

On a Quantum Theory of Emergent Spacetime, Gravity and Life

S. Ying^{1,*}

¹*CryptoGateway Software Inc
Vancouver, BC, Canada*

A unified theory for the emergence of spacetime, gravity and the physical origin of life from the Standard Model of physics is presented. It is shown that when flat meta-spacetime is introduced as a new layer of abstraction, curved classical spacetime emerges when the former is combined with quanta of fundamental excitations in the Standard Model and the polymorphic nature of the corresponding particles is taking into account. Particle polymorphism at quantum level is necessary when the system has one true ground state, nonzero number of false one(s) and finite number of particles within its relativistic event horizon(s). The implications on various fundamental cosmological problems are studied, including an order of magnitude unification of gravity, the gravitation constant G and the cosmological constant Λ using a single parameter free theoretical framework based on the Standard Model, the nature of dark energy, dark matter, gravitation wave, what is a “big bang”, a mechanism for baryogenesis, life cycle of stars and interpretations of their non Newtonian behaviors, a theory for a cyclic intelligible Universe, possibility of “mini bangs” and baryon recycling, etc., are presented. It is claimed that the known fundamental interactions of nature can now be reduced by one with gravity being an emergent phenomenon. An expression that relates G with the speed of light c and matter distribution of celestial objects in the universe is derived. The separation of the concept of meta-spacetime and emergent one provides a nature logical bridge between quantum systems and the measurable classical properties attributed to it through which the “collapsing” of wave function during measurements becomes an objective and predictable dynamical processes rather than an additional external assumption. A “quantization” of emergent spacetime is predicted for massive quantum entities that are shown to be “particle like” and a discrete emergent Newtonian classical dynamics for these particles also emerged. A new foundation for quantum mechanics and quantum field theories is also claimed to be found. The question of the origin of life is investigated from a reductionist point of view based upon the emergent spacetime. The smallest unit of life named the ε -element, which is claimed to has protoconsciousness under the new spacetime, is found to be identifiable to a DNA molecule. A theory for the physical origin and evolution of conscious and life is proposed.

* shuqian.ying@google.com

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I. INTRODUCTION

Quantum Mechanics (QM) which describes microscopic quantum physical processes and on which the Standard Model is based, and General Theory of Relativity (GR) that describes macroscopic world, are both experimentally tested in the domains of their applications. However how a consistent theoretical framework could be constructed to unify the two had been proven to be difficult. There are at least two type of approaches:

A. Gravitational interaction is fundamental

Here, gravitational interaction is fundamental so it is on an equal footing as the other three interactions, namely the strong, electromagnetic (EM) and weak ones. Most of the past efforts are devoted to this direction.

Gravity is described by the well known Einstein's field equation

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + g_{\mu\nu}\Lambda = \kappa T_{\mu\nu} \quad (1)$$

$$R = g^{\mu\nu}R_{\mu\nu} \quad (2)$$

$$\kappa = \frac{8\pi G}{c^4} \quad (3)$$

with G the Newton's gravitation constant, c the speed of causal front (namely the speed of macroscopic light¹ in the absolute vacuum, see Ref. [14]), Λ the cosmological constant, $g_{\mu\nu}$ the metric tensor, $R_{\mu\nu}$ the Ricci curvature tensor, and $T_{\mu\nu}$ the energy momentum tensor. It's an equation that describes how physical entities interact with their spacetime coordination.

Spacetime itself is a member of the said physical entities ever since the advent of GR, which is a significant departure from the previous one, since $T_{\mu\nu}$ contains the contributions of spacetime itself.

Once gravity in a quantum system is considered to be caused by a fundamental interaction, it eventually become the fundamental one that remaining interactions depend upon. This is because it not only has to be quantized, namely provide a definition of its quantum packet of action called *graviton*, but also has to provide a spacetime coordination for itself and other quanta (particles) of strong, EM and weak interactions to play upon. The definition of spacetime (as whole) is therefore recursive in nature. If such a recursion can not be proven to be terminate-able or converging, it ends up self-referential or being trapped in more complicated conceptual loops. They are either tautologies that carry no physical information or inherent contradictory at logic level. Even if it could be proven to converge, recursive concepts do not constitute a good foundation for a theory when it is avoidable or can be represented by more fundamental, non-recursive ones. Because in a rigorous sense, before the conceptual "equation" can be solved or resolved, raising concrete physical questions against the theory, like the simplest one that ask the location of a graviton, becomes impossible. Whether or not the contemporary approaches can pull it off still remains a question. It's certainly a mathematical question of interest to be investigated on its own. The presence of inevitable singularities (see Ref. [1]) and closed timelike curves (or logic loops, see Ref. [2] and K. Gödel) at the classical level, which may or may not be a consequence of the said recursion, make the task of building a logically consistent quantum theory of gravity even harder to accomplish.

The second problem of the current approach is the so called hierarchy problem. The strength of the gravitation constant G implies a $\mathcal{O}(10^{-39}$ or $10^{-37})$ weaker interaction between elementary particles than that of the strong or EM ones. A unification between them requires some delicate art of tuning and/or balancing. The most straight forward assumption is that there exists a new mass scale called Planck mass scale that is

$$m_P \approx 10^{19}m_B, \quad (4)$$

with m_B the mass of lightest baryons, namely that of a proton. It implies there exists a vast and featureless energy scale gap between the Standard Model and the one for gravity. Because any new physics in between will defeat the purpose of a unification of the four fundamental interactions. Albeit such possibilities are interesting from physics point of view, most of the vast mass scale region is far from accessible under current human capabilities. If nothing is of interesting in between indeed, such pursuits will become "wild goose chases". Therefore a better understanding of the nature of the weakness of gravity is important before embark upon such missions.

¹ The speed of light is a classical concept. The quantum correspondence is the speed of a photon. But a photon is a non-localizable quantum object whose speed is a distribution rather than a single value. In order to avoid the current theory to depend on terms that are supposed to be derived or emergent from, the *a priori* term "speed of causal front" is introduced here. It is also the classical speed of the emergent gravitational waves of the current theory.

The third problem of the current approach is the cosmological constant or the dark energy problem. The canonical form of Eq. 1 is

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = \kappa(T_{\mu\nu} - g_{\mu\nu}\rho_{vac}) \quad (5)$$

when gravitational interaction is consider fundamental. Here ρ_{vac} is the vacuum energy density in or of spacetime that causes gravity. Theoretically, it should be of order.

$$\rho_{vac} \sim \Lambda \sim \mathcal{O}(1)m_P^2 \quad (6)$$

But experimental value for Λ , which is of the same order of magnitude as that of ρ_{vac} in Planck mass, is of order

$$\rho_{vac} \sim \Lambda = \mathcal{O}(10^{-122})m_P^2 \quad (7)$$

It is extracted from data obtained in observations of the cosmological expansion of the universe. The staggering discrepancy between the value from straight forward theoretical estimation and the one from experimental observations means that any theory that claims to unify gravity treating gravitation interaction as a fundamental one has to invent a fine tunneling mechanism that could cancel the effects of the vacuum energy to an accuracy of $\mathcal{O}(10^{-122})$. There is no natural way that it can be accomplished. The popular arguments for such a chance due to the existence of a state that satisfies Eq. 7 amongst enormous number other vacuum states is not valid because the quantum “tunneling” effects in a relativistic system to be discussed in the sequel. It will eventually redistribute the energy densely equally amongst them so that the theoretical value in Eq. 6 still holds.

The fourth problem is the flatness problem. It is an empirical fact that the universe at large scale is flat, homogeneous and isotropic to a very high accuracy which is summarized as the cosmological principle. However flat spacetime solution in GR is a very special one, with vanishing weight in its solution space. So a hypothetical inflation period, the mechanism of which can not be repeated under current epoch, is required for GR to be consistent with observations.

B. Gravity is an emergent phenomenon

1. Overview

It is not intended to provide an overview of the previous efforts along the current line here. Most of them are either not successful or lack proper physical interpretation. In fact arriving at Eq. 1 as a first approximation is not hard because once one realize that spacetime can be curved and after assuming that gravity is universal it is the most generic equation that one can write done for slow varying fields when resulting local Lorentz covariance is required.

What is difficult is how to maintain local Lorentz covariance, which is not a solved problem at all (see [14]), during the process; how to provide a right estimate of G , Λ , dark matter effects, what is behind gravitation waves, etc; what is the physics behind; how observed flatness (of the universe) at large scale could be maintained; etc.

2. An initial observation

Let’s do an initial order of magnitude observation that provides us hints as to where and what gravity could emerge from. The current observational value of vacuum energy density ρ_{vac} is $\approx 3.35 GeV/m^3$ if one follows the interpretation of GR given by Eq. 5. It means that the dark energy, if exists, is $\mathcal{O}(1) GeV$ of energy per cubic meter. This does not seem to relate to any known physical energy scale of interest. However such an interpretation of ρ_{vac} is based on the assumption that gravitational physics is at the Planck energy scale (see Sec. I A). For the purpose of current study, such an assumption is not necessary. An proper energy scale ξ that is most likely the one in which gravity could emerge from can be searched for after relaxing the assumption. Therefore let’s assume that Λ can be written as

$$\Lambda = \frac{1}{N_B}\xi^2 = \mathcal{O}(10^{-122})m_P^2 = \mathcal{O}(10^{-84})m_B^2 \quad (8)$$

where N_B is the number of baryons inside the cosmological event horizon or observable universe which can be estimated using the total mass of the observable universe, namely

$$N_B \sim \frac{M_{universe}}{m_B} = \mathcal{O}(10^{80}) \quad (9)$$

and use have been made of Eq. 7 for Λ . Putting this number into Eq. 8, something interesting emerges

$$\xi = \mathcal{O}(10^{-2})m_B \sim 10 \text{ MeV} \quad (10)$$

which is an energy scale between QCD and nuclear interactions. The reason why the factor N_B appear in Eq. 8 will be explained in the sequel. Here, it's sufficient to mention that the dark energy in the present approach is a pure quantum finite size effect with a strength of order N_B^{-1} . It means that gravity could be an emergent phenomena originated from the strong interaction of the Standard Model. Also, in the present approach

$$F_G = \mathcal{O}\left(\frac{1}{\sqrt{N_B}}\right)F_S = \mathcal{O}(10^{-40})F_S \quad (11)$$

where F_G is the strength of the gravitational interaction and F_S is the one for the strong interaction. This is exactly the order of magnitude that can be derived from empirical data. The reason why $\sqrt{N_B}$ appear here follows from the same pure quantum effects mentioned above.

Therefore it seems that we are on the right path²! The task of providing a theoretical reasoning based on QFT as to why N_B should appear here is accomplished in Sec. III.

II. META AND EMERGENT SPACETIME

Spacetime before GR is not associated with any physical entity. Rather, in Kant's view, it is one of the *a priori* knowledge that human use to perceive physical reality, it does not has dynamical properties in and of itself.

It is discussed in Sec. I A that, besides the complexity incurred, treating spacetime as a physical entity may contains logic loops that is not or not easily resolvable, especially in a theory that tries to provide a consistent unification of quantum theories with that of gravity.

Technically, using physical spacetime that has its own dynamics as a coordination system introduces complexities of various kinds. For example, it's known that fields of a quantum field theory (QFT) represent a many (infinite) body quantum system. Before quantization, a spacetime point at which a field has value is a common coordination point for various excitations it represents. It is virtual in nature. There is no universal way of curving it to represent the motion of indefinite number of particles around it when there is gravity described by GR. Instead, it is the amplitude of an excitation coordinated by the point that is physical. Therefore that gravity, if any, should be represented by the distortion of the amplitudes of the field excitations rather than by the *a priori* curvature of spacetime point of the field. Thus just put quantum fields in a curved spacetime can not provide a complete dynamical picture of the physical processes generated by the fields in a gravitational environment. Therefore the spacetime point for the fields is better to be treated as a virtual spacetime point and the gravity, if any, is best to be regarded as an emergent phenomenon that emerges from the quantum dynamics of the fields in the limit of large particle number.

The method proposed in the current study for resolving the said potential logic loop is therefore by first introducing a higher level of abstraction called meta-spacetime or *a priori* spacetime which is referred to as virtual spacetime above, and then treating Einstein's spacetime as a set of observable attributes of a class of concrete macroscopic systems that are coordinated by the meta-spacetime or put it in another way as an emergent entity when the meta-spacetime is associated with the said systems in observations. This can in principle break the above mentioned self referential logic loop.

A. Meta-spacetime

The basic hypothesis of current theory is therefore that:

The spacetime attributes for quantum fields and the spacetime operator for particle wave functions is meta-spacetime rather than physical one. Einstein's spacetime is an emergent entity that combines the underlying meta-spacetime with the quantum system under consideration in physical observations.

The meta-spacetime is a priori flat, which can be inferred from and provide theoretical foundation for the observation that universe is flat at large scale.

Nothingness³ and physical laws in meta-spacetime are invariant under Lorentz transformation.

² I am refraining from using the common term "right track" here since there is literally no established "track" to follow in the subject terrace this work is exploring.

³ See Ref. [14].

According to the theory derived from the above hypothesis presented below, homogeneity and isotropicity of the universe follows from the resulting dynamics.

It should be noted that the conservation of energy, momentum and angular momentum is much easier to understand, formulate and maintain when one starts from a flat spacetime at the quantum level. Their conservation provides necessary underlying constraint for physical processes in the emergent spacetime that is most likely curved. This will be demonstrated in the following sections.

B. Emergent spacetime from a QFT

Given a set of Fock space \mathcal{F} states defined by a QFT

$$\Omega \stackrel{\text{def}}{=} \{|S\rangle | S \in \mathcal{F}\} \quad (12)$$

that corresponds to a classically localizable⁴ probing entity, like the massive baryonic condensed matter probes considered in the current study, the measured spacetime point that can be derived from a combination of the meta-spacetime operators $[\hat{c}\hat{t}, \hat{x}, \hat{y}, \hat{z}]$ and the said entity in a pre-selected reference frame is the set of expectation values

$$[\bar{c}\bar{t}, \bar{x}, \bar{y}, \bar{z}] = \sum_{S \in \Omega} w(S) \langle S | [\hat{c}\hat{t}, \hat{x}, \hat{y}, \hat{z}] | S \rangle \quad (13)$$

$$\sum_{S \in \Omega} w(S) = 1$$

where $w(S)$ is the weight (or eigenvalue of a density matrix) of the state $|S\rangle$ in a statistical assemble with macroscopic number of particles, most favorably a thermal one, with its info-entropy maximized (see Sec. V), and the summation is over all members of the set. $|S\rangle$ is defined on a hypersurface in the meta-spacetime at a fixed t_m . As it is mentioned above, the emergent spacetime coordinates in Eq. 13 depends only on emergent intrinsic properties of the assemble chosen, like the temperature of a thermal assemble. Their dependency on the underlying dynamical details of the probing entity can be made sufficiently small provided that the probing entity contains large enough particles.

It is expected that the 4-dimensional manifold containing $[\bar{c}\bar{t}, \bar{x}, \bar{y}, \bar{z}]$ is not a flat one in general since there is no guarantee that the metric for them is always the Minkowski one. Infinitesimal differences in $[\bar{c}\bar{t}, \bar{x}, \bar{y}, \bar{z}]$, however, does transforms according to Lorentz transformation from a reference frame to another in the corresponding tangent space if the underlying meta-spacetime transforms in the same way so that the mapping from and to the meta- one is conformal. Such a theoretical framework is constructed in Ref. [14].

