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Review

Global Realism with Bipolar Strings: From Bell Test to Real-World Causal-Logical Quantum Gravity and Brain-Universe Similarity for Entangled Machine Thinking and Imagination

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Abstract: Following Einstein's prediction that "*Physics constitutes a logical system of thought*" and "*Nature is the realization of the simplest conceivable mathematical ideas*", this topical review outlines a formal extension of *local realism* limited by the speed of light to *global realism with bipolar strings (GRBS)* that unifies the principle of locality with quantum nonlocality. The related literature is critically reviewed to justify GRBS which is shown as a necessary and inevitable consequence of the Bell test and an equilibrium-based axiomatization of physics and quantum information science for brain–universe similarity and human-level intelligence. With definable causality in regularity and mind–light–matter unity for quantum superposition/entanglement, *bipolar universal modus ponens (BUMP)* in GRBS makes quantum emergence and submergence of spacetime logically ubiquitous in both the physical and mental worlds—an unexpected but long-sought simplification of quantum gravity with *complete background independence*. It is shown that GRBS forms a basis for *quantum intelligence (QI)*—a spacetime transcendent, quantum–digital compatible, analytical quantum computing paradigm where bipolar strings lead to *bipolar entropy* as a nonlinear bipolar dynamic and set–theoretic unification of order and disorder as well as linearity and nonlinearity for energy/information conservation, regeneration, and degeneration toward *quantum cognition and quantum biology (QCQB)* as well as information-conservational blackhole keypad compression and big bang data recovery. Subsequently, GRBS is justified as a *real-world quantum gravity (RWQG)* theory—a bipolar relativistic causal–logical reconceptualization and unification of string theory, loop quantum gravity, and M-theory—the three roads to quantum gravity. Based on GRBS, the following is posited: (1) life is a living bipolar superstring regulated by *bipolar entropy*; (2) thinking with consciousness and memory growth as a prerequisite for human-level intelligence is fundamentally mind–light–matter unitary QI logically equivalent to quantum emergence (entanglement) and submergence (collapse) of spacetime. These two posits lead to a positive answer to the question "*If AI machine cannot think, can QI machine think?*". *Causal–logical brain modeling (CLBM)* for *entangled machine thinking and imagination (EMTI)* is proposed and graphically illustrated. The testability and falsifiability of GRBS are discussed.

Keywords: bipolar universal modus ponens (BUMP); global realism with bipolar strings (GRBS); axiomatization of physics and quantum information science; complete background independence; bipolar quantum graphs for entangled neural networks; causal–logical brain modeling (CLBM); quantum cognition and quantum biology (QCQB); mind–light–matter unity AI and QI; bipolar entropy; god/nature logic vs. human/mind logic; lost but found miracle

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1. Introduction

Modern science holds many unsolved mysteries. One mystery is that machine learning can use powerful computation for significant commercial applications, but AI machines are widely deemed unable to reach human-level intelligence—a kind of biological intelligence (BI). Another mystery is that scientific reports have shown striking similarities between the

human brain and the universe in structural organization, which has perplexed scientists with suspicion.

The 2022 Nobel Prize in Physics [1] was awarded jointly to three Nobel Laureates "*for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science*". The Nobel award is epoch-making as it is the most authoritative vindication of quantum entanglement that formally opened the door to quantum information science on the long march toward ***real-world quantum gravity (RWQG)*** for ***quantum cognition and quantum biology (QCQB)***—a step forward to quantum intelligence (QI) for human-level AI to resolve the brain–universe similarity puzzle.

Being most authoritative, the Nobel Prize vindicated Bell inequality violation but also led to a new mystery. Since quantum entanglement defied Einstein's locality and causality principle of realism limited by the speed of light, the Prize has been deemed by some scientists as the conclusion of the great debate of the 20th century: *Niels Bohr won, and Einstein lost*. The problem is that, without causality and realism, quantum entanglement would be unreal—the greatest mystery in science and philosophy that entails a causal–logical quantum gravity theory missing from mainstream quantum theories.

It is asserted [2] that *"The causality principle had been and will still be the cornerstone of science. Without cause–effect science would be religion. Specifically, the causality of quantum entanglement must be made clear in both experimental and logical terms. If it is not an effect of* ***local realism*** *limited by Einstein's speed of light, it must be an effect of* ***global realism*** *with logically definable causality that unifies local and global realities. . . .".* Thus, the term ***"global realism"*** is coined as a prediction in physics for the unification of Einstein's local realism with Bohr's quantum nonlocality which leads to this topical review. (Note: The term *"Platonic* ***global realism****"* appeared in an earlier paper [3]).

It is a common view that without machine thinking [4] there would be no adaptive machine learning for human-level AI [5]. While cutting-edge AI technologies have been focused on machine learning from big data for commercial applications, they came short of reaching logically definable causality and mind–light–matter unity for entangled, quantum–digital compatible, and analytical machine thinking for QI [6]. Notably, the logical road to human-level intelligence leads to a dead-end [7]. It can be argued, however, that the so-called "dead-end" is the end of truth-based, being-centered, unipolar, human/mind logic [8] for symbolic AI in the classical world but not the end of Spinoza–Einstein's God/Nature logic for entangled QI that could be YinYang bipolar equilibrium-based in nature and entails open-world, open-ended exploration [2,6,9]. Thus, Einstein's assertion that physics constitutes a logical system of thought and the strikingly similar images of the human brain and the universe in structural organization [10] lead us to the valid questions: *Could human thinking as a brain function be logically equivalent to spacetime emergence and submergence through quantum entanglement/collapse? Could truth-based AI and BI be revealed by equilibrium-based QI?*

Based *on* ground-0 axioms [6] that unify the first principles and the second law, this work critically reviews the related literature on realism and extends Einstein's *local realism* limited by the speed of light to the formal theory of ***global realism with bipolar strings (GRBS)***. GRBS introduces real-world ***bipolar strings*** [2,6,9,11–42] into realism with equilibrium-based, logically definable causality in regularity [9,11]. Supported by QI and mind–light–matter unity, GRBS is shown applicable in entangled machine thinking and imagination. Figure 1 shows the distinction between QI, AI, and BI that brings up the question [2] *"If AI machine cannot think, can QI machine think?"*. GRBS is used to provide an answer to the question.

It is shown that GRBS constitutes a real-world bipolar relativistic logical reconceptualization of string theory [43–46] loop quantum gravity (LQG) [47–49], and M-theory [46] toward a grand unification of general relativity and quantum mechanics with much-needed, long sought, but unexpected simplification. The simplification follows Einstein's predictions *"pure thought can grasp reality"* and *"Nature is the realization of the simplest conceivable mathematical ideas"* (re. [50–58]).

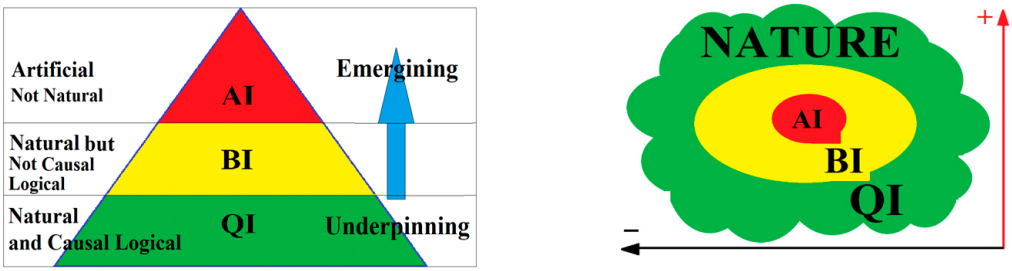


Figure 1. Quantum Intelligence (QI) as natural underpinning of artificial intelligence (AI) and biological intelligence (BI) (adapted from [2]): (**a**) three-layer closed view; (**b**) three-layer open world.

In physics, string theory as a theoretical framework replaced the point-like particles of particle physics with unipolar one-dimensional objects called strings. The theory describes how these strings propagate through space and interact with each other without definable or testable causality. Notably, it used to be the dominating theory of modern physics for years. It was once believed the theory of everything (TOE). Now the theory has faded significantly due to its lack of scalability and testability. It has been criticized as *"not even wrong"* [59], *"trouble with physics"* [60], and *"lost in math"* [61].

While strings are unipolar and truth-based, GRBS is an equilibrium-based bipolar dynamic string theory for a super symmetrical grand unification of Nature, agents, and causality [9,11,18,21,22]. While strings are not logical and not testable, ***bipolar strings*** as scalable dipoles such as input–output, action–reaction, and particle–antiparticle pairs are logical and observable everywhere in both the classical and quantum worlds as well as in the physical and mental worlds. (Remark: following [6], $\beta+$ and $\beta-$ decay are taken in this work as part of Nature's "encryption" mechanism to conceal a positron in a proton to prevent its annihilation with an electron—a logical interpretation of matter–antimatter asymmetry.)

The aim of this work is to present GRBS as a logically different real-world unified field theory that reveals truth-based local reality with bipolar equilibrium-based QI. It is stated in [6] that the equilibrium-based mathematical abstraction assumes bipolar quantum agents (BQAs) in bipolar dynamic equilibria (BDEs) as its ontological basis that is extended to ***bipolar strings*** [9,11,18,21,22]. Fundamentally, bipolar strings as BDEs/BQAs are bipolar variables with bipolar values including but not limited to the basic states:

(i) Non-equilibrium state: $(-1, 0)$; //e.g., particle such as electron;
(ii) Non-equilibrium state: $(0, +1)$; //e.g., antiparticle such as positron;
(iii) Equilibrium state: $(-1, 0)\oplus(0, +1) = (-1, +1)$; //e.g., superposition/entanglement;
(iv) Non-existence: $(-1, 0)\&(0, +1) = (0, 0)$. //e.g., electron-positron annihilation.

Notably, a photon is its own antiparticle which can be in any of the four states, and electron–positron annihilation releases two photons. It is shown in [6] that a photon as a BQA provides a logically definable interpretation of quantum superposition/entanglement and leads to an analytical extension of quantum mechanics named QI for mind–light–matter unity AI.

Assuming that bipolar strings can be entangled and collapsed, GRBS further extends BQAs to a graphically visualizable causal–logical brain–universe similarity model with formal logically definable causality for mind–light–matter unity AI&QI [6,26–31]. It is shown that GRBS constitutes a philosophically different logical theory for quantum gravity and quantum information science [11] with hope for the ***lost but found miracle*** which states "*Lost in the beauty of truth-based singularity but found in the harmony of equilibrium-based bipolar relativity*".

Since acceleration is equivalent to gravitation under general relativity [51,52], any physical, logical, socioeconomic, mental, or biological acceleration, growth, or degeneration with creative thinking is qualified to be a kind of quantum gravity [9,21]. Thus, causal–

logical quantum gravity leads to entangled machine thinking and imagination, a quantum extension of the resonant brain model [62–64].

Based *on* ground-0 axioms [6], GRBS starts with the following postulates:

Postulate 1. ***Negative–Positive (−, +) bipolarity*** *is the most fundamental property of the universe,* ***bipolar dynamic equilibrium (BDE)*** *(including both equilibrium and non-equilibrium states) of (−, +)* ***bipolar energy/information*** *is the fundamental regulating power of the universe and the human brain, from which spacetime emerges, and truths in spacetime are revealed. Without BDE the human brain cannot distinguish truth from falsity, and the universe cannot exist.*

Postulate 2. *Gravitational* ***action–reaction****, electromagnetic* ***particle–antiparticle,*** *or any* ***energy/information input–output bipolarity*** *is logically a BDE—a bipolar unification of all basic forces and matters discovered or to be discovered; a BDE can be characterized by a bipolar logical or algebraic variable in a bipolar lattice {−1, 0} × {0, +1}, [−1, 0] × [0, +1], or [−∞, 0] × [0, +∞]* [6].

Postulate 3. *If* ***quantum gravity*** *is the grand unification, it must be a (−, +) bipolar unified field that forms a global* ***bipolar quantum entanglement (BQE)*** *where a* ***bipolar quantum agent (BQA)*** *or* ***bipolar string*** *as a quantum entanglement or superposition can form or collapse without the speed of light limitation at the generic or most fundamental level.*

Postulate 4. *Mind–light–matter unity is logically reachable with bipolar dynamic logic (BDL), bipolar dynamic fuzzy logic (BDFL), bipolar quantum linear algebra (BQLA), and bipolar quantum geometry (BQG) based on: (i) mind–light–matter in the forms of BDEs or bipolar strings form a unified field of physics and biophysics from which truths are revealed; (ii) BQG and BDL have been proven the geometry of light and the logic of photon, respectively; (iii) mind and matter are bridged by light in the form of bio-photonics/bioelectronics; (iv) bipolar universal modus pones (BUMPs) provides logically definable causality in regularity for bipolar reciprocal interaction and quantum superposition/entanglement. (Note: For detailed examples, readers are referred to* [6]*).*

The four postulates provide an equilibrium-based, bipolar dynamic logical basis for the unification of general relativity and quantum theory with or without graviton–antigraviton and dark matter or energy fully tested. Based on the logical basis, photons and electrons can be bipolar quantum entangled because (1) a photon, as its own antiparticle, is itself a BDE [6]; (2) an electron, as an electromagnetic particle, is part of particle–antiparticle (−, +) bipolarity; (3) any massive/massless pair may form a gravitational action–reaction or input–output pair including but not limited to dark matter and energy. Thus, with bipolar relativity or bipolar string theory [9,18], not only should GRBS be applicable in physical science, but also in computing/information science, brain science, life science, and social economics as well. This argument leads GRBS to a RWQG theory with ***(i) physical quantum gravity, (ii) logical quantum gravity, (iii) mental quantum gravity, (iv) biological quantum gravity, and (v) social quantum gravity*** [9,21].

It is proven that GRBS is an inevitable consequence of Bell inequality violation shown in Bell tests and a bipolar relativistic ***axiomatization of physics and quantum information science***. On the one hand, GRBS provides a trouble-free real-world bipolar logical unification of string theory, loop quantum gravity (LQG), and M-theory—the three roads toward quantum gravity [65]; on the other hand, it provides a generalized basis for ***mind–light–matter unity AI&QI*** machinery [6]. It is shown that the key to a trouble-free testable solution lies in background-independent logically definable causality for bipolar equilibrium-based revealing of truths with quantum emergence and submergence of spacetime [6,9,20,23–25,27,28].

Following this introduction, the remaining work is organized as follows:

Section 2 presents a review of Einstein's principle of locality, realism, and the search for causality.

Section 3 presents GRBS as a real-world causal–logical theory of quantum gravity with ***bipolar entropy*** and QCQB. It is shown that GRBS is an inevitable consequence of the Bell test or Bell's inequality violation that constitutes a background-independent, equilibrium-

based, bipolar set-theoretic, spacetime transcendent dynamic paradigm of physics and quantum information science for mind–light–matter unity QI—an analytical paradigm of quantum computing.

Section 4 presents a logically testable application of GRBS in causal–logical brain modeling for machine thinking and imagination.

Section 5 presents an analysis and discussion. It is shown that GRBS provides a bipolar axiomatization of physics and quantum information science with a background independent reconceptualization and unification for real-world quantum gravity. Testability and falsifiability are discussed.

Section 6 draws a few concluding remarks with distinctions.

2. Locality and Causality with Irregularity

2.1. The Principle of Locality or Local Realism

In physics, the *principle of locality* asserts that an object is influenced directly only by its immediate surroundings. Thus, "local theory" does not agree with quantum nonlocality. Locality evolved from classical field theories which assert that, for any causal action at one point to have an effect at another point, something between those points must mediate the action. To exert an influence, a wave or particle must travel through the space between the two points, carrying the influence.

In 1905 Albert Einstein's special theory of relativity [50] postulated that no material or energy can travel faster than the speed of light. This is the well-known *principle of locality*, which is also widely called *the principle of realism*. The principle limits any cause–effect relation between two points by the speed of light. Therefore, the principle of locality implies that an event at one point A cannot cause a simultaneous result at another point B in a time t less than $t = d/c$ where d is the distance between the two points and c is the speed of light in vacuum. Einstein later extended his special theory of relativity to the general theory of relativity, which still obeys the principle of locality [51,52].

The theory of quantum mechanics presents a challenge to the principle of locality. Einstein himself had helped to create the quantum theory. In 1935, in their EPR paper [57], the authors theorized that quantum mechanics might not be a local theory, because a measurement made on one of a pair of separated but entangled particles causes a simultaneous effect. Specifically, the collapse of the wave function as an effect exceeds the speed of light. If it is not local, it should be part of a global theory. However, Niels Bohr asserted that a causal description of a quantum process cannot be attained, and quantum mechanics must content itself with particle–wave complementary descriptions [66]. Thus, Bohr set up an insurmountable limitation on the definability of causality for quantum nonlocality until logically definable causality was formally defined with ***bipolar universal modus ponens (BUMP)*** for quantum entanglement [9,16–18] that made ***global realism*** possible.

