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. Related literatures are critically reviewed to justify GRBS which is shown a necessary and inevitable consequence of Bell test and an equilibrium-based axiomatization of physics and quantum information science for brain-universe similarity and human-level intelligence. With logically definable causality in regularity for quantum superposition and entanglement, GRBS makes spacetime emergence and submergence ubiquitous in both the physical and mental worlds—an unexpected but long-sought simplification of quantum gravity with brain-universe similarity and 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* 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. Thus, 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 it is posited: (1) life is a living bipolar superstring regulated by *bipolar entropy* that unifies order and disorder; (2) thinking or consciousness 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. The two posits lead to a positive answer to the question *"If AI machine cannot think, can QI machine think?"* Causal-logical brain modeling for *entangled machine thinking and imagination (EMTI)* is proposed and graphically illustrated. Testability and falsifiability of GRBS is discussed.

Keywords—Entangled Bipolar Quantum Neural Network; Global Realism with Bipolar Strings (GRBS); Causal-Logical Brain Modeling (CLBM); Quantum Cognition and Quantum Biology (QCQB); Quantum Intelligence (QI); Blackhole Keypad Compression and Big Bang Data Recovery; Real-World Quantum Gravity (RWQG); Mind-Light-Matter Unity; Bipolar Entropy; Entangled Machine Thinking and Imagination (EMTI); Complete Background Independence; Isomorphistry; Lost in the Beauty of Truth-Based Singularity but Found from the Harmony of Equilibrium-Based Bipolar Relativity

1. Introduction

Modern science got many unresolved 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. Another mystery is that scientific reports have shown striking similarity between the human brain and the universe in structural organization, but that perplexed scientists with suspicion.

The 2022 Nobel prize in physics (Nobel Prize in Physics 2022) 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 Prize is epoch making as it is the most authoritative vindication of quantum entanglement that opened the door for 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 resolved the mystery of Bell inequality but also led to a new mystery. Since quantum entanglement violated Einstein's locality and causality principle of realism limited by the speed of light, the award has been deemed by some scientists as the conclusion of the great debate of 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 modern science that entails a formal causal-logical basis for quantum gravity currently missing from existing quantum theories.

It is asserted (Zhang 2023a) 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. The prediction leads to this paper.

It is a common view that without machine thinking (Turing 1950) there would be no adaptive machine learning for human-level AI (McCarthy 2007). 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 QI (Zhang 2021a). Notably, the logical road to human-level intelligence led to a dead-end (Mason 2010). It can be argued, however, that the so-called dead-end is the end of truth-based being-centered unipolar human/mind logic for AI but not the end of Spinoza-Einstein's God/Nature logic for QI that could be YinYang bipolar equilibrium-based in nature for open-world and open-ended exploration (Zhang 2011,2023a; Zhang and Peace 2013). 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 (Vazza & Feletti 2020) lead us to the valid questions: *Could human thinking as a brain function be logically equivalent to the emergence and submergence of spacetime through quantum entanglement? Could truth-based AI and BI be revealed by equilibrium-based QI?*

Based on ground-0 axioms that unifies the first principles and the second law (2021a), this work critically reviews related literatures on realism and extends *local realism* limited by Einstein's speed of light to the formal theory of ***global realism with bipolar strings (GRBS)*** (Zhang 2023b). GRBS introduces real-world bipolar strings (Zhang 2009b, 2011, 2012b) into realism with logically definable quantum causality in regularity (Zhang 2011, 2023a). Supported with QI and mind-light-matter unity, GRBS is shown applicable in entangled machine thinking and imagination. Fig. 1 shows the distinction of QI from AI and BI that brought up the question (Zhang 2023a) *"If AI machine cannot think, can QI machine think?"* GRBS provides an answer to the question.
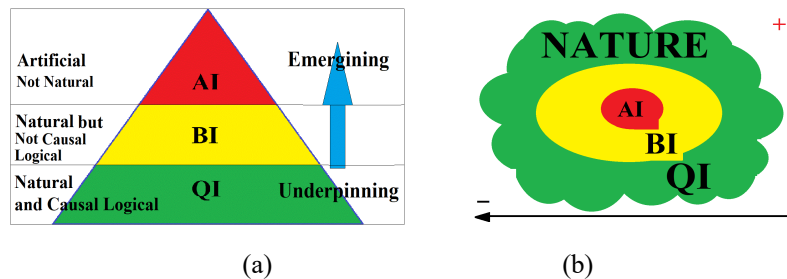
Figure 1. Quantum Intelligence (QI) as Natural Underpinning of Artificial Intelligence (AI) and Biological Intelligence (BI) (Adapted from (Zhang 2023a): (a) 3-Layer Closed View; (b) 3-Layer Open View

It is shown that GRBS constitutes a real-world bipolar relativistic logical reconceptualization of string theory (Witten 1993) (Susskind 2005) (Becker, Becker, Schwarz 2007), loop quantum gravity (LQG) (Rovelli and Smolin 1988; Rovelli 1996, 2008), and M-theory (Witten 1995) toward a grand unification of general relativity and quantum mechanics

with much-needed, long sought, but unexpected simplification. The simplification follows Einstein's predictions (Einstein 1934) *"pure thought can grasp reality"* and *"nature is the realization of the simplest conceivable mathematical ideas."*

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"* (Woit 2006), *"trouble with physics"* (Smolin 2006), and *"lost in math"* (Hossenfelder 2018).

While strings are unipolar truth-based, GRBS is an equilibrium-based bipolar string theory for a super symmetrical grand unification of Nature, agents, and causality (Zhang 2011, 2012a,b, 2016a,b, 2021a) (Gore J, van Oudenaarden A 2009) (Nobel Prize in Physics 2018) (Sandler 2023). 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 (Zhang 2021a) β+ and β– decay is 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.)

Assuming **bipolar strings** as any bipolar agents in dynamic equilibria that can be entangled and collapsed, GRBS further extends bipolar quantum agents (BQAs) (Zhang 2011; Zhang and Peace 2014) to a graphically visualizable causal-logical brain model with formal logically definable causality, mind-light-matter unity, and global energy/information conservation (Zhang 2011, 2018a,b; 2021a). It is shown that GRBS constitutes a philosophically different logical theory for quantum gravity and quantum information science (Zhang 1994-2023) with hope for the miracle of *"lost in the beauty of truth-based singularity but found from the harmony of equilibrium-based bipolar relativity."*

It should be remarked that this work is to present GRBS as a logically different real-world unified field theory that reveals truth-based local reality with equilibrium-based global realism. Since acceleration is equivalent to gravitation under general relativity (Einstein 1915, 1916), any physical, logical, socioeconomic, mental, or biological acceleration, growth, degeneration or creative thinking are qualified to be a kind of quantum gravity (Zhang 2011, 2012b). Based on ground-0 axioms (Zhang 2021a) GRBS makes 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 from which spacetime is emerged, and truths in spacetime are revealed.

Postulate 2. Gravitational *action-reaction*, electromagnetic *particle-antiparticle* or any *energy/information input-output bipolarity* is logically part of 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/algebraic variable in the bipolar quantum lattices $\{-1,0\}\times\{0,+1\}$, $[-1,0]\times[0,+1]$, and/or $[-\infty,0]\times[0,+\infty]$ (Fig. 3).

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* (Zhang 2009, 2011) as an entanglement or superposition can form without the speed of light limitation at the generic or most fundamental level.

The three postulates provide an equilibrium-based, top-down/bottom-up, bipolar logical unification for general relativity and quantum theory with or without graviton-antigraviton fully observed. Based on the above postulates, photons and electrons can be bipolar quantum entangled because (1) photon as its own antiparticle is itself a BDE (Zhang 2021a); (2) electron as an electromagnetic particle is inseparable from particle-antiparticle (-,+) bipolarity; (3) any massive/massless pair may form a gravitational action-reaction or input-output pair including but are not limited to black matter and black energy. Thus, as a bipolar relativity or bipolar string theory (Zhang 2009, 2011), not only should GRBS be applicable in physical science, but also in computing/information science, brain science, life sciences and social science as well.

This argument leads GRBS to a RWBS theory with *(i) physical quantum gravity, (ii) logical quantum gravity, (iii) mental quantum gravity, (iv) biological quantum gravity, and (v) social quantum gravity* (Zhang 2011, 2012b).

It is proven that GRBS is an inevitable consequence of Bell inequality violation shown in Bell test and a bipolar relativistic axiomatization of physics. 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 (Smolin 2001); on the other hand, it provides the basis for mind-light-matter unity AI&QI machinery with a ground-0 unification of the first principles of science and the second law of thermodynamics (2021a). It is shown that a key for a trouble-free testable solution lies in background-independent logically definable causality for bipolar equilibrium-based revealing of truths with quantum emergence and/or submergence of spacetime (Zhang 2011, 2012a, 2016a, 2016b, 2021a).

Notably, the no-communication theorem implies the no-cloning theorem (Park 1970), which states that quantum states cannot be (perfectly) copied. The counter argument is that no-cloning is a human limitation that cannot deny quantum entanglement as a reality of Nature for entangled causal-logical thinking/imagination to enter quantum information science.

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 theory of quantum gravity with bipolar entropy and QCQB. It is shown that GRBS is an inevitable consequence of Bell test or Bell 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 a formal logical reconceptualization and unification for real-world quantum gravity.

Section 6 draws a few conclusional 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 asserts 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 (Einstein 1905) 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 (Einstein 1915, 1916).

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 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 (Einstein, Podolsky, Rosen 1935). Thus, the collapse of the wave function as an effect exceeds the speed of light. But 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 (Bohr 1948). Thus, Bohr set up an insurmountable limitation on the definability of causality for quantum nonlocality until logically definable causality was formally formulated with bipolar universal modus ponens (BUMP) for ubiquitous quantum entanglement (Zhang 2007, 2009a,b, 2011) that opened the door for global realism.