III. RELATIVISTIC QFT FOR THE VISIBLE COSMOS

A QFT represents a quantum many body system. One of the differences between non-relativistic condensed matter system that one can study in a laboratory and the ones that represents relativistic astrophysical systems is in the role an observer plays in the observation process. For a condensed matter system, an observer is an outsider, he or she can probe the system as a whole, with an inverse resolution of the probing instruments larger than the size of the system. Therefore the observable for the said observer could all be global ones. However an astrophysical observer is an insider with an inverse resolution of the probing instruments smaller than the size of the system, he or she can only observe the so called local observables. These two kinds of observables are different in that local observables contain the so called “dark components”⁵, quantum fluctuation effects that persists even in the thermodynamical limit. See Refs. [8] section II.D and [7, 9] for a more detailed discussions.

When cosmological questions are investigated, the largest inverse resolution is the size of the cosmological event horizon, which contains about $N_B \sim 10^{80}$ baryons at the current epoch of the universe. It’s a very large number, much larger than anything found in a condensed matter system studied in a laboratory. Whether or not this can be considered as the proper thermodynamical limit depends on the questions to be asked. For gravitational effects, the number of baryons is at least of order $\sim 10^{27}$ on the Earth and much larger for celestial entities, e.g. $\sim 10^{51}$ for the Earth, it’s not. Therefore, instead of taking the thermodynamical limit first and dropping all small contributions,

⁴ Photons, which is massless and moving around the light cones, are not localizable in the classical limit of $n_\gamma \rightarrow \infty$, where n_γ is the number of photons in a random or thermal assemble. It is expected that they “collapse” to least action classical EM waves, governed by suitably adapted Maxwell’s equations to the curved emergent spacetime of the current theory, starting from all possible set of quantum ones, when the assemble average is taken (see the last few sections of the current work).

⁵ Note that it should not be associated with the effects of dark matter. It will be explained later.

the effects of finite size on observables of a relativistic system need to be carefully investigated to see if there are any accumulative effects that emerges to have finite influence on physical processes of interest, especially when the effective potential of the system contains multiple minima so that there are multiple stable states for the system, namely, one true ground state and non-zero number of meta-stable ones with higher energy densities.

A. Quantum physics of relativistic processes having multiple ground states

Let's consider a general form of the generating functional of a QFT system that can be written as (see, e.g., Ref. [8])

$$e^{A[J, \bar{\eta}_v, \eta_v]} = \int \prod_i D[f_i] D[\Psi] e^{\frac{i}{\hbar} \int d^4x \left(\frac{1}{2} \bar{\Psi} i S_F^{-1}[f] \Psi + \mathcal{L}_B[f] + \bar{\Psi} \eta_v + \bar{\eta}_v \Psi + \sum_k J_k f_k \right)}, \quad (14)$$

where \hbar is the Planck constant which is one in the natural unit, $\mathbf{J} = \{J_1, J_2, \dots, J_n\}$ are a collection of external probing fields coupled to the corresponding boson fields $\mathbf{f} = \{f_1, f_2, \dots, f_n\}$, $\mathcal{L}_B[f]$ is the Lagrangian density for the boson fields \mathbf{J} , and $\eta_v, \bar{\eta}_v$ are external probing Grassmann fields coupled to the fermion fields $\bar{\Psi}, \Psi$. Only one fermion field is shown explicitly here to simplify the notation, there can be more in general. $A[J, \bar{\eta}_v, \eta_v]$ generates the Green functions of the quantum fields. Here fermions are represented by the 8-component Ψ and bosons are also represented using the 2-dimensional representation of the causal time reversal (2DCTR), the reasons for using such representations are given in Refs. [12, 14]. \hbar is written explicitly here the easy the discussions below.

It is commonly believed that in a system described by a QFT only the contributions of the excitations around true ground state contributes, contributions from other ones, if any, approaches to zero or constant when the thermodynamical limit is taken. However that statement can't be always true in a relativistic system that is under gravitational expansion or contraction, like the visible portion of the Universe. This is because there is a largest spatial volume surrounding an observer, which is called the cosmological event horizon, beyond which the observer has no physical means to access. Relativistic causality prohibits the attempt to get the value of global observables by using a set of global probing external fields \mathbf{J} and $[\eta_v, \bar{\eta}_v]$ which extends uniformly to infinity. Therefore it is expected that the contributions from all other false ground states are not fully suppressed.

To study bulk properties, it is believed that the long living contribution of on-shell quasi-particles becomes more and more important and other contributions from the “dark components” becomes lesser important as the resolution of the probing fields becomes lower, see Refs. [8] section II.D and [7, 9]. In such a case, the propagator for an fermionic quasi-particle can be written as

$$S_F = \frac{i}{\hat{p} + \mu O_3 - \Sigma + i\epsilon}. \quad (15)$$

with O_3 the third of the Pauli matrices, \hat{p} the Dirac 4-momentum operator and Σ the “mass” matrix in the 8-component representation for fermions, which is 2DCTR [14] for spin 1/2 particles, has a generic form [8, 14]:

$$\Sigma = \begin{pmatrix} \sigma & D \\ \bar{D} & -\sigma \end{pmatrix} \quad (16)$$

Here, μ^α is the statistical gauge field introduced in [8, 13], the contributions of other tree level boson fields are assumed to be path integrated out, and not shown. Starting from a massless fermion system, the quantity σ is the order parameter for spontaneous chiral symmetry breaking. The sub-matrices D and \bar{D} is related to the order parameter for spontaneous breaking of the $U(1)$ symmetry corresponding to fermion number conservation. When D is finite due to the dynamics of the system, fermion number conservation is spontaneously broken leading to a superfluid phase of the system. If the fermions are not neutral, the phase is also superconducting that breaks also the $U(1)$ gauge symmetry of electromagnetism, which is studied in Ref. [10].

For the light quark system of strong interaction interested here, the superconducting phase is also color superconducting in which the color $SU(3)$ gauge symmetry is also spontaneously broken. For example, if the system is in a state of scalar color superconducting phase [4, 6, 8]

$$D = \gamma^5 \mathcal{A}_c \chi^c, \quad \bar{D} = \gamma^5 \mathcal{A}_c^c \bar{\chi}_c \quad (17)$$

with χ^c and $\bar{\chi}_c$ the pair of order parameters for the scalar color superconducting phase and $(\chi^c)^\dagger = -\bar{\chi}_c$. If the system is in a state of vector superconducting phase [5, 6]

$$D = -\phi_c^c \gamma^\mu \gamma^5 \mathcal{A}_c, \quad \bar{D} = \bar{\phi}_c^\mu \gamma_\mu \gamma^5 \mathcal{A}^c \quad (18)$$

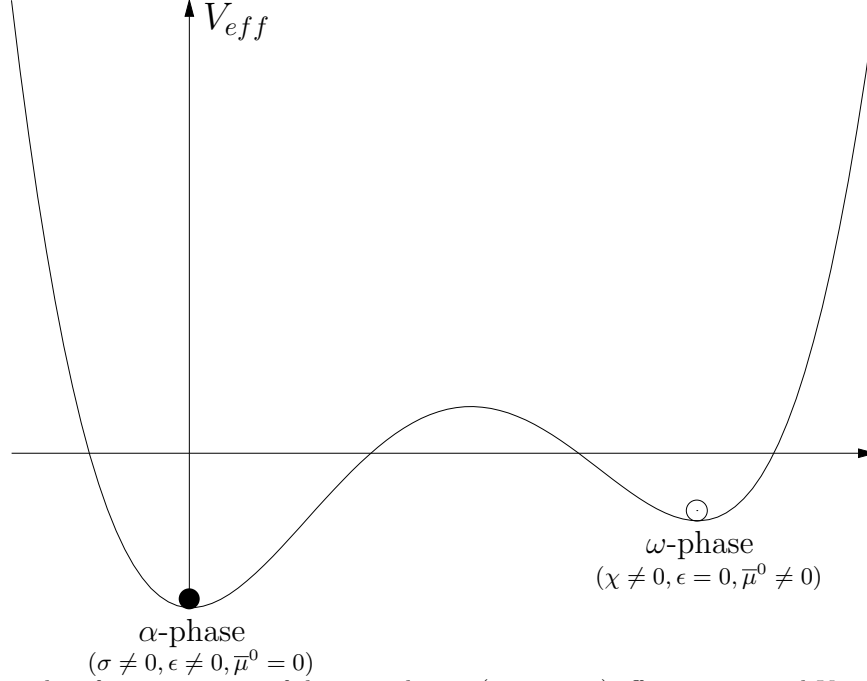


FIG. 1. An illustrative plot of a cross section of the ground state (or vacuum) effective potential V_{eff} across two stable points in its order parameters space. For the light quark system of strong interaction, model studies predicts that there can be two kinds of phases in general: one of them is the spontaneous chiral symmetry breaking phase, called the α -phase; the other is a color superconducting phase of scalar quark pair condensation and vector quark pair condensation. The scalar one is called ω -phase and the vector one is called β -phase, which will not be discussed further here.

with ϕ_μ^c and $\overline{\phi}_c^\mu$ the pair of order parameters for the vector color superconducting phase. \mathcal{A}_c is an antisymmetric matrix and $\mathcal{A}_c = -\mathcal{A}_c^T$.

There is an additional non-perturbative parameter called statistical blocking parameter ϵ , which is introduced in Refs. [8, 9, 11], that is necessary to find and characterize properties of the ground states of the system.

It's found that in the phase where $\sigma \neq 0$, which is called α -phase, fermion and anti-fermion pairs condense, the chiral symmetry of the system is spontaneously broken and $\epsilon = 0$ point is unstable against perturbation. The stable point of the effective potential of the system (see Fig. 1) is at a finite value ϵ_{vac} , however, the $\mu^0 = 0$ point is stable. A non-vanishing ϵ_{vac} prevents the $U(1)$ statistical gauge field μ^α , corresponding to local $U(1)$ complex phase rotation invariance (see Ref. [8]), from becoming long-ranged.

In superfluid phases, where $\chi \neq 0$ or $\phi^\mu \neq 0$, fermion and fermion or anti-fermions and anti-fermion pairs condense, fermion number conservation $U(1)$ symmetry is spontaneously broken and $\epsilon = 0$ point is stable against perturbation. The phase with scalar order parameter non-vanishing is called ω -phase and the vector one with vector order parameter non-vanishing is called β -phase, which will not considered further for simplicity of the discussions since it will not affect the results. The stable point of the effective potential of the system, however, is not at $\bar{n} = 0$. Instead it is at a finite value for localized chemical potential (see [8])

$$\mu \stackrel{\text{def}}{=} \overline{\mu}^0, \quad (19)$$

with two stable values at $\mu = \pm\mu_{vac}$ and $\mu_{vac} > 0$ leading to a superfluid quantum state of matter with finite density and that of matter and anti-matter regions been able to spontaneously separate from each other by quantum “collapsing” onto space-like hypersurfaces, forming causal unconnected regions of matter ($\mu > 0$) and anti-matter ($\mu < 0$). It constitutes a natural mechanism for spontaneous baryogenesis [4], and also spontaneous CP and T violation.

In a superfluid phase of light quarks, color $SU(3)$ local gauge symmetry is spontaneous broken down, gluons become massive and strong interaction at quark level becomes short ranged. This is the well-known Higgs mechanism. The ground state of the system becomes a color superconductor. No colored particle can exist alone because it will be screened shortly after it is created. Extra colored particles, if any, will be pushed to the surface of the system. It is a straight forward color confinement, much like how a charged particle is screened or “confined” in a metal.

The superfluid phase also provides a pathway for color confinement in α -phase⁶ in case the former phase is only a false ground state. This is because quarks with different color in the superfluid phase can be first “flows” to a non screened quark and then get “tunneled” to the α -phase to realize the final total color screening or confinement. The “tunneling” process is explained in the next subsection. Therefore the seemingly complex mechanism of color confinement is in fact very simple to understand within the current theory.

EM local $U(1)$ gauge symmetry is also spontaneously broken down in the superfluid phase of light quark system. However due to the fact that quarks are fractionally charged, the Higgs mechanism does not fully dictate the behavior of the system [10] because the local $U(1)$ gauge symmetry is only partially broken. There are long range longitudinal interaction between baryonic subsystems and charged leptonic subsystems due to the fact that quarks are fractionally charged.

Quantum fluctuations around the order parameter $\bar{\mu}^\alpha$ of the statistical gauge field, namely the

$$\mu'^\alpha = \mu^\alpha - \bar{\mu}^\alpha \quad (20)$$

field (see Refs. [8, 13]), together with the EM, generates EM like hybrid massless excitations that acts **only** between baryonic and leptonic subsystems [10]. This characteristic alone, together with the mechanism under which gravity emerges that is to be explicit in the sequel, could provide a natural mechanism a plethora of astrophysical phenomena. They will be studied in more details in the following sections.

B. Quantum and particle polymorphism

Let's write Fock space state that represent an excitation of a quantum packet (namely constant action having one or multiple \hbar in value) as

$$\mathcal{V} \stackrel{\text{def}}{=} \{v \mid v \in \text{False Ground States}\}, \quad (21)$$

$$|s\rangle = C_0 |s_0\rangle + \sum_{v \in \mathcal{V}} C_v |p_v\rangle + C' |d_{rest}\rangle, \quad (22)$$

where the subindex 0 denotes the true ground state, $|s\rangle$ and $|p\rangle$ a member of the set of quasi-particle excitations around the corresponding ground state, $|d\rangle$ are contributions from off shell “dark components”, and C are normalized coefficients of corresponding components. Standalone excitations $|s\rangle$ and $|p\rangle$ are often been referred to as “particles”, Eq. 22 implies that a quantum packets can be polymorphic in its particle content due to quantum “tunneling” between the corresponding ground state of the conventional particles. This decomposition can be applied to all mutually interacting particles in the system under consideration, like the Standard Model.

Since the present study is interested only in bulk properties in which only long lived excitations are of interest, the contributions from $|d\rangle$ will be ignored in the following. According to Eq. 14 the normalized action (functional) of the fermion can be expressed as

$$\mathcal{A}[\Psi] = \frac{1}{2} \int d^4x \bar{\Psi} (i\rlap{\not{D}} + \mu O_3 - \Sigma) \Psi + \dots \quad (23)$$

It can be decomposed into

$$\mathcal{A} = \mathcal{A}_0 + \sum_{v \in \mathcal{V}} \mathcal{A}_v \quad (24)$$

with \mathcal{A}_0 contributions from excitations around the true ground state and \mathcal{A}_v the ones from the false ground state above.

Quantum effects manifest themselves in contributions from Ψ configurations of constant action with value of one or multiple \hbar (quantum packet) in the path integral over Ψ , the value of their contribution to the action should be comparable, namely

$$\mathcal{A}_i \sim \hbar \quad (i = 0 \text{ or } i \in v). \quad (25)$$

⁶ Color confinement is not an easily explainable phenomenon from nuclear/particle physical point of view since the inception of the concept of colored quarks. That is the reason major practical models for a hadron in use does not really confines quarks.