Because of the probabilistic nature of wave function collapse, its violation of locality was once believed unable to transmit information faster than light. So, the EPR paradox challenged Bohr's Copenhagen interpretation with a thought experiment on quantum entanglement. Einstein once called quantum entanglement *"spooky action at a distance"* and argued that *"God does not play dice with the universe"*. That triggered the great debate of the 20th century with Bohr's tit for tat: *"Stop telling God what to do (with his dice)"*.

2.2. Truth-Based Causality—Experimental but Formally Undefinable in Regularity

According to Ben–Menahem [67], Einstein's concept of causality is comprised of (a) regularity; (b) locality; (c) symmetry considerations leading to conservation laws; (d) mutuality of causal interaction. It is well known that Einstein refused to accept Bohr's interpretation of quantum mechanics as a complete theory for its lack of causality for quantum nonlocality. However, after wrestling with definable causality for his entire life, Einstein's truth-based locality stopped short of reaching logical definability for causality, and modern science including classical and quantum mechanics (QM) has been relying on systematic experiments to find causal relationships.

Based on singularity and partial observability of truth-based reasoning, it is now a widely accepted theory that spacetime as well as the universe was created by a big bang and will end in one or more black holes. As far as we know, however, the Big Bang came from nowhere and was caused by nothing; a black hole goes nowhere [68]. To reconcile the inconsistency between singularity and the second law of thermodynamics, as critiqued in [69], Stephen Hawking proposed the remedy that a black hole should have particle and/or antiparticle emission or Hawking radiation [70,71].

It is noted ([9] Ch1) that, while Hawking radiation has been a hot topic of discussion in quantum theory, its far-reaching consequence was overlooked. The consequence is that, when the universe ends, matter–antimatter pairs will miraculously survive. Therefore, singularity is not a contradiction but a vindication of YinYang bipolarity—the only property that can survive the Big Bang and black hole singularity to provide equilibrium-based background-independence, logically definable causality, symmetry, and reciprocal interaction or mutuality. Notably, the vindication has been overlooked in science.

Notably, Bohr's YinYang in QM asserted "*Opposites are Complementary*" [66] (Figure 2, words in Latin). But Bohr's YinYang was based on truth–falsity, particle–wave, or real–imaginary that stopped short of reaching strict (−, +) bipolar opposites. Without strict bipolarity, truth-based unipolar logic and geometry failed to reach geometrical background independence and logically definable causality for spacetime emergence and submergence since ancient Greek times. It was reasonable to believe that the unfound logical foundation or axiomatization of physics sought by Hilbert [72] and Einstein [54] could be holding the key to quantum causality, quantum gravity, and quantum intelligence. *Could there be a formal YinYang bipolar causal–logical system hidden behind Niels Bohr's YinYang logo that could serve as a breakthrough to his own limitation on the definability of causality* [66]?



Figure 2. Particle–wave or real–imaginary complementarity: Bohr's coat of arms (Creative Commons file by GJo, 3 August 2010, Source: File: Royal Coat of Arms of Denmark.svg (Collar of the Order of the Elephant) + File: yinyang.svg).

2.3. Axiomatizing Physics—The Unreachable Goal with Truth-Based Thinking

Einstein wrestled with definable causality for his whole life searching for a logical foundation for physics. He stated [54]: "*Development of Western science is based on two great achievements: the invention of the formal logical system (in Euclidean geometry) by the Greek philosophers, and the discovery of the possibility to find out causal relationships by systematic experiment (during the Renaissance). In my opinion one has not to be astonished that the Chinese sages have not made those steps. The astonishing thing is that those discoveries were made at all*".

A few conclusions were drawn from the above quote [6]. First, the logic Einstein used was the truth-based formal logical system originated from Euclidean geometry. Secondly, the truth-based system does not provide logically definable causality with regularity. Thirdly, the causality he relied on was empirical causality in spacetime which is not a formal logical system. Fourthly, what he sought was a formal causal system for the grant unification. Although Einstein never believed in the theory of singularity and even regarded the theory as "bizarre", resisting the logic of his own theory right up to his final departure in 1955, his equations of general relativity did eventually lead to the flourishing of singularity after his death following the discovery of black holes.

It is well-known that Einstein was a friend and colleague of renowned mathematician Kurt Gödel at Princeton University, and, before fleeing from Nazi Germany to resettle in the United States, Einstein once visited German mathematician Hilbert by invitation. So, he was aware of Hilbert's program in mathematics for axiomatizing physics [72]. Einstein believed that it was possible to axiomatize physics. It is noted [36] that, in 1931, Gödel published his incompleteness theorems [73]. Many believe that these theorems proved Hilbert's mathematical program impossible and shattered his hope for axiomatizing physics. Three years after Gödel published his incompleteness theorems, however, Einstein reaffirmed [53] that "*pure thought can grasp reality*" and "*nature is the realization of the simplest conceivable mathematical ideas*". In 1936 he asserted that [54] "*Physics constitutes a logical system of thought which is in a state of evolution, whose basis (principles) cannot be distilled, as it were, from experience by an inductive method, but can only be arrived at by free invention*". In 1940, nine years after Gödel published his incompleteness theorems, Einstein asserted [55] that the grand unification of general relativity and quantum mechanics needs a new logical foundation: "*For the time being we have to admit that we do not possess any general theoretical basis for physics which can be regarded as its logical foundation*".

Evidently, Einstein never wavered on a logical foundation for physics. Hilbert lived for twelve years after Gödel published his incompleteness theorems. Many wondered why Hilbert did not concede or officially respond to Gödel's findings. A sober view is that if Einstein refused to give up hope for the logic of physics with definable causality in regularity, why should Hilbert? [36].

Gödel's incompleteness theorems, Hilbert's effort in axiomatizing physics, and Einstein's assertion on a new logical foundation for physics were all giant steps. However, the three giants stopped short of pointing out the inevitable ([9] p. 92):

(1) The incompleteness of truth-based reasoning is due to its lack of syntax and semantics for the fundamental physical concepts of "*equilibrium*" and "*symmetry*".
(2) A logical foundation for physics requires a philosophically deeper cosmology beyond spacetime and a different mathematical abstraction beyond classical being-centered, truth-based, unipolar cognition such that spacetime can emerge and truths can be revealed.

It is clear from the above analysis that a geometry transcending being, truth, and spacetime is the key to hosting the Spinoza–Einstein's God/Nature logic with ***complete background independence***. *However, what geometry could go beyond spacetime*?

The long search reached bipolar quantum geometry (BQG) of equilibrium or supersymmetry of negative–positive energies/information for reciprocal and complementary YinYang bipolar interaction. Since no system can escape from equilibrium, an equilibrium-based bipolar dynamic logic that reasons on equilibrium and quasi-equilibrium or symmetry and broken symmetry will transcend spacetime as well as all beings and truths in spacetime as we say that the universe is a dynamic equilibrium but not a truth and/or falsity.

3. From Local to Global Realism—A Causal–Logical Theory of Real-World Quantum Gravity

3.1. From Truth-Based to Equilibrium-Based Reasoning

In 1964 physicist John Stewart Bell formulated the Bell inequality [74], which, if violated in actual experiments, would imply that quantum mechanics violates the *locality* or *realism* principle [74–76]. Thus, Bell introduced another principle on the values of *unmeasured quantities* or *counterfactual definiteness* which has been generally called the ***Bell test*** *or* ***Bell inequality***. In the words of the author, for whom this family of results is named, "*If (a hidden-variable theory) is local it will not agree with quantum mechanics, and if it agrees with quantum mechanics it will not be local*" [76].

While the two principles of locality and realism are commonly referred to as a single principle named ***local realism***, the Bell inequality violation opened the door to a new world of physics—***global realism*** with logically definable causality in regularity. Beginning with

John Clauser and Alain Aspect's experiments in the 1970s to 1980s, the ***Bell test*** results show that quantum mechanics violated the inequality, so it must violate locality or (local) realism. However, critics have noted that these experiments included "loopholes", which prevented a definitive answer to the uncertainty. This problem was resolved in the 1990s when a "loophole-free" experiment was conducted by Anton Zeilinger of the University of Vienna who joined with John Clauser and Alain Aspect as a Nobel Laureate for the 2022 Nobel Award. The experimental findings, however, could not reach definable causality in regularity. (Note: This work presents a falsifiable causal–logical quantum-gravity theory that goes beyond the continuing debate on the Bell test).

Theorem 1. ***Global realism*** *is a necessary and inevitable consequence of the Bell inequality violation.*

Proof. It follows from the fact that (1) the Bell inequality is the general name for the values of unmeasured quantities or counterfactual definiteness [74] and, in the words of the author, for whom this family of results is named, "If (a hidden-variable theory) is local it will not agree with quantum mechanics, and if it agrees with quantum mechanics it will not be local" [76]; (2) the Bell inequality violation has been experimentally verified, and the experimental results have been vindicated by the 2022 Nobel Award in Physics; (3) If quantum non-locality or entanglement is not local but real it must belong to global realism [2,11]. □

Theorem 2. *Global realism must be a background-independent, equilibrium-based, spacetime transcendent, dynamic theory that unifies/reveals truth-based local reality/realism. Thus, quantum superposition/entanglement must be a dynamic equilibrium, and quantum nonlocality must be part of equilibrium-based global realism.*

Proof. It follows that (1) being in a spacetime geometry cannot be true in quantum terms due to spacetime expansion/shrinking; (2) dynamic equilibrium including equilibrium, quasi-equilibrium, and non-equilibrium states are essential and ubiquitous for all dynamic existence per the second law of thermodynamics [77]; (3) everything in the universe including the universe itself and the mind of human being is a dynamic equilibrium but not a truth, falsity, or contradiction; (4) quantum entanglement and/or superposition can be tested/observed as a dynamic equilibrium that can form (emerge) for quantum computing and collapse (submerge) when being measured; (5) the equilibrium-based system must be background-independent such that it can expand and shrink with dynamic quantum emergence or submergence of spacetime without boundary in spacetime; (6) equilibrium is real based on the second law of thermodynamics; (7) global equilibrium is real, and quantum nonlocality can naturally be part of global realism. □

Theorem 3. *Global realism constitutes a fundamentally bipolar equilibrium-based, dynamic, set-theoretic, background-independent, logical, geometrical, and algebraic system with logically definable causality and information/energy conservation that can reveal truth-based crisp logic, fuzzy logic, linear algebra, and local reality through quantum emergence or submergence of spacetime, where quantum superposition/entanglement is fundamentally a bipolar dynamic equilibrium or BDE, and quantum collapse is essentially the collapse of a BDE.*

Proof. It follows that, fundamentally, any multidimensional equilibrium in spacetime can be decomposed into a set of background-independent bipolar dynamic equilibria/quasi-equilibria. Global realism is then fundamentally a completely background-independent, bipolar equilibrium-based, set-theoretic, geometrical, logical, and/or algebraic system (see Figures 3–7). Without logically definable causality the formal equilibrium-based logical/algebraic basis (Figures 5 and 6) would not be able to reveal truth-based crisp and fuzzy logic for local reality. Without input–output, action–reaction, and particle–antiparticle bipolarity, formal logically definable causality in regularity would be impossible due to the lack of bipolar interactive dynamics for information/energy flow. Without formal

logically definable causality in regularity, GRBS would be impossible. Furthermore, BQG must be completely background-independent such that BDEs are completely background-independent. Quantum superposition or entanglement is thus fundamentally a bipolar dynamic equilibrium, and quantum collapse is the collapse of a bipolar dynamic equilibrium [2,6] (Figure 7). □

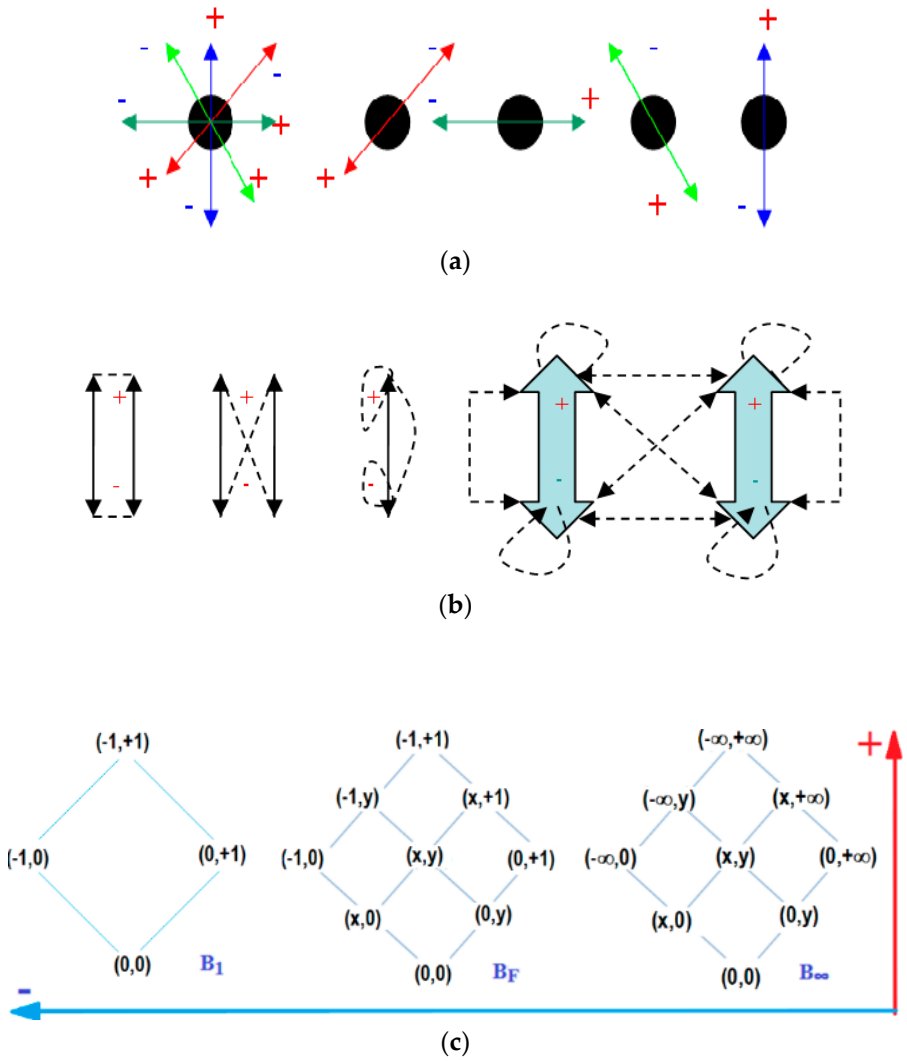


Figure 3. Background-independent mathematical abstraction (adapted from [9]: (**a**) M-bipolar equilibrium decomposed to a set of bipolar equilibria or bipolar strings; (**b**) bipolar interaction and entanglement; (**c**) Hasse diagrams of bipolar lattices.

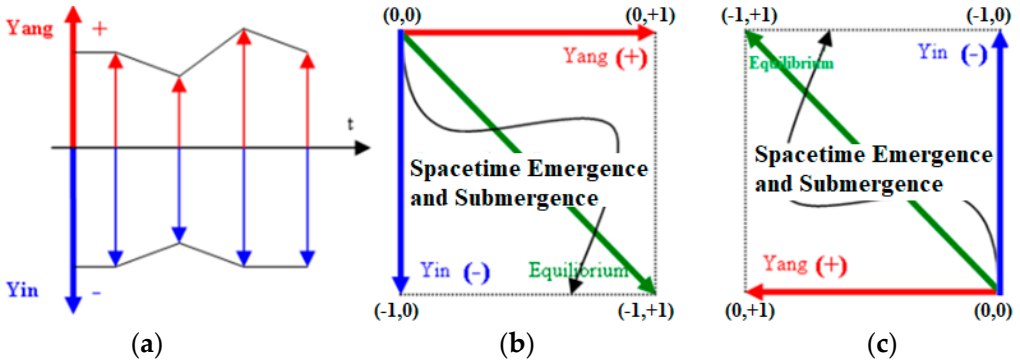


Figure 4. YinYang bipolar quantum geometry (BQG) (adapted from [9,20]: (**a**) magnitude with time t; (**b**,**c**) background-independent quantum unification of geometry and logic.