Because of the probabilistic nature of wave function collapse, its violation of locality was once believed unable to transmit information faster than light. Thus, 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

It is noted in (Zhang 2011, Zhang & Peace 2014), according to Ben-Menahem (Ben-Menahem 1993), 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 on quantum mechanics as a complete theory for its lack of causality for quantum nonlocality. But, after wrestling with definable causality for his entire life, Einstein's truth-based locality came short of reaching logically definable regularity for causality. As a matter of fact, following local realism, causality cannot be formally defined with regularity. Subsequently, modern science including classical and quantum mechanics (QM) have 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. So far as we know, however, the big bang came from nowhere and caused by nothing; a black hole goes nowhere (Hawking & Penrose 1970). To reconcile the inconsistency between singularity and the second law of thermodynamics as critiqued in (Susskind 2008), Stephen Hawking proposed the remedy that a black hole should have particle and/or antiparticle emission or Hawking radiation (Hawking 1974,1975).

It is noted (Zhang 2011 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 big bang and black hole singularity to provide equilibrium-based background-independence, logically definable causality with regularity, symmetry, and reciprocal interaction or mutuality. Evidently, the vindication has been largely ignored in science.

Figure 2. Particle-Wave or Real-Imaginary Complementarity: Bohr's Coat of Arms (Creative Commons file by GJo, 3/8/2010, Source: File:Royal Coat of Arms of Denmark.svg (Collar of the Order of the Elephant) + File:yinyang.svg)

Notably, Bohr's YinYang complementarity in QM asserted "Opposites are Complementary" (Bohr 1948) (Fig. 2). Unfortunately, Bohr's YinYang is based on truth-falsity, particle-wave, or real-imaginary that stopped short of reaching strict (-,+) bipolar opposites for YinYang bipolar relativity (Zhang 2011). 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 time (Zhang 2011, 2016b). It was reasonable to believe that the unfound logical foundation or axiomatization of physics sought by Hilbert (Hilbert 1902) and Einstein (Einstein 1936) could be the key to quantum causality, quantum gravity, and quantum intelligence. ***Could there be a formal YinYang bipolar causal-logical system hidden behind the YinYang logo fond by Niels Bohr that could serve as a breakthrough to his own limitation on the definability of causality*** (Zhang 2011)***?***

2.3 Axiomatizing Physics—The Unreachable Goal of Truth-Based Unipolar Logical Thinking

Einstein wrestled with logically definable causality for his whole life searching for a logical foundation for physics. He stated (Einstein 1953): *"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 (Zhang 2021a). 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 that 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 death in 1955, his equations of general relativity did eventually lead to the flourish 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 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 programs in mathematics and axiomatizing physics (Hilbert 1902). Einstein believed that it is possible to axiomatize physics. It is noted (Zhang & Peace 2013) that, in 1931, Gödel published his incompleteness theorems (Gödel 1931). Many believe that these theorems proved Hilbert's mathematical program impossible and shattered his hope for axiomatizing physics as a related program. Three years after Gödel published his incompleteness theorems, however, Einstein reaffirmed (Einstein 1934) that *"pure thought can grasp reality"* and *"nature is the realization of the simplest conceivable mathematical ideas."* In 1936 he asserted (Einstein 1936): *"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 (Einstein1940) 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 12 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?

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. It is remarked, however, the three giants stopped short of pointing out the inevitable (Zhang 2011, pp92):

(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 for hosting the Spinoza-Einstein's God/Nature logic with complete background-independence. *But what geometry could possibly go beyond spacetime?*

The long search reached bipolar quantum geometry (BQG) (Zhang 2011,2012a,2021a) of equilibrium or supersymmetry of negative-positive energies/information for reciprocal 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 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 Bell inequality (Bell 1964, 1966), which, if violated in actual experiments, would imply that quantum mechanics violates either the **locality** or **realism** principle. Thus, Bell introduced another principle on the values of **unmeasured quantities** or **counterfactual definiteness** which has been generally called **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."* (Bell 1987)

While the two principles of locality and realism are commonly referred to as a single principle named **local realism**, the violation of Bell inequality opened the door to a new world of physics—**global realism** (Zhang 2023a). Beginning with John Clauser and Alain Aspect's 1970s to 1980s experiments, **Bell test** results of the Bell inequality show that quantum mechanics seemed to violate the inequality, so it must violate either 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 1990s when "loophole-free" experiment was carried out by Anton Zeilinger of University of Vienna who joined with John Clauser and Alain Aspect as a Nobel Laureate for the 2022 Nobel Award. Thus, we have

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

Proof. It follows from: (1) Bell inequality is the general name for the values of unmeasured quantities or counterfactual definiteness (Bell 1964) 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." (Bell 1987); (2) 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 (Zhang 2023a).

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 essentially a dynamic equilibrium, and quantum nonlocality must be part of global realism.

Proof. It follows from: (1) truth cannot be out there existing independently of the human mind (Rorty 1989), and 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 (Zhang 2021a); (3) everything in the universe including the universe itself and the mind of human being is a dynamic equilibrium but not a truth or falsity (Zhang 2011, 2021a); (4) quantum entanglement and/or superposition can be 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) global equilibrium is real based on the second law of thermodynamics; (7) since global equilibrium is real, 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 (BDE), and quantum collapse is essentially the collapse of a BDE.

<u>Proof.</u> It follows from that, fundamentally, any multidimensional equilibrium can be decomposed into a set of 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 (Zhang 2021a, 2023a)(see Figs. 3-7). Without logically definable causality the formal equilibrium-based logical/algebraic basis (Figs. 5-6) 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 a fundamentally bipolar dynamic equilibrium, and quantum collapse is essentially the collapse of a bipolar dynamic equilibrium (Zhang 2021 a)(Zhang 2023a) (Fig. 7).

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 geometrical and logical unification of general relativity and quantum mechanics for RWQG.

<u>Proof.</u> It follows from

(1) General relativity is a physical theory about space and time. According to general relativity, spacetime is a 4-dimensional object that must obey an Einstein equation, which explains how matter curves the spacetime. Without the geometry of light and logic of photon, however, it has been shown (Zhang 2021a) that observer-observability forms a paradox in modern science, truth-equilibrium finds no unification, and mind-light-matter unity is unreachable in spacetime.

(2) It is shown (Zhang 2021a) 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 photon, background-independent bipolar quantum geometry or BQG and bipolar dynamic logic or BDL have been identified as the geometry of light and logic of photon with logically definable causality for quantum emergence/submergence of spacetime and energy/information conservation with equilibrium and harmony (Zhang 2021a, 2018a).

*(4) Following (1) to (3) **global realism** must necessarily be a geometrical and logical unification of general relativity and quantum mechanics for RWQG with quantum emergence and submergence of spacetime (Re. Fig. 8).*

3.2 From Bipolar Dynamic Equilibrium to Bipolar Strings

To visualize global realism in graphical forms and physical terms, we introduce bipolar strings (Zhang 2009; 2011; 2012b) as a real-world string theory that unifies the concept of BQAs (Zhang 2011; Zhang and Peace 2014) with string theory.

Definition 1. Bipolar string is a BQA in a BDE characterized by a bipolar logical/algebraic state (Re. Postulates 1-3) that can form a bipolar quantum entanglement or BQE.

Definition 2. Bipolar generic string is a string with elementary (-,+) bipolar poles, each of which cannot be further decomposed. The two poles can be alternating until being measured.

Definition 3. Bipolar superstring is a composite or entangled set of multiple bipolar generic strings 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 4. Gravitation among cosmological objects is fundamentally a super symmetrical entanglement of bipolar strings with or without graviton-antigraviton pairs.

Postulate 5. 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 leads to a completely background-independent RWQG theory—a bipolar unification that bypassed the difficulty.

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

Proof. Following Theorem 1-4, Definition 1-4, Postulates 4-5, without bipolar strings there would be no bipolar dynamic equilibrium and no logically definable causality (Zhang 2011).

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

Proof. It follows directly from Theorem 5.

Postulate 6. Thinking and imagination is fundamentally a cognitive process 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 7. Machine thinking and imagination is a basis and prerequisite for adaptive machine learning and human-level intelligence.

Based on Definitions 1-4 and Postulates 1-4, action-reaction and particle-antiparticle bipolarity are unified. Now, a quantum entanglement of two elementary particles forms a bipolar generic string; an atom, a star, a pair of interactive stars or universes form superstrings.

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

Proof. Notably, the first principles of science and the second law of thermodynamics are unified with ground-0 axioms. Following Theorems 1-6, Definitions 1-4, Postulates 4-7, and Ref. (Zhang 2021a), without GRBS there would be no being, no truth, no first principles of science, no second law of thermodynamics, and no reality.
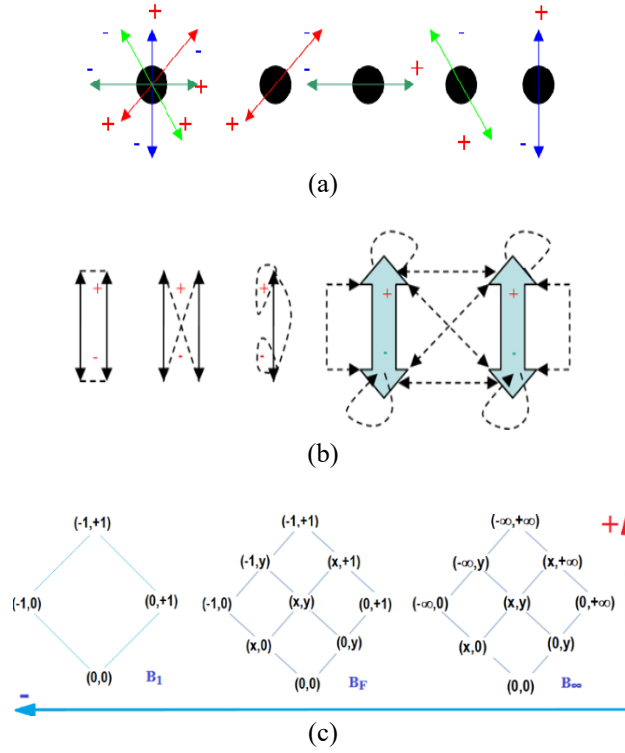
(a)

(b)

(c)