The contributions from excitations around the true ground state has a normalized coefficient $C_0 \sim \mathcal{O}(1)$. The action from excitations around the other false ground states, if any, can be written as

$$\mathcal{A}_v \sim \Delta\varepsilon_v N_{Cv} \chi_v |C_v|^2 \quad (26)$$

because of the positive difference in energy density $\Delta\varepsilon_v$ between the false ground state v and the true one, N_{Cv} is the number of condensate pairs that is supposed to be very large, χ_v the value of the order parameter, and C_v is the coefficient defined in Eq. 22. $|C_v| > 0$ is required by the principle of stable action. It implies

$$|C_0| \sim \mathcal{O}(1) \quad (27)$$

$$|C_v| \sim \mathcal{O}(1) \frac{m_\xi^4}{\Delta\varepsilon_v \sqrt{N_{Cv}}}, \quad (28)$$

where m_ξ is some typical mass scale of the system. In case of the light quark system interested in the current study, it's most natural to set $m_\xi = m_B$ with m_B the mass of a nucleon. So Eq. 22 can be reduced to

$$|s\rangle = C_0 |s_0\rangle + \sum_{v \in \mathcal{V}} \frac{c_v}{\sqrt{N_{Cv}}} |p_v\rangle \quad (29)$$

for a sufficiently large system. Here

$$|c_v| \sim \mathcal{O}(1) \frac{m_\xi^4}{\Delta\varepsilon_v}. \quad (30)$$

Here the amplitude C_0 can be derived from

$$\langle s|s\rangle = 1$$

with a consistent approximation in its Taylor expansion in $1/\sqrt{N_{Cv}}$.

It is expected that $\Delta\varepsilon_v$ is not constant in meta-spacetime when finite density of other quantum excitations in localized regions (in meta-spacetime) are present since they could induce changes in $\Delta\varepsilon_v$ due to the underlying dynamics of the system. Let's decompose them further:

$$\Delta\varepsilon_v = \Delta\varepsilon_v^0 (1 + \eta_v) \quad (31)$$

$$|p_v\rangle = c_v^0 |e_v\rangle + \delta c_v |l_v\rangle \quad (32)$$

where the asymptotical constant part of $\Delta\varepsilon_v$ is denoted as $\Delta\varepsilon_v^0$,

$$\eta_v = \delta\varepsilon_v / \Delta\varepsilon_v^0, \quad (33)$$

which is the ratio of the increase in energy density of the false ground state v (relative to the true ground state) due to local dynamics of the system in the presence of excitations (matter) on top of true ground state to its asymptotic value. According to standard scattering theory of QM, $|e_v\rangle$ represents the extended part (linear combination of *in* and phase shifted *out* asymptotical free states in the background of $\Delta\varepsilon_v^0$), and localized part $|l_v\rangle$ that $\delta\varepsilon_v$ is responsible for. Here, according to Eq. 30

$$|c_v^0| \sim \lambda, \quad (34)$$

$$|\delta c_v| \sim -|d_v| \eta_v + \mathcal{O}(\eta_v^2) + \dots \quad (35)$$

where

$$\lambda = m_\xi^4 / \Delta\varepsilon_v^0 \sim \mathcal{O}(1) \quad (36)$$

is a constant, $|d_v| \sim \mathcal{O}(1)$.

It means that any quantum packet of excitation contains not only the main contributions from quasi particles of the true ground state but also the ones from quasi particles of other false ground state, if any, that are suppressed by a factor of $1/\sqrt{N_{Cv}}$. This is referred to as *particle polymorphism* in the current theory.

So one can express the expectation value of an operator \hat{O} in $|s\rangle$ at meta-time t_m in a given reference frame as

$$\overline{O}[s, t_m] = Z \langle s_0 | \hat{O} | s_0 \rangle |_{t_m} - \sum_{v \in \mathcal{V}} \frac{\eta_v}{\sqrt{N_{Cv}}} \left(d_v \langle s_0 | \hat{O} | l_v \rangle |_{t_m} + d_v^* \langle l_v | \hat{O} | s_0 \rangle |_{t_m} \right) + \sum_{v \in \mathcal{V}} \frac{|c_v^0|^2}{N_{Cv}} \langle e_v | \hat{O} | e_v \rangle |_{t_m} + \dots, \quad (37)$$

where $Z = |C_0|^2$. Only the interference terms between quasi particle states around the true ground state and the local part of quasi particle states around the false ground state and the diagonal terms from extended part of quasi particle states of the false ground states are shown, other ones, having different spectra, has vanishing contribution due to destructive interferences. It can be seen that \bar{O} is a function(al) of the state s . Since t_m is not directly observable in macroscopic systems, it is related to the emergent time t which can be derived from the above by applying it to \hat{t}_m , namely $\bar{O} = \hat{t}_m$. According to Eq. 37, one gets,

$$Z = 1 + \sum_{v \in \mathcal{V}} \frac{\eta_v}{\sqrt{N_{Cv}}} (d_v \langle s_0 | l_v \rangle |_{t_m} + d_v^* \langle l_v | s_0 \rangle |_{t_m}) - \sum_{v \in \mathcal{V}} \frac{|c_v^0|^2}{N_{Cv}} + \dots \quad (38)$$

For simplicity of the expressions, the dependency on t_m and eventually on the emergent one, t , will be made implicit in the following.

Eq. 37 can be further generalized to

$$\bar{O}[S] = Z \langle S_0 | \hat{O} | S_0 \rangle - \sum_{v \in \mathcal{V}} \frac{\eta_v}{\sqrt{N_{Cv}}} \left(d_v \langle S_0 | \hat{O} | L_v \rangle + d_v^* \langle L_v | \hat{O} | S_0 \rangle \right) + \sum_{v \in \mathcal{V}} \frac{|c_v^0|^2}{N_{Cv}} \langle E_v | \hat{O} | E_v \rangle + \dots, \quad (39)$$

$$Z = 1 + \sum_{v \in \mathcal{V}} \frac{\eta_v}{\sqrt{N_{Cv}}} (d_v \langle S_0 | L_v \rangle |_{t_m} + d_v^* \langle L_v | S_0 \rangle |_{t_m}) - \sum_{v \in \mathcal{V}} \frac{|c_v^0|^2}{N_{Cv}} + \dots \quad (40)$$

with $|S\rangle$ multi-particle state, according to Eq. 35, which is valid if $\eta_v \ll 1$, where the lower cased states are replaced by upper case ones to represent the fact that the discussions about single quantum packet excitations can be generalized to include the multi quantum packet excitations of multiple particles. For macroscopic, “classical”, systems that are interested in the current study

$$\bar{O} = \sum_{S \in \Omega} w(S) \bar{O}[S] = Z \bar{O}_0 + \delta \bar{O}_{loc} + \delta \bar{O}_{vac} \quad (41)$$

with \mathcal{F} the Fock space of the underlying QFT of interest, $w(S)$ the weight of $|S\rangle$ in an assemble, most likely a thermodynamical one. Here $\delta \bar{O}_{loc}$ is the contributions from false ground states due to matter concentration and $\delta \bar{O}_{vac}$ is the one from energy density difference between the true ground state and the false one(s). All dependencies of \bar{O} on the properties of microscopic quantum states involved are removed after the assemble average. It depends only on emergent intrinsic properties associated with assemble, like the temperature if the assemble is a thermal one.

In case of the light quark system of the Standard Model, assuming that there is only one superfluid phase, say the scalar one, then

$$\delta \bar{O}_{loc} \sim \mathcal{O} \left(\frac{\eta}{\sqrt{N_B}} \right), \quad (42)$$

$$\delta \bar{O}_{vac} \sim \mathcal{O} \left(\frac{1}{N_B} \right), \quad (43)$$

where N_B is the number of condensing quark pairs (see Eq. 9) in the superfluid phase.

IV. EMERGENT SPACETIME

The foundation is laid for derive how observable spacetime emerges from strong interaction at the quantum level described by meta-spacetime. Spacetime operator that is consistent with Lorentz covariance (see Ref. [12]) is using the 2DCTR representation of quantum fields [14]:

$$\hat{t} = \int d^3 x_m \bar{\hat{\Phi}}(\mathbf{x}_m, t_m) t_m \hat{\Phi}(\mathbf{x}_m, t_m), \quad (44)$$

$$\hat{\mathbf{x}} = \int d^3 x_m \bar{\hat{\Phi}}(\mathbf{x}_m, t_m) \mathbf{x}_m \hat{\Phi}(\mathbf{x}_m, t_m) \quad (45)$$

in a specific reference frame. Here $\hat{\Phi}$ is the field operator, t_m is the meta-time and \mathbf{x}_m is the meta-3-space coordinates on the space-like meta-hypersurface at t_m on which the 3-integration is performed.

For a single particle state

$$\bar{t}[s, t_m] \stackrel{\text{def}}{=} \langle s | \hat{t} | s \rangle_{t_m} = \int d^3 x_m \bar{\Phi}(\mathbf{x}_m, t_m) t_m \Phi(\mathbf{x}_m, t_m) \quad (46)$$

$$\bar{\mathbf{x}}[s, t_m] \stackrel{\text{def}}{=} \langle s | \hat{\mathbf{x}} | s \rangle_{t_m} = \int d^3 x_m \bar{\Phi}(\mathbf{x}_m, t_m) \mathbf{x}_m \hat{\Phi}(\mathbf{x}_m, t_m), \quad (47)$$

where Φ is the wave function for $|s\rangle$ in meta-spacetime. A more concise way is use a 4-vector to represent emergent spacetime point x^μ :

$$x^0[s, t_m] = c\bar{t}[s, t_m], \quad (48)$$

$$x^i[s, t_m] = \bar{\mathbf{x}}^i[s, t_m], \quad \{i = 1, 2, 3\}. \quad (49)$$

As it is discussed in Ref. [14] that infinitesimal differences in emergent spacetime δx^μ in which the changes in metric can be ignored transforms in the same way as the corresponding meta-spacetime from one reference frame to another, namely they also transform according to Lorentz transform in the corresponding tangent space.

A. The spectra of light quasi quarks

For light quarks in strong interaction, their wave functions can be obtained by solving the equations in meta-momentum space (see [12])

$$(\not{p} + \gamma^0 \mu O_3 - \Sigma) U(\mathbf{p}) = 0, \quad (50)$$

where mass matrix is given in Eq. 16 and μ is defined in Eq. 19. It has twelve solutions if the flavor (or isospin) degrees of freedom are suppressed. For the scalar superfluid state, it can be reduced to

$$(\not{p}_+ - \sigma)u_1 + \gamma^5 \mathcal{A}_c \chi^c u_2 = 0, \quad (51)$$

$$\gamma^5 \mathcal{A}_c \bar{\chi}_c u_1 + (\not{p}_- + \sigma)u_2 = 0. \quad (52)$$

Here $p_\pm^\alpha = \{p^0 \pm \mu, \mathbf{p}\}$, u_1 is the upper four component and u_2 is the lower four component of U .

It can be shown that there are four solutions for quarks having the same color as the non-vanishing $\bar{\chi}_c$

$$\epsilon_{\mathbf{p}} = \pm (E_{\mathbf{p}} \mp \mu) \quad (53)$$

with $E_{\mathbf{p}} = \sqrt{\mathbf{p}^2 + \sigma^2}$, the \pm sign in front represent two branches of solution and the one inside the bracket denotes two solutions: the first has its upper 4-components non-vanishing and the second has its lower 4-components non-vanishing. Particle excitations are associated with the subset of solutions that have positive energies and anti-particle ones are associated with the subset of solutions that have negative energies. The rest of the two quarks couples to each other by the antisymmetric matrix $\mathcal{A}_c = -\mathcal{A}^c$ in the color space. For this pair of quarks, there are two degenerate sets of solutions each of which contains four solutions

$$\epsilon_{\mathbf{p}} = \pm \sqrt{(E_{\mathbf{p}} \mp \mu)^2 + \chi^2 \mp 2 \left(\sqrt{E_{\mathbf{p}}^2 \mu^2 + \sigma^2 \chi^2} - E_{\mathbf{p}} \mu \right)} \quad (54)$$

with the \mp sign inside the square root taking the same value for the corresponding solution. Again, particle excitations are associated with the subset of solutions that have positive energies and anti-particle ones are associated with the subset of solutions that have negative energies

1. σ -phase

Here the stable excitations are around the true ground state that have $\sigma \neq 0$, $\{\chi, \mu\} = 0$ for all 12 solutions. Each solution is of the form

$$\epsilon_{\mathbf{p}} = \sqrt{\mathbf{p}^2 + \sigma^2} \quad (55)$$

$$U = \begin{pmatrix} u_1 \\ 0 \end{pmatrix} \quad or \quad \begin{pmatrix} 0 \\ u_2 \end{pmatrix} \quad (56)$$

$$\epsilon_{\mathbf{p}} = -\sqrt{\mathbf{p}^2 + \sigma^2} \quad (57)$$

$$V = \begin{pmatrix} v_1 \\ 0 \end{pmatrix} \quad or \quad \begin{pmatrix} 0 \\ v_2 \end{pmatrix} \quad (58)$$

(u_1, u_2) and (v_1, v_2) are standard positive and negative energy solutions of 4-component Dirac equation for massive fermions. There is no mixing between the upper and lower 4-components.

2. ω -phase

Here the stable excitations are around the true ground state that have $\sigma = 0$, $\{\chi, \mu\} \neq 0$. If the quark has the same color as the non-vanishing $\bar{\chi}_c$, then there are four solutions

$$\epsilon_{\mathbf{p}} = \pm |\mathbf{p}| \mp \mu \quad (59)$$

and solution is also of the form

$$U = \begin{pmatrix} u_1 \\ 0 \end{pmatrix} \quad or \quad \begin{pmatrix} 0 \\ u_2 \end{pmatrix} \quad (60)$$

No further classification of the solutions in terms of positive or native energy or μ is necessary in the following, So they will be denoted as such to simplify the discussion. For details, see Ref. [12]. The energy of the rest of the two quarks with different colors are

$$\epsilon_{\mathbf{p}} = \pm \sqrt{(|\mathbf{p}| \mp \mu)^2 + \chi^2} \quad (61)$$

Each solution is of the form that mix the upper and lower 4-components

$$U = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \quad (62)$$

with u_1 related to u_2

$$\not{p}_+ u_1 + \gamma^5 \mathcal{A}_c \chi^c u_2 = 0, \quad (63)$$

$$\gamma^5 \mathcal{A}_c \bar{\chi}_c u_1 + \not{p}_- u_2 = 0. \quad (64)$$

It can be shown that Eq. 46 evaluated in 3-meta-momentum space

$$\begin{aligned} \bar{t}[s] &= \int d^3 p \bar{U}(\mathbf{p}) U(\mathbf{p}) t_m = \int d^3 p (\bar{u}_1(\mathbf{p}) u_1(\mathbf{p}) + \bar{u}_2(\mathbf{p}) u_2(\mathbf{p})) t_m \\ &= \int d^3 p \left(1 - \frac{\chi^2 [(\chi^2 \mp 2\mu |\mathbf{p}|) + 2\mu (\epsilon_{\mathbf{p}} + \mu)]}{(\chi^2 \mp 2\mu |\mathbf{p}|)^2} \right) \bar{u}_1(\mathbf{p}) u_1(\mathbf{p}) t_m \\ &= \int d^3 p \left(\pm 2\mu \frac{(\epsilon_{\mathbf{p}} \mp |\mathbf{p}|)}{\chi^2} + \mathcal{O}(\mu^2) \right) \bar{u}_1(\mathbf{p}) u_1(\mathbf{p}) t_m \xrightarrow{\mu \rightarrow 0} 0, \end{aligned} \quad (65)$$

at small μ for quarks with different color as that of the order parameter χ^c in the superfluid ω -phase. Namely 2/3 of the quarks has no emergent time when $\mu \rightarrow 0$ in the superfluid phase.

