is an extension of the wave function  $\Psi$  in quantum physics. Holographic action integrates over both time and space, while the action in quantum physics integrates over time only. Holographic action is an extension of quantum physics from 1-dimensional time to 2-dimensional EI spacetime. Quantum physics is a special case of holographic action, where the space component  $\sigma$  is integrated out, and only time component  $\tau$  remains.

The holographic action presented here shares similarities with the Polyakov action in string theory. However, our approach is more fundamental as it is derived from the holographic principle and does not presuppose the existence of strings. The EI spacetime can be viewed as the worldsheet of a fundamental string, and the physical spacetime as the target space. Our framework provides a deeper understanding of the origin and meaning of the worldsheet and its properties.

In the presence of a background field  $G^{\mu\nu}$  in physical space, the holographic action is:

$$A_h = i\alpha \int_0^T d\tau \int_0^L d\sigma G^{\mu\nu} \partial_\tau X_\mu \partial_\sigma X_\nu . \tag{7}$$

The holographic function  $\Psi_h$  now becomes:

$$\begin{aligned} & \Psi_h(X^\mu(L, T), G^{\mu\nu}(X^\mu(L, T))) \\ &= \sum_{\text{sum over possible } X_\mu \text{ and } G^{\mu\nu}} \exp\left[i\alpha \int_0^T d\tau \int_0^L d\sigma G^{\mu\nu} \partial_\tau X_\mu \partial_\sigma X_\nu\right]. \end{aligned} \quad (8)$$

The calculation of the holographic function  $\Psi_h$  is similar to the wave function but has a critical difference. The holographic function  $\Psi_h$  has a specific value. It represents the possible information encoded in a hologram from which a system is projected.

In this holographic quantum theory, all physical phenomena emerge from the hologram described by the holographic action and function. In our previous work [10], we show that this holographic action turns out to be the generalized action encompassing quantum physics, string theory, general relativity and thermodynamics. We show that all phenomena and laws of physics emerge from the holograms represented by the holographic action. Specifically, it indicates the following: 1) Elementary particles, gravity and gauge interactions and the classical equations of motion are the emergence of the hologram due to Poincaré symmetry, diffeomorphic symmetry and Weyl symmetry, respectively. 2) Dark matter and dark energy are the vibrations on the horizon scale of the universe. 3) Cosmological constant is calculated to be  $3 \times 10^{-122}$  in Planck unit, in agreement with the cosmological constant deduced from astrophysical observation 4) The observed spacetime is negatively curved if its dimension is greater than 4, positively curved if its dimension is less than 4, and flat if its dimension is 4. 5) It gives the mathematical formula to derive the entropy of black hole and study the internal dynamics of black hole. 6) It provides the mathematical framework to study the dynamics of spacetime compactification and the large hierarchy between Planck scale and electroweak scale. We suggest that the holographic quantum theory may be the unified theory that can solve some problems that are impossible to be addressed in Standard Model. Below, we will present a possible scheme based on this holographic quantum theory to explain the matter-antimatter asymmetry and the C, P, and CP symmetry violation in weak interaction SU(2) but not in other gauge interactions.

## 2.1. Supersymmetric Extension and Sector Separation

To incorporate fermions, we extend the model to a supersymmetric holographic framework with a 10-dimensional physical spacetime  $X_\mu$  ( $\mu = 0, 1, \dots, 9$ ) and corresponding fermionic counterparts ( $\psi^\mu$ ,  $\tilde{\psi}^\mu$ ). The 2D EI spacetime is extended to a superspace  $(\sigma, \tau, \theta_\sigma, \theta_\tau)$ , which can be expressed in conformal coordinates  $(z, \bar{z}, \theta, \bar{\theta})$  with:

$$\begin{aligned} \sigma^1 &= \sigma, \quad \sigma^2 = i\tau \\ z &= \sigma^1 + i\sigma^2, \quad \bar{z} = \sigma^1 - i\sigma^2 \\ \theta^1 &= \theta_\sigma, \quad \theta^2 = i\theta_\tau \\ \theta &= \theta^1 + i\theta^2, \quad \bar{\theta} = \theta^1 - i\theta^2. \end{aligned}$$

One usually calls  $z$  the holomorphic, left-moving, and  $\bar{z}$  the anti-holomorphic,

the right-moving part [8] [9].

In the superspace, the observable spacetime  $X^\mu(z, \bar{z}, \theta, \bar{\theta})$  includes both the bosonic spacetime  $X^\mu(z, \bar{z})$  and its fermionic counterpart  $\psi^\mu(z, \bar{z})$  and  $\tilde{\psi}^\mu(z, \bar{z})$ :

$$X^\mu(z, \bar{z}, \theta, \bar{\theta}) = x^\mu + \theta\psi^\mu + \bar{\theta}\tilde{\psi}^\mu + \theta\bar{\theta}F^\mu.$$

The term  $F^\mu$  is the auxiliary field, which can usually be eliminated through the equations of motion.