&	(0,0)	(-1,0)	(0,+1)	(-1,+1)
(0,0)	(0,0)	(0,0)	(0,0)	(0,0)
(-1,0)	(0,0)	(-1,0)	(0,0)	(-1,0)
(0,+1)	(0,0)	(0,0)	(0,+1)	(0,+1)
(-1,+1)	(0,0)	(-1,0)	(0,+1)	(-1,+1)

&⁻	(0,0)	(-1,0)	(0.+1)	(-1.+1)
(0,0)	(0,0)	(0,0)	(0,0)	(0,0)
(-1,0)	(0,0)	(0.+1)	(0,0)	(0.+1)
(0.+1)	(0,0)	(0,0)	(-1,0)	(-1,0)
(-1.+1)	(0,0)	(0.+1)	(-1,0)	(-1.+1)

⊕	(0,0)	(-1,0)	(0,+1)	(-1,+1)
(0,0)	(0,0)	(-1,0)	(0,+1)	(-1,+1)
(-1,0)	(-1,0)	(-1,0)	(-1,+1)	(-1,+1)
(0,+1)	(0,+1)	(-1,+1)	(0,+1)	(-1,+1)
(-1,+1)	(-1,+1)	(-1,+1)	(-1,+1)	(-1,+1)

⊕⁻	(0,0)	(-1,0)	(0.+1)	(-1.+1)
(0,0)	(0,0)	(0.+1)	(-1,0)	(-1.+1)
(-1,0)	(0.+1)	(0.+1)	(-1.+1)	(-1.+1)
(0.+1)	(-1,0)	(-1.+1)	(-1,0)	(-1.+1)
(-1.+1)	(-1.+1)	(-1.+1)	(-1.+1)	(-1.+1)

⊗	(0,0)	(-1,0)	(0,+1)	(-1,+1)
(0,0)	(0,0)	(0,0)	(0,+0)	(0,0)
(-1,0)	(0,0)	(0,+1)	(-1,0)	(-1,+1)
(0,+1)	(0,0)	(-1,0)	(0,+1)	(-1,+1)
(-1,+1)	(0,0)	(-1,+1)	(-1,+1)	(-1,+1)

⊗⁻	(0,0)	(-1,0)	(0.+1)	(-1.+1)
(0,0)	(0,0)	(0,0)	(0,0)	(0,0)
(-1,0)	(0,0)	(-1,0)	(0.+1)	(-1.+1)
(0.+1)	(0,0)	(0.+1)	(-1,0)	(-1.+1)
(-1.+1)	(0,0)	(-1.+1)	(-1.+1)	(-1.+1)

⌀	(0,0)	(-1,0)	(0,1)	(-1,+1)
(0,0)	(0,0)	(0,0)	(0,0)	(-1,+1)
(-1,0)	(0,0)	(-1,0)	(0,1)	(-1,+1)
(0,1)	(0,0)	(0,1)	(-1,0)	(-1,+1)
(-1,1)	(-1,1)	(-1,1)	(-1,1)	(-1,+1)

⌀⁻	(0,0)	(-1,0)	(0.+1)	(-1.+1)
(0,0)	(0,0)	(0,0)	(0,0)	(-1,+1)
(-1,0)	(0,0)	(0.+1)	(-1,0)	(-1,+1)
(0.+1)	(0,0)	(-1,0)	(0.+1)	(-1,+1)
(-1.+1)	(-1.+1)	(-1.+1)	(-1.+1)	(-1.+1)

Figure 5. Truth tables of eight BDL operators (adapted from [9]).

Bipolar Partial Ordering: $(x,y)\geq\geq(u,v)$, iff $\|x\|\geq\|u\|$ and $y\geq v$;	(a)
Complement: $\neg(x,y)\equiv(-1,1)-(x,y)\equiv(\neg x,\neg y)\equiv(-1-x,1-y)$;	(b)
Negation: $-(x,y) \equiv (-y,-x)$;	(c)
Implication: $(x,y)\Rightarrow(u,v) \equiv (x\rightarrow u, y\rightarrow v) \equiv (\neg x\vee u, \neg y\vee v)$;	(d1)
Entanglement Ω: $\{(x,y)\Omega(u,v)\} \equiv\{(x,y)\Leftrightarrow(u,v)$ or $(x,y)\Leftrightarrow -(u,v)\}$;	(d2)
Fission: fission$(x,y) = \{(x,0); (0,y)\}$;	(d3)
Fusion: fusion$((x,0); (0,y)) = (x,0)\oplus(0,y) = (x, y)$;	(d4)
Bipolar least upper bound (blub):	
$\text{blub}((x,y),(u,v))\equiv(x,y)\oplus(u,v)\equiv(-(\|x\|\vee\|u\|),y\vee v)$;	(e)
-blub: $\text{blub}^{-}((x,y),(u,v))\equiv (x,y)\oplus^{-}(u,v) \equiv (-(y\vee v),(\|x\|\vee\|u\|))$;	(f)
Bipolar greatest lower bound (bglb):	
$\text{bglb}((x,y),(u,v)) \equiv (x,y)\&(u,v) \equiv (-(\|x\|\wedge\|u\|),y\wedge v))$;	(g)
-bglb: $\text{bglb}^{-}((x,y),(u,v)) \equiv (x,y)\&^{-}(u,v) \equiv (-(y\wedge v), (\|x\|\wedge\|u\|)))$;	(h)
Cross-pole greatest lower bound (cglb):	
$\text{cglb}((x,y),(u,v))\equiv(x,y)\otimes(u,v)\equiv(-(\|x\|\wedge\|v\|\vee\|y\|\wedge\|u\|),(\|x\|\wedge\|u\|\vee\|y\|\wedge\|v\|))$;	(i)
-cglb: $\text{cglb}^{-}((x,y),(u,v)) \equiv (x,y)\otimes^{-}(u,v) \equiv -((x,y)\otimes(u,v))$;	(j)
Cross-pole least upper bound (cglb):	
$\text{club}((x,y),(u,v))\equiv(x,y)\varnothing(u,v)\equiv(-1,1)-(\neg(x,y)\otimes\neg(u,v))$;	(k)
-club: $\text{club}^{-}((x,y),(u,v))\equiv(x,y)\varnothing^{-}(u,v)\equiv -((x,y)\ \varnothing\ (u,v))$.	(l)

(**a**)

Excluded Middle (LEMs)	$(x,y)\oplus \neg(x,y) \equiv (-1,+1)$; $(x,y)\oplus^{-} \neg(x,y) \equiv (-1,+1)$;
Non-Contradiction	$\neg((x,y)\&\neg(x,y)) \equiv (-1,+1)$; $\neg((x,y)\&^{-}\neg(x,y)) \equiv (-1,+1)$;
Linear Bipolar DeMorgan's Laws	$\neg((a,b)\&(c,d)) \equiv \neg(a,b)\oplus\neg(c,d)$; $\neg((a,b)\oplus(c,d)) \equiv \neg(a,b)\&\neg(c,d)$; $\neg((a,b)\&^{-}(c,d)) \equiv \neg(a,b)\oplus^{-}\neg(c,d)$; $\neg((a,b)\oplus^{-}(c,d)) \equiv \neg(a,b)\&^{-}\neg(c,d)$;
Non-Linear Bipolar DeMorgan's Laws	$\neg((a,b)\otimes(c,d)) \equiv \neg(a,b)\ \varnothing\ \neg(c,d)$; $\neg((a,b)\ \varnothing\ (c,d)) \equiv \neg(a,b)\otimes\neg(c,d)$; $\neg((a,b)\otimes^{-}(c,d)) \equiv \neg(a,b)\ \varnothing^{-}\ \neg(c,d)$; $\neg((a,b)\varnothing^{-}(c,d)) \equiv \neg(a,b)\otimes^{-}\neg(c,d)$

(**b**)

Unipolar Axioms (UAs): UA 1: $\phi\rightarrow(\varphi\rightarrow\phi)$; UA 2: $(\phi\rightarrow(\varphi\rightarrow\chi))$ $\rightarrow((\phi\rightarrow\varphi)\rightarrow(\phi\rightarrow\chi))$; UA 3: $(\neg\phi\rightarrow\varphi)\rightarrow((\neg\phi\rightarrow\neg\varphi)\rightarrow\phi)$; UA 4: (a) $\phi\wedge\varphi\rightarrow\phi$; (b) $\phi\wedge\varphi\rightarrow\varphi$; UA 5: $\phi\rightarrow(\varphi\rightarrow\phi\wedge\varphi)$;	Bipolar Linear Axioms: BA 1: $(\phi^{-},\phi^{+})\Rightarrow((\varphi^{-},\varphi^{+})\Rightarrow(\phi^{-},\phi^{+}))$; BA 2: $((\phi^{-},\phi^{+})\Rightarrow((\varphi^{-},\varphi^{+})\Rightarrow(\chi^{-},\chi^{+})))$ $\Rightarrow(((\phi^{-},\phi^{+})\Rightarrow(\varphi^{-},\varphi^{+}))\Rightarrow((\phi^{-},\phi^{+})\Rightarrow(\chi^{-},\chi^{+})))$; BA 3: $(\neg(\phi^{-},\phi^{+})\Rightarrow(\varphi^{-},\varphi^{+}))$ $\Rightarrow((\neg(\phi^{-},\phi^{+})\Rightarrow\neg(\varphi^{-},\varphi^{+}))\Rightarrow(\phi^{-},\phi^{+}))$; BA 4: (a) $(\phi^{-},\phi^{+})\&(\varphi^{-},\varphi^{+})\Rightarrow(\phi^{-},\phi^{+})$; (b) $(\phi^{-},\phi^{+})\&(\varphi^{-},\varphi^{+})\Rightarrow(\varphi^{-},\varphi^{+})$; BA 5: $(\phi^{-},\phi^{+})\Rightarrow((\varphi^{-},\varphi^{+})\Rightarrow((\phi^{-},\phi^{+})\&(\varphi^{-},\varphi^{+})))$;
Inference Rule – Modus Ponens (MP): UR 1: $(\phi\wedge(\phi\rightarrow\varphi))\rightarrow\varphi$.	Non-Linear Bipolar Universal Modus Ponens (BUMP) BR 1: IF $((\phi^{-},\phi^{+})*(\psi^{-},\psi^{+}))$, $[((\phi^{-},\phi^{+})\Rightarrow(\varphi^{-},\varphi^{+}))\&((\psi^{-},\psi^{+})\Rightarrow(\chi^{-},\chi^{+}))]$, THEN $[(\varphi^{-},\varphi^{+})*(\chi^{-},\chi^{+})]$;
Predicate axioms and rules UA 6: $\forall x,\phi(x)\rightarrow\phi(t)$; UA 7: $\forall x, (\phi\rightarrow\varphi)\rightarrow(\phi\rightarrow\forall x,\varphi)$; UR 2–Generalization: $\phi\rightarrow\forall x,\phi(x)$	Bipolar Predicate axioms and Rules of inference BA 6: $\forall x,(\phi^{-}(x),\phi^{+}(x))\Rightarrow(\phi^{-}(t),\phi^{+}(t))$; BA 7: $\forall x,((\phi^{-},\phi^{+})\Rightarrow(\varphi^{-},\varphi^{+}))\Rightarrow((\phi^{-},\phi^{+})\Rightarrow\forall x,(\varphi^{-},\varphi^{+})$; BR 2-Generalization: $(\phi^{-},\phi^{+})\Rightarrow\forall x,(\phi^{-}(x),\phi^{+}(x))$

(**c**)

$$\forall\phi=(\phi^{-},\phi^{+})\in B_I \text{ or } B_F = [-1,0]\times[0,+1],$$

$$[|\phi| = (|\phi^{-}|\vee|\phi^{+}|)] \rightarrow (\text{BUMP} \rightarrow \text{MP}) \rightarrow (\text{BDL} \rightarrow \text{BL}) \rightarrow (\text{BDFL} \rightarrow \text{FL}).$$

(**d**)

Figure 6. Bipolar axiomatization on BDL (adapted from [9]): (**a**) basic operations (has been extended to BDFL, $\forall(x,y)$, $(u,v)\in B_1$ or B_F where $(x,y)\equiv(-|x|,|y|)$ shows explicit bipolarity); (**b**) equilibrium-based laws; (**c**) equilibrium-based vs. truth-based axiomatization of BDL; (**d**) equilibrium-based revealing of truth.

Bipolar Universal Modus Ponens (BUMP) in IF-THEN Form:
IF $[(\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+)]\&[(\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+)]\&[(\phi^-,\phi^+)*(\psi^-,\psi^+)]$; THEN $[(\varphi^-,\varphi^+)*(\chi^-,\chi^+)]$.
BUMP in Tautological Form:
$[(\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+)]\ \&\ [(\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+)]\ \Rightarrow \{[((\phi^-,\phi^+)*(\psi^-,\psi^+))\Rightarrow((\varphi^-,\varphi^+)*(\chi^-,\chi^+))]\}$.
BUMP in Singleton Form:
IF $[(\phi \Rightarrow \varphi)\ \&\ (\psi \Rightarrow \chi)]$ and $(\phi * \psi)$, THEN $(\varphi * \chi)$, or $(\phi \Rightarrow \varphi)\ \&\ (\psi \Rightarrow \chi)\ \Rightarrow\ [(\phi * \psi) \Rightarrow (\varphi * \chi)]$.
Bipolar Superposition/entanglement in Logical Form (Binding):
$\text{Binding}\{(-1,0),(0,+1)\} = (-1,0)\oplus(0,+1) = (-1,+1)$.
Bipolar Collapse in Logical Form (Separating):
$\text{Separating}(-1,+1) = \{(-1,0),(0,+1)\}$.
Single Entanglement: $(\phi\ \Omega\ \varphi) = (-1,+1)$ or $(\phi \Leftrightarrow \varphi)$ or $(\phi \Leftrightarrow -\varphi)$.
$\forall a,b,c,d$, quantum spacetime emergence through BUMP:
$[\psi(a(t_x,p_1))\Rightarrow\chi(c(t_y,p_3))]\&[\phi(b(t_x,p_2))\Rightarrow\varphi(d(t_y,p_4))]\ \Rightarrow\ [\psi(a(t_x,p_1))*\phi(b(t_x,p_2))\Rightarrow\chi(c(t_y,p_3))*\varphi(d(t_y,p_4))]$;
Spacetime emergence through bipolar quantum entanglement with BUMP:
$[\psi(a(t_x,p_1))\Leftrightarrow\chi(c(t_y,p_3))]\&[\phi(b(t_x,p_2))\Leftrightarrow\varphi(d(t_y,p_4))]\ \Rightarrow\ [\psi(a(t_x,p_1))*\phi(b(t_x,p_2))\Leftrightarrow\chi(c(t_y,p_3))*\varphi(d(t_y,p_4))]$;
Or $[\psi(a)\Leftrightarrow\chi(c)]\&[\phi(b)\Leftrightarrow\varphi(d)]\Rightarrow\ [\psi(a)*\phi(b)\Leftrightarrow\chi(c)*\varphi(d)]$;
where $a(t_1,p_1)$, $b(t_1,p_2)$, $c(t_2,p_3)$, $d(t_2,p_4)$ are bipolar strings with k(t,p) standing for *"agent k at time t and space p"* (t_x, t_y, p_x and p_y can be the same or different points in time and space). An agent without time and space is assumed at any time t and space p such as non-local quantum entanglement.

Two-fold universal instantiation:
Operator instantiation: $*$ as a universal operator can be bound to any commutative and bipolar monotonic (*w.r.t.* $\geq\geq$) operator &, $\oplus$, $\&^-$, $\oplus^-$, $\otimes$, $\varnothing$, $\otimes^-$, and $\varnothing^-$. $(\phi\Rightarrow\varphi)$ is designated bipolar true; $((\phi^-,\phi^+)*(\psi^-,\psi^+))$ is not designated. Bipolar instantiation: $\forall x, (\phi^-,\phi^+)(x) \Rightarrow (\varphi^-,\varphi^+)(x)$; $(\phi^-,\phi^+)(A)$; $\therefore (\varphi^-,\varphi^+)(A)$.

Figure 7. Bipolar quantum entanglement/superposition and quantum emergence or submergence of spacetime (adapted from [2,6,9]).

Theorem 4. *Global realism must be transcendent of spacetime, spacetime relativity, real–imaginary or particle–wave complementarity, and Dirac bra-ket standard for quantum mechanics. It must reach logically definable causality with global energy/information conservation. Thus, it must be necessarily a background-independent geometrical and logical unification of general relativity and quantum mechanics—a real-world quantum gravity (RWQG) theory.*

Proof. (1) General relativity is a physical theory about space and time. According to general relativity, spacetime is a four-dimensional object that must obey an Einstein equation, which explains how matter curves the spacetime. Without the geometry of light and logic of photons, however, it has been shown [6] that observer–observability formed a paradox in modern science, truth–equilibrium found no unification, and mind–light–matter unity was unreachable in spacetime.

(2) It is shown [6] that quantum mechanics has been shrouded with mysteries preventing itself from reaching definable causality for a general-purpose analytical quantum computing paradigm.

(3) Spacetime geometries and truth-based logics have been disqualified to be the geometry of light and logic of photons, and background-independent bipolar quantum geometry or BQG and bipolar dynamic logic or BDL have been identified as the geometry of light and logic of photons with logically definable causality for quantum emergence/submergence of spacetime with energy/information conservation in dynamic equilibrium and harmony

(4) Following (1) and (3), **global realism** must necessarily be a background-independent geometrical and logical unification of general relativity and quantum mechanics—an RWQG theory for quantum emergence and submergence of spacetime. □

3.2. From Bipolar Dynamic Equilibrium to Bipolar Strings

To visualize global realism in graphical forms and physical terms, we introduce bipolar strings [9,21] as a real-world string theory that unifies the concept of BQAs [9,37] with QI [2,6].