B. Metric for emergent spacetime

The difference in emergent time between two meta-time slice can be evaluated using the decomposition Eqs. 39, 40 and 41

$$\begin{aligned} \delta \bar{t} &= \sum_{S \in \Omega} w(S) (\bar{t}[S, t_{m2}] - \bar{t}[S, t_{m1}]) \\ &= \delta \bar{t}_0 \left(Z + \frac{\delta \bar{t}_{loc} + \delta \bar{t}_{vac}}{\delta \bar{t}_0} \right). \end{aligned} \quad (66)$$

where $\delta \bar{t}_0$ is the emergent time difference when $N_C \rightarrow \infty$, which corresponds to a flat emergent spacetime since the underlying meta-spacetime is assumed to be flat. The change to the metric due to a finite N_C is

$$\sqrt{g^{00}} = Z + \frac{\delta \bar{t}_{loc} + \delta \bar{t}_{vac}}{\delta \bar{t}_0} \quad (67)$$

Let's suppose that $\eta_v = 0$, namely there is no other matter besides the one under consideration. From Eq. 46, one gets

$$\sqrt{g^{00}} = 1 - \frac{1}{N_C} \text{Tr} \int d^3p \tilde{w}(\mathbf{p}) |c_v(\mathbf{p})|^2 + \frac{1}{N_C} \frac{\text{Tr} \int d^3p \tilde{w}(\mathbf{p}) |c_v(\mathbf{p})|^2 \bar{U}_v(\mathbf{p}) U_v(\mathbf{p})}{\text{Tr} \int d^3p \tilde{w}(\mathbf{p}) \bar{U}_0(\mathbf{p}) U_0(\mathbf{p})} \quad (68)$$

with normalization condition

$$U^\dagger(\mathbf{p}) U(\mathbf{p}) = 1$$

imposed, where the meta-3-momentum space is used represent the quasi-particle excitation state, the trace “Tr” is over all the internal degrees of freedom, $\tilde{w}[\mathbf{p}]$ is the weight in the assemble of free quasi-particles, which depends implicitly on the internal degrees of freedom, can be derived from the general weight $w[S]$ since S is simply a direct produce of the single quasi particle states that make up the multi-particle state under the current condition.

1. σ -phase as true ground state

In the phase where σ -phase is the true ground state, the false ground state is the ω -phase of superfluidity at $\mu = 0$ (there is no matter under current context). According to Eq. 65 that is valid for 2/3 of the quarks in the ω -phase,

$$\sqrt{g^{00}} = 1 - \frac{2\xi_\alpha}{3N_C} \quad (69)$$

with $\xi_\alpha \sim \mathcal{O}(1)$ a positive constant. Therefore

$$\sqrt{g^{00}} < 1, \quad (70)$$

which means that the metric for emergent time interval is different from 1.

2. ω -phase as true ground state

In the phase where ω -phase is the true ground state, the false ground state is the α -phase of spontaneous chiral symmetry breaking at $\mu > 0$, For 2/3 of quarks with different color from χ^c , it is true that

$$\bar{U}_0(\mathbf{p}) U_0(\mathbf{p}) \ll \bar{U}_v(\mathbf{p}) U_v(\mathbf{p}) \quad (71)$$

for small enough μ due to Eq. 65. It results in

$$\sqrt{g^{00}} > 1, \quad (72)$$

which means that the metric for emergent time interval is also different from 1.

C. Emergent spacetime acceleration and cosmological constant

According to Ref.[12, 14], quantum fields in the 2DCTR representation transforms as

$$\begin{aligned} \frac{\delta \hat{\phi}_1(x_m)}{\delta ct_m} &= \partial_0 \hat{\phi}_1(x_m) + \frac{1}{c^2} \mathcal{M} \mathbf{a}_m \cdot (\mathbf{x}_m \partial_{m0} + ct_m \nabla_m) \hat{\phi}_2^T(-x_m), \\ \frac{\delta \hat{\phi}_2(x_m)}{\delta ct_m} &= \partial_0 \hat{\phi}_2(x_m) + \frac{1}{c^2} \mathcal{M} \mathbf{a}_m \cdot (\mathbf{x}_m \partial_{m0} + ct_m \nabla_m) \hat{\phi}_1^T(-x_m) \end{aligned}$$

in an accelerated coordinate system with $\hat{\phi}_{1,2}$ the corresponding upper or lower component of the quantum field and \mathbf{a}_m the 3-acceleration vector of an observer in the meta-spacetime. It means that the wave function of a unit of

quantum excitation transforms the same way

$$\frac{\delta\phi_1(x_m)}{\delta ct_m} = \partial_0\phi_1(x_m) + \frac{1}{c^2}\mathcal{M}\mathbf{a}_m \cdot (\mathbf{x}_m\partial_{m0} + ct_m\nabla_m)\bar{\phi}_2^T(-x_m), \quad (73)$$

$$\frac{\delta\phi_2(x_m)}{\delta ct_m} = \partial_0\phi_2(x_m) + \frac{1}{c^2}\mathcal{M}\mathbf{a}_m \cdot (\mathbf{x}_m\partial_{m0} + ct_m\nabla_m)\bar{\phi}_1^T(-x_m) \quad (74)$$

where $\phi_{1,2}$ is the corresponding upper or lower component of the wave function for the corresponding field. It involves a mixing of the upper and lower components when an accelerating coordinate system is used.

For the light quark system, it follows from Eq. 29 that there is also a dynamical mixing between the upper and lower components due to quantum “tunneling” caused by the fact that only a finite number of baryons inside of the cosmological event horizon are observable. The relative amplitude of the mixing for a quantum packet of excitation is derived base on similar action principle Eq. 25. These actions are computed along a common meta-time interval (which is let to approach to infinity later). However, if different ground states are single out to be considered alone, the same meta-time interval maps to different emergent time intervals due to change in the corresponding metric. So when these actions are compared in the emergent spacetime using, instead, a common emergent time interval of the true ground state, the actions from different ground states become different from each other, most likely deviate from $\mathcal{O}(\hbar)$ significantly. These differences are amplified when the emergent time interval is let to goto infinity and number of particles in the assemble for an probing baryonic object becomes macroscopically large. From the principle of stable action $\delta\mathcal{A} = 0$ for the system the emergent spacetime manifold has to adapt to the requirement, namely it should behaves in a way such that only those emergent spacetime trajectories for the probing object that come from the dominate true ground state should survive in large particle number limit. Therefore there should be an accelerating co-moving coordinate or reference frame in the emergent spacetime coordinate in which, after average over a macroscopic number of particles and their quantum states in said assemble, the corresponding probing object emerges as the most particle like that has a localized form, namely the “classical” one, the one whose quantum features (e.g., the “tunneling” effects) and wave nature are erased as much as possible by having a unique classical trajectory that stabilizes the action in the emergent spacetime.

From Eq. 69 and more generally Eq. 68, one can see that such effects on emergent spacetime manifold can be described by Riemann’s geometry that can be defined solely by the metric $g_{\mu\nu}$ tensor. $\delta\mathcal{A}$ mentioned above can therefore be represented as a variation in the metric. It had been studied in the context of the “dark energy” problem. Namely, according to Einstein

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + g_{\mu\nu}\Lambda = 0 \quad (75)$$

with the cosmological constant given by

$$\Lambda = \frac{\lambda^2 c_\Lambda}{N_B} \quad (76)$$

where λ is defined in Eq. 36, $|c_\Lambda| \sim \mathcal{O}(1)$ and N_B is the number of baryons within the cosmological event horizon.

Eq. 75 is the Einstein’s GR equation in the absence of any matter. It implies that the universe is expanding and the expansion is an accelerating one in the α -phase where the ω -phase is the false ground state.

Eq. 8 as a numerological presumption has now a physical foundation. Instead of a problem, the so called “dark energy” is an initial entry point of the current theory into the physical reality.

In the ω -phase where the α -phase is the false ground state, physical processes are dominated by quantum effects and the concept of emergent spacetime or Eq. 75 on small scales that is based upon the assumption that a clear localizable classical picture will emerge is less clear. Here the wave nature of particles could still survive in the large particle limit manifest itself as “classical” macroscopic waves, like what happens to photons in the α -phase dominated state discussed above in which the macroscopic waves are EM waves governed by Maxwell’s equations. Its an area that is not well understood due to our lack of physical experiences in there, it is worth to be explored theoretically in the future.

However a general physical picture at cosmological scale can be extrapolated. Suppose there is a mechanism in which the ω -phase dominated state would start to be energetically favored as the next phase of the α -phase dominated one due to the accelerated expansion of the dominating α -phase, a phase transition is expected. The baryon density is very small at the beginning which is not a stable state because there is a lower energy state at finite density. The universe will shrink to increase its baryon density so that the finite $\pm\mu_{vac}$ at which the effective potential V_{eff} is minimized is eventually reached. Such a contraction can be represented, effectively, as accelerated contraction in its emergent spatial dimensions, similar to what it is represented in the α -phase dominated state, creating a big “crunch”. It will be discussed in the section about a hypothetical cyclic intelligible Universe.

D. Emergent dual spacetime

Only the matter-less case in which the energy density gap between the true ground state and the false one remains constant is studied in the previous subsections. Let's consider the $\delta\bar{t}_{loc}$ contribution to the metric Eq. 67. Following Eqs. 35, 39, one has

$$\delta\bar{t}_{loc} \propto \frac{\delta\varepsilon_v}{\Delta\varepsilon_v^0 \sqrt{N_C}} \quad (77)$$

$\delta\varepsilon_v$ is the deformation of the energy density difference $\Delta\varepsilon_v$ in the presence of matter which can be computed, at least in principle, from the underlying dynamics of the system using a real time relativistic quantum field theory at finite density and temperature [12] where the energy density ε can be identified with the value of one of the minima of the effective potential V_{eff} (see Refs. [8, 9] and Fig. 1) corresponding to the ground state of interest. While V_{eff} can be used to study the uniform (in meta-spacetime) ground states, the effective action \mathcal{A}_{eff} introduced in Refs. [8, 9] as a canonical functional of the baryon number density n_B can be used to study the dynamics of the statistical gauge field excitations μ'^α corresponding to a varying n_B . So when it is expanded around a background with vanishing baryon number density,

$$\delta\varepsilon_v(x_m) = f[n_B](x_m) = a_1|n_B(x_m)| + \mathcal{O}(n_B^2) + \dots \quad (78)$$

where a_1 is the (functional) Taylor expansion coefficient of $f[n_B]$ at $f[0]$. a_1 is not zero since it is related to the differences in the discontinuous finite jump in μ across the $n_B = 0$ surface. This is because either the presence of baryons or anti-baryons will cause the energy density gap in V_{eff} between the false ground state and the true one to change in the same direction around **the** $n_B = 0$ **background** due to the fact that $V_{eff}(\delta n_B) = V_{eff}(-\delta n_B)$ around $n_B = 0$ surface (or cross section), which is relevant to the current epoch of the universe.

However around a finite background baryon density, one has

$$\delta\varepsilon_v(x_m) = f[n_B](x_m) = a_1 n_B(x_m) + \mathcal{O}(n_B^2) + \dots, \quad (79)$$

which is relevant to the in which the ω -phase is the true ground state.

So the emergent Eq. 68 contains a local matter term

$$\sqrt{g^{00}} = 1 + \frac{K \rho_B}{m_B \sqrt{N_B}} + \frac{\mathcal{O}(1)}{N_B} (\dots) \quad (80)$$

where in the current epoch of the universe $\rho_B > 0$ and in the baryon dominated blocks of the superfluid state of the universe, $\rho_B > 0$ for baryons and $\rho_B < 0$ for anti-baryons. Here the $1/N_B$ term are considered in previous subsection, $\rho_B = m_B n_B$ is the mass density of baryons, n_B is assumed to sufficiently small, and $K \sim \mathcal{O}(1)$ is a constant. Therefore Eq. 75 is completed as

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + g_{\mu\nu} \Lambda = \kappa M_{\mu\nu}, \quad (81)$$

where

$$\kappa \sim \pm \frac{\mathcal{O}(1)}{\sqrt{N_B}} \quad (82)$$

and the mass tensor $M_{\mu\nu}$ depends on ρ_B .

Note that, from the formulation of finite density and temperature QFT (see [12]), $\delta\varepsilon_v$ and therefore $\sqrt{g^{00}}$ depends, canonically, on the **baryon number density** only, which is represented by the mass density ρ_B of baryons, rather than the total energy density of any physical entity. It does not include even the internal kinetic energy. This is very different from GR in which any type of energy and momentum, even that of the spacetime itself, contributes. The prediction following the current theory that the curvature of emergent spacetime must depend on a dimensionless pure numerical quantity rather than a dimensional one is metaphysically more natural to the present author even outside of the current theory. It also removes, once for all, the contradictions and controversies caused by the inferences that the absolute value of zero point energies, inherent to quantum field theories, play physical roles in gravitational process. Here only the differences between them matter.

So let's write $M_{\mu\nu}$ as

$$M^{\alpha\beta} = \rho_B u^\alpha u^\beta + U^{\alpha\beta} \quad (83)$$

with u^α the (emergent) 4-velocity of the macroscopic baryonic matter (fluid), namely

$$u^\alpha u_\alpha = 1.$$

$U^{\alpha\beta}$ is the contribution of other dynamical excitations, like the long range part of the hybrid excitations of EM and statistical gauge degrees of freedom. It can be decomposed into transverse and longitudinal parts

$$U^{\alpha\beta} = aT^{\alpha\beta} + bL^{\alpha\beta}, \quad (84)$$

where a and b are coefficients of order $\mathcal{O}(1)$ and could be zero. They could be different in different phases of the universe.

1. Gravity

In the current epoch of the universe, $\bar{n}_B \approx 0$, where \bar{n}_B is the background baryon number density. The minimum of V_{eff} along the constant μ (and therefore \bar{n}_B) cross section at the false ground state valley of the ω -phase is above its local true minimum that is at a finite $\pm\mu_{vac}$ (corresponding to non-vanishing $\pm\bar{n}_B$), see Ref. [8, 13]. Since μ is a monotonic increase function of n_B , increasing n_B helps to lower the energy of the ω -phase, so a_1 in Eq. 78 must be negative. Baryonic entity in the α -phase tends to attract others ones to get closer. Therefore

$$\kappa = \frac{8\pi G}{c^4} > 0.$$

There is gravity for baryons in or around baryon concentrated regions (namely, $\mu > 0$) and anti-baryons in anti-baryon concentrated regions (namely, $\mu < 0$). According to Eq. 78, for anti-baryons in or around baryon concentrated regions and baryons in or around anti-baryon concentrated regions, there is still gravity because $\bar{n}_B \approx 0$ at present.

In astrophysical/cosmological phenomena that are accessible, the difference between Eq. 81 and GR equation in Eq. 1 is not significant enough to be already observed because $m_B \gg \Delta E$ with ΔE the typical energy upper limit including the internal energies, energies other participants like leptons and photons, short lived mesons, etc..

Eq. 11 as another numerological presumption has now the same physical foundation as the one for Eq. 8.