The holographic action with no background field is:

$$A_s[X, \gamma] = \alpha \int dz d\bar{z} d\theta d\bar{\theta} D_{\bar{\theta}} X^\mu D_\theta X_\mu. \tag{9}$$

here, the super-derivative  $D_{\bar{\theta}}$  and  $D_\theta$  is defined as:

$$D_\theta = \partial_\theta + \theta\partial_z, \quad D_{\bar{\theta}} = \partial_{\bar{\theta}} + \bar{\theta}\partial_{\bar{z}}.$$

After integrating over the fermionic coordinates  $(\theta, \bar{\theta})$ , the action (9) becomes [8] [9]:

$$A_2 = \alpha \int d^2z \left[ \partial_z X^\mu \partial_{\bar{z}} X_\mu + \psi^\mu \partial_{\bar{z}} \psi_\mu + \tilde{\psi}^\mu \partial_z \tilde{\psi}_\mu + F^\mu F_\mu \right]. \tag{10}$$

From the action (10), one can obtain the equations of motion:

$$\partial_z \partial_{\bar{z}} X_\mu = 0 \tag{11}$$

$$\partial_{\bar{z}} \psi_\mu = 0 \tag{12}$$

$$\partial_z \tilde{\psi}_\mu = 0 \tag{13}$$

The classical Equation (11) indicates that at the classical level, physical spacetime  $X_\mu$  contains two separate parts, one part only lives in holomorphic sector  $X^\mu(z)$  and the other part only lives in anti-holomorphic sector  $X^\mu(\bar{z})$ , *i.e.*,

$$X^\mu(z, \bar{z}) = X^\mu(z) + X^\mu(\bar{z}).$$

Equation (12) implies that the fermion  $\psi_\mu$  is a function of  $z$  only (holomorphic), while Equation (13) implies that fermion  $\tilde{\psi}_\mu$  is a function of  $\bar{z}$  only (anti-holomorphic). We propose that  $\psi_\mu$  represents matter and  $\tilde{\psi}_\mu$  represents antimatter. This natural separation of matter and antimatter into two distinct sectors is a key feature of our model and provides a compelling explanation for the observed matter dominance in the universe.

In the Dirac equation, antimatter naturally emerges as part of its solution—appearing as the complex conjugate of matter and residing in a distinct sector. This aligns seamlessly with our proposal and findings, offering further confirmation and corroboration. Indeed, our model provides a compelling interpretation: the seemingly mysterious sectors in the Dirac framework correspond to the holomorphic and anti-holomorphic domains, each hosting matter and antimatter respectively.

### 2.2. Interaction between Sectors

In the presence of background fields represented by the metric tensor  $G_{\mu\nu}$  and the

anti-symmetric tensor  $B_{\mu\nu}$ , which lead to the gravity and gauge interaction, respectively, the two sectors, the holomorphic sector  $\psi_\mu$  and anti-holomorphic sector  $\tilde{\psi}_\mu$  can interact. With these background fields, the holographic action  $A_2$  in the superspace becomes:

$$A_s[X, \gamma] = \alpha \int dz d\bar{z} d\theta d\bar{\theta} (G_{\mu\nu} + B_{\mu\nu}) D_{\bar{\theta}} X^\mu D_\theta X^\nu, \quad (14)$$

after integrating over the fermion coordinates  $(\theta, \bar{\theta})$ , the action becomes [8] [9]:

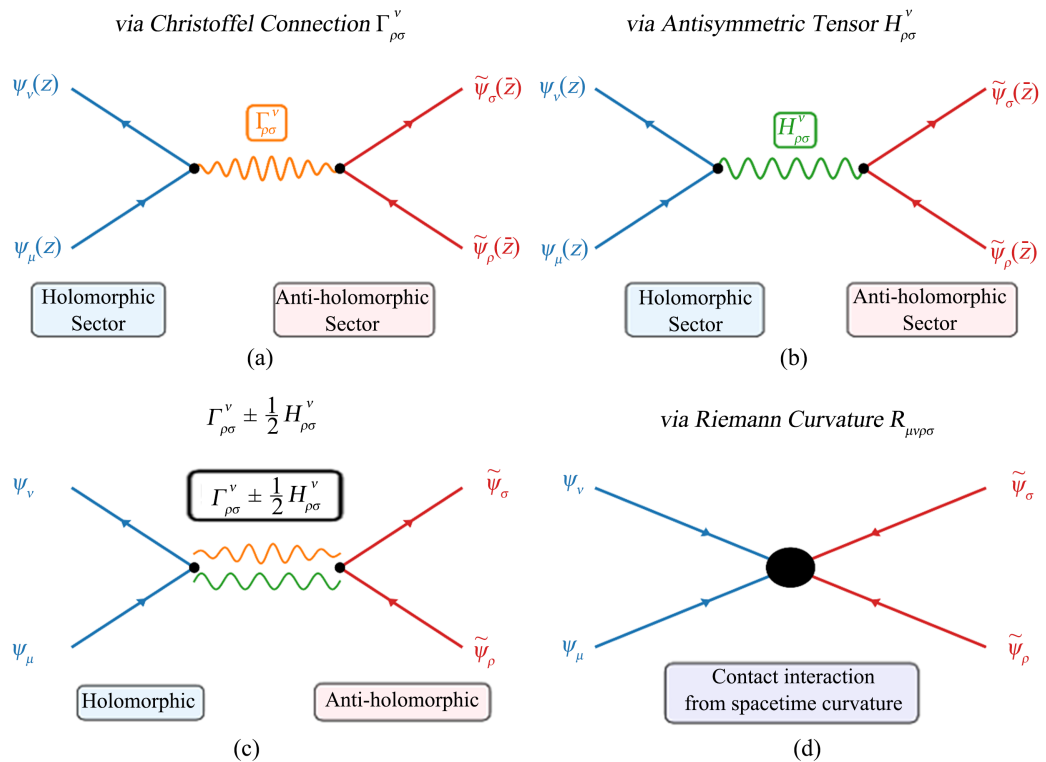
$$A_2 = \alpha \int dz d\bar{z} \left[ (G_{\mu\nu} + B_{\mu\nu}) \partial_z X^\mu \partial_{\bar{z}} X^\nu + G_{\mu\nu} (\psi^\mu D_{\bar{z}} \psi^\nu + \tilde{\psi}^\mu D_z \tilde{\psi}^\nu) + \frac{1}{2} R_{\mu\nu\rho\sigma} \psi^\mu \psi^\nu \tilde{\psi}^\rho \tilde{\psi}^\sigma \right]. \quad (15)$$

The covariant derivatives are:

$$D_{\bar{z}} \psi^\nu = \partial_{\bar{z}} \psi^\nu + \left[ \Gamma^{\nu}_{\rho\sigma}(X) + \frac{1}{2} H^{\nu}_{\rho\sigma}(X) \right] \partial_{\bar{z}} X^\rho \psi^\sigma, \quad (16)$$

$$D_z \tilde{\psi}^\nu = \partial_z \tilde{\psi}^\nu + \left[ \Gamma^{\nu}_{\rho\sigma}(X) - \frac{1}{2} H^{\nu}_{\rho\sigma}(X) \right] \partial_z X^\rho \tilde{\psi}^\sigma, \quad (17)$$

here,  $\Gamma^{\nu}_{\rho\sigma}(X)$  is the Christoffel connection. It is related to the gravitational interaction.  $H^{\nu}_{\rho\sigma}(X)$  is the anti-symmetric tensor field strength related to the gauge interaction. The  $\Gamma^{\nu}_{\rho\sigma}(X)$  Christoffel connection and  $H^{\nu}_{\rho\sigma}(X)$  bring about the interaction between the holomorphic and the anti-holomorphic fields, as illustrated below in **Figure 1**.



**Figure 1.** Illustrations of different forms of interactions between the matter and antimatter sectors. (a) Gravitational interaction; (b) Gauge interaction; (c) Combined interaction; (d) Four-fermion interaction.

Furthermore, the term  $\frac{1}{2}R_{\mu\nu\rho\sigma}\psi^\mu\psi^\nu\tilde{\psi}^\rho\tilde{\psi}^\sigma$  appearing in (15) also generates the interaction between the holomorphic and the anti-holomorphic fields. These interaction terms allow for the creation of antimatter in the matter-dominated holomorphic sector, consistent with experimental observations.

### 2.3. Effective Lagrangian

The holographic action  $A_s[X, \gamma]$  is invariant under the following three transformations [8]-[10]:

- 1) D-dimensional Poincaré transformation;
- 2) Diffeomorphism transformation;
- 3) Two-dimensional Weyl transformation.

Holographic action therefore has three symmetries: Poincaré symmetry, diffeomorphism symmetry, and Weyl symmetry. As we point out in [10], the emergence of elementary particles from the holographic action is due to Poincaré symmetry, emergence of the gravity and gauge force is due to diffeomorphism symmetry, and emergence of the classical equations of motion is due to the Weyl invariance.