Figure 3. Background-independent mathematical abstraction (adapted from (Zhang 1998, 2011): (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
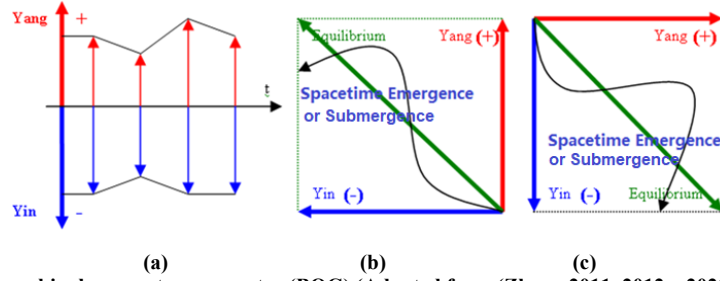

(a) (b) (c)

Figure 4. YinYang bipolar quantum geometry (BQG) (Adapted from (Zhang 2011, 2012a, 2021a)): Magnitude model; (b)-(c) Background independent quantum emergence or submergence of spacetime

Figure 5. Truth tables of eight BDL operators (adapted from (Zhang 2011))

10

(a)

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: $\{(x,y)\Omega(u,v)\} \equiv\{(x,y)\Leftrightarrow(u,v) \text{ or } (x,y)\Leftrightarrow\neg(u,v)\}$;	(d2)
Fission: $\text{fission}(x,y) = \{(x,0); (0,y)\}$;	(d3)
Fusion: $\text{fusion}((x,0); (0,y)) = (x,0)\oplus(0,y) = (x, y)$;	(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: $\text{blub}^\neg((x,y),(u,v))\equiv (x,y)\oplus^\neg(u,v) \equiv (-(y\vee v),(|x|\vee|u|))$;	(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: $\text{bglb}^\neg((x,y),(u,v)) \equiv (x,y)\&^\neg(u,v) \equiv (-(y\wedge v),(|x|\wedge|u|)))$;	(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: $\text{cglb}^\neg((x,y),(u,v)) \equiv (x,y)\otimes^\neg(u,v) \equiv -((x,y)\otimes(u,v))$;	(j)
Cross-pole least upper bound (cglb):	
$\text{club}((x,y),(u,v))\equiv(x,y)\oslash(u,v)\equiv(-1,1)-(\neg(x,y)\otimes\neg(u,v))$;	(k)
-club: $\text{club}^\neg((x,y),(u,v))\equiv(x,y)\oslash^\neg(u,v)\equiv -((x,y) \oslash (u,v))$.	(l)

(b)

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	$\neg((a,b)\&(c,d)) \equiv \neg(a,b)\oplus\neg(c,d)$; $\neg((a,b)\oplus(c,d)) \equiv \neg(a,b)\&\neg(c,d)$; $\neg((a,b)\&^\neg(c,d)) \equiv \neg(a,b)\oplus^\neg\neg(c,d)$; $\neg((a,b)\oplus^\neg(c,d)) \equiv \neg(a,b)\&^\neg\neg(c,d)$;
Non-Linear Bipolar DeMorgan's Laws	$\neg((a,b)\otimes(c,d)) \equiv \neg(a,b) \oslash \neg(c,d)$; $\neg((a,b)\oslash(c,d)) \equiv \neg(a,b)\otimes\neg(c,d)$; $\neg((a,b)\otimes^\neg(c,d)) \equiv \neg(a,b)\oslash\neg(c,d)$; $\neg((a,b)\oslash^\neg(c,d)) \equiv \neg(a,b)\otimes^\neg\neg(c,d)$

(c)

Unipolar Axioms (UAs):	Bipolar Linear Axioms:
UA1: $\phi\rightarrow(\varphi\rightarrow\phi)$; UA2: $(\phi\rightarrow(\varphi\rightarrow\chi))$ $\rightarrow((\phi\rightarrow\varphi)\rightarrow(\phi\rightarrow\chi))$; UA3: $(\neg\phi\rightarrow\varphi)\rightarrow((\neg\phi\rightarrow\neg\varphi)\rightarrow\phi)$; UA4: (a) $\phi\wedge\varphi\rightarrow\phi$; (b) $\phi\wedge\varphi\rightarrow\varphi$; UA5: $\phi\rightarrow(\varphi\rightarrow\phi\wedge\varphi)$;	BA1: $(\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow(\phi^-,\phi^+))$; BA2: $((\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow(\chi^-,\chi^+)))$ $\Rightarrow(((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\Rightarrow((\phi^-,\phi^+)\Rightarrow(\chi^-,\chi^+)))$; BA3: $(\neg(\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))$ $\Rightarrow((\neg(\phi^-,\phi^+)\Rightarrow\neg(\varphi^-,\varphi^+)) \Rightarrow (\phi^-,\phi^+))$; BA4: (a) $(\phi^-,\phi^+)\&(\varphi^-,\varphi^+)\Rightarrow(\phi^-,\phi^+)$; (b) $(\phi^-,\phi^+)\&(\varphi^-,\varphi^+)\Rightarrow(\varphi^-,\varphi^+)$; BA5: $(\phi^-,\phi^+)\Rightarrow((\varphi^-,\varphi^+)\Rightarrow((\phi^-,\phi^+)\&(\varphi^-,\varphi^+)))$;
Inference Rule – Modus Ponens (MP): UR1: $(\phi\wedge(\phi\rightarrow\varphi))\rightarrow\varphi$.	Non-Linear Bipolar Universal Modus Ponens (BUMP) BR1: IF $((\phi^-,\phi^+)*(\psi^-,\psi^+))$, $[((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\&((\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+))]$, THEN $[(\varphi^-,\varphi^+)*(\chi^-,\chi^+)]$;
Predicate axioms and rules UA6: $\forall x,\phi(x)\rightarrow\phi(t)$; UA7: $\forall x, (\phi\rightarrow\varphi)\rightarrow(\phi\rightarrow\forall x,\varphi)$; UR2–Generalization: $\phi\rightarrow\forall x,\phi(x)$	Bipolar Predicate axioms and Rules of inference BA6: $\forall x,(\phi^-(x),\phi^+(x))\Rightarrow(\phi^-(t),\phi^+(t))$; BA7: $\forall x,((\phi^-,\phi^+)\Rightarrow(\varphi^-,\varphi^+))\Rightarrow((\phi^-,\phi^+)\Rightarrow\forall x,(\varphi^-,\varphi^+))$; BR2-Generalization: $(\phi^-,\phi^+)\Rightarrow\forall x,(\phi^-(x),\phi^+(x))$

(d)

$$\forall\phi = (\phi^-,\phi^+)\in B_1 \text{ or } B_F = [-1,0]\times[0,+1],$$
$$[|\phi|=(|\phi^-|\vee|\phi^+|)] \rightarrow (\text{BUMP} \rightarrow \text{MP}).$$

Figure 6. Bipolar axiomatization on BDL (adapted from (Zhang 2011)): (a) Basic operations (has been extended to BDFL, $\forall(x,y),(u,v)\in B_1$ or B_F, $|x|$ is used for explicit bipolarity); (b) Equilibrium-based laws; (c) Equilibrium-based vs truth-based axiomatization of BDL; (d) Equilibrium-based revealing of truth (has been extended to BDFL)

Bipolar Universal Modus Ponens (BUMP) in IF-THEN Form:
IF $[(\phi^-,\phi^+)\Rightarrow(\phi^-,\phi^+)]\&[(\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+)]$ & $[(\phi^-,\phi^+)*(\psi^-,\psi^+)]$; THEN $[(\phi^-,\phi^+)*(\chi^-,\chi^+)]$.

BUMP in Tautological Form:
$[(\phi^-,\phi^+)\Rightarrow(\phi^-,\phi^+)]$ & $[(\psi^-,\psi^+)\Rightarrow(\chi^-,\chi^+)]$ $\Rightarrow \{[((\phi^-,\phi^+)*(\psi^-,\psi^+)) \Rightarrow ((\phi^-,\phi^+)*(\chi^-,\chi^+))]\}$.

BUMP in Singleton Form:
IF $[(\phi \Rightarrow \phi)$ & $(\psi \Rightarrow \chi)]$ and $(\phi * \psi)$, THEN $(\phi * \chi)$, or $(\phi \Rightarrow \phi)$ & $(\psi \Rightarrow \chi) \Rightarrow [(\phi * \psi) \Rightarrow (\phi * \chi)]$.

Bipolar Superposition/entanglement in Logical Form (Binding):
Binding$\{(-1,0), (0,+1)\} = (-1,0)\oplus(0,+1) = (-1,+1)$.

Bipolar Collapse in Logical Form (Separating):
Separating$(-1,+1) = \{(-1,0), (0,+1)\}$.

Single Entanglement: $(\phi \Omega \phi) = (-1,+1)$ or $(\phi \Leftrightarrow \phi)$ or $(\phi \Leftrightarrow -\phi)$.

$\forall$a,b,c,d, quantum spacetime emergence through BUMP:

$[\psi(a(t_x,p_1))\Rightarrow\chi(c(t_y,p_3))]\&[\phi(b(t_x,p_2))\Rightarrow\phi(d(t_y,p_4))] \Rightarrow [\psi(a(t_x,p_1))*\phi(b(t_x,p_2))\Rightarrow\chi(c(t_y,p_3))*\phi(d(t_y,p_4))]$;

Spacetime emergence through bipolar quantum entanglement with BUMP:

$[\psi(a(t_x,p_1))\Leftrightarrow\chi(c(t_y,p_3))]\&[\phi(b(t_x,p_2))\Leftrightarrow\phi(d(t_y,p_4))] \Rightarrow [\psi(a(t_x,p_1))*\phi(b(t_x,p_2))\Leftrightarrow\chi(c(t_y,p_3))*\phi(d(t_y,p_4))]$;

Or $[\psi(a)\Leftrightarrow\chi(c)]\&[\phi(b)\Leftrightarrow\phi(d)]\Rightarrow [\psi(a)*\phi(b)\Leftrightarrow\chi(c)*\phi(d)]$;

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.

<u>Two-fold universal instantiation:</u>
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 $\varnothing^-$. $(\phi\Rightarrow\phi)$ is designated bipolar true; $((\phi^-,\phi^+)*(\psi^-,\psi^+))$ is not designated. Bipolar instantiation: $\forall$x, $(\phi^-,\phi^+)(x) \Rightarrow (\phi^-,\phi^+)(x)$; $(\phi^-,\phi^+)(A)$; $\therefore$ $(\phi^-,\phi^+)(A)$.