Since EM interaction is short ranged in a superfluid phase for the baryonic sector due to its ability to absorb the longitudinal massless Goldstone boson of the spontaneous local $U(1)$ symmetry breaking (the Higgs mechanism, see Ref. [10]), the contributions from them can be ignored. So here $a = 0$ in $U^{\alpha\beta}$ of Eq. 84. $b \neq 0$ because the longitudinal $L^{\alpha\beta}$ is originated from the long range density compression excitations (of the un-cancelled Goldstone bosons in the superfluid phase). It does influence $\delta\epsilon_v$ in Eq. 77 by altering the metric of the emergent spacetime. It, together with the transverse ones, is responsible for the observed “gravitational waves” in true ground state of α -phase the of current theory.

It’s well known that the solution to Eq. 81 for homogeneous and isotropic matter distribution can be expressed using Friedmann–Lemaître–Robertson–Walker (FLRW) metric with the scale factor ζ satisfying

$$\frac{\dot{\zeta}^2}{\zeta^2} = \frac{8\pi G}{3}\rho_B + \frac{c^2}{3}\Lambda, \quad (85)$$

$$\frac{\ddot{\zeta}}{\zeta} = -\frac{4\pi G}{3}\rho_B + \frac{c^2}{3}\Lambda \quad (86)$$

where the contribution from $U^{\alpha\beta}$ is ignored. It differs from solutions for GR in that it does not contain the contribution from the pressure p and the mass density is the sum of the mass of individual baryons in the system. It is consistent with the thermodynamics in the emergent spacetime that is discussed in Sec. V. Therefore current theory prevents the universe from becoming, against principles and intuitions in other areas of physics, a “free lunch provider” of energy during its expansion.

2. Topology, vorticity and charged leptons

As it is shown in Ref. [10], there remains long range interactions between charged baryonic subsystem and charged leptonic subsystem in the ω -phase due to partial spontaneous breaking of the $U(1)$ local gauge symmetry for EM as a result of the fact that quarks in the baryonic subsystem are fractionally charged. There is no Higgs mechanism in this particular sector. This renders the charged leptonic subsystem of matter different from other types of the same and

raises the need for having an independent emergent spacetime that couples to the main baryonic spacetime via EM interaction in the true ground state (the α -phase), forming a dynamical system that has rich dynamics and features capable of interpreting a wide range of cosmological phenomena some of which are still not well understood, free of or with reduced (in principle) arbitrary parameters and ad hoc particles.

In a perfect situation, the ground state in ω -phase would be a featureless superfluid. But such a state is not stable against external perturbations like the presence and motion of matter in the α -phase. It will carry, in addition to quantum density waves, vortices and turbulent regions.

For a single vortex (see Ref. [8]), there are topological constraints, namely

$$\oint_{\partial\Sigma_m} d\mathbf{l}_m \cdot \boldsymbol{\mu} = 2n\pi, \quad (n = 0, \pm 1, \pm 2, \dots), \quad (87)$$

where $\boldsymbol{\mu}^i$ ($i = 1, 2, 3$) are the spatial components of the statistical gauge field, Σ_m is the surface in meta-spacetime that contains the vortex and line integration is around the edge $\partial\Sigma_m$ of Σ_m . It implies that

$$\boldsymbol{\mu} \propto \frac{1}{r_m} \quad (88)$$

where r_m is the radius of $\partial\Sigma_m$ when it is a circle with its center coincides that of the vortex. Eq. 88 is a robust constraint since Eq. 87 is a topological property of the underlying quantum superfluid.

Leptons, and all other kinds of particles that interact with the baryonic subsystem, will acquire corresponding finite excitation components in the false ground states (C_v terms of Eq. 22) due to the interaction with the baryonic subsystem. Decomposition Eqs. 29 and 33 are still valid. The excitation component of a charged lepton inside a superfluid vortex is dragged along with the vortex with a reduced energy

$$\delta\varepsilon_v \propto -|\boldsymbol{\mu}|. \quad (89)$$

From Eqs. 73 and 74 one can infer that the emergent spacetime for an assemble of charged leptons, with base metric defined by the baryonic subsystem (since all measurement apparatus are made of baryons), has additional sub-features within a quantum vortex in the false ground state of superfluidity, the ω -phase, of the true ground state, the α -phase.

Just like the discussion given for the uniform acceleration due to “dark energy”, the emergent spacetime for an assemble of charged leptons has an acceleration toward the center of the said vortex to cancel the contributions of its component in the false ground state so that their action is a stable one (or they become most particle like or “classical”) as a whole (see Sec. IV C). Due to Eqs. 88 and 89, such an acceleration satisfies

$$a \sim \frac{\mathcal{O}(1)}{\sqrt{N_B}} \times \frac{V_M}{r} \quad (90)$$

with V_M the strength of an assemble of vortices within the region of interest and r_m mapped to the emergent r . This is different from Newtonian gravity experienced by a macroscopic massive object which can be written in a similar form

$$a \sim \frac{\mathcal{O}(1)}{\sqrt{N_B}} \times \frac{M_g}{r^2} \quad (91)$$

where M_g is the source of the gravity within the region of interaction.

The equation for the emergent spacetime of charged leptons can therefore be written in a more generic form, namely

$$r_{\mu\nu} - \frac{1}{2}g_{\mu\nu}r + g_{\mu\nu}\Lambda + \kappa_L V_{\mu\nu} = \kappa M_{\mu\nu}, \quad (92)$$

where $r_{\mu\nu}$ is the corresponding Ricci curvature tensor,

$$\kappa_L \sim \frac{\mathcal{O}(1)}{\sqrt{N_B}} \quad (93)$$

and $V_{\mu\nu}$ vorticity tensor generated by vortices and turbulence in the false ground state of superfluid. The contribution of $V_{\mu\nu}$ is put on the left-hand-side of the equation to reflect the fact that, like Λ , it originates from the quantum properties of the ground states rather than the matter on top of it, albeit vortices in the superfluid are likely to be indirectly induced by the helical motion of the baryonic matter on top of it via the mediation of charged leptons.

The form of the transverse part $T^{\alpha\beta}$, which is contributed by the long range part of the hybrid EM excitations in the superfluid phase, is well known

$$T^{\alpha\beta} = F^{\alpha\nu} F^{\beta}_{\nu} - \frac{1}{4}g^{\alpha\beta} F^{\mu\nu} F_{\mu\nu}, \quad (94)$$

where $F^{\alpha\beta}$ is the hybrid EM field. The proper form for the longitudinal $L^{\alpha\beta}$ or event $M^{\alpha\beta}$ will be investigated in future studies.

3. Dual spacetime and coupling

Charged leptons in celestial entities are in one of or a mixture of the following two forms:

1. **Bounded form:** There is competition between the gravitational and vorticity interactions, Both baryonic component and the charged leptonic component of matter tries to follow their own geodesic but could not because they have to move together in the emergent spacetime. As a result, matter molecules or internally ionized celestial bodies will contain small “gravitational electric dipole moment” (GEDM) which contains an internal Coulomb interaction between the two components capable of correcting the mismatch. The strength of the GEDM is of order $1/\sqrt{N_B} \sim 10^{-40}$. They are not an easily accessible property in domestic observations. However their astrophysical effects are not negligible as it is discussed below.
2. **Ionized form:** Macroscopic number of baryonic and charged leptonic entities move according to their own geodesic. The baryonic matter becomes charged on celestial scale with a straight of order $N/\sqrt{N_B}$ as well, where N is the number of particles in the celestial entity. In addition to the gravitational one, they influence each other also via long range EM interactions of order $N \times 10^{-2}$, which is $\mathcal{O}(10^{38})$ times stronger.

4. Antigravity in the ω -phase

If the universe is in ω -phase, $\mu = \pm\mu_{vac} \neq 0$. The minimum of V_{eff} along the constant μ at the false ground state valley of the α -phase is above its local true minimum which is at $\bar{n}_B = 0$, see Ref. [8, 13]. Decreasing \bar{n}_B helps to lower the energy density of the α -phase, so a_1 in Eq. 78 must be positive. Baryonic entity in the ω -phase tends to avoid others ones by staying away from each other. Therefore

$$\kappa < 0.$$

There is anti-gravity for baryons in baryon concentrated regions (namely, $\bar{n}_B > 0$) and for anti-baryons in anti-baryon concentrated regions (namely, $\bar{n}_B < 0$). Also for anti-baryons in baryon concentrated regions and baryons in anti-baryon concentrated regions, there is gravity.

E. Cosmos and the Gravitation Constant

The above quantum level discussions provide an order of magnitude estimation of Newton’s gravitation constant G . A more precise formula relating G and the distribution of baryonic material universe can be deduced based upon the physical mechanism for gravity provided by the current theory using relativistic classical mechanics.

1. The mass of the visible universe is zero

The visible universe, namely the materials included by the cosmic event horizon of an observer, is a view of the Universe that is almost invariant under a Lorentz transformation since the Universe is known to be almost uniform at large scales and because of the invariance of the speed of causal front (or light) under the same transformation.

Let’s introduce two observers of the Universe A and B . If B is accelerated, his/her inertia is proportional to his/her own mass only and has nothing to do with his/her view of the Universe, namely the universe within his/her cosmic event horizon. But for observer A , B ’s acceleration accelerated not only him/her -self but also the visible universe of his/her (see Eq. 111). Therefore, B ’s inertia is the sum of the two. So the inertia of the visible universe must be zero.

This is consistent with hypotheses in Sec. II A, since a massless universe is consistent with the flatness of the Universe beyond cosmic event horizons. It also implies scaling invariance⁷ of the Universe beyond the cosmic horizons scales.

⁷ It sometimes is referred to as conformal invariance in the literature. But conformal invariance refers to different kind of invariance in the current study, namely it is about mathematical mapping between two coordinate systems, not about physical properties of the system.

2. An equation for gravitation constant

Let's hypothetically consider an effort to pull every celestial objects in the visible universe to distances far apart from each other that approaches infinity. Then the energy gained, according to $E = Mc^2$, is

$$c^2 (M_\infty - M_u) = c^2 M_\infty = W \quad (95)$$

$$M_\infty = \sum_i m_i \quad (96)$$

$$W = -U_u \quad (97)$$

Here M_∞ is the total mass of the celestial objects that were originally in the cosmic event horizon of an observer, M_u the the mass of the current universe which is zero, W is the work needed to pull the celestial objects apart, the summation is over all celestial objects with the cosmic event horizon of the observer with m_i the mass of a member celestial object, and U_u is the gravitational potential representing of all materials within the cosmic event horizon, assuming an asymptotic zero value for it, when they are pulled far apart as described above. These simple equations are valid within the Hubble event horizon in the current theory for Gravity because energy is known to be conserved therein (Sec. V). Since, due to the accelerated expansion of the universe (see Sec. VI), the Hubble event horizon differs from the cosmic one only slightly, they are assumed to be valid even for the cosmic event horizon in the following.

According to the current theory, gravity is caused by the interference term between the uniform background and localized distortions of the emergent spacetime, namely δO_{loc} in Eq. 41, which when it's applied to the evaluation of U_u , one has an estimate

$$U_u = -2GM_\infty \sum_i \frac{m_i}{r_i} \quad (98)$$

which holds since the value is dominated by contributions from those celestial objects that are close to the cosmic event horizon of the observer, namely the Newtonian gravitational potential between all celestial objects within the cosmic event horizon of an observer and an hypothetical massive object of mass M_∞ located at the observer at a cosmic time earlier than the current one due to relativistic time dilation taken by the light signal from a particular celestial object to reach the observer. The factor 2 is here due to the fact that it comes from the interference term (see Eq. 41)). When the above equations are combined, one gets

$$G = \frac{c^2}{2 \sum_i \frac{m_i}{r_i}} \quad (99)$$

that quantitatively unifies Gravity with the Standard Model of physics.

Similar equation was originally obtained, implicitly, by D. W. Sciama in 1952 in seeking for an “adequate theory of inertia” following a very different physical picture and chain of reasoning.

An order of magnitude estimation of the above equation using the known total mass and radius of the universe indeed yield the correct order of magnitude for G .

V. ENTROPY AND LOCALIZATION OF THERMODYNAMICS

Thermodynamics can be derived from an application of statistical mechanics to the underlying dynamics using the imaginary time version of the relativistic finite temperature and density QFT given in Ref. [12], which contains general expressions and a derivation of a set of exact results for free particles based on grand canonical assemble. The emergent properties here are intrinsic ones like the temperature, chemical potential, etc.. These are good enough if the whole system is in thermal equilibrium so that, besides spatial boundaries, it has no dependency on spacetime. However, unlike a non relativistic domestic condensed matter system, such a static state of “heat death” may never be reached for something as large as the Universe, where relativistic effects are not negligible, in a foreseeable future.

At the current epoch of the universe, the majority of local regions in meta-spacetime with sufficiently large sizes could be regarded as already in thermal equilibrium within a reasonable accuracy. Therefore one could envision that there are a non uniform mesh grid to be layout in the meta-spacetime where the size of each grid is determined by the requirements: 1) it has to be large enough to include a macroscopic number of particles and is locally thermalized to the required accuracy; 2) it has to be also small enough that the intrinsic thermo properties does not vary to a degree that violates the accuracy requirements. The subsystem in each grid becomes a localized thermal system with its emergent spacetime computed within the same grid. The largest grid would be the visible universe itself.

As a result, it is expected that intrinsic thermodynamical properties of a so localized macroscopic entity in emergent spacetime depends not only on the emergent spacetime, which could be small or irrelevant, but also on the metric of it. This render the correct form of laws of thermodynamics in the emergent spacetime to be different from the ones derived by assuming spacetime is a fundamental physical entity.

Micro-canonical assemble is the simplest one to reveal the differences. Here the thermodynamical potential is the Boltzmann entropy

$$S = k_B \ln W_m \quad (100)$$

with k_B Boltzmann constant and W_m the number of all available microscopic quantum states within a thin total energy shell, which takes the same value in both the meta- and the emergent view, in the meta- phase space with infinitesimally small thickness. In light of later developed information theory, W_m can be identified with something proportional to the information volume of the system in the said shell. It is the maximization of an info-entropy functional of the probability of microscopic quantum states in the said shell, or thermalized one. It is an increasing function of the spatial volume of the quantum system in the meta-spacetime, e.g. for free particles,

$$W_m \propto V_m^N \quad (101)$$

where V_m is the meta-volume and N is the total number of particles. Since meta-spacetime is not directly observable, one needs to use the corresponding emergent spacetime volume V . For a uniform system, V is related to V_m as

$$V = \zeta_m^3 V_m = \zeta^3 V_0 \quad (102)$$

where ζ_m is the scale factor relating an emergent spacetime volume and the corresponding meta-spacetime one and ζ , introduced in Eqs. 85 and 86, is the scale factor relating the emergent spacetime volume and the corresponding asymptotic emergent spacetime one V_0 at spatial infinity or an reference volume in the emergent spacetime at a chosen emergent time t_0 . Therefore for a uniform system, Eq. 100 can be written as

$$S = k_B \ln W \left(\frac{V}{\zeta^3} \right) + \dots \quad (103)$$

where W is the apparent information volume in the emergent spacetime and ζ the scale factor introduced above. This is consistent with solution to Eq. 81 in case of homogeneous and isotropic matter distribution using the FLRW metric, namely Eqs. 85 and 86.

Therefore a pure expansion or contraction of emergent spacetime in a co-expanding or co-contracting region of the Universe, like the region included by the Hubble event horizon, does not alter the entropy, energy, etc., therein, according to the current theory. Since S is the generating function of thermodynamics in the micro-canonical assemble, all thermodynamical quantities generated from it depend on $\tilde{V} = V/\zeta^3$ only, which is an invariant quantity under pure emergent spacetime rescaling. It is significantly different in physics from the traditional interpretation of the expansion (or contraction) of the universe in which entropy or energy has to be created from (or sunken into) nothing within a co-expansion (or co-contraction) region of space, e.g. inside the Hubble event horizon. Here, there is no such kind of free-lunch.