The Weyl invariance is automatically preserved at the first order in holographic actions. However, higher-order corrections could possibly violate it. For instance, in string theory [8] [9], it is shown that there are the following second-order corrections to the string action:

$$\beta_{\mu\nu}^G = \alpha R_{\mu\nu} + \frac{\alpha}{4} H_{\mu\lambda\omega} H_\nu^{\lambda\omega} + O(\alpha^2), \tag{18}$$

$$\beta_{\mu\nu}^B = \frac{\alpha}{4} \nabla^\omega H_{\mu\lambda\omega} + O(\alpha^2). \tag{19}$$

The preservation of the Weyl Invariance at the higher orders requires the following:

$$\beta_{\mu\nu}^G = \beta_{\mu\nu}^B = 0.$$

It is notable that  $\beta_{\mu\nu}^G = 0$  leads to the generalization of Einstein’s equation with the source terms obtained from the anti-symmetric tensor. The equation  $\beta_{\mu\nu}^B = 0$  is the anti-symmetric generalization of Maxwell’s equations. By requiring the Weyl invariance, one can obtain the equations of motion for Einstein’s general relativity and gauge interactions. From the derived classical equation, one can obtain the effective Lagrangian:

$$S = \kappa \int d^D x (-G)^{1/2} \left[ R - \frac{1}{12} H_{\mu\nu\lambda} H^{\mu\nu\lambda} + \dots \right].$$

Notice, through calculating higher order corrections, one can obtain more equations of motion which may deduce the masses of particles, higher order interactions, and more.

### 2.4. Compactification

To derive the four-dimensional spacetime and the gauge interactions  $SU(3) \times$

$SU(2) \times U(1)$  of the Standard Model, we propose that the ten-dimensional spacetime ( $M = 0, 1, \dots, 9$ ) undergoes compactification into a four-dimensional physical spacetime, with six of the dimensions curled up at extremely small scales.

The idea of compactification was first introduced in the Kaluza-Klein framework as a scheme for unifying gravity with the electromagnetic force. In this approach, the familiar four-dimensional spacetime metric  $G^{\mu\nu}$  ( $\mu, \nu = 0, 1, 2, 3$ ) is extended to a five-dimensional spacetime  $G^{MN}$  ( $M, N = 0, 1, 2, 3, 4$ ). If the extra spatial dimension ( $M = 4$ ) is compactified—curled up so tightly that it cannot be observed—the resulting five-dimensional spacetime effectively reduces to four dimensions [8]-[10].

Under this compactification, the five-dimensional metric  $G^{MN}$  decomposes into [8] [9]:

- The four-dimensional spacetime metric  $G^{\mu\nu}$ ;
- A four-dimensional vector field  $A^\mu$  (interpreted as the electromagnetic potential);
- A scalar field  $\phi$ .

An invariant five-dimensional length element becomes:

$$ds^2 \equiv G^{MN} dx_M dx_N = G^{\mu\nu} dx_\mu dx_\nu + \phi^2 (A^\mu dx_\mu + dx_4)^2.$$

The field equations are derived from the five-dimensional Einstein equations together with the geodesic hypothesis. This procedure yields both the equations of general relativity and electrodynamics, thereby unifying the gravitational and electromagnetic fields within a single mathematical framework. Furthermore, the theory demonstrates that electric charge is quantized and directly related to the compactification scale.

In this paper, we propose a specific compactification and symmetry-breaking scheme in which all fermionic particles acquire  $SU(2)$  charge, at the same time, charge symmetry, parity symmetry, and CP symmetry are naturally broken within the  $SU(2)$  sector, while remaining intact in the  $U(1)$  and  $SU(3)$  sectors at leading order.

## 2.5. Boson/Fermion Condensation and Symmetry Breaking

Boson or fermion condensation and symmetry breaking involve boson or fermion particles forming collective states (condensates) that break underlying symmetries, leading to phenomena like superconductivity, superfluidity, and particle mass generation (Higgs mechanism) [20]-[26].

Boson condensates (like BEC) break symmetries (e.g.,  $U(1)$  for particle number), creating massless Nambu-Goldstone (NG) bosons (phonons) and massive gauge bosons. In fermion condensates, fermions pair up to form composite bosons (Cooper pairs), which then condense, creating an energy gap in the fermion spectrum (e.g., superconductivity). This breaks the  $U(1)$  gauge symmetry, giving mass to the “charged” excitations (Bogoliubov quasiparticles) and creating a collective mode (Higgs-like), which in turn gives mass to gauge bosons and fermi-

ons.