Figure 7. Bipolar quantum entanglement/superposition and quantum emergence or submergence of spacetime (adapted from (Zhang 2011, 2021a, 2023a)
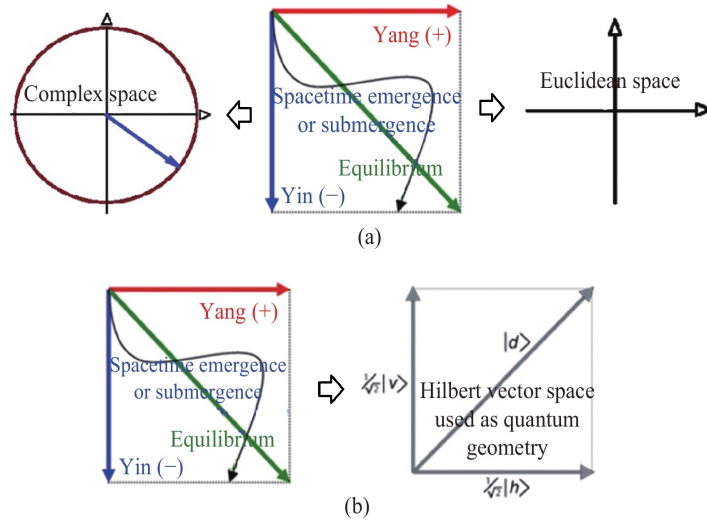

Figure 8. Spacetime emergence/submergence (adapted from (Zhang 2012a, 2021a)

3.3 Mind-Light-Matter Unity

It is argued (Zhang 2023a) 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 (Zhang 2011, 2021a, 2023) that BDL), BDFL) and BQLA in the completely 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 (Zhang 2021a) 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 bipolar dynamic equilibrium.

It is noted in (Zhang 2021a): *"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 (Zhang 2023a): *"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."* (Figs. 9-10)

With QI Turing's machine thinking puzzle (Turing 1950) became logically solvable. It is asserted (Zhang 2023a): *"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 (Turing 1950) 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?'"*
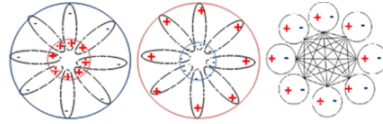

Figure 9. Bipolar unification of matter and antimatter (adapted from (Zhang 2012b))
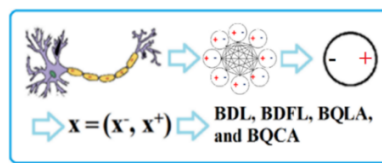

Figure 10. Mind-light-matter unity in logical terms where any observation, imagination or mental activity needs light to bridge mind and matter (Adapted from (Zhang 2018b, 2021a))

3.4 Bipolar Entropy—Equilibrium-Based Unification of Order-Disorder and Symmetry-Asymmetry

While entropy is a measure of disorder, we define bipolar entropy as a unification of order and disorder.

Definition 5. *Bipolar entropy* is logically a bipolar fuzzy set in the bipolar (quantum) lattice $[-1,0] \times [0,+1]$ (see Fig. 3).

It is shown (Zhang 2018a, 2021a) that bipolar energy/information can be conserved in an entangled bipolar quantum cellular automaton (BQCA) with BQLA. Equations (1a,b,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 BQLG matrix at time t. For $\forall (x, y), (u, v) \in B\infty = [-\infty, 0] \times [0, +\infty]$, we have (Zhang 2012b):

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

Bipolar Elementary Addition/Superposition: $(x, y)+(u, v) = (x+u, y+v)$.   (1b)

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

Why do we need BQLA and BQCA while linear algebra has been taught in college algebra class for centuries? A simple answer is that classical linear algebra does not reserve dynamic bipolar equilibrium information. For instance, (-0.1, +0.1) and (-1000000, +1000000) are different I/O bipolar balances, but in classical linear algebra we have (-0.1 + 0.1) = (-1000000 + 1000000) = 0. With bipolarity, let the absolute bipolar elementary energy $|\varepsilon|(x,y)=|x|+|y|$ and let $|\varepsilon_{col}|M_{*j}(t)$ be the energy/information of a column of a BQLG matrix $M(t)$, we have Eqs. 2(a,b,c) for a BQCA (Zhang 2011,2012b):

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

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

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

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

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

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

Based on Eqs. 1-2, M(t) can be called a **bipolar entropy** matrix—a bipolar relational or algebraic matrix 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 an entanglement for energy/information conservation toward a global equilibrium with local regeneration (or growth) and degeneration (or aging) in physical, logical, mental, biological, and quantum-bioeconomical terms (Zhang 2011). 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 paradigm (Zhang 2011, 2012b, 2018a, 2019b, 2021a,b).

Notably, Schrödinger's book *What is Life?* (Schrödinger 1944) 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**. Without bipolar dynamic equilibrium, however, his negentropy and free energy as unipolar concepts could not free himself from truth-based and being-centered singularity to reach definable causality. As a result, he stopped short to discover **bipolar entropy** to unify order and disorder for the bipolar coexistence of Nature. Similarly, Schrödinger's Cat paradox on quantum superposition remained a mystery for nearly two centuries (re. Zhang 2021a).

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 (Zhang 2021a). With bipolarity, the new entropy measures provide logically definable causality for bringing disorder, randomness, or uncertainty to an entanglement of equilibrium and harmony with mind-light-matter unity for AI&QI (Zhang 2011, 2018a, 2019b, 2021a,b).

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 mind-light-matter unitary 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 can serve as a set-theoretic causal-logical regulatory measure for order and disorder or symmetry and asymmetry of bipolar superstrings toward energy/information equilibrium and non-equilibrium 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. Eqs. 2 show that all bipolar superstrings can be regulated by bipolar entropy for equilibrium and non-equilibrium states.

Postulate 8. *Life* is a mind-light-matter unitary bipolar superstring regulated by bipolar entropy; *consciousnes*s is logically equivalent to mind-light-matter unitary quantum emergence of spacetime through quantum entanglement.

Postulate 9. Energy/information can be conserved through a pair of black-white wholes that form an entangled wormhole or Einstein-Rosen bridge.

Based on Eq. 2a, Postulate 9 can be illustrated with an example of information conservational security. Figs. 11a,b show the 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. And then the data received can be decrypted using the keypad with "big bang (or white hole)" data recovery (Zhang 2019b).
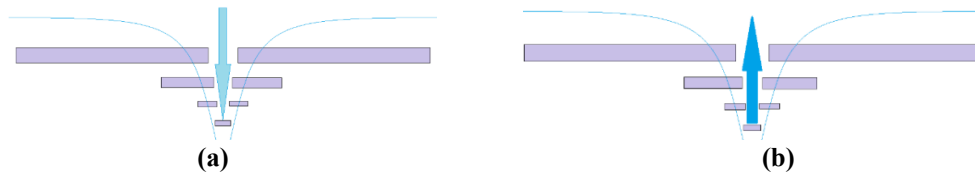

| (a) | (b) |

Figure 11. Information conservational security (Adapted from (Zhang 2019b): (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—Toward 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 (Rovelli 2008) such as in the vicinity of black holes or similar astrophysical objects. Evidently, while QG as a truth-based paradigm so far avoided the historical topics of logically definable causality and mind-light-matter unity (Zhang 2021a), the equilibrium-based approach brought QG to the real world.

It is noted (Zhang 2018a) 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."*

It is asserted (Zhang 2021b) 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."*

The bipolar axiomatization (Figs. 2-10) of GRBS presents a real-world logical unification of string theory, LQG, and M-theory—the three roads to quantum gravity (Smolin 2001). Assuming action-reaction and particle-antiparticle bipolarity as the most fundamental property of the universe, GRBS constitutes a minimal but most general axiomatization of physics—a

logical basis of *YinYang Bipolar Relativity* that unifies the first principles of science and the second law of thermodynamics (Zhang 2011, 2021a).

Bipolar relativity was alternatively named as an equilibrium-based bipolar string theory (Zhang 2009, 2012b). Now, the bipolar set-theoretic property is supported by the unique formal background-independent BQG and BDL/BDFL (Figs. 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 (Zhang 2021a). 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 a 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 to reach 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 nonlocality (re. Figs. 7,8). But 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) ⊕ (0,+1) = (−1,+1);
Submergence or collapse:
Separating(−1,+1) = {(−1,0), (0,+1)}.

GRBS logically reformulated string theory to a bipolar formal system for a real-world causal-logical reasoning. While string theory got into a major controversy in science, LQG aims to merge quantum mechanics and general relativity by incorporating matter of the Standard Model with posited spacetime structures as finite loops woven into spin networks or spin foam. So far, 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 4-dimensional framework (with or without supersymmetry), and 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 not only can 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 Figs. 12-13, that generalize strings to the real world at different levels including but are not limited to multiverse cosmological, galaxy, atomic, and subatomic levels that assume complete background independence. Fig. 12a shows a quantum emergence or submergence of spacetime at the big bang and blackhole level; 12b shows a quantum emergence or submergence of spacetime at the particle-antiparticle level; 12c shows unified loop quantum processes of multiverses and/or spin foams; 12d shows a bipolar string in a logical circle. Fig. 13a shows a bipolar generic string as a quantum entanglement; 13b shows a bipolar superstring as a hypothetical wormhole of two entangled universes—one submerges in a blackhole and another emerges from a white hole; 13c shows a composite of bipolar strings; 13d shows a composite of bipolar superstrings or multiverses.

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 (Fig. 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 (Zhang 2012b).