More specifically, the change in total entropy of the universe in the current epoch due to the pure emergent spacetime expansion decreases with time since galaxies continue to move out of its cosmic event horizon, which can be inferred using Eq. 101. This is quite different from the old views, in which entropy can be counter intuitively generated out of nothing as the universe expands. However it does not violate the second law of thermodynamics since the universe is not a closed system due to the fact that baryonic matter is exchanged across its cosmic event horizon. Therefore the current theory removes one of the theoretical obstacles in formulating a theory for a cyclic universe to be presented in the sequel.

VI. THE “DARK MATTER” PROBLEM

Due to the existence of the $\propto 1/r$ interactions (see Eq. 90) for galaxies on top of quantum turbulence inside the false ground state, virial theorem for power law gravitational potential could not apply. Therefore the basis of Zwicky’s conclusion is valid only in regions of space in which the said turbulence can be ignored. Albeit there are a few exceptions, most of the clusters of galaxies does seems to contain quantum turbulence in the false ground state of their region of space and in between them. There observational evidences that the so called “dark matter” is needed to be introduced in order for Newtonian dynamics to be able to account for them. The current theory provides an alternative mechanism for their interpretation.

The velocity curve of most galaxies can also be explained by the competition between the gravitational interaction $\propto 1/r^2$ and the vorticity interaction of $\propto 1/r$ experienced by charged leptons inside of the neutral gas or stars of a galaxy that contains a non-empty collection of central quantum vortices in the false ground state. It also can explain why some galaxy, like NGC 1277 or NGC 3647, do not follow the velocity curve of most galaxies. It's because they have no or very small number of associated central quantum vortices in the false ground state or having most of its central quantum vortices stripped away during intergalactic interaction according to the current theory. The recent observation of the separation of the so called “dark matter”, which is interpreted as the central quantum vortices associated with the galaxies in the cluster, with the so called “normal matter”, that can be associated with the GECP plasma and quantum turbulence in the false ground of the current theory, in MACS J0018.5+1626 seems to be consistent with the above dynamics. Here the phenomenon could be interpreted if one assumes an initial condition in which the average orientations of the vortices in the colliding galaxy clusters are pointing to the similar direction which provides additional attractive forces, on average, between the vortices attached to the galaxies involved in a cluster on top of gravity. In case the said average orientations are pointing opposite directions, the effects will be opposite and in addition the some of the vortices involved will annihilate with each other resulting in an reduction in total vorticity.

The left behind x-ray emitting region at the center after collision of two galaxies can also be explained. They could be the retained turbulence (web of inter-connected quantum vortices) after the collision and annihilation of the vortices in the corresponding galaxies and nebulae of neutral molecules (and some trapped charged leptons, stripped away from their associated molecules) in them, forming a mixture of quantum turbulence in the false ground state of superfluidity and hot x-ray emitting interstellar gravitational plasma (see Sec. VIII C) in the α -phase within the same region. This is explained in more details in Sec. VIII A.

According to empirical observations, the cross over region of the velocity curve between the Newtonian one and the non-Newtonian one for different galaxies that exhibits such a phenomenon is at a universal acceleration called Milgrom acceleration $a_0 \approx 1.2 \times 10^{-10} m/s^2$ based on which the Modified Newtonian dynamics (MOND) of his was proposed. Such a universality has also a simple interpretation in the current theory, namely it implies $\kappa_L V$ of Eq. 92 and κM of Eq. 81 are proportional to each other, independent of the galaxy under investigation, namely

$$\frac{\kappa_L V}{\kappa M} = const \quad (104)$$

where V is the strength of vorticity and M is the central mass, which means the strength of central vorticity in a galaxy is proportional to its central mass. Instead of being a un-expected behavior it is the most natural assumption one would expect.

Given the new physical mechanism introduced, the reliance on “dark matter” mechanism or MOND to explain cosmological phenomena is greatly reduced. Whether or not the contributions of “dark matter” or MOND can be deemed unnecessary remains a question to be further investigated in more quantitative studies. These are certainly not simple tasks since it involves a understanding and description of the complex physical behavior of the quantum turbulence, e.g., interactions between quantum vortices, their collective behavior, etc., inside the false ground state.

VII. GRAVITATIONAL WAVES

Baryon number density fluctuations inside the superfluid false ground state in the ω -phase can also cause metric change according to Eq. 77.

The EM $U(1)$ local gauge symmetry and baryonic $U(1)$ local phase gauge symmetry are both spontaneously broken down in the superfluid ω -phase. According to Higgs mechanism, there would be no massless (long range) excitation due to the corresponding local gauge symmetry, provided that the corresponding charge of the symmetry takes the same value (see. Ref. [10]). This condition is not satisfied in the Standard Model since quarks carry fractional charges and leptons have integral charges. It was shown in Ref. [10] that the effects of longitudinal massless Goldstone bosons of the symmetry breaking still manifest in the physical Fock space. They lead to massless quantum baryon density waves that can be represented using the statistical gauge field Eq. 20. When combined with EM excitations, these massless waves does not couple within the baryonic subsystem of the same flavor due to Higgs mechanism. Due to the difference in charge, they also create long range massless interactions between baryonic subsystems of different flavor. The EM interaction between baryonic system and charged leptonic system can be effectively described using a model in which the scalar part of the electric charge of the light quarks in the flavor space is reduced or even diminished due to the spontaneous baryonic $U(1)$ symmetry breaking.

However, the quantum density waves in the false ground state of superfluidity have influences on emergent spacetime in the form of causing changes to the metric of emergent spacetime, which can be seen by following Eq. 77, resulting in

generating a wave behavior for the emergent spacetime which is also long ranged. Such emergent massless “classical” waves travel at the speed of causal front or c . They can be identified with gravitational waves observed.

One of the phenomenological differences in predictions from the GR is that the gravitational wave here is driven by the longitudinal component of a 4-vector field, namely the statistical gauge field. The second difference is that it is more ubiquitous due to the fact that it has multiple sources, namely in addition to the merger of massive black holes or neutron stars, it also includes, e.g., vortex interactions during galactic collisions or even during relative motion and interaction between celestial sized star material entities inside an effective “magnetic/electric” environment in the ocean of quantum liquid of superfluid and turbulence of the false ground state, pre- “big bang” remnants, etc.. It also couples with the real cosmic micro waves (CMB) via its effects on the curvatures of the emergent spacetime to thermalize with the CMB to have the same temperature. Sec. VIII K discusses its phenomenological implications.

VIII. COSMOLOGICAL PHENOMENA

Now, let’s dive deeper into the realm of reality.

A. Physics of quantum vortices

In the absence of quantum vortices in the false ground state, the gravitational influence around massive celestial entities are spherically symmetric. However when there are vortices, which most likely to take the same direction, associated with the said entities, these vortices create an azimuthal symmetric environment along the direction of the vortices for the matter inside and around the said entities at distances that are large enough. These quantum vortices in the false ground state can provide and sustain an effective magnetic environment that has the right order of magnitude in strength required for cosmology (see below). This is because the circular motion of the charged quark or anti-quark pairs generates EM fields. But EM gauge symmetry is only partially broken in the superfluid of the false ground state, namely Meissner effects are not fully on due to the fact that EM excitations still contain massless or long range components when baryons interact with charged leptons. Most of the said effective magnetic lines are expected to be trapped inside the center of the quantum vortices⁸ at small distances from the center of the celestial entities and spread out at larger enough distances.

Since the said magnetic fields are generated inside the false ground state, the amplitudes of their contributions to the physical process in the true ground state is reduced by a factor of $\sim \mathcal{O}(1)/\sqrt{N_B}$. Therefore it is kind of “gravitational EM phenomenon” that only directly affects charged leptons. Their effects on the baryonic matter is via the coupling of the dual emergent spacetime described in Sec. IV D 3. Due to particle polymorphism discussed in Sec. IIIB, quanta in the false ground state constitute part of the corresponding “particle” in the true ground state that can be observed with an amplitude $\sim \mathcal{O}(1/\sqrt{N_B})$. One could effectively think of a neutral molecule in the presence of quantum vortices in the false ground state of superfluidity as a gravitationally effective charged particles (GECP) comprising atom/molecule or charged free/ionized leptons whose charge is $\sim Q_e/\sqrt{N_B}$ and with mass of that of corresponding particle, where Q_e is the total charge of charged leptons bound to it or the charge of the unit charge of unbound charged leptons, while treating the quantum vortices as if they corresponding to an effective magnetic field environment in the α -phase.

The effects are so small that one could only expect that they manifest only at celestial baryonic number and emergent spacetime scales. This explains why some of the gravitational phenomena are similar in pattern to what EM plasma effects are here on the Earth but there seems to be no known mechanism to generate them base on classical Newtonian and Maxwell dynamics because EM processes in the true ground state are either tens of orders of magnitude (namely, $\sim 10^{-2}\sqrt{N_B} \sim 10^{38}$) too strong for astrophysical processes or lacking natural sources and drives (dynamo) because the universe is neutral in charge on average and is not that hot in between interstellar spaces for molecular ionization to manifest on astrophysical spacetime scales (> 1 AU and $<$ size of cosmic horizon) and particle numbers ($> 10^{51}$). The observed **coexistence** of Newtonian dynamics and vorticity and plasma like behaviors in celestial processes require that their strength must be of the same order of magnitude. The mechanism given here is capable of satisfy this requirement And it also provide opportunities for us to simulate some of celestial processes related to vorticity on the Earth at reduced baryon number and spacetime scales via domestic EM experiments, like what is done on the behavior of true EM plasma, that can be easily handle domestically so that some relevant insight

⁸ Just like what a type-II superconductor would do in superconducting condensed matter systems on the Earth but without the need to turn the center of the vortices into non-super conducting phase.

or understanding can be achieved. Therefore some of the physical mechanism and/or pictures on which the following discussions are based is derived from the observed plasma physics on the Earth.

GECPs trapped and confined inside a vortex radiates synchrotron like or inverse compton scattering like radiations under the same effective “magnetic” environment maintained by the quantum vortices or turbulent regions in the false ground state of the universe. Such kind of synchrotron radiation will be referred to as gravitational synchrotron radiation or just synchrotron radiation in the following. The ionized charged leptons portion of the GECP assemble emits high energy photons due to their smaller mass which allows them to acquire high accelerations. The atomic or molecular portion of the same assemble emits photons at energies $\mathcal{O}(10^{-3})$ times lower than their charged lepton counterparts because of their larger masses. Under the same condition, the observed x-ray and γ -ray radiations are therefore most likely originates from the charged leptons while the low energy radiations, like the radio waves, are most likely coming from the atoms or molecules therein. The portion of each depends upon the degree of ionization of the GECP assemble. Since there are celestial number of particles ($\sim \mathcal{O}(10^{51})$) involved, the $\mathcal{O}(1/\sqrt{N_B})$ suppression factor is key to give rise to radiations at brightnesses of the right order of magnitude that does not deviate from astrophysical/cosmological observations significantly.

The energy of the gravitational synchrotron or effective inverse compton scattering radiation phonons can also be very high because of the interaction between ionized charged leptons and collective baryonic quantum turbulence in the false ground state having energy scale of that of QCD, namely around 1 GeV . As it is observed in domestic experiments on true EM plasma, which is governed by physics on the atomic energy scale of 1 eV , charged leptons in GECPs could produce gravitational synchrotron or effective inverse compton scattering radiations with energies much larger than 1 GeV ,

For bounded charged leptons, their energy levels are also expected to be changed in or around a quantum vortices environment. Here gravitational Zeeman effects and other effective magnetic field related effects are expected to be observable from stars with strong central quantum vortices attached. This could explain the origin and strength of magnetic fields of stars or even planets, especially those extreme ones like magnetars, extracted from observational data and answer the question: what is the nature of celestial dynamo?. Here again the interplay between the largeness of astrophysical number and the smallness of “quantum tunneling” suppression number renders a understanding of these effects in terms of EM theoretically valid.

The next question is what is the effective EM like manifestation in the current epoch of the universe of the quantum vortices in the corresponding false ground state? It is obvious that a quantum vortex represents certain collective circular motion of the baryonic condensate in the false ground state. It is safe to assume the false ground state is neutral so for each “up” quark, there are two “down” quarks in the condensate. Therefore the circular motion will have no EM effects on the baryonic component of the GECPs. However this is not true for charged leptons according to Ref. [10]. If the charge of a light quarks is written as

$$q = q_s + \sigma_3 q_v \quad (105)$$

where σ_3 is the third one of the Pauli matrices in the flavor space of light quarks spanned by up and down quarks with $q_s = 1/6$ the scalar component and $q_v = 1/2$ the vector one, then the effective q_s is effectively reduced for charged leptons in any superfluid phase that breaks the $U(1)$ symmetry corresponding to baryon number conservation down spontaneously. Such a reduction in q_s renders the false ground state effectively negatively charged⁹ for charged leptons. In addition there are still long range interaction between baryonic matter and the leptonic one since the EM local gauge symmetry is only partially breaks down in the ω -phase of superfluidity (see Ref. [10]). Therefore the circular motions of the quark condensate in the false ground state of superfluidity generates gravitational effective background magnetic fields for GECPs with a strength that are of order $\mathcal{O}(1/\sqrt{N_B})$. The total effective gravitational EM fields that a GECP experiences are built on top of such kind of background magnetic/electric fields together with the contributions from the motion of other GECPs and other kind of charged sources which could lead to a complex dynamical system. It could explain why ubiquitous celestial scaled patterns of something resembling “plasma” and “magnetic” are found in the neutral universe that neither dominates nor be dominated by but manages to coexists with patterns generated by Newtonian gravity.

B. Active life cycle of stars

Herbig-Haro objects are jets observed that are associated with the process of star formation from interstellar gas clouds through a process call gravitational collapse. The jets could serve as channels to carry away the energy and

⁹ Or positively charged for antimatter dominated universes.

angular momentum of the collapsing gas molecules so that they can, on average, continuously fall, all the way down until they condense into the region sustained by a star. Without them, the molecules in the gas will stop falling, on average, at certain point during the process and they most likely will not rotating on average because their total initial average angular momentum is most likely close to zero. However it is still not clear how these jets can be dynamically generated in Newtonian gravity.

There is a natural mechanism in the current theory. According to which, rotating baryonic molecular or atomic gas will interact with the false ground state of superfluidity to alter its state of motion due to the fact that the superfluid in the false ground state is effectively negatively charged for charged leptons (in the current universe), which will rotate in the opposite direction of those charged leptons inside the GECPs so that the original zero gravitational effective magnetic flux is changed as little as possible (Faraday’s law of induction and Meissner effects for effectively charged superfluids)¹⁰.

Because quantum vortices are quantized according to Eq. 87 the subset of the gas molecules that are capable of triggering the false ground state to change the state of corresponding vortices by giving away a portion of their energy and either gain or loss angular momentum are those that they have high enough angular speed. In addition the vortices will also provide effective magnetic environment for those GECPs. Instead of been bounced off the center in all directions, some of the falling GECPs will be trapped by the vortices to move within them to form jets of star materials, a behavior similar to the birkeland currents, that continuously carry away the energy and balance the angular momentum of the falling gas molecules so that the remaining molecules can condense toward the center and has a finite average angular momentum, forming a stable star and the planet system associated with it.