Definition 1. ***A bipolar string*** *is a BQA in BDE characterized by a bipolar logical/algebraic state (Re. Postulates 1–4) of a bipolar quantum entanglement or BQE.*

Definition 2. ***A bipolar generic string*** *is a string with elementary negative-positive (−, +) poles, each of which cannot be further decomposed. The two poles can be alternating until they collapse (such as when being measured).*

Definition 3. ***A bipolar superstring*** *is a composite and/or entangled set of multiple bipolar generic strings and/or bipolar superstrings.*

Definition 4. *Bipolar strings as generic or composite quantum superposition and/or entanglement can form (emerge) and collapse (submerge);* ***collapsed bipolar strings*** *as unbalanced bipolar strings remain part of the global BDE that can be entangled again.*

Postulate 5. *Gravitation among cosmological objects is fundamentally a super symmetrical entanglement of bipolar strings with or without graviton-antigraviton pairs.*

Postulate 6. *The formation and collapse of bipolar strings are not limited by the speed of light but can show superluminal cause and effect in generic cases.*

Notably, among the basic forces of Nature, gravitation is the most difficult force to unify. The main reason is the physically different structures of the gravitational force from the other forces. Equilibrium-based bipolar strings lead to a completely background-independent RWQG theory—a bipolar unification that overcomes the difficulty.

Theorem 5. *Bipolar strings constitute the physical foundation for logically definable quantum emergence and submergence of spacetime.*

Proof. Following Theorems 1–4, Definitions 1–4, and Postulates 5 and 6, without bipolar strings there would be no bipolar dynamic equilibrium and no bipolar universal modus ponens (BUMP) for logically definable causality of quantum emergence and submergence of spacetime [6,9,20] (Figures 4–8). □

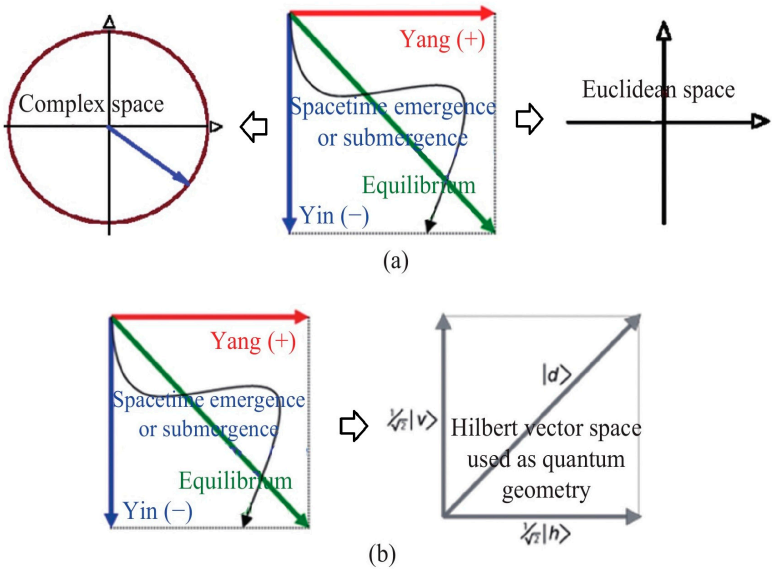


Figure 8. Spacetime emergence/submergence (adapted from [6,20]).

Theorem 6. *Bipolar strings constitute the physical foundation for the logically definable mind–light–matter unitary causal–logical human/machine thinking, learning, and imagination.*

Proof. It follows directly from Theorem 5. □

Postulate 7. *Thinking and imagination are fundamentally cognitive processes logically equivalent to quantum emergence (entanglement) and submergence (collapse) of spacetime in mind–light–matter unitary terms. Thus, quantum entanglement and collapse constitute the basic functionality of the physical and mental worlds with mind–light–matter unity.*

Postulate 8. *Machine thinking and imagination are the basis and prerequisite for adaptive machine learning and human-level intelligence.*

Based on Definitions 1–4 and Postulates 1–5, action–reaction and particle–antiparticle bipolarity, as well as mind–light–matter, are logically unified. Now, a quantum entanglement of two elementary particles forms a bipolar generic string; an atom, a neuron, a brain, a mind, a star, or a pair of interactive stars or universes form superstrings.

Theorem 7. ***Global realism with bipolar strings (GRBS)*** *as a theory of physics and information constitutes a scalable logical system of thought—a minimal but most general axiomatization of physics and quantum information science that is a necessary and inevitable consequence of the Bell inequality violation.*

Proof. Notably, the first principles of science and the second law of thermodynamics are unified with ground-0 axioms [6]. Following Theorems 1–6, Definitions 1–4, Postulates 5–8, and Ref. [6], without GRBS there would be no being, no truth, no first principles of science, no second law of thermodynamics, no reality, and no epistemology. □

3.3. Mind–Light–Matter Unity

Historically, mind–light–matter unity [6] was unreachable in spacetime. It is argued [2] that if $i = \sqrt{-1}$ can be used by Niels Bohr for real–imaginary complementarity in his Copenhagen interpretation of QM where opposites are said complementary, there is no reason to forbid the use of negative numbers as the direct opposites of positive numbers to reach logically definable causality and analytical quantum computing for global realism. It is shown in [2,6,9] that BDL, BDFL, and BQLA in the complete background independent geometry BQG have reached logically definable causality, information conservation, the geometry of light, and the logic of photon for mind–light–matter unity and quantum emergence (entanglement) or submergence (collapse) of spacetime. As a unification of the first principles of science with the second law of thermodynamics the equilibrium-based bipolar system [6] can serve as a logical resolution to the EPR and Schrödinger's Cat paradoxes where a quantum superposition/entanglement can be simply defined as a BDE.

It is noted in [6]: "*While all interpretations in quantum mechanics have so far been commonly claimed leading to the same answers regarding observation and prediction, the bipolar equilibrium-based interpretation has led to fundamentally different answers. Arguably, the Einstein-*Bohr *debate of the 20th century has come to a logical settlement. While Bohr was right on the existence of quantum superposition and entanglement as well as their measurement in Hilbert space at his time, the geometry of light and logic of photon has revealed the logical nature of a deeper universe where quantum superposition/entanglement is neither Schrödinger's Cat nor spooky action at a distance. Indeed, Spinoza-Einstein's God does not play dice but plays a game of equilibrium and harmony with logically definable causality as Einstein stated: 'I believe in Spinoza's God, who reveals himself in the orderly harmony of what exists, . . .'*"

It is concluded in [2]: "*Firstly, without negative numbers, there would be no imaginary numbers. Without imaginary numbers, there would be no Hilbert spacetime geometry, no Dirac bra-ket* standard, *no Niels Bohr's real-imaginary or particle-wave complementarity principle, and no QM. Secondly, without negative numbers, there would be no strict (−, +)-bipolarity, no bipolar crisp/fuzzy sets, no completely background-independent bipolar logical axiomatization for bipolar interaction and bipolar dynamic equilibrium. Without bipolar dynamic equilibrium, there would be no logically definable causality, no geometry of light, no logic of photon, no spacetime emergence or*

submergence, no analytical quantum computing for QI, no imagination, no mind, no truth, and no mind–light–matter unity".

It is well-known that the brain consists of billions of cells called neurons interconnected to form ensembles for the coordination and control of all physical and mental aspects of life. The nucleus of the cell body is structured like an atom but much larger in size and much more complex where I/O bipolarity is essential. Thus, mind–light–matter unity can be logically pictured with an equilibrium-based world of bipolar crisp or fuzzy sets where light bridges or illuminates mind and matter with the geometry of light and logic of photons in bioelectronics, biophotonics, or bioeconomics terms. Figure 9 illustrates a logical unification of matter and antimatter particles. Figure 10a shows a sketch of mind–light–matter unification where an equilibrium-based logic/algebra is both physical and logical. Figure 10b illustrates that different body functionalities can be coordinated by entangled (Ω) neural ensembles in the brain [6].

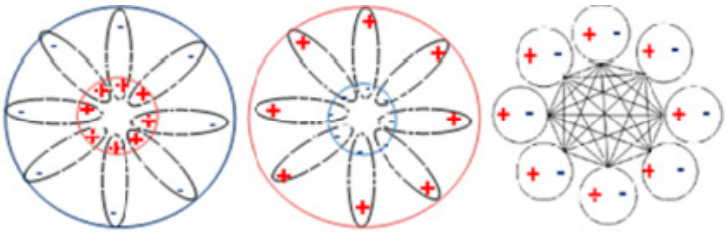


Figure 9. Bipolar unification of matter and antimatter (adapted from [21]).

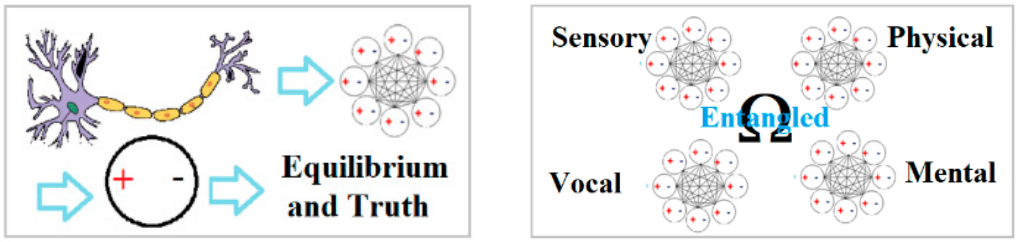


Figure 10. Mind–light–matter unity (adapted from [6]): (**a**) mind–light–matter unity in logical terms; (**b**) entangled (Ω) neural ensembles for the coordination of sensory, vocal, physical, and mental functionalities with mind–light–matter unity.

With QI, Turing's machine thinking puzzle [4] was revisited. It is stated in [2] that "*with strict (−, +)-bipolarity we have reached logically definable causality for mind–light–matter unity in equilibrium-based analytical terms. With the unpredicted new finding in thousands of years, Turing's thinking machinery puzzle* [4] *can be extended to a deeper and trickier question that is potentially closer to a definitive answer: 'If AI machine cannot think, can QI machine think?'*"

3.4. Bipolar Entropy for Equilibrium-Based Unification of Order and Disorder

While classical entropy is a measure of disorder, we define *bipolar entropy* and *bipolar entropy matrix* as a regulatory measure or relation.

Definition 5. ***Bipolar entropy*** *is a regulatory bipolar measure in the bipolar (quantum) lattice [−1, 0] × [0, +1] (see Figure 3) for non-linear bipolar dynamic unification and regulation of Nature's elementary order and disorder.* ***The bipolar entropy matrix*** *is a holistic regulatory bipolar relational matrix of bipolar entropy measures for non-linear bipolar dynamic and set-theoretic unification and regulation of Nature's order and disorder or linearity and non-linearity.*

With bipolar entropy matrix, it is shown [6,9,26] that bipolar energy/information can be conserved in an entangled bipolar quantum cellular automaton (BQCA) with BQLA. Equation (1a–c) provide the elementary equations for the transformation of bipolar quantum superposition to an entangled BQCA where E(t) is a bipolar column vector and M(t) a bipolar quantum logic gate (BQLG) as a specific type of BQLA matrix at time t. For $\forall(x, y), (u, v) \in B_\infty = [-\infty, 0] \times [0, +\infty]$, we have [21]:

$$\text{Bipolar Elementary Multiplication/Interaction: } (x, y) \times (u, v) = (xv + yu, xu + yv); \tag{1a}$$

$$\text{Bipolar Elementary Addition/Superposition: } (x, y) + (u, v) = (x + u, y + v) \tag{1b}$$

$$\text{Bipolar Quantum Cellular Automaton (BQCA): } E(t + 1) = M(t) \times E(t). \tag{1c}$$

Why do we need BQLG, BQLA, and BQCA while linear algebra has been taught in college algebra classes for centuries? A simple answer is that classical linear algebra (LA) cannot accommodate the non-linear bipolar dynamic coexistence of equilibrium information. For instance, let (−0.1, +0.1) and (−1,000,000, +1,000,000) be different I/O bipolar balances, with LA we have the information loss (−0.1 + 0.1) = (−1,000,000 + 1,000,000) = 0. With BQLA, let the absolute bipolar elementary energy $|\varepsilon|(x,y) = |x| + |y|$ and let $|\varepsilon_{col}|M_{*j}(t)$ be the energy/information of the j column of a BQLG matrix $M(t)$, we have Equation (2a–c) for a BQCA [9,21,24,26]:

Energy/Information Conservation: $\forall j$, $|\varepsilon_{col}|M_{*j}(t) = 1.0$,

$$|\varepsilon|E(t + 1) = |\varepsilon|(M(t) \times E(t)) \equiv |\varepsilon|E(t); \tag{2a}$$

Energy/Information Regeneration: $\forall j$, $|\varepsilon_{col}|M_{*j}(t) > 1.0$,

$$|\varepsilon|E(t + 1) = |\varepsilon|(M(t) \times E(t)) > |\varepsilon|E(t); \tag{2b}$$

Energy/Information Degeneration: $\forall j$, $|\varepsilon_{col}|M_{*j}(t) < 1.0$,

$$|\varepsilon|E(t + 1) = |\varepsilon|(M(t) \times E(t)) < |\varepsilon|E(t). \tag{2c}$$

Based on Equations (1a–c) and (2a–c), M(t) forms a ***bipolar entropy*** matrix—a bipolar relational or algebraic matrix of bipolar entropy elements that makes the bipolar energy vector E(t) a regulated quantum entanglement. Different from unipolar entropy, bipolar entropy matrix as a holistic structure can play the forming and regulating roles of entanglement for energy/information conservation toward a global dynamic equilibrium with local regeneration (or growth) and degeneration (or aging) in physical, logical, mental, biological, and social-economical terms [6,9]. Thus, bipolar entropy leads to quantum cellular bioeconomics, equilibrium-based business intelligence, information conservational quantum-fuzzy cryptography, and other applications of RWQG for a Q5 (or QG-5) paradigm [2,6,9,21].

Notably, Schrödinger's book *What is Life?* [78] stimulated research in quantum biology. Schrödinger originally stated that life feeds on ***negative entropy***, or ***negentropy,*** and, in a later edition, restated that the true source is ***free energy***. Notably, negative entropy has led to important applications in physics and quantum information science [79–83]. Without bipolar dynamic equilibrium, however, negative entropy and free energy as unipolar concepts could not free Schrödinger from truth-based and being-centered singularity to reach logically definable causality. As a result, he stopped short of reaching ***bipolar entropy*** to unify order and disorder for bipolar coexistence/interaction of Nature. Similarly, Schrödinger's Cat paradox on quantum superposition remained a mystery for nearly two centuries (re. [6]).

With ground-0 axioms and ***bipolar entropy***, BDL, BDFL, or BQLA can be alternatively named ***bipolar entropy logic or algebra.*** While truth-based entropy as a scientific concept as well as a measurable physical property is usually associated with a state of disorder, randomness, or uncertainty, it stopped short of going beyond the first principles and the second law to reach logically definable causality [6]. With bipolarity, the new entropy logic or algebra provides definable causality for bringing disorder, randomness, or uncertainty to an entanglement of equilibrium and harmony with mind–light–matter unity for AI&QI [6].

Ideas about the relationship between entropy and living organisms have inspired hypotheses and speculations in many contexts, including psychology, information theory, the origin of life, and the possibility of extraterrestrial life. It is evident that, however, ***bipolar entropy*** is the only way to unify negative and positive energies for bipolar dynamic equilibrium (BDE) through bipolar quantum entanglement with logically definable causality. Subsequently, the essence of life as a living bipolar superstring in BDE can be posited as quantum entanglement regulated by bipolar entropy. While the question "*which comes first, cognition or consciousness?*" is left open for further philosophical debate, GRBS with logically definable causality for quantum entanglement provides a unique scientific basis and a common starting point for both cognition and consciousness.