Note that, at all levels of composition (re. Fig. 7), the following bipolar logical interactions form a loop process of bipolar states (Re. Fig. 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) $(-1,0)\otimes(-1,0) = (0,+1)$; //blackhole transiting to big bang or particle action-reaction
(4) $(0,+1)\&(-1,0) = (0,0)$; //annihilation or transformation
(5) BUMP: $[(A\Leftrightarrow B)\&(C\Leftrightarrow D)]\Rightarrow[(A*C)\Leftrightarrow(B*D)]$. //$*$ is bipolar interaction/integration
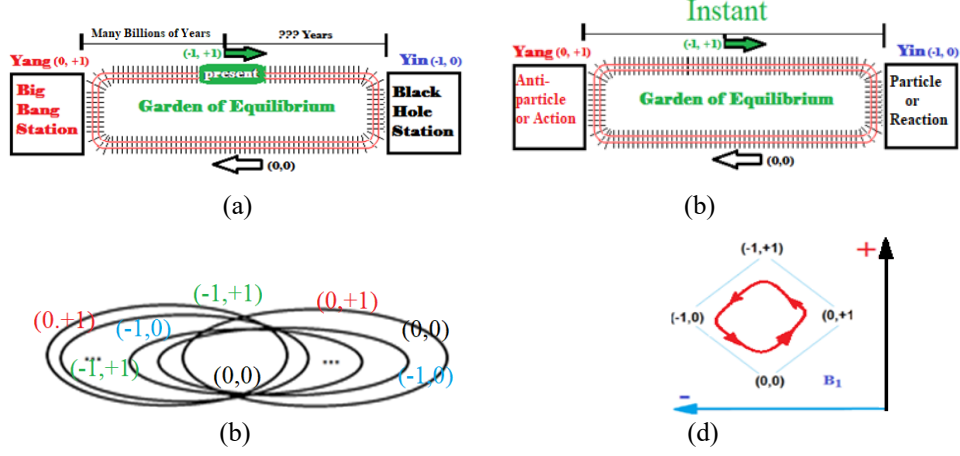

(a) (b)

(b) (d)

Figure 12. Background Independent GRBS: (a) A cyclic process model of quantum emergence and submergence of spacetime (adapted from (Zhang 2012a)); (b) A cyclic process model of quantum emergence and submergence of spin foam spacetime (adapted from (Zhang 2012a)); (c) Unified quantum processes of multiverses and/or spin foam loops (adapted from (Zhang 2012a)); (d) The quantum logical and geometrical nature of a cyclic process model for bipolar strings or loops as a entangled-collapse-nihilation-reappearance circle
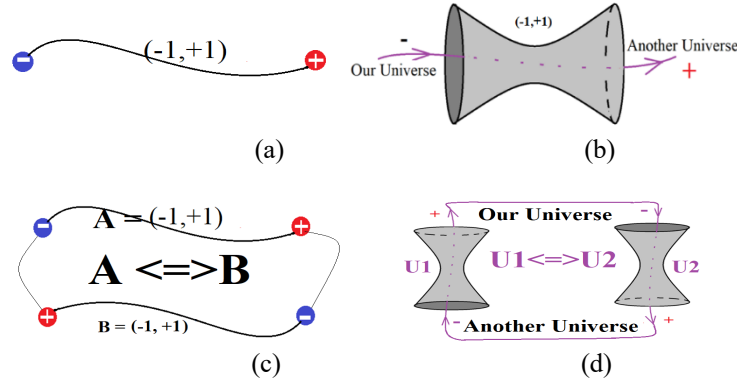

(a) (b)

(c) (d)

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 entangled bipolar strings A and B to a composite bipolar string; (d) Entanglement of two bipolar superstrings U1 and U2 to a composite bipolar string

4.4 Entangled Bipolar Quantum Neural Network for Causal-Logical Brain Modeling and Entangled Machine Thinking and Imagination

While machine learning from data has been focused on using powerful computation, digital or quantum, for commercial applications, it is widely deemed unable to reach human-level AI because machines are believed unable to think. *"If AI machine cannot think, can QI machine think?"* That was the question asked in an earlier paper (Zhang 2023a). 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.

Fig. 14 shows a bipolar superstring multiverse CLBM based on BUMP for EMTI. Following Postulate 6, 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.
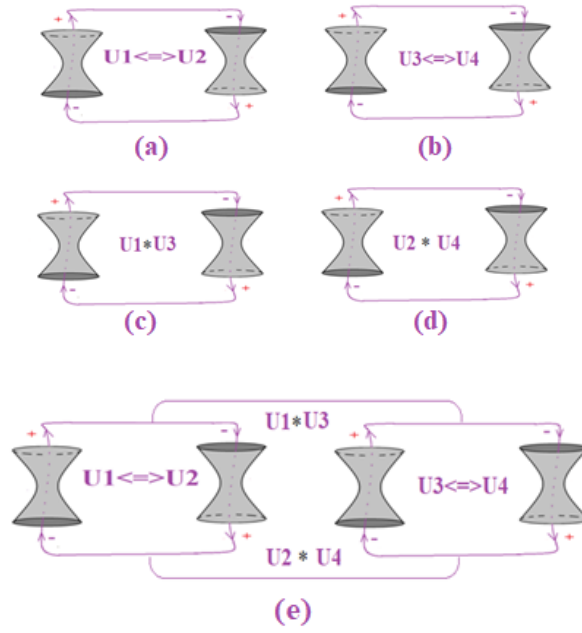
Figure 14. Illustration of a causal-logical brain model (CLBM) with entangled bipolar quantum neural networks based on bipolar universal modus ponens (BUMP) where a star ∗ is any bipolar interaction: If (a) universes U1 and U2 are entangled, and (b) U3 and U4 are entangled; then (c) any interaction ∗ 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 Fig. 14 be an ***entangled bipolar cognitive map (EBCM)***—an extension of bipolar cognitive map (BCM) or bipolar fuzzy cognitive map (BFCM) (Zhang 1994, 1998, 2003a,b, 2011) of a college student. First, the student may wonder or imagine how multiverses be entangled logically with Hawking's negative-positive energies (Hawking and Mlodinow 2010). Evidently, based on the ubiquitous scalability and integrability of BUMP we have the following universal solution for all entangled bipolar superstrings:

$$[(U1 \Leftrightarrow U2) \& (U3 \Leftrightarrow U4)] => [(U1*U3) \Leftrightarrow (U2*U4)]. \qquad (3)$$

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 Eq. (3) (re. Fig. 14) can be instantiated to different truth-based sentences. For instances:

(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 superstrings in the mind of a human being or in the memory of a humanoid. While bio-photonics must play the bridge role between mind and matter in a human brain for the 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 from the geometry of light and logic of photon in quantum-digital compatible terms (Zhang 2021a) (re. Figs. 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?

Postulate 10. Entanglement of bipolar strings can be scaled up for unlimited creative machine thinking and imagination assuming unlimited emergence of new concepts in memory through 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 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 *[(U5⇔U6)&(U7⇔U8)] => [(U5∗U7)⇔(U6∗U8)].* Adding the new entanglement to the earlier one in memory we have a bigger mental picture (Fig. 15).

Career Path1 (job path):

[(U1(study)⇔U2(gpa))&(U3(degree)⇔U4(job))]

=>[(U1(study)∗U3(degree))⇔(U2(gpa)∗U4(job))];   (4)

Career Path2 (graduate study path):

[(U1(study)⇔U2(gpa))&(U5(ra)⇔U6(re))&(U7(ga)⇔U8(phd))]

=>[(U1(study)∗U5(ra)∗U7(ga))⇔(U2(gpa)∗U6(re)∗U8(phd))].   (5)

Career Path2 indicates: *"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 &* res...
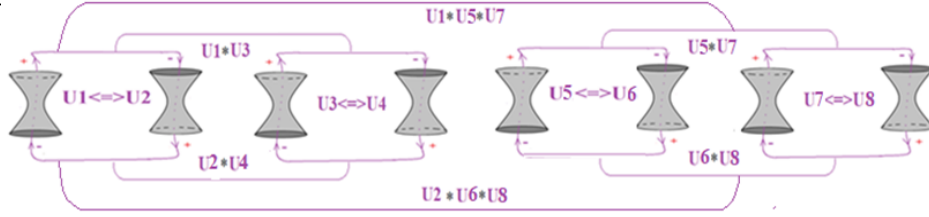

Figure 15. Entanglement of two different career paths for machine thinking

Theorem 9. With bipolar universal modus ponens or BUMP, thinking and consciousness can be fundamentally 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 can follow the same logic of BUMP for bipolar entanglement/collapse with logically definable, scalable, interactive, and integrative causality (re. Fig. 7).

A comparison of Eqs. 2 and 3 with Fig. 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, Eqs. 2 and 3 would be actually spacetime emergence/submergence in the mind following BUMP as shown in Fig. 7. Surprisingly, EMTI with a CLBM is unified with GRBS as a kind of quantum gravity for QCQB. It should be noted that, while crisp bipolarity is used for illustration purpose in the related figures, in fuzzy or algebraic cases there could be an infinite number of bipolar granularities to support focus generation in cognitive mapping or pattern recognition in machine learning from EBCMs, a typical task for GPU. Fig. 16 shows two separate foci corresponding to Career Path1 and Path2, respectively.
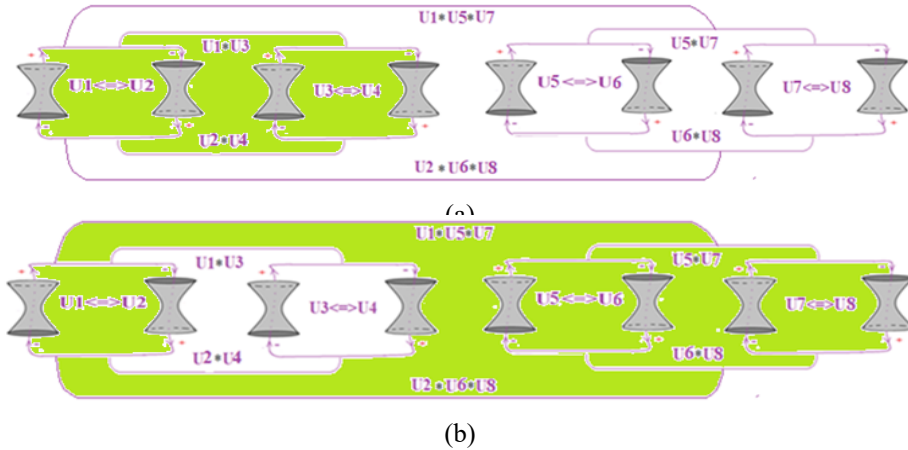

(a)

(b)

Figure 16. (a) Focus Generation for Career Path1; (b) Focus Generation for Career Path2

4.5 Road to Human-Level Intelligence

Now, career Path1 and Path2 in Fig. 15 show two competitive options for further reasoning. Someone may wonder: *What are the differences of EMTI from rule-based reasoning?*

Evidently, while if-then production rules are coded into machines by programmers based on truth-based unipolar Boolean logic or fuzzy logic, entangled machine thinking is based on equilibrium-based bipolar strings that make reciprocal bipolar interaction possible—the key for entangled thinking. While truth is static that belongs to AI, 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 a precedence and 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 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 (Zhang 2016a, 2018b, 2021a). Thus, EMTI forms a mind-light-matter unity CLBM for QCQB with QI that is theoretically different from AI.