The number and strength of quantum vortices associated with a protostar is expected to increase during the star material falling stage since they play the role of the carrier of extra energy and unbalanced angular momentum so that the falling material matter can be slowed down and acquire required angular momentum to concentrate into the region of a stable star. In the meantime, the vortex bundle gets squeezed into narrow straight lines caused by the out flow jets of relativistic GECPs due to the z–pinch effects inside the intergalactic “plasma” consists of GECPs, similar to the ones found in EM plasma of charged particles. Nuclear fusions may occur in such a highly compressed state of GECP jets inside the vortex lines in the bundle under right conditions. After falling material matter is fully evolved into a stable rotating star, such kind of driving force diminishes. At this stage, there is only weak bounds between extra vortices and the star. It is not impossible for them to become free or be pushed away or merged into by the ones in center of their cluster, if any, or by the ones at their galactic center since vortices do interact with each other via interactions between GECP birkeland currents that depend on their relative flow direction and strength. Since the interaction between two vortices carrying birkeland current vanishes when they are perpendicular to each other, it is possible that those stars having their local vortices perpendicular to the central ones could retain a significant percent of them during their active lifetime. In addition, the z–pinch effects of the GECP current become smaller and smaller as the strength of the said current is being reduced, the size of the corresponding vortex bundle gets larger and spread out more. The disk like planetary system found in most stars could be one of the following consequences. Some existing studies, based upon the existence of hypothetical planetary “magnetic” fields, do indicates that such a mechanism is possible. The current theory provides the source and dynamo for such kind of gravitational effective magnetic fields supported by the combined contributions from spread out vortices in the false ground state of superfluidity around the star and the motion of GECPs in or around them. Such a mechanism could even be scaled down to be applied to the formation of planets of a star, like the Saturn. More studies are required in this direction.

At the end of a star’s active life, the outward nuclear fusion pressure is unable to balance the gravitational pull leading to its collapse, which will be accompanied by outward bursts of the GECP forming a structure called planetary nebula with different shapes. Some of them are bipolar and most of others have somewhat spherical symmetry. It is expected that there will be a bipolar planetary nebula for stars having strong central quantum vortices attached after the end of its life, while for other ones who have had most of their vortices stripped away during their active lifetime, the planetary nebula will be non-bipolar with certain spherical symmetry.

It is observed, with 5σ confidence, that the majority of bipolar ones near the bulge of the Milky Way have their major axes aligned in directions parallel to the galactic disk. Such a behavior is consistent with predictions of the current theory which, as discussed above, allow stars to have higher probability to keep those quantum vortices created during its birth for a longer time.

A spherical symmetric planetary nebula or some thing looks like that does not always implies a sufficiently smaller associated quantum vorticity of the star system whose collapse creates the nebula. One of the simpler exceptional cases is the merger a binary star system in which the stars are spinning in opposite directions. Instead of extending far into the interstellar space, the energetically favored configuration for the associated quantum vortices is to join together

¹⁰ The large scale and slower celestial phenomena (compared to those ones originated from true EM processes) observed in stars and planets that are attributed to magnetic fields are most likely the residue result of these two counter rotating entities that can generate gravitational effective magnetic fields on the order of $\mathcal{O}(1/\sqrt{N_B})$ weaker that only act on charged leptons in a GECP.

to form vortex lines confined within a region of thin torus where individual vortex join head to tail to become a closed loop when the stars are far apart enough. This torus will be referred to as vortex ring in the following. Albeit the said ring could be deformed to more complex shapes as the stars getting closer and before the eventual merger, it shall still be referred to as vortex ring in the following for simplicity. If it happens that the rotation plane of the binary system is approximately perpendicular to the the associated quantum vortices of each star, then a spherically symmetric resulting nebula is supposed to be observed. In this case the vortex ring, which sweeps out an 2-dimensional shell due to the rotation of the binary stars, becomes the energy dissipater for the binary system (so that the stars can get ever closer and eventually merge) that stores the energy of the initial binary system when the stars are far apart and also absorbs, “magnetically” traps and confines, via the associated quantum vortices, a significant portion of the outflow GECPs during the star merger to becomes extremely hot. This prevents the vortex ring from eventually collapse with the stars into its destination entity. Then the next stage starts, namely, the vortex ring shrink in diameter and cools itself by releasing its energy, which would be extraordinary in observable signatures compared to what is expected from the standard astrophysical model based solely on Newtonian dynamics, via the spherically symmetric out flow of plasma of GECPs in filaments. The said signatures includes but not limited to brightness, wave length in the background EM spectrum, etc., due partly to the highly excited nature of the hot plasma within the vortex ring. At the same time, the spherical region spanned by the vortex ring becomes an gravitational synchrotron or effective inverse compton scattering radiation (see more detailed discussions in Sec. VIII F) emitting pulsar having a wide spectrum range, including radio waves, x-rays, and even γ -rays. The frequency of the pulsation could be related to the frequency of a resonating and propagating quantum density wave, which could be induced by the out going gravitational waves created by the rotating binary stars when the rotation plane of the binary system is not exactly perpendicular the spin direction of the stars, within the vortex ring, which couples to and modulate the density of the GECP in the vortex ring via the corresponding emergent gravitational wave. Therefore the pulsation frequency can be in the millisecond range when the propagating gravitational wave is indeed in the vortex ring without requiring that the vortex ring to have size comparable to a neutron star or smaller. The pulsar can also be observed in almost any direction due to its spherical symmetry.

This new physical process can explain the rare and also hard to understand celestial event called SN 1181, currently identified as a supernova event, in which, the stars in the initial binary system can be determined to be both hydrogen and helium depleted and relatively small white dwarfs that merged into another white dwarf. The related millisecond pulsar which can be identified with the observed 3C 58 is the rotating vortex ring of the current theory. Given the propagating gravitational wave modulation mechanism described above, the fact that the vortex ring has a size on the order of related normal stars, which is much larger than any neutron stars, does not prevents it from becoming a millisecond pulsar. It is expected that most of the other “extraordinary” behaviors and features of resulting collection of celestial entities in the region can be described in terms of this model,

Such a process could also be applied to merger of two neutron stars or even black holes that has the right initial configuration.

If the opposite spin direction of the binary star system discussed above is parallel to the rotation plane, one still expect bipolar nebulae with no or weak central jets. The torus containing the quantum vortices also lies in the rotation plane. It will be deformed to an helical tube around the original torus as the binary system dumps more and more energy into it as their distance becomes smaller and smaller until the eventual merger. This is because, instead of shot out as straight line, the central quantum vortices has a lower energy configuration, namely they will wrap around and shrink (be pinched) into the original torus to join the quantum vortices inside to become helical. What happens is that instead of being spherical symmetric, the planetary nebula is formed from collapse of the helical vortex ring, which is extraordinarily hot due to absorbing the outburst of GECPs from the merging stars. Indeed, such kind of disk (or ring) planetary nebulae are observed in, e.g., NGC 7293, NGC 6720, etc., albeit they are being interpreted as the result of the collapse of single stars in literatures. Some observed Wolf-Rayet systems and associated nebulae could also be of such a kind, if they have no or weak associated jet following axial nebulae.

The newly observed “real-time” evolution of the SN 1987A fit quite nicely with the general dynamical prediction, namely the out going central ring plus an out going and spread out “jet like” cone of bipolar supernovae for a collapsed star or star system that’s in an environment that its central vortices is allowed to retain, as it is discussed above.

The presence of a false ground state of superfluidity in the α -phase provides a physical base for a new mechanism, absent in Newtonian dynamics, of rapid star formation inside an interstellar gas cloud with zero total angular momentum on average, to dissipate energy, to acquire required angular momentum and eventually collapse and condense into a rotating stable star.

The very same energy dissipation mechanism can also be applied to the formation of galaxies and even the central black holes therein. It gives rise a natural explanation to the existence of fully formed galaxies even before 1 billion years after the “big bang” recently observed by JWST. Without the said mechanism, it is necessary to assume a much older age for the universe than currently estimated one, namely the age of 13.8 billion years, which is inferred from data of other observations.

C. EM radiation spectra of stars and planetary nebulae

P. M. Robitaille put forward the statement that “the Sun is not gaseous” nor is it in the state of EM plasma. The reasons are that the temperature of the exterior shell region of convection (which will be referred to as “surface” in the following) of the Sun, which could be estimated to be at around $5778K$ at the start of the photosphere, are orders of magnitude too low for significant ionization of an entity consists of atomic (hydrogen) gas. If the Sun is gaseous, photons in it have too weak interactions with the neutral hydrogen atoms inside to be thermalized with the gas. What one expects to observe therefore are discrete spectra lines on top of a continuous one corresponding to the energy levels of the electron in a hydrogen atom. But the observed light spectrum from the Sun are mostly continuous one similar to Planck’s blackbody radiation. The observed surface features of the Sun also indicate it’s non gaseous, condensed matter behavior when the possibility of plasma state is excluded (Unzicker). A reasonable way out of the dilemma is to assume that the Sun is made of liquid of condensed hydrogen atoms in a violently convective and hot environment near the surface of the Sun. Given the weakness of gravity and the known properties of liquid hydrogen on the Earth, which has a critical upper temperature limit of mere $32.938K$, it requires new physical mechanisms, which are yet to be discovered, for a liquid state of hydrogen atoms to be reached at temperature above $6000K$ near the surface solely due to the gravitational pressure.

Under the current theory, however, the potential dilemma can be resolved naturally. According to which the Sun can be in a state of effective “plasma”, which will be referred to as gravitational plasma in the following, that is the combination of GECP gas which includes not only charged free electrons but also contribution from **all** neutral atoms with number on the celestial scale and the underlying quantum turbulence in the false ground state inside the region defined by the photosphere of the Sun. The liquid like behaviors with a relatively sharp surface is caused not by the atoms in the true ground state but by the superfluid in the false ground state. The surface features of the Sun are also generated by the said gravitational plasma inside the effective “magnetic” environment whose dynamo can be associated with the quantum vortices and turbulence in the superfluid false ground state of the universe. The sheer number of GECPs provides a physical basis for a viable mechanism for the thermalization of photons with the hadronic environment despite the effective charge of a GECP is reduced by a factor of $1/\sqrt{N_B}$. Therefore the conventional zone of the Sun can be a gaseous entity at $\sim 6000K$ on the surface that has a mostly continuous spectra of blackbody radiation and celestially *scaled up*¹¹ plasma like pattern and structure without the need of any ad hoc mechanism and fittings. It’s known that plasma on earth are volatile and not stable. However the gravitational plasma for GECPs are relatively much more stable at the scaled up spacetime scales due to the presence and support of the corresponding quantum vortices and turbulence in the false ground state. For example the ripples triggered by solar activities observed on its “surface” could be attributed to dynamical behaviors of the gravitational plasma or even to the gravitational waves caused by the density fluctuations in the false ground state of superfluidity.

Such a mechanism can also be applied to studies of most of the normal stars or even those non-main sequence ones on the same topic.

Another phenomenon of similar nature that can not be explained satisfactory using contemporary cosmological models is the observed photo emission lines from planetary nebulae that should be forbidden due to symmetry considerations, like those from Eskimo Nebula NGC 2392 and Red Spider Nebula NCG 6537. The contemporary explanations are based on the assumption that there are extremely high temperature ($> 10^4K$) and density electron gas in the corresponding nebula, sustained by the central star capable of providing extremely powerful ultraviolet radiation so that an environment inside the nebula is maintained that allows the otherwise parity violating (in empty space) photo emission transition to occur. Such kind of extreme and unnatural conditions, which are also in contradiction with other observational data about the central star, are not required here because, as discussed above, there exists environments of strong vorticity in bipolar or other more complex non-spherical symmetric planetary nebulae. The underlying quantum vortices and turbulence in the region will induce GEDM inside each atom or molecule therein which generates a background parity asymmetry for those parity violating photo emission lines to appear, with a suppression factor of $1/\sqrt{N_B}$. Such a mechanism works only in bipolar or other complex non-spherical planetary nebulae where the vorticity is strong according the current theory. It’s quite interesting to see if it’s indeed the case.

D. Neutron stars

The normal method of predicting the state of the nuclear matter inside of a neutron star is by using knowledge gained in experimental studies of few particle nucleon-nucleon interaction at zero density here on the Earth and

¹¹ On the emergent spacetime scale that describes the celestial sizes and the pace of motion of those discernable features of the Sun and particle number that is increased from 10^{23} to 10^{51} or larger.

extend it to the exploration of nuclear matter at finite densities, like inside of a neutron star.

It's worth mentioning that the results of the said extension is different in conventional theory using the 4-component fermion Dirac representation and in the current theory in which the 2DCTR representation is used (see Ref. [12] Sec. IV.D). Compared to conventional approaches, nucleon–nucleon attractive interactions due to exchanges of scalar mesons, like σ and π , are greatly reduced due to cancellation at finite density in the current theory while repulsive interactions from exchanges of vector mesons between nucleons in the same environment remains almost unchanged. Thus nucleons would resist being merged together to form quark matter longer than what is expected under high pressure. Therefore the expected formation of quark matter (in the true ground state of α -phase) in the interior of a neutron star, if exists, would require significantly higher pressure than what is expected in conventional theories discussed in literatures.

E. Globular clusters

Globular clusters contain old stars that aged around 10 billion years. They could keep their static, dense and near spherical symmetric clusters for billions of years. It is hard to conceive a dynamical model for such kind of static structures base solely on Newtonian gravity. Albeit there are dynamical models that claim to be able to explain the observable phenomena, these models must also provide at least one consistent explanation, using the same mechanism, for why stars could be formed from primordial interstellar molecular gas (see above) and, on the other hand, a globular cluster is capable of maintaining its structure without eventually condensing into a giant black hole in the end.

The current theory provides a single consistent framework for accommodating these phenomena.

Most of the stars in a globular cluster are small or mid-sized red giants and white dwarfs that have lived long enough to become stabilized at its outer regions. According to discussion given in Sec. IV D 3, some of the charged leptons (of order $1/\sqrt{N_B}$) carried by GECPs are moved close to one side of the bounding shell region, which will be referred to as “surface” in the following, of the gravitational plasma star leaving the corresponding surface close to the other side of the star oppositely charged due the effects of the central galactic quantum vortices in the false ground state of superfluidity. It is expected that large scale convection due to nuclear fusions have decreased or even stopped influencing the surface of these non main sequence stars, their GEDMs become stable. Therefore, instead of each individual molecule in them, these stars as whole have finite GEDMs that are so large, due to the increased diameters of them, that their GEDMs have celestial effects. Because the GEDMs of the stars are aligned in the same direction, they have repelling force between each other that is of the same order in strength as that of the gravity. It allows fully gravitational effective ionized stars with stable surfaces in galaxies to neither fly away from each other due to the EM repulsion nor collapse into the center due to gravitational attraction but to form stable near spherical symmetric clusters.

Since the force between electric dipoles drops off as $\sim 1/\tilde{r}^3$ with \tilde{r} the mutual distance, which is faster than the gravitational one of $\sim 1/r^2$, it is not hard to infer that it is energetically favored when the density of stars with GEDM around a central gravitational attractor decreases as the distance of the stars from the center, which is denoted as r , increases. This mechanism alone can provide the most simple basis for an explanation of all of the above mentioned properties without any complicated dynamical models.