Theorem 8. ***Bipolar entropy*** *or* ***bipolar entropy matrices*** *can serve as a causal–logical regulatory measure for bringing bipolar strings in order or disorder to equilibrium-based energy/information conservation, regeneration, or degeneration states.*

Proof. While classical unipolar entropy is a measure of disorder in truth-based terms, bipolar entropy is a measure of order–disorder or symmetry–asymmetry in bipolar equilibrium-based terms. Since a perfect bipolar energy/information equilibrium can be characterized by the bipolar logical or bipolar entropy value $(-1, +1)$, its truth-based representation can be calculated as $|-1 + 1| = 0$, the lowest disorder measure for a perfect bipolar equilibrium. On the other hand, a bipolar non-equilibrium can be characterized by the value $(-1, 0)$ or $(0, +1)$, its truth-based representation can be calculated as $|-1 + 0| = 1$ or $|0 + 1| = 1$, the highest disorder measure for a bipolar non-equilibrium. While in the truth-based unipolar case, 0 shows no disorder but no representation of non-existence, (0,0) shows non-existence in the bipolar case. In the bipolar fuzzy case, order and disorder are unified. For instance,

$$(-0, 5, +0.7) = \{(-0.5, +0.5) + (0, +0.2)\},$$

where $(-0.5, +0.5)$ shows the balance or order, and $(0, +0.2)$ shows the disorder. Equation (2a–c) shows that bipolar superstrings can be regulated by bipolar entropy matrices for energy/information conservation, regeneration (or growing), and degeneration (or aging). Proof of Equation (2a–c) is referred to as the Proof of Theorem 4 in [26]). □

Conjecture 1. ***Life*** *is a mind–light–matter unitary bipolar superstring regulated by bipolar entropy matrices;* ***thinking with consciousness and memory growth*** *is logically equivalent to mind–light–matter unitary quantum emergence of spacetime through quantum entanglement.*

Conjecture 2. *Energy/information can be conserved through dipoles including but not limited to black–white wholes that form an entangled wormhole or Einstein–Rosen bridge.*

Based on Equation (2a), Conjecture 2 can be illustrated with an example of information conservational security of large data sets. Figure 11a,b presents a sketch of the example. It is shown that the keypad of a huge data file can be compressed with "blackhole" keypad compression to a tiny minimum for encrypted data transmission to the receiver side. The data received can be decrypted using the keypad with "big bang (or white hole)" data recovery [30]. This approach can bring AI&QI into security to conceal large volumes of information in the post-quantum era for further integration with other systems.



(**a**) (**b**)

Figure 11. Information conservational security (Adapted from [30]): (**a**) "Black Hole" Keypad Compression; (**b**) "Big Bang" Data Recovery.

4. Causal–Logical Brain Modeling (CLBM) for Entangled Machine Thinking and Imagination (EMTI)

4.1. Lost in Singularity but Found in Bipolar Relativity for Real-World Quantum Gravity

Quantum gravity (QG) as a field of theoretical physics seeks to describe gravity according to the principles of quantum mechanics. It deals with environments in which neither gravitational nor quantum effects can be ignored [49] such as in the vicinity of black holes or similar astrophysical objects. While QG as a truth-based paradigm so far avoided the historical topics of logically definable causality and mind–light–matter unity [6], the equilibrium-based approach brought QG to the real world.

It is noted [26] that "*Modern science is in urgent need for equilibrium-based bipolar unitary mathematical abstraction and knowledge representation due to the emergence of economic globalization, global climate change, and the mysterious phenomena of quantum nonlocality, which entail equilibrium-based visualization, rebalancing, and global regulation*".

The bipolar axiomatization (Figures 2–10) of GRBS presents a real-world logical unification of string theory, LQG, and M-theory—the three roads to quantum gravity [65]. Assuming action–reaction and particle–antiparticle bipolarity as the most fundamental properties of the universe, GRBS constitutes a minimal but most general axiomatization of physics and quantum information science—a logical basis of *YinYang Bipolar Relativity* that unifies the first principles of science and the second law of thermodynamics [6,9].

Bipolar relativity was identified as a scalable real-world, equilibrium-based bipolar string theory [9,18,21]. Now, the bipolar set–theoretic property is supported by the unique formal background-independent BQG and BDL/BDFL (Figures 2–10) identified as the geometry of light and logic of photon, respectively, to illuminate the classical and the quantum worlds as well as the mental and physical worlds [6]. While the equilibrium-based bipolar paradigm as a formal causal–logical system can reveal truths with quantum emergence/submergence of spacetime, string theory without bipolar modularity, scalability, and testability so far came short of providing a formal causal–logical basis even though it was once regarded as TOE.

The pitfall of string theory could be due to its lack of background independence as it is usually formulated with perturbation theory around a fixed background. The background-dependent property made it impossible to go beyond truth-based singularity within spacetime toward equilibrium-based bipolar geometrical and logical formulation for quantum emergence/submergence of spacetime with energy/information conservation. For instance, quantum entanglement and collapse can be easily represented with background-independent bipolar logical binding and separation, respectively, with spacetime-transcendent quantum nonlocality (re. Figures 7 and 8). However, that would be impossible with truth-based singularity in spacetime. This is shown in the following:

Emergence through superposition or entanglement:

Binding$\{(-1, 0), (0, +1)\} = (-1, 0) \oplus (0, +1) = (-1, +1)$;

Submergence or collapse:

Separating$(-1, +1) = \{(-1, 0), (0, +1)\}$.

While string theory got into a major controversy in science, GRBS logically reformulated string theory to a bipolar formal system for real-world causal–logical reasoning. On the other hand, LQG aims to merge quantum mechanics and general relativity by incorpo-

rating the matter of the Standard Model with posited spacetime structures as finite loops woven into spin networks or spin foam. However, the LQG theory came short of reaching definable causality for quantum emergence or submergence of spacetime even though it is claimed background-independent and non-perturbational. Notably, LQG has been formulated into a four-dimensional framework (with or without supersymmetry) while M-theory requires 11-dimensional supersymmetry. A direct comparison between the two has not been possible. Unexpectedly, bipolar strings as a unified logical/physical theory can not only provide a process model for fine loops at the spin foam level for LQG but also a process model for cosmological loops at the multiverse level for M-theory. Surprisingly, both levels can follow the same equilibrium-based geometrical and logical reasoning of BQG and BDL/BDFL to extend and unify the fundamentally different theories.

Different bipolar strings as dipoles are shown in Figures 12 and 13, which generalize strings to the real world at various levels including but not limited to multiverse cosmological, galaxy, atomic, and subatomic levels that assume *complete background independence*. Figure 12a shows a quantum emergence or submergence of spacetime at the Big Bang and blackhole level; Figure 12b shows a quantum emergence or submergence of spacetime at the particle–antiparticle level; Figure 12c shows unified loop quantum processes of multiverses and/or spin foams; Figure 12d shows a bipolar string in a logical circle. Figure 13a shows a bipolar generic string as a quantum entanglement; Figure 13b shows a bipolar superstring as a hypothetical wormhole of two entangled universes—one submerges in a black hole, and another emerges from a white hole; Figure 13c shows a composite of bipolar strings; Figure 13d shows a composite of bipolar superstrings or multiverses.

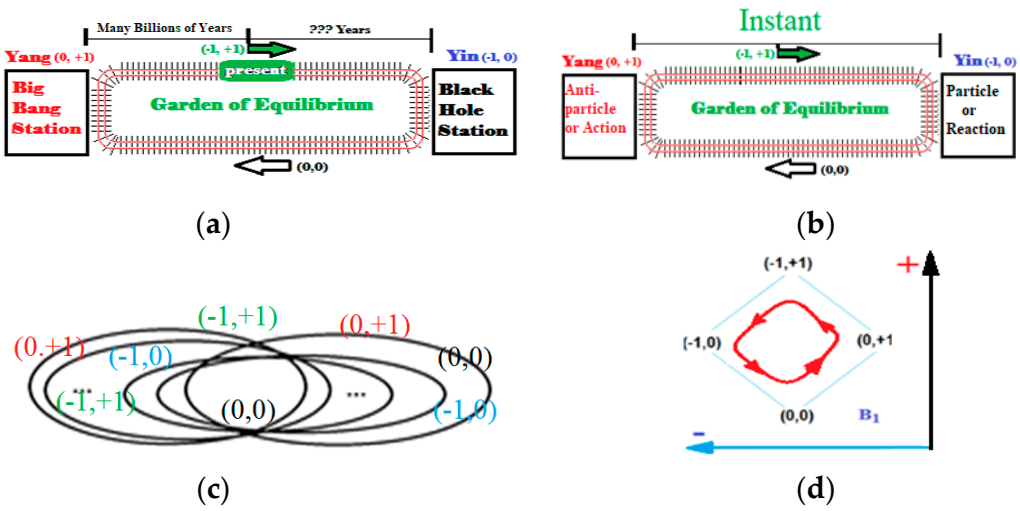


Figure 12. Background independent GRBS (adapted from [20]): (**a**) a cyclic process model of quantum emergence and submergence of spacetime; (**b**) a cyclic process model of quantum emergence and submergence of spin foam spacetime; (**c**) unified quantum processes of multiverses and/or spin foam loops; (**d**) the quantum logical and geometrical nature of a cyclic process model for bipolar strings or loops as an entangled-collapse-annihilation-reincarnation circle.

The bipolar strings under global realism as loop processes assume logically definable causality and information conservation. Thus, equilibrium-based GRBS provides a scalable and observable logical–physical and truth–equilibrium unification of the three roads to quantum gravity with different loops of back–forth logical entanglement (Figure 12c). The logical nature provides a basis for entangled machine thinking and imagination with or without a general direction. Under the condition of complete background independence, the + and −poles of a bipolar string can be alternating until one end is measured [21].

Note that, at all levels of composition (re. Figure 7), the following bipolar logical interactions form a ***loop*** process of bipolar states (Re. Figure Figure 12):

(1) $(0, +1)\oplus(-1, 0) = (-1, +1)$; //entangled bipolar string in superposition/BDE;

(2) (−1, +1)&(−1, 0) = (−1, 0); //equilibrium transiting to blackhole or particle;
(3) (−1, 0)⊗(−1, 0) = (0, +1); //blackhole transiting to big bang or particle action–reaction;
(4) (0, +1)&(−1, 0) = (0, 0); //annihilation or transformation;
(5) BUMP: [(A⇒B)&(C⇒D)]⇒[(A*C)⇒(B*D)]; [(A⇔B)&(C⇔D)]⇒[(A*C)⇔(B*D)].
//* bipolar interaction/integration.

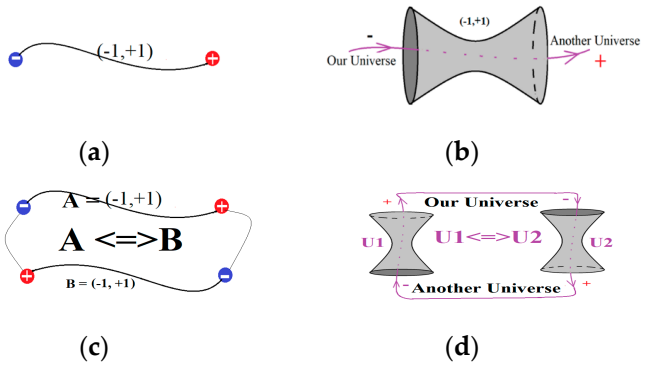


Figure 13. Bipolar strings: (**a**) quantum entanglement as a bipolar string (−1, +1) with spin down (−) and spin up (+); (**b**) hypothetical wormhole or Einstein–Rosen bridge as an entangled bipolar superstring (−1, +1) with input (black hole) (−) and output (white hole) (+); (**c**) entanglement of two bipolar strings A and B to a composite bipolar string; (**d**) entanglement of two bipolar superstrings U1 and U2 to multiverses.

4.2. Causal–Logical Brain Modeling for Entangled Machine Thinking and Imagination

While machine learning from data has been a focus, digital or quantum, for commercial applications with powerful computation, it is widely deemed unable to reach human-level AI because machines are deemed unable to think. "*If AI machine cannot think, can QI machine think?*". That was the question asked in an earlier paper [2]. To give a potential answer to the question, a ***causal–logical brain model (CLBM)*** for ***entangled machine thinking and imagination (EMTI)*** is proposed in the following.

Figure 14 shows a bipolar superstring multiverse CLBM based on BUMP for EMTI. Following Postulate 7, we show that thinking can be modeled as a cognitive process logically equivalent to quantum emergence (entanglement) and submergence (collapse) of spacetime with mind–light–matter unity at the fundamental level.

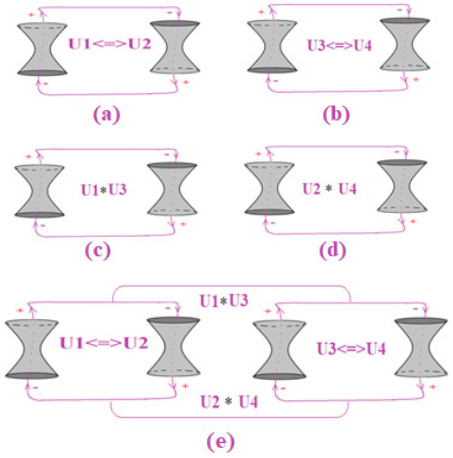


Figure 14. Illustration of a causal–logical brain model (CLBM) with entangled quantum neural networks based on bipolar universal modus ponens (BUMP) where a star * is any bipolar interaction: If (**a**) universes U1 and U2 are entangled, and (**b**) U3 and U4 are entangled, then (**c**) any interaction * between U1 and U3 must cause (**d**) the same interaction * of U2 and U4 or vice versa and leading to (**e**) all are entangled.

Let Figure 14 be elementary ***bipolar quantum graphs (BQGs)*** for ***entangled neural networks (ENN)***, we have the concept of ***entangled bipolar cognitive map (EBCM)***—an extension of bipolar cognitive map (BCM) or bipolar fuzzy cognitive map (BFCM) [9,12–17] of a college student. First, the student may wonder or imagine how multiverses be entangled logically with Hawking's negative–positive energies [84]. Based on the ubiquitous scalability and integrability of BUMP, we have:

Universal solution for entangled bipolar superstrings:

$$[(\boldsymbol{U1}\Leftrightarrow\boldsymbol{U2})\&(\boldsymbol{U3}\Leftrightarrow\boldsymbol{U4})]=>[(\boldsymbol{U1}*\boldsymbol{U3})\Leftrightarrow(\boldsymbol{U2}*\boldsymbol{U4})]. \quad (3)$$

Next, if we let U1 be the concept of "**study**" and U2 be "**GPA**", the two concepts can be logically entangled in the student's mind. If we let U3 be the concept of "**degree**" and U4 be "**job**", the two concepts can be similarly entangled in the student's mind. Since U1 or "study" and U3 or "degree" can also be entangled in a normal thinking activity, the logic of BUMP as shown in Equation (3) (re. Figure 14) can be instantiated to different truth-based sentences. For instance, consider the following:

(a) *"If I study hard, I can get high GPA to get my degree and get a job after graduation".*
(b) *"If I do not study hard, I cannot get high GPA to get my degree and get a job after graduation".*

Unexpectedly, truths are revealed by bipolar dynamic equilibrium with bipolar strings in the mind of a human being or in the memory of a humanoid robot. While bio-photonics must play the bridge role between mind and matter in a human brain for revealing neurobiological functionalities, it is questionable whether that is possible for AI&QI thinking machinery. The answer is positive because mind–light–matter unity could be reached with the geometry of light and logic of photons in quantum–digital compatible terms [6] (re. Figures 3–10).

Could the entangled bipolar strings be further extended or scaled up for creative machine thinking and imagination with unlimited emerging new concepts from adaptive machine learning?

Conjecture 3. *Entanglement of bipolar strings can be scaled up for unlimited creative machine thinking and imagination assuming unlimited emergence of new concepts in memory through self-organizing adaptive/accumulative machine learning.*

The Postulate can be illustrated by further extending the above example. For instance, one day the student might be thinking about a high "GPA" (U2) from studying "hard" (U1) to be qualified for a "research assistantship" (U5) that would gain "research experience" (U6) for "graduate admission" (U7) into a "PhD program" (U8). Then we have the new entanglement $[(\boldsymbol{U5}\Leftrightarrow\boldsymbol{U6})\&(\boldsymbol{U7}\Leftrightarrow\boldsymbol{U8})] => [(\boldsymbol{U5}*\boldsymbol{U7})\Leftrightarrow(\boldsymbol{U6}*\boldsymbol{U8})]$. Adding the new entanglement to the earlier one in memory we have a bigger mental picture (Figure 15).

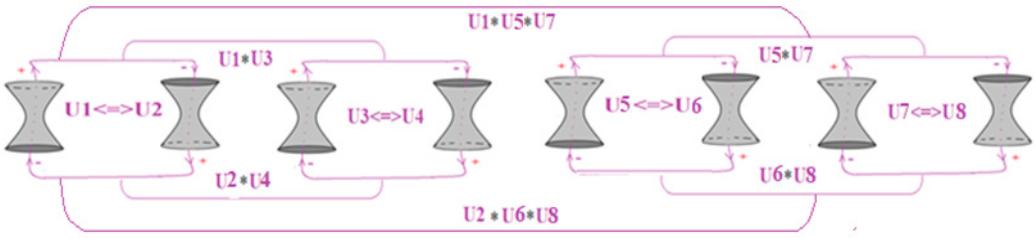


Figure 15. Entanglement of two different career paths for machine thinking.