In our paper [10], we have discussed a compactification mechanism driven by bosonic condensation, which dynamically initiates the compactification and breaks supersymmetry (since some spacetime takes on specific value, this explicitly breaks supersymmetry). At lower energy scales, fermionic condensation further breaks the gauge symmetry to  $U(1) \times SU(2) \times SU(3)$ . As noted in [10], this dynamic symmetry-breaking scheme makes it possible to dynamically generate the large hierarchy between the electroweak scale and Planck scale, the Higgs bosons, the multigeneration of elementary particles, and even the masses of the gauge bosons and elementary particles from holographic action.

### 2.6. Mass Generation through Fermion Condensation

With the fermion condensation, the fermion mass, gauge field and Higgs boson can obtain mass. The interaction terms such as:

$$G_{\mu\nu}\psi^\mu \left[ \Gamma^{\nu}_{\rho\sigma}(X) + \frac{1}{2}H^{\nu}_{\rho\sigma}(X) \right] \partial_{\bar{z}}X^\rho\psi^\sigma$$

$$G_{ik}\tilde{\psi}^i \left[ \Gamma^{\nu}_{\rho\sigma}(X) - \frac{1}{2}H^{\nu}_{\rho\sigma}(X) \right] \partial_zX^\rho\tilde{\psi}^\sigma$$

brings about the interactive terms:

$$G_{\mu\nu}G_{ik} \left[ \Gamma^{\nu}_{\rho\sigma}(X) + \frac{1}{2}H^{\nu}_{\rho\sigma}(X) \right] \partial_{\bar{z}}X^\rho \left[ \Gamma^{\nu}_{\rho\sigma}(X) - \frac{1}{2}H^{\nu}_{\rho\sigma}(X) \right] \partial_zX^\alpha\psi^\sigma\psi^\mu\tilde{\psi}^\beta\tilde{\psi}^i$$

and the term:  $\frac{1}{2}R_{\mu\nu\rho\sigma}\psi^\mu\psi^\nu\tilde{\psi}^\rho\tilde{\psi}^\sigma$ .

The fermion condensation brings the coupling of fermion and anti-fermion,  $\psi^\mu\tilde{\psi}^\beta$ . This coupled fermion-antifermion can serve as Higgs boson. This Higgs boson can generate the mass terms to gauge fields, to fermions, and to the Higgs boson through the terms above.

Notice that the mass generating terms through gauge interaction are proportional to  $\partial_zX^\alpha\partial_{\bar{z}}X^\rho$ . From the study of string theory, we know that:

$$X^\alpha = x^\alpha + p_L^\alpha z + p_R^\alpha \bar{z} + i \left( \frac{1}{\pi\alpha} \right)^{1/2} \sum_{\substack{n=-\infty \\ n \neq 0}}^{\infty} \frac{1}{n} \left[ \alpha_n^\alpha \exp(-i\pi n z) + \tilde{\alpha}_n^\alpha \exp(-i\pi n \bar{z}) \right].$$

When some of the space coordinates are compactified,  $p_L^\alpha$  or  $p_R^\alpha$  are quantized. This means that the mass term is proportional to the product of integer  $mn$ , with  $m$  and  $n$  being integers. This leads to the creation of a series of generations of fermions. This can explain the existence of generations for fermions, with the generation not necessarily limited to 3.

### 3. Results: Matter-Antimatter Asymmetry and the Origin of CP Violation

Building on the holographic framework, we now present the model that explains the observed matter-antimatter asymmetry and the origin of CP violation.

### 3.1. Matter-Antimatter Asymmetry

According to our proposal, Equations (11), (12), and (13) indicate that in free spacetime—absent of gravity and gauge interactions—matter and antimatter, represented by  $\psi_\mu(z)$  and  $\tilde{\psi}_\mu(\bar{z})$ , reside in distinct domains: the holomorphic and anti-holomorphic sectors, respectively. In the presence of background fields associated with gravity and gauge interactions, however, Equation (15) demonstrates that the matter and antimatter sectors can interact through gravitational and gauge couplings, represented by  $\Gamma^\nu_{\rho\sigma}(X)$  and  $H^\nu_{\rho\sigma}(X)$  and the interaction terms,  $R_{\mu\nu\rho\sigma}(X)\psi^\mu\psi^\nu\tilde{\psi}^\rho\tilde{\psi}^\sigma$  enabling antimatter to emerge within the holomorphic universe and matter within the anti-holomorphic one. This dynamic interplay reflects the phenomena observed in nature.

From this perspective, the model naturally places matter and antimatter in separate universes. It provides a compelling explanation for why our observable universe consists predominantly of matter, with antimatter appearing only through interaction-driven processes. Each realm is governed by its own holomorphic or anti-holomorphic structure, and their separation accounts for the observed asymmetry between matter and antimatter.