A natural follow up question is: *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 be used to model or simulate mental problems with drastic bipolar oscillation, chaos, and dichotomy (Zhang 2011; Zhang et al. 2007, 2011) due to **bipolar entropy** that unifies 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 could be: *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 unlimited quantum emergence or submergence of spacetime with logically definable causality in BUMP for human-level mind-light-matter unity AI&QI (Re. Fig. 7).

It can be further questioned: *How could multiverses or superstrings in Figs. 14-16 be applicable while M-theory is still hypothetical?*

While entangled spacetime emergence/submergence is still a matter of debate, James Webb Space Telescope is reshaping cosmology, and some evidence of cyclic cosmology has been reported (An et al. 2020). Regardless of the unsettled nature of this issue, equilibrium-based bipolar strings and superstrings or multiverses as imaginary structures in the mind are both logical and physical that can conserve information and can reveal truths. Logically, BUMP can reveal MP. Such property makes them ideal for mind-light-matter unitary creative thinking and imagination towards the development of human-level AI&QI machinery through quantum entanglement with logically definable causality. Furthermore, without creative thinking and imagination for new theories there would be no experimental observation. The observational proof of light bending around celestial object was preceded by Einstein's prediction in his relativity theory; the actual observation of blackholes did not come until decades later after blackhole theory was established; Bell inequality violation could not have been tested without 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 comparable with any historical breakthroughs.

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

Notably, the logical road to human-level AI has led to a dead end (Mason 2010), but QI = AI $\cup$ BI (re. Fig. 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 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 bipolar 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 (Zhang 2021a).

While the above machine thinking illustration belongs to soft science for intuitive illustration, in hard science such as in particle physics and quantum biology (Hawking 1974,1975; Hawking and Mlodinow 2010; Xu et al. 2021; Sandler 2023; Sui 2023; Guo et al. 2020) bipolar interaction would be actual quantum emergence and/or submergence of spacetime logically defined with BUMP (Re. Fig. 7). Thus, creative thinking and imagination with mind-light-matter unity are fundamentally quantum emergence (entanglement) and submergence (collapse) of spacetime (Re. Theorems 6,7) 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 different reasons, quantum entanglement in a machine can emerge and submerge or collapse in quantum-digital compatible terms (Zhang 2023a), and a machine will not get tired from creative thinking and imagination.

Evidently, a causal-logical brain model provides a basis for adaptive machine learning. With quantum-digital compatibility (Zhang 2021a,2023), bipolar quantum entanglement becomes part of an analytical paradigm of QI where a multipolar system consists of a set of bipolar strings in bipolar dynamic equilibrium states (Fig. 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 and human intelligence.

Prediction 1. The intellectual gap in creativity between humanoids and humans can be bridged with entangled machine thinking, imagination, and adaptive/accumulative machine learning through a "growing up" training process with sufficient learning cases, provided that GRBS and QI are logically valid. (Note: Machine learning is not covered in this work).

Now we have one more question: *Can a machine pass the Turing test?*

Recall that Turing Test (Turing 1950) 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.

Prediction 2. It is possible for a humanoid's causal-logical brain to reach human-level intelligence to pass the Turing test provided (i) GRBS and QI are logically valid, and (ii) learning examples are adequate or unlimited for adaptive/accumulative machine learning.

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 (Einstein 1936) 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 (Zhang 2023a) that, while the notion "God logic" (Zhang and Peace 2013) might be irritating to some scientists, if God and Nature are for the same reality, *"God logic"* becomes a unified notion of God/Nature logic. That was exactly defined by the philosopher Spinoza (Baruch Spinoza 1677). 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" or "God logic" has been widely regarded by scientists, theists or atheists, as the ultimate goal of modern physics to develop a logical understanding of the laws of Nature. But that seemed to take researchers forever to accomplish unless God/Nature logic were found. Indeed, it has been impossible to reach the goal with truth-based logical thinking within spacetime geometry because spacetime can emerge/submerge from/to a completely background independent geometry (Zhang 2011) (Zhang 2016b) (Zhang 2021a). Fundamentally speaking (Zhang 2016b), *"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."*

Equilibrium-based GRBS is supported by numerous observations or facts in science history. The long search for ether and monad found no result, and the modern quest for monopoles and strings turned out no concrete findings, but dipoles are everywhere. Without a formal equilibrium-based bipolar logical basis to extend MP to BUMP, Aristottle's causality principle—the cornerstone of science—was logically undefinable with MP for thousands of years even with the second law of thermodynamics—the paramount law of modern science. Without YinYang bipolarity, Hilbert as a great mathematician failed to solve his Problem 6—axiomatizing physics in Hilbert spacetime geometry (Hilbert 1902); Einstein as a great physicist stopped short of reaching definable causality for his grand unification; Dirac bra-ket standard was disproven to be the geometry of light and the logic of photon for mind-light-matter unity (Zhang 2021a); Niels Bohr as a founding father of QM asserted that quantum causality is unattainable, and quantum mechanics has to content itself with particle-wave complementary descriptions (Bohr 1948). 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* (Smolin 2001), 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* (Smolin 2006).

Notably, Lee Smolin is a strong advocate of background independence and a foreseer in science. He is the first theoretical physicist who made the prediction that the three approaches, namely, string theory, LQG, and M-theory, may be approximations of a single, underlying theory (Smolin 2001). The insurmountable barrier had, however, been that, without bipolar dynamic equilibrium, being and truth as a static concept in spacetime geometry could not go beyond spacetime to reach complete background independence with logically definable causality in regularity for quantum gravity and spacetime emergence/submergence. 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 (cf. Zhang 2021a).

Among the distinguished scientists, black hole theorist Steven Hawking was once near the bipolar dynamic equilibrium-based GRBS theory. His book *The Grand Design* (Hawking and Mlodinow 2010, p5) pronounced: *"Philosophy is dead" "M-theory predicts that a great many universes were created out of nothing" "Their creation does not require the intervention of some supernatural being or God."* It is noted in (Zhang 2012a) that, *"when they advocated M-theory and nihilism, however, they also promoted the concept of negative-positive energies (Hawking and Mlodinow 2010, p179-180) 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 Laureate in physics Roger Penrose is the strongest advocate for cyclic cosmology and dipoles. He proposed the Conformal Cyclic Cosmology (CCC) model (Penrose 2010) that iterates through infinite cycles in the framework of general relativity. On the other hand, he suggested that dipoles (Tuszynski et al. 1995) could serve as a physical basis of quantum gravity and quantum biology for consciousness (Hameroff and Penrose 2014) 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 (Zhang 2021a). the key here is not the detail of measurement but logically definable causality in regularity (Zhang 2011,2012a,b) for global realism to reveal spacetime as emergence/submergence through ubiquitous quantum entanglement (Penrose 2005) in both physical and mental worlds. 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?

The word "YinYang" was originally used to distinguish (-,+) bipolarity from (0,1) binary logic which has been widely called bipolar logic in digital logic design but actually meant to be bipolar transistor logic where a transistor is NP bipolar but the logic implemented is bivalent (Zhang 2011). Should bipolarity be a modern physics and psychiatry concept in the West? As noted in the preface of Ref. (Zhang 2011): "*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 key reason why bipolarity without YinYang was unable to reach the geometry of light and the logic of photon for complete background-independence (Zhang 2021a). As stated by American linguist Alford (Alford 1993), YinYang "*represents a higher level of formal operations, .., which lies beyond normal Western Indo-European development.*"

For instances: (1) The term "bipolar logic" was widely used as a misnomer for bivalent logic in digital circuit design that actually meant to be "*binary logic implemented by bipolar transistors*"—a typical example of truth-based human/mind logic of the classical world revealed by equilibrium-based God/Nature logic of GRBS; (2) In modern psychiatry, negative (-) is used to indicate depression, positive (+) is used to indicate mania, and zero (0) is used to indicate 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 $(-1+1) = (-0.1+ 0.1) = 0$; (3) "Entangled thought" in modern psychology is used for "intrusive thought"—a mental condition that needs medical attention, but quantum entanglement should be an ubiquitous causal-logical concept transcending the classical and quantum worlds as well as the mental and physical worlds.

While the binary digits 1 and 0 have been used in digital computers to indicate (-,+) bipolarity, respectively, negative numbers have been prohibited to enter logical formulation for logically definable causality due to the claim of (-,+) isomorphistry—a kind of sophistry on isomorphism (cf. Zhang 2021b, 2023) (PubPeer 2021-2023). It is commonsense, however, without bipolar dynamic equilibrium of negative-positive energies/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 (re. Zhang 2012a). With GRBS, the multiverses with chaos are unified in a global dynamic equilibrium in supersymmetry; the human mind may enjoy mental equilibrium and may suffer from bipolar disorder as well.

Naturally, the Dao of YinYang has been widely influential in philosophy and science in Asia and the world (e.g. (Gore & van Oudenaarden 2009) (Zia et al. 2023) (Turner 2023)). Without a formal geometrical and logical basis, however, it had been widely deemed an unscientific concept by the scientific community including but not limited to Chinese scientists. It is noted in (Zhang 2018b,c) that Chinese logician and philosopher Jin Yuelin almost failed to mention "YinYang" in his book *On Dao* (Jin 1940). Instead, he interpreted the Dao as

Heisenberg's uncertainty principle in QM (Heisenberg 1927). It is a typical example of some modern Chinese philosophers' attempts to Westernize the Dao logically and ontologically by disregarding YinYang bipolarity—the essence of the Dao in *Yijing—The Book of Change,* which asserted *"One Yin and one Yang constitute what called the Dao."*

Subsequently, in the history of science few ventured to devote lifetime effort in the development of a formal equilibrium-based logical basis for YinYang bipolar coexistence to reach logically definable causality with regularity. Such an effort could be deemed "foolish", "futile", and "doomed" to fail. Remarkably, due to the (-,+) isomorphism claim in mathematics, the negative sign has been forbidden to enter logical formulation even after Hilbert and Bohr used $i = \sqrt{-1}$ as a basis for imaginary numbers in Hilbert space (cf. (Gautam 2022), (Zhang 2021b, 2023)). Ironically, with Leibniz (0,1) binary interpretation and Bohr's particle-wave or real-imaginary interpretation 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 (-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 (Zhang 2011; PubPeer 2021-2023; 2021b).