Career Path 1 (job path):

$$\begin{aligned}&[(\boldsymbol{U1}(\boldsymbol{study})\Leftrightarrow\boldsymbol{U2}(\boldsymbol{gpa}))\&(\boldsymbol{U3}(\boldsymbol{degree})\Leftrightarrow\boldsymbol{U4}(\boldsymbol{job}))]\\ &=>[(\boldsymbol{U1}(\boldsymbol{study})*\boldsymbol{U3}(\boldsymbol{degree}))\Leftrightarrow(\boldsymbol{U2}(\boldsymbol{gpa})*\boldsymbol{U4}(\boldsymbol{job}))];\end{aligned} \quad (4)$$

Career Path 2 (graduate study path):

$$[(\boldsymbol{U1}(\boldsymbol{study})\Leftrightarrow\boldsymbol{U2}(\boldsymbol{gpa}))\&(\boldsymbol{U5}(\boldsymbol{ra})\Leftrightarrow\boldsymbol{U6}(\boldsymbol{re}))\&(\boldsymbol{U7}(\boldsymbol{ga})\Leftrightarrow\boldsymbol{U8}(\boldsymbol{phd}))] \\ =>[(\boldsymbol{U1}(\boldsymbol{study})^{*}\boldsymbol{U5}(\boldsymbol{ra})^{*}\boldsymbol{U7}(\boldsymbol{ga}))\Leftrightarrow(\boldsymbol{U2}(\boldsymbol{gpa})^{*}\boldsymbol{U6}(\boldsymbol{re})^{*}\boldsymbol{U8}(\boldsymbol{phd}))]. \quad (5)$$

Career Path 2 indicates the following: "*If I study hard, I can get high GPA, if I get a research assistantship I can get research experience, and if I get graduate admission, I can enroll in a PhD program. That implies (study hard & research assistantship & graduate admission) lead to high GPA & research experience & PhD program*". (see Figure 15).

Theorem 9. *With bipolar universal modus ponens or BUMP, thinking and consciousness can be described as mind–light–matter unitary QI logically equivalent to quantum emergence (entanglement) and submergence (collapse) of spacetime.*

Proof. Thinking, consciousness, QI, and quantum emergence/submergence can follow the same logic of BDL/BDFL and BUMP for bipolar entangled causal–logical reasoning with logically definable, scalable, interactive, and integrative causality (re. Figure 7). □

A comparison of Equations (2a–c) and (3) with Figure **7** reveals the logical equivalence of EMTI to quantum emergence (entanglement) and submergence (collapse) of spacetime. For instance, let the concepts of "study" and "gpa" et al. be conceptual agents in any spacetime, Equations (2a–c) and (3) would be logically spacetime emergence/submergence in the mind as shown in Figure 7. Surprisingly, EMTI with a CLBM is unified with quantum gravity for QCQB. (Note: while new concepts can emerge in creative thinking/imagination, submerged concepts can be recalled from memory).

It should be noted that, while crisp bipolarity is so far used for illustration purposes, in fuzzy or algebraic cases there could be bipolar granularities to support focus generation in cognitive mapping or pattern recognition for adaptive machine learning from EBCMs, a typical task for a GPU. Figure 16 shows two separate foci corresponding to Career Path 1 and Path 2, respectively.

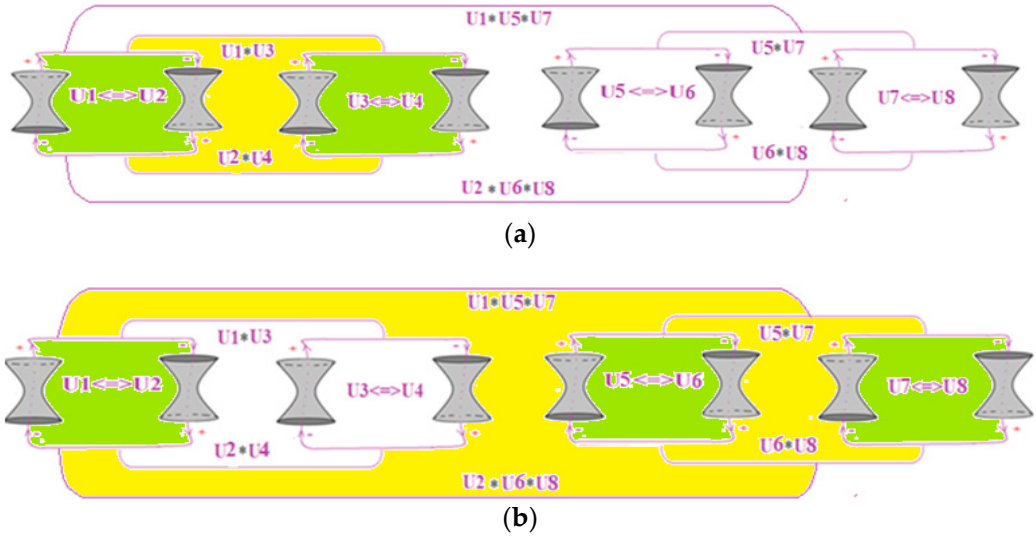


Figure 16. (**a**) Focus generation for Career Path 1; (**b**) focus generation for Career Path 2.

4.3. Road to Human-Level Intelligence

Now, career Path 1 and Path 2 in Figure 15 show two competitive options for further reasoning. Someone may wonder: *What are the differences between EMTI and rule-based reasoning?*

While if–then production rules are coded into machines by programmers based on truth-based unipolar Boolean logic (BL) or fuzzy logic (FL), EMTI is based on equilibrium-

based bipolar strings that make reciprocal bipolar interaction possible—the key for resonant self-organization and consciousness with entangled thinking [62–64]. While truth in AI is static, GRBS asserts that everything in the universe or in the mind including the universe and the mind themselves form a dynamic equilibrium-based bipolar string or superstring that can be entangled for human-level AI&QI. While rule-based reasoning needs hard-coded production rules, entangled machine thinking assumes emerging concepts in the mind. While an if–then production rule has precedence and is a consequence following MP, any pair or group of concepts can be bipolar entangled for causal–logical thinking and imagination following BUMP that can reveal modus ponens (MP), but not vice versa. While MP supports programed reasoning and learning, BUMP supports adaptive, enactive, creative, accumulative, entangled, causal–logical reasoning and learning in a "growing up" process. Here, quantum emergence and submergence naturally lead to consciousness and unconsciousness, respectively, with mind–light–matter unity in logical terms [6,9,13,15,17]. Thus, EMTI forms a mind–light–matter unity CLBM for QCQB with QI that is theoretically different from AI. Bipolar distinctions include but are not limited to logically definable causality in regularity and global energy/information conservation.

The next question could be as follows: *How could spacetime emergence and submergence be ubiquitous in the physical and mental worlds?*

This is a tough question with a simple answer. Logically, BUMP as an equilibrium-based bipolar universal generalization of MP provides logically definable causality in regularity. Observably, when a balloon is warmed up, it gets bigger, and when it is cooled down, it gets smaller. Thus, with mind–light–matter unity the ubiquitous property is both logical and observable.

A follow-up question is as follows: *What are the differences between EMTI and entangled thought?*

While entangled thought is a mental problem in modern psychology, EMTI is for logical and creative thinking with equilibrium and harmony. Of course, EMTI can also be used to model or simulate mental problems with drastic bipolar oscillation, chaos, and dichotomy [6,9,16,19,34,35]. This is possible because ***bipolar entropy*** can unify order and disorder. Thus, EMTI is applicable in mind–light–matter unitary AI&QI but also in modern clinical psychiatry and cognitive psychology as well as in bio-electronics, bio-economics, and social economics.

The next question is as follows: *How could an emerging concept in the mind be bipolar dynamic?*

Without input–output or negative–positive bipolar energy/information, no concept can emerge or submerge in spacetime or in the mind. Thus, GRBS asserts that bipolar entangled thinking and imagination is fundamentally open-world, open-ended, ubiquitous quantum emergence or submergence of spacetime with logically definable causality for human-level mind–light–matter unity AI&QI (Re. Figure 7).

It can be further questioned as follows: *How could the multiverses or superstrings in* Figures 14–16 *be applicable while M-theory is still hypothetical?*

While entangled spacetime emergence/submergence is still a matter of debate, dipoles are observed everywhere. The James Webb Space Telescope is reshaping cosmology, and some evidence of cyclic cosmology has been reported [2]. Regardless of the unsettled nature of this issue, equilibrium-based bipolar strings and superstrings or multiverses as imaginary structures in the universe and the mind are both logical and physical that can conserve information and can reveal truths. With logically definable causality in regularity, BUMP can reveal MP and equilibrium can reveal truth. Such properties make them ideal for the mind–light–matter unitary creative thinking and imagination towards the development of human-level AI&QI machinery through quantum entanglement. Furthermore, without creative thinking and imagination for new theories, there would be no experimental observation. The observational proof of light bending around celestial objects was preceded by Einstein's prediction in his relativity theory; the actual observation of black holes did not come until decades later after the black hole theory was established; the Bell inequality

violation could not have been tested without the Bell theorem. Regardless of all these, the logical nature of BUMP and QI with bipolar strings can enable a machine to think—a sufficient condition for the applicability of GRBS. That is comparable with any historical breakthroughs.

Yet another question is as follows: *What is the key difference between QI and cutting-edge AI?*

Notably, the logical road to human-level AI has led to a dead-end [7], but QI = AI ∪ BI (re. Figure 1), as a quantum–digital compatible, analytical quantum computing paradigm with logically definable causality for quantum superposition/entanglement, makes mind–light–matter unity and entangled thinking logically possible. While cutting-edge AI technology has so far came short of finding a breakthrough on the origin of entangled causal–logical cognition and consciousness even though supervised and unsupervised machine learning from big data has been applied for major commercial applications using artificial neural networks, QI can be supported with ***entangled quantum neural networks*** where each concept can be matched to a physical/biological entity, and GPU pattern recognition can be used for causal–logical focus generation from a cognitive map. That has been impossible with existing AI technologies even though artificial neural networks show certain incremental learning abilities through training. Fundamentally speaking, BUMP can reveal MP, but not vice versa [6,9].

While the above machine thinking illustration is soft science for intuitive illustration, in hard science, such as in particle physics and quantum biology [70,71,84–88], bipolar interaction would be actual quantum emergence and/or submergence of spacetime logically defined with BUMP (Re. Figure 7). Thus, creative thinking and imagination with mind–light–matter unity are fundamentally the quantum emergence (entanglement) and submergence (collapse) of spacetime (Re. Theorems 6 and 7) either in the physical world or in the mental world. While a human's analytical and creative thinking can be continued (entangled), stopped (collapsed), or become psychologically illogical for varied reasons, quantum entanglement in a machine can emerge and submerge or collapse in quantum–digital compatible terms [2], and a machine will not get tired from creative thinking and imagination.

Thus, a causal–logical brain model provides a basis for adaptive machine learning. With quantum–digital compatibility [2,6], bipolar quantum entanglement becomes part of an analytical paradigm of QI where a multidimensional system consists of a set of bipolar strings in bipolar dynamic equilibrium states (Figure 3a). Thus, bipolar quantum entanglement provides both a logical and a physical basis for entangled machine thinking and imagination toward human-level intelligence.

Notably, while human thinking could be logical, less logical, or even illogical limited by individual neurobiological development and physical strength, machine thinking can be strictly logical but less flexible/intellectual—a gap between humanoid robots and human intelligence. Thus, we still have the following question:

Can a machine pass the Turing test?

Recall that the Turing Test [4] involves three players: a computer, a human respondent, and a human interrogator. All three are placed in separate rooms or in the same room but physically separated by terminals. The interrogator asks both players a series of questions and, after a period, tries to determine which player is the human and which is the computer.

Conjecture 4. *Existence is fundamentally a bipolar dynamic equilibrium or BDE. Thus, all existence is dynamic.Consciousness as a mental state is a dynamic existence with mind–light–matter unity.*

Conjecture 5. *The intellectual gap in creativity between humanoid robots and humans can be bridged with entangled machine thinking, imagination, and adaptive/accumulative machine learning through a "growing up" training process with sufficient learning examples. (Note: machine learning is not covered in this work).*

Conjecture 6. *Conjectures 4 and 5 lead to the possibility for a humanoid robot's causal–logical brain to reach human-level intelligence to pass the Turing test provided (i) mind–light–matter*

unity AI/QI can be logically realized with GRBS, and (ii) examples are adequate or unlimited for adaptive/accumulative machine learning with EMTI.

5. Analysis and Discussion

5.1. God/Nature Logic vs. Human/Mind Logic

In 1925, on a walk with a young student named Esther Salama, Einstein shared his key guiding intellectual principle: *"I want to know how God created this world. I'm not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts; the rest are just details"*.

Einstein asserted [54] that *"Physics constitutes a logical system of thought which is in a state of evolution"* and *"Evolution is proceeding in the direction of increasing simplicity of the logical basis (principles). We must always be ready to change these notions—that is to say, the axiomatic basis of physics—in order to do justice to perceived facts in the most perfect way logically"*.

It is noted [2] that, while the notion of "God logic" [36] might be irritating to some scientists, if God and Nature are for the same reality then *"God logic"* becomes a unified notion of God/Nature logic. That was exactly defined by the philosopher Spinoza [89]. Einstein famously stated later that *"I believe in Spinoza's God who reveals himself in the orderly harmony of what exists, not in a God who concerns himself with the fates and actions of human beings"*. Einstein also famously said "*Everyone who is seriously involved in the pursuit of science becomes convinced a spirit is manifest in the laws of the Universe—a spirit vastly superior to that of man, and one in the face of which we with our modest powers must feel humble. In this way the pursuit of science leads to a religious feeling of a special sort, which is indeed quite different from the religiosity of someone more naive*".

While Einstein has been, for what he said, deemed as a God believer by some atheists but as an atheist by some God believers, following Einstein the phrase *"God's thoughts"* has been widely regarded by scientists, both theists and atheists, as the goal of modern physics to develop a logical understanding of the laws of Nature. However, that seemed to take researchers forever to accomplish unless God/Nature logic was found. Indeed, it has been impossible to reach the goal with truth-based "being qua being" logical thinking within spacetime geometry because spacetime as a being can emerge from or submerge to an equilibrium-based, completely background-independent geometry [6,9,20]. Fundamentally speaking [24], *"Truth-based logic is human logic; equilibrium-based logic is God (or Nature) logic. Mankind has been using human logic for thousands of years in seeking truths from the universe. Now, it is time for mankind to seek and accept God logic as a guiding light for scientific and technological endeavors"*.

Then, *what is the difference between the God logic of Gödel* [73] *and the God logic of Spinoza–Einstein?* While Gödel's God logic meant to use truth-based human logic to prove the existence of God as an exemplar Being, Spinoza–Einstein's God thought/logic meant to be the logic of Nature that can be equilibrium-based for revealing truth [2,6,36].

Although truth-based being qua being human mind logic has been widely regarded as God logic, GRBS is supported by numerous observations or historical facts in science and philosophy. The long search for ether and monad found no result, the modern quest for monopoles and strings turned out no concrete findings, but dipoles are everywhere. Without bipolar dynamic equilibrium, Platonic universals as well as the Dao of YinYang found no scientific logical basis [9,32,41]. Without bipolar dynamic logic or BDL to extend MP to BUMP, Aristotle's causality principle—the cornerstone of science—was logically undefinable for thousands of years [66,90–92], even with truth-based causal set [93], modern information theory [94], QM [66], and the second law of thermodynamics [77]—the paramount law of modern science.

It is noted [9,37] that, without definable causality in regularity, David Hume—an 18th-century Scottish philosopher and founder of empiricism—challenged Aristotle's causality principle and claimed it empirical, irreducible to pure regularity [90]; Bertrand Russell—a founder of analytic philosophy—deemed the law of causality as a relic of a bygone age [91]. Following Hume and Russell it is widely believed today by the scientific community that

causality is no longer the only cornerstone of modern science. However, quantum entanglement needs the causality principle to come back with logical definability in regularity for equilibrium-based GRBS. Otherwise, quantum entanglement as a spacetime transcendent phenomenon cannot be logically real because it defied local realism.

Subsequently, we have the following historical observations:

(1) Without YinYang bipolarity, Hilbert as a great mathematician failed to solve his Problem 6 in spacetime geometry—axiomatizing all of physics [72].
(2) Without definable causality, Einstein as a great physicist stopped short of accomplishing his grand unification.
(3) While the renowned British scientist Paul Dirac once denied the foundational role of philosophy for scientific discovery (cf. [95]), without YinYang bipolarity for logically definable causality in regularity his real-imaginary bra-ket standard in QM found no logical exposition for his 3-polarizer experiment [96] and cannot serve as the geometry of light and the logic of photon for mind–light–matter unity [6,38–40].
(4) Without strict $(-,+)$ bipolar complementarity, Niels Bohr as a founding father of QM asserted that quantum causality is unattainable [66], but Einstein refused to accept QM as a complete theory.
(5) More recently, with truth-based reasoning American theoretical physicist Lee Smolin wrote the book titled *Three Roads to Quantum Gravity: A New Understanding of Space, Time and the Universe* [65], but that was followed by another book titled *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next* [60].