At the same time, the permeability between these domains—manifested in the emergence of antimatter within the holomorphic sector and matter within the anti-holomorphic one—illustrates a subtle interplay that aligns with physical observations. This duality evokes a deeper symmetry, suggesting that the apparent imbalance may in fact represent a hidden equilibrium across complementary domains. In this way, the framework not only explains the dominance of matter in our universe but also situates it within a broader, symmetric structure that unifies matter and antimatter across distinct yet interconnected realms.

### 3.2. Compactification and the Origin of Gauge Symmetries

We propose that our 4-dimensional spacetime, gravity, and  $SU(3) \times SU(2) \times U(1)$  gauge interactions are the result of a compactification from a 10-dimensional spacetime. Six of these dimensions are compactified, giving rise to the gauge symmetries  $SU(3) \times SU(2) \times U(1)$  of the Standard Model. The compactification scheme is as follows:

- Four of the ten spacetime dimensions remain uncompactified, corresponding to the observed 4-dimensional spacetime.
- The remaining six dimensions are compactified in a structured manner:
- One compactified dimension gives rise to the  $U(1)$  gauge interaction  $\alpha$ ,
- Two compactified dimensions generate the  $SU(2)$  gauge interaction  $\delta$ ,
- Three compactified dimensions produce the  $SU(3)$  gauge interaction  $\zeta$ .

In this case,  $G^{MN}(M, N = 0, 1, \dots, 9)$  decomposed into spacetime matrix in 4-dimensional spacetime, gauge interaction fields, and some additional fields. The fermions  $\psi^M$  and  $\tilde{\psi}^M$  are now decomposed into:  $\psi^{\mu\alpha\delta\zeta}$  and  $\tilde{\psi}^{\mu\alpha\delta\zeta}$ . Here,  $\mu$  expresses the coordinates in 4-dimensional space,  $\alpha$  expresses the indices in  $U(1)$

gauge interaction,  $\delta$  expresses the indices in SU(2) gauge interaction, and  $\zeta$  expresses the indices in SU(3) gauge interaction. If a fermion does not have  $\alpha$ ,  $\delta$  or  $\zeta$  indices, it means that it does not transform under U(1), SU(2) or SU(3) gauge group, *i.e.*, it does not have U(1), SU(2) or SU(3) charge, respectively.

### 3.3. Universality of SU(2) Gauge Interaction

We propose that the SU(2) gauge interaction is unique because the two compactified dimensions giving rise to it are the direct projections of the 2D EI spacetime. Since all fields are fundamentally defined on the EI spacetime, all elementary particles must carry SU(2) charge. In contrast, the other compactified dimensions are “extra”, and particles need not have coordinates in these dimensions, explaining why not all particles carry U(1) or SU(3) charge.

### 3.4. The Origin of CP Violation in the SU(2) Gauge Sector

The origin of CP violation in our model is tied to the structure of the Lorentz group in 4-dimensional spacetime, which is isomorphic to  $SU(2) \times SU(2)$  [27]. We propose that the weak SU(2) gauge group is identified with one of these SU(2) groups. This identification leads to a natural asymmetry in the transformation properties of matter and antimatter.

Specifically, matter particles (in the holomorphic sector) transform as doublets under the first SU(2) group but the singlet under the second SU(2) group, while antimatter particles (in the anti-holomorphic sector) transform as singlets under this group but a doublet under the second SU(2) group. This is summarized in **Table 1** below, which compares our model to the Standard Model.

**Table 1.** Comparison of SU(2) representation of matter and antimatter in holographic model and Standard Model.

Particle Type	Representation in Our Model (Under Weak SU(2))	Standard Model Representation (Left-Handed)
Matter (e.g., quarks, leptons)	Doublet in the first SU(2) and singlet in the second SU(2)	Doublet
Antimatter (e.g., antiquarks, antileptons)	Singlet in the first SU(2) and doublet in the second SU(2)	Singlet

This inherent asymmetry in the gauge representation of matter and antimatter under the weak SU(2) group is the source of C, P, and CP violation in the weak interaction. Other gauge interactions, such as U(1) and SU(3), do not share this connection to the Lorentz group structure and thus do not exhibit CP violation at the leading order.