Nevertheless, at Ancient Greek times when negative numbers were forbidden in the West, isomorphism started to form a research community in mathematics. While negative and positive numbers are not the same type of numbers (PubPeer 2021-2023) (Zhang 2021b), now in the world-wide fuzzy set community, it has been typical for isomorphistors to cite plagiarisms as requested by a reviewer/plagiarizer to falsely claim (-,+) isomorphism again and again but ignored the plain fact that negative and positive numbers are not the same type, and the order-isomorphic observation can only justify linear properties of truth-based sets/fuzzy sets not equilibrium-based, bipolar fynamic, non-linear properties.

It is asserted (Zhang 2021b) that *"Seeking God's logic is science; isomorphistry with truth-based supremacy might be a human play of God's role."* Fundamentally, truth-based logic as a human/mind unipolar linear logic cannot be used to forbid scientists to seek and accept 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. Here, one is equilibrium-based non-linear bipolar dynamic that reveals truth in spacetime; another is truth-based, linear, unipolar, and static within certain spacetime.

Strangely, bipolar fuzzy set theory (Zhang 1994, 1998) was repeatedly plagiarized before and after being recognized by Lotfi Zadeh (Zadeh 2008)—founder of fuzzy logic (Zadeh 1965). In 2000 it was plagiarized by a researcher in an Eastern country to *"bipolar-valued fuzzy sets"* that denied the philosophical and/or ontological basis of the theory (cf. (Zhang 2021b)). Following the 2000 plagiarism, betting on (-,+) equivalence/isomorphistry to win, ignoring repeated warnings, with decade-long social construction and abduction efforts, in a 2021 book a professor in another Eastern country plagiarized YinYang bipolar crisp and fuzzy sets/logics in the lattices $\{-1,0\} \times \{0,+1\}$ and $[-1,0] \times [0,+1]$ to YangYin bipolar crisp/fuzzy sets/logics in the lattices $\{0,+1\} \times \{-1,0\}$ and $[0,+1] \times [-1,0]$, respectively, and renamed bipolar fuzzy equilibrium relation (or cognitive map) to bipolar fuzzy equivalence relation (or graph). When he was caught of academic stealing, he argued that (-,+) bipolarity was itself plagiarism due to isomorphism and, therefore, he was entitled to plagiarize it (cf. Zhang 2021b, 2023a).

Evidently, without basic understanding on background independence the (-,+) to (+,-) plagiarizer failed to realize that his effort would win him the top ranking of being a most laughable plagiarism in science history. Furthermore, the plagiarizer tried to religionize and/or politicize YinYang in effort of justifying his plagiarism but "overlooked" the historical fact that YinYang as an ancient indigenous philosophy of Nature in Asia found its formal equilibrium-based logical basis in America thousands of years later with definable causality in regularity for quantum entanglement, mind-light-matter unity, and GRBS beyond Leibnizian and Bohr's interpretations, that would be a beautiful story in science philosophy—a sharp contrast to his top ranking among laughable plagiarisms.

5.3 The Search for a Definitive Battleground of Quantum Gravity with Complete Background-Independence

Background independence has been a long-sought property in the quest for quantum gravity (Smolin 2005, 2006). 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." (Weinstein and Rickles 2023)

Observably, besides YinYang bipolar relativity (Zhang 2011) no other formal logical system has so far been reported for complete background independent reasoning with logically definable causality enabled by BQG as the geometry of light and BDL as the logic of photon (Zhang 2021a). While the pitfall of string theory could be its lack of background independent property, the other two roads, namely, LQG and M-theory have been claimed background independent. But why did they two also come short of finding a definitive battleground for quantum gravity?

The crux of the problem was identified as the lack of a precise definition for complete background independence (Zhang 2016b). It is asserted 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."*

It is noted that, 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 (Zhang 2016b). For instance, according to Wikipedia (8/20/2023), *"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 asserted that the above definition failed to realize that YinYang bipolar coordinate transcends spacetime and is completely background independent (Zhang 2011,2012a,b; Zhang and Marchetti 2015a,b; Zhang 2016b). Without YinYang bipolarity, it would be impossible to reach any reciprocal, adaptive, creative, enactive, or affective interactions for reductionism and emergence. After all, without bipolarity the geometry of light and the logic of photon (Zhang 2021a) would be unreachable for logically definable causality and background independent causal-logical thinking and imagination beyond spacetime. Subsequently, spacetime geometry became the only choice without mind-light-matter unity for thousands of years. Remarkably, reductionism enabled the identification of YinYang bipolarity as the most fundamental logical property of physical existence for quantum emergence and submergence or collapse with information conservation, where emergence enables bipolar strings to be entangled/composed to bipolar superstrings or multiverses. Evidently, truth-based logic as a unipolar logic of the human mind cannot be physical, reciprocal, adaptive, and creative with quantum interaction and entanglement.

Thus, the unnecessary and insufficient 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 come short of finding a definitive logical battleground for quantum superposition and entanglement while YinYang bipolar relativity with bipolar strings reached the goal decade earlier (Zhang 2009a,b, 2011, 2012a, 2021a).

It is proposed in (Zhang 2016b, 2021a) that a geometry with complete background independence must satisfy the 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., Photon can be anywhere).

In the above definition, the condition of *"coordinate-free"* was removed from the popular definition. Subsequently, it is shown that BQG as the geometry of light with the YinYang coordinate satisfies the conditions of complete background independence (Zhang and Marchetti 2015a,b; Zhang 2021a) (re. Figs. 4 and 8) and led to quantum emergence and submergence of spacetime in both macroscopic cosmological multiverse level and microscopic spin foam level in logical terms (Fig. 12).

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, the mathematics of LQG still need to reveal a workable solution.

Remarkably, while background independence has been sought in quantum gravity research, it is largely 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 sets and fuzzy sets have been applied in both the classical and the quantum worlds (Re. (Zhang 2021a,b; 2023)) without which formal logically definable causality would be impossible for GRBS. 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.

5.4 Axiomatizing Physics 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 (Zhang 2023a):

(1) Particles and antiparticles can be posited the only things that survived a big bang and a black hole due to Hawking radiation or particle-antiparticle emission (Hawking 1974), and Newtonian action-reaction can be ubiquitous in the classical and quantum worlds in both crisp or fuzzy, 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 (Zhang 2011; Zhang 2021a; Zhang 2012a). 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 hole and big bang forms a universe-wide or galaxy-wide dipole—an Einstein-Rosen Bridge (Einstein and Rosen 1935) or wormhole (Dobrev 2015). Furthermore, such dipoles (or wormholes) can be generalized to any dipole from the global cosmological levels to the atomic and subatomic levels. The generalization leads to YinYang bipolar relativity (Zhang 2009, 2011). Subsequently, any 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 different 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. Evidently, 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 observable facts 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 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. Evidently 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 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 different possible symmetries are left open for further research effort, the observable supersymmetry of negative-positive energies can be posited 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—a minimal but most general solution to Hilbert Problem 6 that has remained unsolvable for a century. As a logical system the axiomatization is logically provable and analytically testable for mind-light-matter unity (Zhang 2011,2021a). This fact leads to the Q5 paradigm of real-world causal-logical quantum gravities for quantum information science and human-level intelligence beyond the three roads toward quantum gravity (Smolin 2001).

(1) **physical quantum gravity** (Zhang 2011, 2012b, 2016b, 2019b, 2021a; Zhang & Marchetti 2015a,b,c; Tuszynski et al. 1995; The Nobel Prize in Physics 2008, Hameroff and Penrose 2014; 2022; Laipaporn et al. 2022; Sandler 2023; Wang et al. 2023);

(2) **logical quantum gravity** (Zhang 2003a,b, 2011, 2012a, 2013, 2018a, 2019a,b, 2021a,b, 2023; Zhang & Peace 2013, 2014; Zhang et al. 2009; Marchetti 2020; Gao et al. 2022; Delgado and Cardoso-Isidoro 2023; Zhao et al. 2023; Xu et al. 2023; Zhang 2023; Avishai 2023);

(3) **mental quantum gravity** (Zhang 2007, 2009a,b, 2011, 2016a, 2017, 2018b, 2021a, 2023; Zhang, Pandurangi & Peace 2007; Zhang et al. 2008; Gunji et al. 2022; Nishiyama et al. 2023; Bahador and Lankarany 2023);

(4) **biological quantum gravity** (Zhang 2009b, 2013; Zhang et al. 2009; Zhang & Marchetti 2015a,c; Gore and van Oudenaarden 2009);

(5) **social quantum gravity** (Re. Zhang 2021b; Zhang, Peace, Han 2016; Flink & Yolles 2018; Jana et al. 2023; Kure 2023; Garg et al. 2023).

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 dynamics for mind-light-matter unitary quantum cognition and consciousness, a typical, example is creative thinking and imagination; *biological quantum gravity* as part of 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 its application in logical quantum gravity for post-quantum cryptography (Zhang 2019b).

It is remarked (Zhang 2011; Zhang 2012b) that, while the Q5 paradigm may sound like a mission impossible, it actually follows a single condition and an undisputable observation:

1) Condition: A bipolar string as a bipolar dynamic equilibrium is a generic form of any multidimensional equilibrium from which nothing can escape (Fig. 3);

2) Observation: Bipolar quantum entanglement as a bipolar string/superstring is testable/observable and logically definable (Figs. 12-15).

While truth cannot be out there existing independently from the human mind (Rorty 1989), 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 mind-light-matter unity AI&QI (Zhang 2021a). Now we are ready to ask about the three gigantic questions (Penrose 2005) (Lloyd 2006):

1) Could equilibrium-based information conservational bipolar quantum computing be the key to reveal the ubiquitous effect of quantum entanglement (Penrose 2005; Zhang 2018a)?