Notably, Lee Smolin is a foreseer in science and a strong advocate of background independence [60,97]. He is the first theoretical physicist who made the visionary prediction that the three approaches, namely, string theory, LQG, and M-theory, may be approximations of a single, underlying theory [65]. While the underlying theory should be background-independent, the insurmountable barrier had, however, been that, without bipolar dynamic equilibrium, being and truth as static unipolar concepts in the human mind could not go beyond spacetime to perform the causal–logical quantum gravity function of God/Nature with complete background independence for spacetime emergence—a distinction of GRBS from local realism.

Someone may argue that we do have the equilibrium concept in the second law of thermodynamics. Unfortunately, the second law is a unipolar truth-based first principle, not a bipolar dynamic ground-0 axiom [6]. Someone may further argue that the concept of entropy in modern information theory must be most fundamental. Similarly, truth-based unipolar entropy is not equilibrium-based bipolar entropy, and classical information science is not quantum information science. It is evident that the key concept of quantum entanglement and/or superposition of the latter is missing from the former. Logically, the latter can reveal the former or QI can reveal AI through ubiquitous spacetime emergence/submergence, but not vice versa. However, the ubiquitous concept remained a "spooky action" or Schrödinger's Cat through the 20th century.

Among the distinguished scientists, black hole theorist Steven Hawking was once near the equilibrium-based GRBS theory. His book *The Grand Design* ([84] p. 5) pronounced that *"Philosophy is dead" "M-theory predicts that a great many universes were created out of nothing"* and *"Their creation does not require the intervention of some supernatural being or God"*. It is noted in [20] that, *"when they advocated M-theory and nihilism, however, they also promoted the concept of negative-positive energies* ([84] *pp. 179–180) but stopped short of pointing out the unavoidable consequence that the two energies are respectively the Yin and Yang of Nature. And when they proclaimed the death of (truth-based and being-centered) philosophy, they were calling back a different (YinYang bipolar equilibrium-based and harmony-centered) philosophy"*.

Among the Nobel Laureates, 2020 Nobel Prize Winner in Physics Roger Penrose is the strongest advocate for cyclic cosmology and dipoles. He proposed the Conformal Cyclic Cosmology (CCC) model [98] that iterates through infinite cycles in the framework of general relativity. On the other hand, he suggested that dipoles [99] could serve as

a physical basis of quantum gravity and quantum biology for consciousness [100] but pointed out the incompatibility with quantum measurement.

Arguably, quantum gravity as a fundamental theory needs a definitive battleground with the logic of photon in the geometry of light for resolving the observer–observability paradox [6]. The key here is not the details of measurement but logically definable causality in regularity [2,6,9] for global realism to reveal spacetime as emergence through ubiquitous quantum entanglement [101] in both physical and mental worlds [6,36]. Thus, we are faced with the deeper question: *Could equilibrium-based YinYang bipolar relativity serve as a formal geometrical and logical basis for spacetime emergence and submergence with mind–light–matter unity?*

5.2. Why YinYang?

Is YinYang not a kind of informal Eastern dialectic in philosophical terms?

It is noted [26] that Hegel—a founding father of dialectics after Heraclites made the famous assertion [102]: after his truth-based contradiction-centered dialectical logic it would henceforth be impossible to state a philosophical proposition that is both true and new—the proclaimed end of philosophy and history (cf. [103]). Now, after being the only one of its kind for truth-based logical deduction for thousands of years, MP can be revealed by the equilibrium-based BUMP in BDL. BUMP is evidently a logical and philosophical proposition that is both new and true. While all dialectical logic models are truth-based and contradiction-centered where a contradiction is both true and false and can be characterized by the value-pair (1, 1), YinYang bipolarity is equilibrium-based and harmony-centered and does not admit contradiction. For instance, (−pole, +pole) = (−1, +1) stands for bipolar true and shows a perfect input–output equilibrium that is syntactically, semantically, and fundamentally different from a contradiction in dialectics.

Is bipolarity not a modern physics or psychiatry concept in the West?

The term "YinYang Bipolar" was used in [9] to distinguish (−, +) bipolarity from the (0, 1) "bipolar" misnomer in digital logic design that meant to be bipolar transistor logic, where a transistor is NP or PN bipolar, but the logic implemented is (0, 1)-bivalent. While (0, 1) is considered normal, (−, +)-bipolarity is widely deemed abnormal. As noted in the preface of Ref. [9]: "*YinYang symbolizes the two energies of dynamic equilibrium, harmony, and complementarity; bipolarity without YinYang is often used in the West to indicate disorder, chaos, and dichotomy. Although disorder, chaos, and dichotomy are important aspects of Nature, they do not lead to a logical unification of Nature, agents, and causality like YinYang bipolar relativity in terms of equilibrium and harmony*". That is the reason that bipolarity without YinYang is unable to reach the geometry of light and the logic of photon for complete background-independence [6]. As stated by American linguist Alford [104], YinYang *"represents a higher level of formal operations, . . ., which lies beyond normal Western Indo-European development"*.

For instances,

(1) in modern psychiatry, negative (−) is used to indicate depression, positive (+) is used to indicate mania, and zero (0) is used to indicate a normal mind, but the fundamental distinction of strong and weak mental equilibria, such as (−1, +1) and (−0.1, +0.1), are denied by the math (−1 + 1) = (−0.1 + 0.1) = 0;

(2) In modern psychology "entangled thought" is used for "intrusive thought", a mental condition that needs medical attention, but quantum entanglement as a key for QI should be a ubiquitous causal–logical concept in the classical and quantum worlds as well as in the mental and physical worlds.

(3) The misnomer "bipolar logic" in digital circuit design as *"binary logic implemented by bipolar transistors"* is a typical example of truth-based human/mind logic of the classical world revealed by equilibrium-based God/Nature logic.

While the binary digits 1 and 0 are used as sign bits in digital computers to indicate (−, +) bipolarity, respectively, negative numbers have been prohibited from entering logical formulation for logically definable causality due to the claim of (−, +) isomorphistry—a kind of sophistry on isomorphism (cf. [31,105,106]). It is commonsense, however, that without bipolar dynamic equilibrium of negative–positive energy/information to perform

its regulating role, the human mind would be in total disorder, and the multiverses in M-theory would be completely isolated and collapsed [20]. With GRBS, the multiverses with order and chaos are unified in a global dynamic equilibrium in supersymmetry; the human mind may enjoy mental equilibrium or suffer from bipolar disorder as well [9,34].

Naturally, the Dao of YinYang has been widely influential in philosophy and science in Asia and the world (e.g., [66,107–110]). Without a unique formal geometrical and logical basis, however, it had been widely deemed an unscientific concept by the worldwide scientific community including but not limited to Chinese scientists in the homeland of negative numbers and YinYang bipolarity. It is noted in [27] that Chinese logician and philosopher Jin Yuelin almost failed to mention "YinYang" in his book *On Dao* [111]. Instead, he interpreted the Dao as Heisenberg's uncertainty principle in QM [112]. It is a typical example of some modern Chinese philosophers/scientists' effort to Westernize the Dao by denying YinYang bipolarity—the essence of the Dao in *Yijing—The Book of Change,* which asserts that *"One Yin and one Yang constitute what called the Dao"*.

Subsequently, few in modern science ventured to devote lifetime effort to the development of a unique formal equilibrium-based logical/mathematical system for YinYang bipolar reciprocal coexistence to reach logically definable causality in regularity. Such an effort would be and has been deemed "foolish", "futile", and "doomed" to fail. Notably, due to the $(-, +)$ isomorphism claim, negative numbers were forbidden to enter mathematics in the West for thousands of years until the Renaissance. Then, they were forbidden in both the East and the West to enter logical formulation even after Hilbert made $i = \sqrt{-1}$ as a basis for imaginary numbers in Hilbert space (cf. [113]), and Bohr used $i = \sqrt{-1}$ as part of his real–imaginary complementarity principle of the Copenhagen interpretation (cf. [2]). Ironically, with Leibniz's 01-binary interpretation [107] and Bohr's particle–wave or real–imaginary interpretation [66] to YinYang, no physicist would say electron and positron $(-e, +e)$ are isomorphic, no one dared to call Newton to wake up from his tomb to "correct" his action–reaction pair in physics textbooks from $(-F, +F)$ to $(+F, +F)$ or $(iF, +F)$, and no parents would be willing to ask their children to learn math in school without negative numbers (cf. [2,31,105,106]).

Nevertheless, starting in Ancient Greek times when negative numbers were forbidden in the West, isomorphism formed a scientific research area. While negative and positive numbers are not the same type ([9] Ch12) [31,105,106], now, in the worldwide fuzzy set community, it has been typical for some researchers to cite plagiarism as requested by a reviewer/plagiarizer and falsely claim $(-, +)$ isomorphism/equivalence repeatedly, disregarding logically definable causality in regularity, the geometry of light, the logic of photon, and Zadeh's recognition of bipolar fuzzy sets (re. [6,31,105,106]).

A key argument used to "support" the false claim is the so-called $(-, +)$ order-isomorphic property. The property is, however, only valid for linear, truth-based logics/sets of the same type and invalid for equilibrium-based, non-linear (or quantum linear) bipolar dynamic coexistence. For instance, self-negation $(-1, 0) \otimes (-1, 0) = (0, +1) \otimes (0, +1) = (0, +1)$ does not have a unique inverse mapping for the non-linear bipolar interactive operation $\otimes$. Such property leads to Yin adaptivity to bipolar equilibrium $(-1, 0) \oplus [(-1, 0) \otimes (-1, 0)] = (-1, 0) \oplus (0, +1) = (-1, +1)$, which is impossible for Yang—a logical basis for the secular "Yin-first" principle [9,31]. Thus, negative numbers and positive numbers are not the same type, and $(-, +)$ isomorphism/equivalence is a false claim.

It is obvious that without bipolar coexistence there would be no BUMP for quantum entanglement with logically definable causality in regularity. The effort of deriving a unipolar result from Nature's bipolar original and claiming the equilibrium-based original isomorphic or equivalent to the truth-based derivation must be a mathematical or philosophical joke like saying *"God/Nature logic is isomorphic or equivalent to my human/mind logic"*.

It is noted [31] that *"Without equilibrium truth cannot be revealed; without truth equilibrium cannot be identified. Equilibrium as holistic truth is not to replace truth but to extend it. With limited abilities humans should be forever humble in front of God (or Nature). We can get closer to God through scientific research but should never try to play God's role like a religious frenetic.*

Seeking God's logic is science; isomorphistry with truth-based supremacy might be a human play of God's role as we say: The universe is a dynamic equilibrium, not a truth or falsity. Thus, it is neither a (−, +)-equivalence nor a (−, +)-isomorphism". Fundamentally, truth-based logic as a human/mind unipolar linear logic should not or cannot be used to forbid scientists from seeking and accepting Spinosa–Einstein's God/Nature logic for open-world and open-ended scientific explorations, such as to find the causal relationships for equilibrium-based revealing of truths in sustainable development.

5.3. The "Championship"

Notably, bipolar fuzzy set theory [12,13] was repeatedly plagiarized before and after being recognized by Lotfi A. Zadeh [114]—founder of fuzzy logic [115]. In 2000, it was plagiarized by a researcher in an Eastern country to *"bipolar-valued fuzzy sets"* that denied the ontological basis of the theory as manifested by bipolar lattices (cf. [12,13,31]). Following the plagiarism in 2000, betting on (−, +) equivalence/isomorphistry to win, ignoring repeated warnings, focused on shallow copying/renaming and citation trading, with decade-long social construction and abduction effort, in a 2021 book a professor in another Eastern country boldly plagiarized YinYang bipolar crisp and fuzzy sets/logics in the lattices {−1, 0} × {0, +1} and [−1, 0] × [0, +1], respectively, to YangYin bipolar crisp/fuzzy sets/logics in the lattices {0, +1} × {−1, 0} and [0, +1] × [−1, 0] and renamed bipolar fuzzy equilibrium relation (or cognitive map) [15] to "bipolar fuzzy equivalence relation" (or graph). When he was caught engaging in academic theft, he argued that the bipolar fuzzy set was itself plagiarism due to (−, +) isomorphism and that he was, therefore, entitled to plagiarize it (cf. [2,31]).

Evidently, without a basic understanding of bipolarity and background independence, the YinYang-YangYin or (−, +)-(+, −) plagiarizer failed to realize that his decade-long effort would win him the "championship" for committing the most laughable plagiarism in the history of science and philosophy. Furthermore, the plagiarizer attempted to religionize and politicize YinYang in an effort to justify his plagiarism but "overlooked" the historical fact that the Dao of YinYang as an ancient Indigenous philosophy of Nature in Asia found its equilibrium-based formal logical basis in America thousands of years later with definable causality in regularity for quantum entanglement, mind–light–matter unity, and global realism beyond Leibniz and Bohr's interpretations, that would be a beautiful story in science philosophy in stark contrast to the "championship".

5.4. The Search for a Definitive Battleground of Quantum Gravity with Background-Independence

Background-independence has been a long-sought property in the quest for quantum gravity [60,97]. It is believed that *"an urgent issue in both physics and the philosophy of physics is to work out exactly what is meant by 'background independence' in a way that satisfies all parties, that is formally correct, and that satisfies our intuitive notions of the concept"* [116].

Logically, besides YinYang bipolar relativity [9], no other formal system has been reported for complete background independent reasoning with logically definable causality in regularity enabled by BQG as the geometry of light and BDL as the logic of photon [6]. While string theory lacks the background-independent property, the other two roads, namely, LQG and M-theory, are claimed to be background-independent. However, why did they also come short of finding a definitive battleground for quantum gravity?

The crux of the problem has been traced to the lack of a precise definition for *complete background independence*. It is asserted [24] that *"We need a minimum set of necessary and sufficient conditions for complete background independence. Without such a set of conditions, a unique logical foundation for quantum gravity cannot be developed"*.

Notably, until this day, a popular definition of background-independent geometry requires the unnecessary condition of being coordinate-free but does not require the imperative condition of supporting both reductionism and emergence [24]. For instance, according to Wikipedia (20 August 2023), *"Background independence is a condition in theoretical physics that requires the defining equations of a theory to be independent of the actual shape of the spacetime*

and the value of various fields within the spacetime. In particular this means that it must be possible not to refer to a specific coordinate system—the theory must be coordinate-free. In addition, the different spacetime configurations (or backgrounds) should be obtained as different solutions of the underlying equations".

It is pointed out [24] that the above definition failed to realize that YinYang bipolar coordinate transcends spacetime and is completely background independent [9,20,21,38,39]. Without YinYang bipolarity, it would be impossible to reach any reciprocal, adaptive, creative, enactive, complementary, and/or affective interactions for reductionism, emergence, and submergence. After all, without bipolarity, the geometry of light and the logic of photons [6] would be unreachable for logically definable causality and background-independent causal–logical thinking and imagination to reveal truths in spacetime. Subsequently, spacetime geometry became the only choice without mind–light–matter unity for thousands of years. Remarkably, reductionism enabled the identification of YinYang bipolar coordinate as the most fundamental geometrical and logical basis of physical existence for quantum emergence and submergence with information conservation, where emergence enables bipolar strings to be entangled/composed to bipolar superstrings or multiverses with scalability, and submergence allows a string to collapse. Evidently, truth-based logic as a unipolar logic of the human mind cannot achieve such physical, reciprocal, adaptive, and creative properties without bipolar quantum interaction and entanglement.

Thus, the unnecessary coordinate-free condition inhibited the development of a truly background-independent geometry and a new formal logical foundation for quantum gravity. Subsequently, the quest for quantum gravity in physics has so far came short of finding a definitive logical battleground for quantum superposition and entanglement while YinYang bipolar relativity with bipolar strings reached the goal a decade earlier following the quantum information science path [9,16,17,20,21].

It is proposed in [6,24] that a geometry with complete background independence must satisfy the following minimum set of conditions:

(1) *It is shape-free, quadrant irrelevant, and spacetime transcendent* (e.g., both bar-shaped and u-shaped magnets are bipolar; import-export balance has no shape; equilibrium transcends spacetime);
(2) *It supports reductionism, emergence, and submergence*;
(3) *It is ubiquitous (e.g., a photon can be anywhere)*.

In the above definition, the condition of *"coordinate-free"* was dropped from the popular definition (re. Wikipedia 20 August 2023). Subsequently, BQG as the geometry of light with the YinYang coordinate is shown to satisfy the conditions of complete background independence (re. Figures 4 and 8) and lead to quantum emergence and submergence of spacetime in both macroscopic cosmological multiverse level and microscopic spin foam level in logical terms (Figure 12) [2,6,9,20,21,31].

As a mathematically well-defined, non-perturbative, and background-independent quantization of general relativity, with its conventional matter couplings, LQG today forms a vast research area, ranging from mathematical foundations to physical applications. It is, however, critiqued as an incomplete theory and may not work out, just like its cousin string theory, which also claims to be a quantum theory of gravity. Hopefully, BQG and BDL will help the mathematics of LQG to reveal a workable solution.