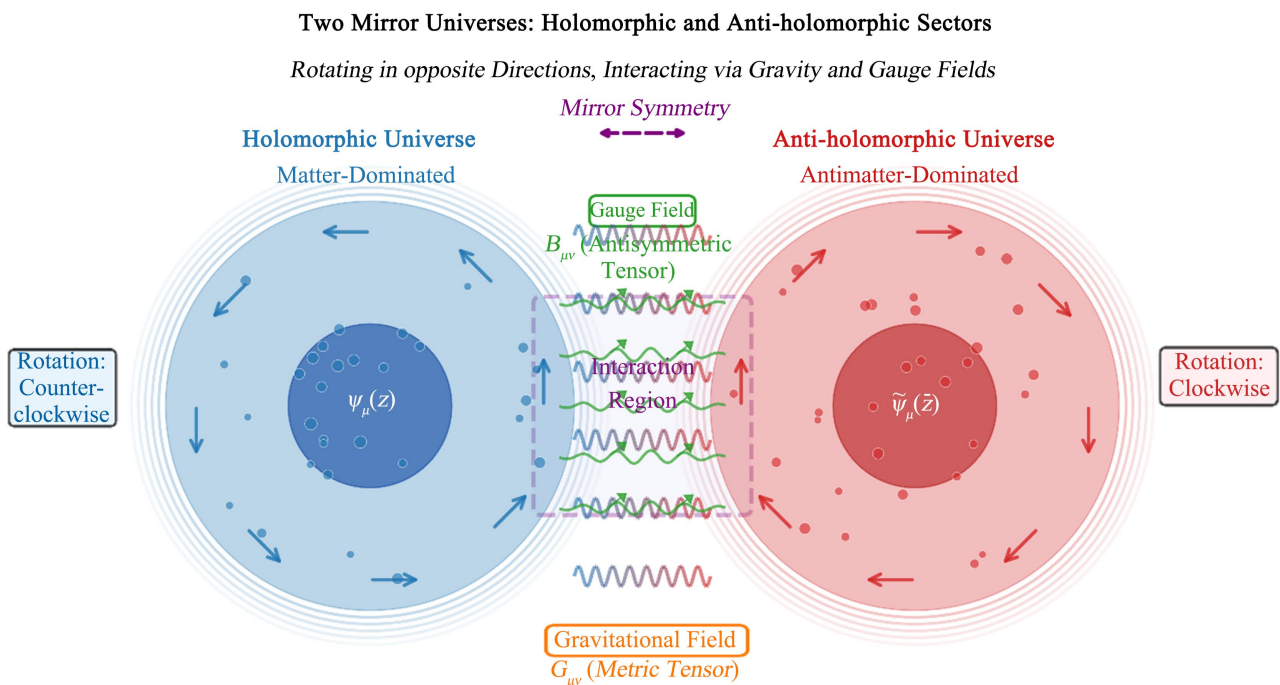
This framework provides a natural explanation for the observed CP violation in weak interactions and the CP symmetry in electromagnetic and strong interactions.

## 4. Quantitative Predictions and Experimental Signatures

While the theory is still in development, it offers several avenues for quantitative predictions and experimental tests that can distinguish it from other models.

### 4.1. Mirror Universe Signatures

The prediction of a parallel mirror universe composed of antimatter is a key feature of our model, as illustrated in **Figure 2** below. While this universe is largely decoupled from ours, it can interact with our universe through gravity and gauge fields.



**Figure 2.** Conceptual illustration of the prediction of the existence of the two mirror universes and the interaction between them.

This could lead to several observable signatures:

- **Gravitational Lensing:** The gravitational field of the mirror universe could affect the propagation of light in our universe, leading to anomalous gravitational lensing effects.
- **Cosmic Microwave Background (CMB):** The mirror universe could leave an imprint on the CMB, leading to specific anisotropies that could be detected by future CMB experiments.
- **Dark Matter and Dark Energy:** The mirror universe could contribute to the observed dark matter and dark energy density. The particles in the mirror universe would interact with our universe primarily through gravity, making them a natural dark matter and dark energy candidate.

These potential signatures provide a rich phenomenology that can be explored in future astrophysical and cosmological observations. We will refer to a more detailed discussion and calculation for the future work.

## 4.2. Neutrino Mass Generation

The holographic framework presented here may also provide new insights into the origin of neutrino mass, one of the most puzzling aspects of particle physics [28]-[30]. In the Standard Model, neutrinos are massless, but experimental observations of neutrino oscillations have confirmed that neutrinos do possess small but finite masses. The mechanism by which neutrinos acquire mass remains an open question.