2) Could logically definable causality be the foundation for small-scale quantum computing to understand the universe completely (Lloyd 2006; Zhang 2018a)?

3) Could the human brain be similar to the universe in dynamics (Vazza & Feletti 2020)?

It seems that the answers must be YES for all three questions. Otherwise, equilibrium-based energy/information conservation and logically definable causality could not be paramount laws of modern science (Zhang 2018a). The two paramount laws make equilibrium-based GRBS logically attainable, ubiquitous, and applicable for programming the universe (Lloyd 2006) and the mind (Zhang 2017, 2018b) 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.

5.5 Testability and Falsifiability

While monopole has not been found in physics, dipoles are observed everywhere. As a basis of string theory, monopoles and strings are too far away from reality. For instance, it is not clear how monopoles and strings can form an atom with equilibrium or non-equilibrium. In contrast, we have:

1) Modus ponens (MP) can be derived/revealed from bipolar universal modus ponens (BUMP) (Zhang 2011) but not vice versa—a proof of bipolar equilibrium-based generalization of truth with formal, logically definable causality for ubiquitous, scalable, integrative, and interactive entanglement/collapse;

2) Unlike the predicted but unverified existence of monopoles in string theory, dipoles are observable and ubiquitous, bipolar quantum entanglement is both physical and logical that can reach GRBS with logically definable causality in regularity (Zhang 2011);

3) BQG and BDL have been identified as he geometry of light and logic of photon, respectively, to reach a logical exposition (Zhang and Marchetti 2015a,b; Zhang 2021a) for Dirac 3-polarizer experiment (Dirac 1930);

4) Entangled photons have been logically proven YinYang bipolar quantum entanglement in nature (Zhang and Marchetti 2015a,b; Zhang 2021a);

5) Bipolar atoms and neurons can reach mind-light-matter unity for AI&QI in logical and geometrical terms (Zhang 2021a);

6) YinYang bipolar quantum entanglement of two photons have been independently tested and observed (Zia et al. 2023);

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 (Vazza & Feletti 2020).

8) Since GRBS has been proven a necessary and inevitable consequence of Bell inequality violation, it can be falsified if (i) monopoles were observed as the most fundamental existence free from action-reaction, particle-antiparticle, and input-output bipolarity and causality; (ii) Bell inequality violation were overturned, and quantum nonlocality were falsified. (Note: Monopoles free from bipolar interaction would disprove the validity of bipolar strings)

6. Conclusions

Following Einstein's prediction that physics constitutes a logical system thought, GRBS has been presented as a complete background-independent geometrical/logical axiomatization of physics for RWQG and quantum information science based on ground-0 axioms. GRBS has been proven a necessary and inevitable consequence of Bell inequality violation. With equilibrium-based bipolar strings, local realism has been extended to global realism supported by formal logically definable causality, QI, bipolar entropy, spacetime emergence and submergence, and mind-light-matter unity QCQB. Spacetime emergence/submergence through quantum entanglement/collapse provides a common causal-logical foundation for the consciousness of the human brain and the dynamics of the universe. Major advantages of the background-independent approach include but are not limited to: (1) it can reveal the ubiquitous effects of quantum entanglement; (2) it can achieve information regeneration, degeneration, and conservation for growing, ageing, and equilibrium-based reasoning; (3) it provides a causal-logical theory on brain-universe similarity in dynamics toward human-level AI&QI. Entangled machine thinking and imagination has been illustrated with a causal-logical brain model supported by entangled bipolar quantum neural networks. Testability and falsifiability of GRBS has been discussed.

Distinctions of GRBS from local realism include but are not limited to the following in alphabetical order (Note: "bipolarity" is used for "YinYang bipolarity"):

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

(2) bipolarity vs. singularity;

(3) bipolar complementarity vs. real-imaginary or particle-wave complementarity;

(4) bipolar dynamic (crisp) logic (BDL) vs. unipolar Boolean logic (BL);

(5) bipolar dynamic fuzzy logic (BDFL) vs. unipolar fuzzy logic (FL);

(6) bipolar entropy vs. unipolar entropy;

(7) bipolar G-CPT symmetry vs. unipolar CPT symmetry;

(8) bipolar quantum geometry (BQG) vs. spacetime and bra-ket quantum geometry;

(9) bipolar quantum linear algebra (BQLA) vs. linear algebra (LA);

(10) bipolar relation vs. binary relation;

(11) bipolar reflexivity vs. unipolar reflexivity;

(12) bipolar symmetry vs. unipolar symmetry;

(13) bipolar transitivity vs. unipolar transitivity;

(14) bipolar superstrings vs. M-theory;

(15) bipolar universal modus ponens (BUMP) vs. modus ponens (MP);

(16) causal-logical spin processes vs. spin loops;

(17) complete background-independence vs. incomplete background dependence;

(18) dynamic vs. static;

(19) entangled causal-logical machine thinking and imagination vs. programmed machine learning and computation;

(20) equilibrium-based bipolar quantum cellular automata vs. truth-based unipolar cellular automata;

(21) equilibrium-based generalization of CPT symmetry vs. truth-based CPT symmetry;

(22) equilibrium-base geometry of light and logic of photon vs. bra-ket standard;

(23) equilibrium relation vs. equivalence relation;

(24) equilibrium-based revealing of truths vs. truth-based reasoning;

(25) real-world quantum gravity vs. quantum gravity without a definitive battleground;

(26) fuzzy equilibrium relation vs. fuzzy similarity relation;

(27) geometry of light vs. geometry of spacetime;

(28) global realism with bipolar strings (GRBS) vs. local realism limited by the speed of light;

(29) God/Nature/logic vs human/mind/logic;

(30) ground-0 axioms vs. first principles and second law;

(31) information-energy conservation vs. observation;

(32) logic of photon vs. logic of human mind;

(33) logically definable causality vs. undefinable experimental/probabilistic causality;

(34) mind-light-matter unity vs. mind-matter unity mystery;

(35) order-disorder unification vs. order-disorder separation;

(36) quantum emergence and submergence of spacetime vs. spacetime dominance;

(37) quantum gravity for quantum information science vs. quantum gravity for blackholes;

(38) quantum intelligence (QI) vs. artificial intelligence (AI);

(39) real-world bipolar strings vs. untestable one-dimensional strings;

(40) real-world ubiquitous quantum gravity vs. unfound quantum gravity;

(41) scalable bipolar strings vs. unscalable one-dimensional strings;

(42) spacetime transcendent bipolar relativity vs. spacetime relativity;

(43) ubiquitous effects of bipolar quantum entanglement vs. unknown effects of quantum entanglement;

(44) YinYang bipolar relativity vs. space-time relativity.

In summary, the GRBS theory as a relativistic, logical, and physical reconceptualization and unification of truth-based local reality with equilibrium-based quantum nonlocality provides logically definable causality for quantum emergence or submergence of spacetime—a key for revealing the ubiquitous effects of quantum entanglement with mind-light-matter unity QCQB toward creative machine thinking, learning, and imagination. It has been shown that (1) the essence of life as a living bipolar superstring in BDE can be modeled as a mind-light-matter unitary quantum entanglement regulated by bipolar entropy; (2) logically definable causality provides a unique scientific basis and a common starting point.

Since causality is formally defined with BUMP that reveals MP, and BDL/BDFL/BQLA reveals BL/FL/LA, respectively, GRBS is to reveal local realism but does not exclude it. It does, however, lead to logical resolutions to major paradoxes in quantum theory and provides a unifying causal-logical basis for mind-light-matter unity AI&QI machinery toward human-level creative thinking, accumulative learning, and imagination. While compatibility of GRBS with the Standard Model has been left open for further research efforts, some unifying properties have been examined and illustrated in complete background-independent logical/algebraic terms. Observability, scalability, and testability of GRBS have been illustrated/discussed with examples. Thus, GRBS can be posited to be a real-world relativistic causal-logical reconceptualization of quantum gravity with unexpected but much-needed simplification.

It should be remarked that GRBS as a formal unified logical/physical theory makes Nature-human unity a scientific topic that entails quantum nonlocality, global environment protection, global economy regulation, and mind-light-matter unity QCQB in equilibrium and harmony. It is posited that QI can serve as a foundation toward human-level machine intelligence in both logical and physical terms. On the other hand, it is hoped that GRBS can help humanity in sustainable scientific research and development for Nature-human harmony on or beyond the Earth planet. 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 quantum gravities.

As a final note, it should be further clarified that GRBS is reached by following the computer and quantum information science path instead of the one-dimensional string theory path in physics. That is normal as GRBS is supposed to be logician's work but not buried in physical detail. Rooted in YinYang bipolar relativity (Zhang 2011) the GRBS theory happened to be a reconceptualization, simplification, and unification of string theory, loop-quantum gravity, and M-theory—the three roads to quantum gravity as envisioned by physicists in the last century. As a logical foundation, GRBS provides an entry for quantum gravity to enter the real world with many unsolved problems in AI, QI, and computer science centered on quantum entangled spacetime emergence/submergence for revealing the mystery of the human brain black-box to an AI/QI white-box machinery.

Alternatively, GRBS could be named as *global realism with bipolar dynamic equilibria (GRBDE)*. It can be observed, however, that GRBS holds the advantage over GRBDE in terms of entangled graphical representation, information visualization, physical reconceptualization and unification of string theory, LQG, and M-theory to a single, underlying theory (Smolin 2001). Hopefully, GRBS has brought real-world causal-logical observability, scalability, and testability to quantum gravity as an open-world and open-ended but definitive battleground for real-world applications.

Finally, with a formal logical 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 YinYang bipolarity would be able to inject new life into the faded TOE of truth-based singularity, this work has shown the potential of the equilibrium-based GRBS theory for major scientific advances especially for the development of mind-light-matter unitary AI/QI machinery toward human-level intelligence. Thus, with entangled machine thinking and imagination, our AI&QI humanoids should keep the hope alive for the miracle of reaching human-level intelligence just as string theory was once lost in the beauty of truth-based singularity but found from the harmony of equilibrium-based bipolar relativity and global realism.

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