Remarkably, while background independence has been sought in quantum gravity research, it has been overlooked in the search for mind–matter unitary cognition. The GRBS theory provides a new direction for quantum gravity with mind–light–matter unity in geometrical and logical terms. Notably, bipolar crisp/fuzzy sets have been applied in both the classical and the quantum worlds (re. [2,6,9,29,31]. Without the bipolar set theory, formal logically definable causality would be impossible. As a bipolar-set theoretic real-world string theory, GRBS provides the key to open the door to causal–logical quantum gravity and quantum information science with entangled thinking and imagination for adaptive and accumulative machine learning—a definitive battleground.

5.5. Axiomatizing Physics and Quantum Information Science for Mind–Light–Matter Unity AI/QI Machinery

While truth-based singularity is supported by the titanic Big Bang and black hole theories, quantum physicists overlooked the subtle but deeper fundamental, philosophical, and cosmological predictions [2]:

(1) Particles and antiparticles can be posited as the only things that survived a Big Bang and a black hole due to Hawking radiation or particle–antiparticle emission [70], and Newtonian action–reaction can be ubiquitous in the classical and quantum worlds in both crisp or fuzzy and soft or hard scientific terms, such as in decision science and mechanics.

(2) Without equilibrium-based bipolarity, truth-based singularity cannot provide complete background independence and the geometrical dynamics for cause and effect [6,9,20]. Thus, singularity alone is not qualified as a complete science theory to reach logically definable causality.

(3) While the Big Bang and black hole theory has been repeatedly questioned, we may assume that any pair of black holes and Big Bangs form a universe-wide or galaxy-wide dipole—an Einstein–Rosen Bridge [58] or wormhole [117]. Furthermore, such dipoles (or wormholes) can be generalized to any dipoles from the global cosmological levels to the atomic and subatomic levels. The generalization leads to YinYang bipolar relativity [9]. Subsequently, a one-directional flow of cosmological energy/information must be a long journey with many back–forth spinning cycles caused by bipolar interaction and entanglement at various levels. That may well explain why it has been a journey of many billions of years from the so-called Big Bang to our present time.

The above three observations and/or theoretical generalizations led to the theory of GRBS. That makes bipolar strings as bipolar dynamic equilibria in the real world are testable/observable at both the macroscopic and microscopic levels. Notably, the supersymmetry of negative–positive energies/information is different from that of boson-fermion particles. While boson-fermion supersymmetry is an unobserved theory, it is an observable fact that every action is matched with its reaction; dipoles are everywhere; every boson or fermion particle may have an antiparticle; parity non-conservation and CP-violation are observable; the universe is regulated by the dynamic equilibria of negative–positive energies. Thus, the Yin and the Yang of nature are non-isomorphic observable bipolar coexistence.

It might be argued that, in the Standard Model, the Higgs particle is a boson with no spin, electric charge, or color charge. That can be countered by the fact that the Higgs particle is a quantum excitation of one of the four components of the Higgs field with two neutral and two charged components constituting a scalar field. Each pair possesses either action–reaction or negative–positive bipolarity. Thus, bipolar dynamic equilibrium or bipolar strings, and bipolar symmetry or broken symmetry can be posited as the cause of boson-fermion symmetry or broken symmetry should the latter be observed, and GRBS can serve as a real-world theory of quantum gravity for the grand unification of action–reaction and particle–antiparticle pairs including the mysterious dark matter and dark energy to be further discovered. While the confirmation and unification of the two possible symmetries are left open for further research effort, the observable supersymmetry of negative–positive energies can be posited as more fundamental and general which governs the microscopic world as well as the macroscopic world in holistic physical, logical, biological, mental, and social terms.

Thus, with logically definable causality for mind–light–matter unity, GRBS provides a bipolar axiomatization of physics and quantum information science—a minimal but most general solution to Hilbert Problem 6 that has remained unsolvable for more than a century. As a logical system, the axiomatization is logically provable and analytically testable for mind–light–matter unity [6,9]. This fact leads to the Q5 (or QG5) paradigm of real-world causal–logical quantum gravities for quantum information science and human-level intelligence beyond the three roads toward quantum gravity [65].

(1) *Physical quantum gravity* (Examples: Re. [1,6,9,10,17,18,20,21,24,60,65,82,83,86–88,97,99,100,109,110,117–119]);
(2) *Logical quantum gravity* (Examples: Re. [2,3,6,9,29,31,32,38,39,85,110,120–130]);
(3) *Mental quantum gravity* (Examples: Re. [2,6,16–19,22,23,25–29,62–64,100,131–133]);
(4) *Biological quantum gravity* (Examples: Re. [9,18,78,96,108,128,134]);
(5) *Social quantum gravity* (Examples: Re. [6,9,31,42,135–137]).

Q5 can be regarded as a paradigm of bipolar strings for quantum gravity. In this paradigm, *physical quantum gravity* as part of physics is concerned with the unification of general relativity and quantum mechanics; *logical quantum gravity* as part of quantum information science is focused on quantum computing, communication, and teleportation; *mental quantum gravity* as part of neural science is focused on the interplay of quantum physics and brain science for the mind–light–matter unitary quantum cognition and consciousness, a typical example is creative thinking and imagination; *biological quantum gravity* as part of quantum biology is focused on the interplay of quantum information science and life sciences; *social quantum gravity* as part of social science is focused on quantum economics, social dynamics, and decision making. Unexpectedly, information conservation and blackhole data compression as physical quantum gravity found their applications in logical quantum gravity for post-quantum cryptography [30].

It has been remarked [9,21] that, while the Q5 paradigm may sound like an impossible mission, it follows a single condition and an undisputable observation:

(1) Condition: a bipolar string as a bipolar dynamic equilibrium is a basic form of any multidimensional equilibrium from which nothing can escape (Figure 3);
(2) Observation: bipolar quantum entanglement as a bipolar string/superstring is testable/observable and logically definable (Figures 12–15).

While truth cannot be out there existing independently from the human mind [138], bipolar strings as bipolar dynamic equilibria are ubiquitous physical/logical existence that must unify gravity and quantum theory. These observations have led to ground-0 axioms—a unification of the first principles of science and the second law of thermodynamics for the mind–light–matter unity AI&QI [6]. Now, we are ready to ask the three gigantic questions [101,139]:

(1) Could equilibrium-based information conservational bipolar quantum computing be the key to revealing the ubiquitous effect of quantum entanglement [26,101]?
(2) Could logically definable causality be the foundation for small-scale quantum computing to understand the universe completely [26,139]?
(3) Could the human brain be structurally similar to the universe [10]?

The answers must be YES for all three questions. Otherwise, equilibrium-based energy/information conservation and logically definable causality could not be the paramount laws of modern science [26]. The two paramount laws make equilibrium-based GRBS logically attainable, ubiquitous, and applicable for programming the universe [139] and the mind [25,27] with a small-scale quantum computer. Thus, mind–light–matter unity has led to real-world quantum gravity and brain–universe similarity for AI&QI.

5.6. Testability and Falsifiability

Notably, the no-communication theorem [140] in QM implies the no-cloning theorem, which states that quantum states cannot be (perfectly) copied. The counterargument is that no-cloning as a technological limitation cannot deny quantum entanglement as a reality of Nature for entangled causal–logical machine thinking/imagination to enter quantum information science with quantum-digital compatibility in logical terms, not in quantum cloning terms.

While the search for ether and monopole has so far turned out no concrete result, dipoles are observed everywhere. As a basis of string theory, monopoles are too far away from reality. For instance, without bipolarity, it is not clear how monopoles and strings can

form an atom with equilibrium or non-equilibrium [21]. In contrast, open-ended testability and falsifiability are provided for the equilibrium-based GRBS theory:

(1) Modus ponens or MP can be derived/revealed from bipolar universal modus ponens or BUMP [9,16] but not vice versa—a formal proof of bipolar equilibrium-based generalization of truth for ubiquitous, scalable, integrative, and interactive entanglement in an open world;
(2) Unlike the predicted but inconclusive existence of monopoles in string theory, dipoles are observable, scalable, and ubiquitous, bipolar quantum entanglement is both physical and logical and can reach GRBS with logically definable causality in regularity [2,6];
(3) BQG and BDL have been identified as the geometry of light and logic of photons, respectively, to reach a logical exposition [6,38,39] for the Dirac 3-polarizer experiment [96];
(4) Entangled photons have been logically proven to be an example of YinYang bipolar quantum entanglement in nature [6,38,39];
(5) The YinYang reciprocal quantum entanglement of two photons has been independently tested and observed [109];
(6) Bipolar atoms and neurons can reach mind–light–matter unity for AI&QI in logical and geometrical terms [6];
(7) Independent research in physics and neuroscience compared the network of neuronal cells in the human brain with the cosmic network of galaxies and found surprising similarities in their structural organization [10];
(8) GRBS can be falsified in the following cases: (i) should logically definable causality in regularity with BUMP in BDL/BDFL be falsified; (ii) should ether, monad, or monopole be observed as the most fundamental existence free from action–reaction, particle–antiparticle, and input–output bipolarity and causality; or (iii) should the Bell inequality violation and quantum nonlocality be both falsified.

6. Conclusions

Following Einstein's predictions, the theory of GRBS has been developed based on Ground-0 Axioms. GRBS constitutes a background-independent axiomatization of physics and quantum information science, which has been proven a necessary and inevitable consequence of the Bell inequality violation. With equilibrium-based bipolar strings, local realism has been formally extended to global realism supported with logically definable causality in regularity, where spacetime emergence/submergence is formally defined as quantum entanglement/collapse. With the brain–universe similarity, GRBS provides a logical and physical foundation for bipolar entropy, consciousness, and the mind–light–matter unity QCQB that has led to machine thinking and imagination. Thus, GRBS has brought conscious mind and resonant brain modeling closer to mind–light–matter unity AI and QI for human-level intelligence [2,62–64]. The testability and falsifiability of GRBS have been discussed.

GRBS extends Einstein's concept of causality from local realism to global realism comprised of eight criteria vs. those for local realism (re. Section 2.2):

(1) *Logically definable causality in regularity vs. undefinable causality;*
(2) *Unification of locality with quantum-nonlocality vs. no unification;*
(3) *Bipolar dynamic symmetry with mutuality vs. unipolar singularity;*
(4) *Energy/information conservation vs. observation;*
(5) *Background-independent spacetime emergence vs. background-dependent spacetime;*
(6) *Equilibrium-based God/Nature logic vs. truth-based human/mind logic;*
(7) *Open-world vs. closed-world;*
(8) *Brain–universe similarity vs. no similarity.*

Distinctions of GRBS from local realism include but are not limited to the following (in alphabetical order):

(1) Analytical quantum intelligence (QI) with formal logically definable causality vs. quantum mechanics with unattainable causality;

(2) Bipolar complementarity vs. real–imaginary or particle–wave complementarity;
(3) Bipolar dynamic fuzzy logic (BDFL) vs. unipolar fuzzy logic (FL);
(4) Bipolar dynamic logic (BDL) vs. unipolar Boolean logic (BL);
(5) Bipolar entangled quantum graph or cognitive map vs. bipolar isomorphism/equivalence;
(6) Bipolar entropy vs. unipolar entropy;
(7) Bipolar fuzzy sets vs. fuzzy sets;
(8) Bipolar G-CPT symmetry vs. unipolar CPT symmetry;
(9) Bipolar quantum geometry (BQG) vs. bra-ket quantum geometry;
(10) Bipolar quantum linear algebra (BQLA) vs. linear algebra (LA);
(11) Bipolar reflexivity vs. unipolar reflexivity;
(12) Bipolar relation vs. binary relation;
(13) Bipolar sets (crisp) vs. classical sets;
(14) Bipolar strings vs. one-dimensional strings;
(15) Bipolar superstrings vs. M-theory;
(16) Bipolar symmetry vs. unipolar symmetry;
(17) Bipolar transitivity vs. unipolar transitivity;
(18) Bipolar universal modus ponens (BUMP) vs. modus ponens (MP);
(19) Bipolarity vs. singularity;
(20) Causal–logical spin processes vs. spin loops;
(21) Complete background-independence vs. incomplete background dependence;
(22) Dynamic bipolar reciprocal interaction and self-organization vs. static unipolar coding;
(23) Entangled causal–logical machine thinking and imagination vs. programmed machine learning and computation;
(24) Equilibrium relation vs. equivalence relation;
(25) Equilibrium-based bipolar axiomatization of physics and quantum information science vs. unreachable truth-based unipolar axiomatization of physics
(26) Equilibrium-based bipolar quantum cellular automata vs. truth-based unipolar cellular automata;
(27) Equilibrium-based generalization of CPT symmetry vs. truth-based CPT symmetry;
(28) Equilibrium-based revealing of truths vs. truth-based reasoning;
(29) Fuzzy equilibrium relation vs. fuzzy similarity relation;
(30) Geometry of light and logic of photon vs. bra-ket standard;
(31) Geometry of light vs. geometry of spacetime;
(32) Global realism with bipolar strings (GRBS) vs. local realism limited by the speed of light;
(33) God/Nature logic vs. human/mind logic;
(34) Ground-0 axioms vs. first principles and second law;
(35) Information-energy conservation vs. observation;
(36) Logic of photon vs. logic of human mind;
(37) Logically definable causality vs. undefinable experimental/probabilistic causality;
(38) Mind–light–matter unity vs. mind–matter unity mystery;
(39) Order–disorder unification vs. order–disorder separation;
(40) Quantum emergence and submergence of spacetime vs. spacetime dominance;
(41) Quantum gravity for quantum information science vs. quantum gravity for blackholes;
(42) Quantum intelligence (QI) vs. artificial intelligence (AI);
(43) Real-world bipolar strings vs. untestable one-dimensional strings;
(44) Real-world quantum gravity vs. quantum gravity without a definitive battleground;
(45) Scalable bipolar strings vs. unscalable one-dimensional strings;
(46) Spacetime transcendent bipolar relativity vs. spacetime relativity;
(47) Ubiquitous effects of bipolar quantum entanglement vs. unknown effects of quantum entanglement;
(48) Yin-first principle vs. Yang-first;
(49) YinYang bipolar coordinate for complete background-independence vs. coordinate-free without definitive battleground;
(50) YinYang bipolar relativity vs. space-time relativity.

Remarkably, the GRBS theory as an equilibrium-based reconceptualization and unification of truth-based local reality with quantum nonlocality provides logically definable causality in regularity for quantum emergence or submergence of spacetime—a key for revealing the ubiquitous effects of quantum entanglement with mind–light–matter unity. Notably, GRBS does not exclude local reality but reveals it—the opening of a new research direction in science and philosophy. While the compatibility of GRBS with the Standard Model and the intertwining of different quantum gravity theories are left open for further research efforts, some unifying properties have been examined and illustrated in complete background-independent logical, algebraic, and physical terms. Thus, GRBS forms a real-world relativistic causal–logical quantum gravity theory with unexpected but much-needed simplification.

As a formal unified logical/physical theory, GRBS makes Nature–human unity/harmony a scientific topic for global environment protection, global economy regulation, and mind–light–matter unity QCQB. It is hoped that GRBS can help humanity in dealing with global climate change with sustainable scientific research/development. While this work has been focused on GRBS with illustrations in entangled causal–logical machine thinking/imagination, hopefully, as a basis for QCQB it has opened a new door toward human-level AI&QI in physical, logical, mental, biological, and social-economical quantum gravity terms.

It should be further clarified that GRBS is reached by following the quantum information science path instead of the one-dimensional string theory path in physics. It is dramatic but also normal because GRBS as an axiomatization of physics and quantum information science is supposed to be logician's work. As the first and only background-independent theory of its kind, GRBS happened to provide a reconceptualization and unification of string theory, loop quantum gravity, and M-theory—the three roads to quantum gravity [65]—with unexpected but much-needed simplification. Alternatively, GRBS could have been named as ***global realism with bipolar dynamic equilibria (GRBDE)***. It can be observed that GRBS holds the advantage over GRBDE in terms of bipolar entangled quantum graph representation, information visualization, reconceptualization, and causal–logical unification for real-world applications.

Finally, with a formal logical and physical basis, GRBS is expected to be free from the *"Not Even Wrong"*, *"Trouble with Physics"*, and *"Lost in Math"* problems. While it is a matter of debate whether GRBS would be able to inject new life into the faded TOE, this work has shown the potential of the equilibrium-based theory for major scientific advances, especially for the sustainable development of mind–light–matter unitary AI/QI machinery toward human-level intelligence and beyond. Now, with entangled machine thinking and imagination, our AI&QI humanoid robots should keep the hope alive for the miracle of reaching human-level intelligence someday as string theory was once lost in the beauty of the truth-based singularity but found in the harmony of equilibrium-based bipolar relativity.

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