Our holographic model predicts the existence of right-handed anti-neutrino in the mirror universe. This right-handed anti-neutrino is a  $SU(2)$  singlet. It does not directly interact with neutrino through  $SU(2)$ . However, our model predicts their interaction through gravity expressed by the term such as

$\frac{1}{2}R_{\mu\nu\rho\sigma}(X)\psi^\mu\psi^\nu\tilde{\psi}^\rho\tilde{\psi}^\sigma$  in (15). This also provides a natural mechanism for generating small neutrino masses or neutrino oscillation. It could lead to deriving a specific mass hierarchy and mixing pattern for neutrinos. The smallness of the neutrino mass is naturally explained by the suppressed interaction between the two sectors. All of these predictions can be tested in future neutrino oscillation experiments.

## 4.3. Other Predictions

This model can also be applied to study the dynamics of the Big Bang and to prediction of the observed baryon-to-photon ratio ( $\eta \approx 6 \times 10^{-10}$ ). A precise calculation would require a detailed model of the compactification and the symmetry-breaking scales, but our model provides a clear path to such a calculation.

## 5. Discussion

The holographic model presented in this paper offers a novel and unified approach to several long-standing problems in fundamental physics. By grounding the theory in the holographic principle, we have developed a framework that not only provides a natural explanation for the observed matter-antimatter asymmetry and the origin of CP violation but also offers a deeper understanding of the structure of the Standard Model itself.

One of the most significant results of our model is the natural separation of matter and antimatter into distinct holomorphic and anti-holomorphic sectors. This provides a compelling explanation for the observed matter dominance in our universe, a problem that has been a major challenge for cosmological models. **Table 2** below provides a comparative analysis of our model with the Standard Model and other baryogenesis mechanisms.

The explanation for the exclusive C, P, and CP violation in the weak interaction is another major strength of our theory. By linking the weak  $SU(2)$  gauge group to the structure of the Lorentz group, our model provides a fundamental reason for this asymmetry, in contrast to the Standard Model, where it is an ad-hoc feature.

**Table 2.** Comparative analysis of holographic model with the Standard Model and other baryogenesis mechanisms.

Feature	Standard Model	Other Baryogenesis Mechanisms (e.g., Leptogenesis)	Holographic Model
<b>Matter-Antimatter Asymmetry</b>	Explained by CP violation in the CKM matrix, but the effect is too small.	Postulates new particles and interactions to generate a lepton asymmetry, which is then converted to a baryon asymmetry.	Matter and antimatter are intrinsically separated into two sectors. The observed asymmetry is a natural consequence of this separation.
<b>Origin of CP Violation</b>	A fundamental parameter in the CKM matrix, with no explanation for its origin or value.	Introduced through new complex phases in the couplings of new particles.	Arises from the fundamental structure of the Lorentz group in 4D spacetime and the identification of the weak SU(2) group with one of its SU(2) subgroups.
<b>Universality of Weak Charge</b>	An observational fact with no theoretical explanation.	Does not address this question.	Explained by the proposal that the SU(2) gauge interaction arises from the projection of the fundamental 2D EI spacetime.

The proposed holographic framework also aligns well with the principles of quantum information theory, which has been a fruitful area of research in fundamental physics. The idea that physical spacetime itself is an emergent property of a more fundamental informational structure is a recurring theme in modern theoretical physics, and this work provides a concrete and well-developed model that realizes this idea.

However, the theory is still in its early stages of development, and further work is needed to fully explore its consequences and test its predictions. One of the immediate studies is to derive the full Standard Model from this holographic model. While the paper provides a plausible mechanism for the emergence of the U(1), SU(2), and SU(3) gauge groups, a detailed derivation of the particle content of the Standard Model, including the masses and mixing angles of the quarks and leptons, is a necessary next step. It would also be interesting to conduct a more detailed analysis within the context of the current model to derive the large hierarchy between Planck scale, grand unification scale, and electroweak scale and deduce the Standard Model, including the masses of elementary particles. We will refer this to the future work.

## 6. Conclusions

In this paper, we have presented a novel framework based on a holographic unified theory that provides a natural and direct explanation for the observed matter-

antimatter asymmetry and the origin of CP violation. By proposing that matter and antimatter reside in separate holomorphic and anti-holomorphic sectors of a universe projected from a 2D elementary information spacetime, our model resolves the puzzle of matter's dominance in our observed universe. The theory also explains the universality of the SU(2) weak charge and the exclusive nature of C, P, and CP violation in the weak interaction, deriving these features from the fundamental structure of spacetime and the Lorentz group without the need for ad-hoc assumptions or fine-tuning.

While the theory is promising, it is still in its early stages. Future work will focus on developing the model further, including a detailed derivation of the Standard Model particle spectrum and a thorough investigation of its experimental signatures. The ideas presented in this paper open up new avenues for research and offer a fresh perspective on the fundamental laws of nature. We are hopeful that this work will stimulate further investigation into the holographic principle and its potential to unify our understanding of the universe.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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