Charged leptons also provide a $1/r_z$ attractive force for them toward the center of the said quantum vortices. The stars, via the mediation of all of the charged leptons inside the stars, experience additional interactions of the same nature gravitational one. Therefore the off galactic plane dynamics of globular clusters could be more complicated than the one determined by a single $1/r$ force from the center of the hosting galaxy, which predicts simple elliptical orbits that passes through the galactic disk for them. Without the central gravitational force, the current theory predicts that globular clusters will orbits the central quantum vortices and will never cross the galactic disk. In realistic situations, it will take much longer for their orbits to cross the galactic disk.

The physical processes discussed here can be applied to other similar celestial entities like the elliptical bulge in spiral galaxies and elliptical galaxies. It could also affects the star formation, processes near the center of a galaxy where the hydrogen and other light atoms have larger GEDM aligned in a similar direction that their gravitational clustering tendency is statistically suppressed. It also affects the dynamics in and of the postulated accretion disk, if any, in standard cosmological model based solely on GR near a black hole when attached quantum vortices of the current theory is assumed to exist.

F. Fermi bubbles and galactic jets

Fermi bubbles discovered in the Milky Way are not something expected based on contemporary cosmological models according to which such a structure must be originated from a period of relative short (100,000 years) violent outburst

of the central black hole, namely Sagittarius A*, by engulfing masses tens of thousands of that of the Sun just a few million years ago. It is quite unlike the quiet Sagittarius A* we observed today. Therefore the only reasonable assumption would be that it is a transient event on the cosmological scale. But such a bubble like structures are not uncommon in other galaxies albeit the gamma ray, if any, from them are not possible to observe. Therefore it is quite likely that they are not that a rare structure at all and could be long living stable entities.

The current theory provides a persistent mechanism for them. According to which there should be attached central quantum vortices in the false ground state of superfluidity at the center of our home galaxy. The gamma- or x-rays observed are just one of the observables of the central quantum vortices. They are expected to contain highly concentrated parallel magnetic field lines and GECPs in and around them are forced to move in circular trajectories and emits gravitational synchrotron or effective inverse compton scattering radiations ranging from gamma-ray, x-ray ones to radio waves in the false ground state. The low energy radiations are most likely caused by the much heavier neutral atoms or molecules in the GECPs. As discussed above the current theory also guarantee that the brightness of these radiations will be at the right order of magnitude that is consistent with observations.

G. Black holes, singularities, frame dragging and closed timelike curves

There are still spacetime singularities and black holes for massive celestial entities according to Eq. 81, but that equation is valid only when the emergent spacetime curvature is sufficiently small. It is conceivable from how the current theory of emergent spacetime is constructed that the simple form of Eq. 81 and even the very concept of emergent spacetime become invalid at the length scales around that of QCD, which are significantly smaller than the Planck one.

As to the question of how the baryonic subsystem behaves when it is compressed beyond the density of nuclear matter or neutron stars remains to be investigated in future more quantitative studies. There could be black hole like entity for outside observers by having, e.g. an event horizon, but the physical processes inside of it should definitely be different from the one predicted by GR or any quantized version of it that treat spacetime as a physical entity.

The classical frame dragging effects¹² are absent in the current theory due to the fact that the Eqs. 81–83 imply that the curvature of the emergent spacetime at a given point is independent of the motion of its main source, namely it only depends on the baryon number density there. This is quite different from GR. However it does not implies that the rotational motion of the baryonic matter has no effects. Rather such effects are represented in Eq. 92 which characterizes the effects of the vorticity in the false ground state of superfluidity on the charged leptons which in turn affects the motion of GECPs via the much stronger real EM interaction. In fact the physics of the rotating matter near black holes is richer than what is predicted by GR in which, for a given mass of a black hole, frame dragging has a one to one relationship with the rotation angular speed. There is no such a deterministic relationship in the current theory, as it is described in the previous subsections. In addition, the gravitational effective “electrodynamics” here is much richer in content than the one, called the Gravitoelectromagnetism, for GR. The recent observed celestial phenomena manifested in some collisions between galaxy clusters (MACS J0018.5+1626) seems to be consistent with such a claim under the interpretive framework of the current theory (see Sec. VI).

For example, the current theory provides a direct and faster mechanism for formation of black holes. Such a mechanism is indispensable for a natural explanation of the existence of black holes like CEERS 1091, UHZ1 and more specifically LID-568 in the early universe, any of which have an age less than a billion years, for it is not constrained by the Eddington limit due to the fact that it leads to a new and more efficient energy dissipation and angular momentum re-distribution mechanism for the falling hydrogen gas clouds to collapse into the central black hole. Here, in addition to the EM radiations, the quantum vortices and turbulence in the false ground state of superfluidity could become the dominating energy and angular momentum absorber and re-distributor of the falling gas cloud. The mechanism is also discussed when the star formation process is explained.

Due to the independence of emergent spacetime from the motion of baryonic matter, the current theory also avoids the true paradoxical existence of closed timelike curves (or logic loops) found in exact solutions of GR (Ref. [2] and K. Gödel) for rotating black holes that lead to a violation of the principle of causality.

Standard cosmological models predicts that there should exists a significant percentage of long living supermassive black hole pairs co-rotating at distances of order of parsec because there is not obvious mechanism for them to further dissipate their energies so that their mutual distance could be reduced further after getting into a state in which they are a few parsecs apart. But such a significant number of said pairs are not observed. This is referred to as the final-parsec problem.

¹² There are quantum or emergent dragging effects however. See discussions in Sec. XII A 4.

The current theory provides a natural mechanism for how their energies are to be dissipated: rotating black hole pairs can create quantum vortices and turbulence in the false ground state of superfluidity. It is qualitatively the same mechanism as the one used to explain the formation of stars discussed above.

H. Interstellar physical phenomena

The interaction between the intergalactic GECPs with the quantum turbulence in the false ground state of superfluidity can generate interest interstellar gravitational plasma phenomena, e.g., the hard to understand origin of galactic magnetic fields, plasma like filaments formation, the intergalactic cosmological scale magnetic fields, some out of thin air gamma-, x-, and radio wave burst events having unknown or observable origins, etc.. They remain to be the subjects to be studied in the future.

It's believed that the interstellar space is filled with plasma of some sort because otherwise the universe would not be so transparent at the absorption spectra of neutral atoms as it is seen today. Voyager 1 space probe detected a kind of “cosmic hum” as it was flying out of the solar system, which could be attributed to the existence of such a “plasma”. However, to maintain a true EM plasma state in the interstellar space requires extremely high temperature, which does not have a reasonable origin inside the mostly void interstellar space. Overcoming the overwhelming EM ($\sim 10^{38}$) neutralization long range force of Coulomb and maintaining large celestial scale electrically charge regions is not an astrophysical possibility. In fact the mechanism for the origin of such kind of plasma that attributed to the re-ionization epoch of the early universe is already hard to establish. Some data from James Webb telescope seems to suggest it could attributed to the ultraviolet radiations from dwarf galaxies in the early universe, but whether or not it is sufficient is not conclusive. Even this is true, maintaining the ionization during the long expansion of the overall cold universe represented by the CMB, which couples strongly with charged particles via EM interaction, is another problem since it is not a favored and stable state against thermalization.

The effective gravitational plasma generated by the GECPs and celestial scale EM like behavior as a result of them provides a way out of the dilemma since it allows cold neutral atoms in GECPs to participate in the process of generating the observed plasma effects and the “hum” because the background of GECPs are **effectively** negatively charged (with a $\sim 1/\sqrt{N_B}$ reduction in strength) for charged leptons (namely, electrons) due to the existence of a false ground state of superfluidity.

I. Quantum vortices and their manifestation

After discussed the expected effects of quantum vortices in the false ground state of superfluidity on the motion GECPs, its natural to explore the consequences of mutual interaction between vortices in the quantum turbulent environment there. The galactic activities in the true ground state of α -phase can results in regions of quantum turbulence in the corresponding false ground state in which lines, loops or rings of quantum vortices coexists. If a pair of vortex loops or rings having opposite vorticity directions and similar sizes collide in the meta-spacetime, which is expected to has a very small probability, they could annihilate each other releasing energies far exceed what is expected from particle annihilation in the Standard Model since a quantum vortex is a quantized collective motion (see discussions in Sec. XII B 3) in the false ground state that is triggered by and acting as energy dissipater and storage for active macroscopic galactic activities in the true ground state. Again the probability of detecting such an event in the true ground state will be reduced by a factor of $\sim 1/\sqrt{N_B}$ since it happens in the false ground state.

According to the current theory, the observed Oh-My-God particles and the late Amaterasu particle, which seems to pop out from nowhere and be capable of persisting the energy of a fast moving baseball, could be the results of annihilation of a pair of relatively small (domestically sized) but possibly numerous quantum vortex rings or loops in the turbulent environment of the false ground state floating in interstellar spaces near the solar system or even the Earth and having opposite vorticity direction and similar sizes in the false ground state. This explains why particles with so much energy could even been observed on the Earth.

One could further speculate that could some of the cosmic events attributed to supernovae or hypernovae be the results of the collision and subsequent annihilation of larger, celestial sized, having near opposite vorticity, and free quantum vortices? For example, the observed but hard to understand Luminous, Fast, Blue, Optical Transient (LFBOT) objects, like AT2023fhn (the Finch)?

Could some of the odd radio circles (ORC) observed be one of the manifestations of closed ring like quantum vortex bundles in the false ground state of superfluidity of the universe? The reason, under the current scenario, for their manifestation only in radio frequencies is that they were so stretched in sizes during their formation that they have very low temperature inside and the GECPs trapped within are mainly neutral atoms and molecules circulating at much larger radiuses due to the fact that they have masses much larger ($> \mathcal{O}(10^3)$) than that of the charged leptons

so that the spectrum of the corresponding gravitational synchrotron radiations are shifted down to lower frequencies into the region of radio waves.

The unexpected detection of “space roar” that is about 6 times larger than theoretical predictions of contemporarily theories by the Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission (ARCADE) project remains to be explained. The above mentioned synchrotron radiation due to vorticity in the background of emergent spacetime could provide a natural mechanism for the observed phenomenon.

J. Large scale structures

It’s not hard to image that most of the quantum vortices and turbulent regions in the false ground state of superfluidity in the α -phase of the universe associated with rotating celestial entities that are discussed above can’t extend to infinity in length in straight lines, the energetically most favored configurations for them is to connect with each other to form a complex web of virtual flux tubes of quantum vortices and turbulence.

What roles are played by such kind of web in the formation of the large scale multi-galactic structures, like cosmic ring, filament, and vine structures etc., is an interesting subject to be further investigated.

The international pulsar timing array (IPTA) experimental collaboration is observing the oscillation and vibration of the spacetime (emergent one in the current theory) at the cosmological scales. More and more data was gathered and the efforts are continuing. What was found is that the universe is “vibrating”. While their origin could only come from the original “big bang” or collisions and merger of super-massive black holes, they are much more prevalence in the current theory, as discussed above, since, here, the universe contains an ocean of quantum liquid of superfluid in its false ground state that influences the physical processes and the metric of emergent spacetime ever so slightly in the background. Therefore the IPTA types of experiment, with enough accuracy, could provide evidences for or against such kind of predictions of the current theory, when compared with the ones from GR.

K. CMB and cosmic radiation dipole

Data compiled by Mali Land-Strykowski, Geraint F Lewis, Tara Murphy (published in Sep 26 of 2025) show significant differences between the measured dipole in cosmic radiation distribution from CMB and from distant sources, raising the question of which one is best to define the cosmic rest frame.

The effective CMB of the current theory is a mixture of CMB of EM origin and the contribution of the primordial gravitational wave excitations that tend to thermal equilibrate with the portion of CMB inside the local galaxy (see Sec. VII). It is most likely distorted and dragged along by the cylindrical environment of our galaxy due to the existence of significant central vorticity discussed above and in, e.g., Sec. VI, VIII A etc.. Therefore the CMD dipole observed on Earth contains strong galactic local effects that has to be removed, if the current theory holds. This is a topic to be studied in more numerical details in the future.

IX. BIG QUESTIONS

An attempt is made to address some of the “big questions” in cosmology about the Universe beyond our cosmological event horizon base on the current theory, in addition to Sec. IV E. This is possible because the underlying quantum physics extends beyond the said horizon due to their quantum non-local nature, namely there can be quantum correlations between two points at any spatial distances.

A. Baryogenesis

The question of where the baryons come from in the Universe given the fact that the best fundamental QFT underlying the microscopic quantum constitutes of it is symmetric in matter and anti-matter and the Universe have finite “beginning time”, the time when the so called “big bang” occurred ~ 13.8 billions years ago. Any “post-bang” imbalance in matter/anti-matter distribution in the earlier Universe could not **causally grow** larger than the current cosmological event horizon and is therefore detectable via astrophysical means. However no such an anti-matter dominated region is observed so far. The strength of CP violation observed in neutral kaon system described using the Standard Model can create matter and anti-matter asymmetry but it is not sufficient to produce the amount observed neither. Thus the Universe couldn’t had started from a state in which matter and anti-matter are symmetric in content or having “nothing” in material. However such kind of state is more desirable theoretically and, to some,

more beautiful because it eliminates the necessity of introducing ad hoc parameters and performing fine tuning and thus have more predictive power since “nothing” in reality needs no more metaphysical cause. The conflict between theoretical expectation and observational facts are regarded by some one of the instances of the “great tragedy of science” (Thomas Huxley) in earlier literatures and created the so called “baryogenesis problem”.

However the conclusions of the above analyzers are base upon classical physics, they are not necessarily valid if the fact that what underlies the Universe is a quantum reality is taken into account, as it was pointed out early in Ref. [4]. The Universe can, according to current theory, start from “nothing” in material (and possibly also in energy) and becomes what is known today through a spontaneous matter/anti-matter symmetry breaking and quantum mechanical separation of matter and anti-matter regions in a macroscopic quantum state (e.g. a superfluid one) realized by “collapsing” onto a space-like hypersurface in the emergent spacetime, which is discussed in Sec. XII A) in the following, during the phase transition. The “collapse” chooses a matter or anti-matter region for a future observer therein, which can be anything smaller than the whole, that has the rational capabilities (see Sec. XIII below), e.g., a member of homo sapiens, to define what itself is made of and what direction of meta-time it’s experiencing according to which the nature of the region can be inferred due to the fact that it is part of the entangled whole.

If it is assumed that the Universe as a whole, including the regions outside of our cosmological event horizon, was in the superfluid ω -phase before the current α -phase. As it is shown in Refs. [8, 9, 11] the localized chemical potential μ (see Eq. 19) for true minima of the effective potential in the ω -phase is not located at $\mu = 0$ but rather at $\mu = \pm\mu_{vac}$ with μ_{vac} having a finite positive value, which violates intrinsic time reversal invariance spontaneously. And thus the above mentioned collapse is energetically favored. Similar to a hydrogen atom can jumping from an excited state to a lower one by emitting a photon, the Universe can do the same kind of thing which leads to the genesis of baryons.

Thus, in the quantum Universe, there is no unavoidable conflict between the theoretical preference of a symmetric Universe in which matters are created from “nothing” in material and observational facts despite the fact that such a preference is more of a good metaphysical belief than a scientific requirement. It’s “good” because it avoids the challenge related to the fine tuning of the initial cosmological boundary conditions.

B. “Big Bang”

The so called “big bang” in the current theory refers to a phase transition from a hypothetical superfluid ω -phase to the α -phase. There is no singularities in spacetime according to the current theory. However the volume of the superfluid phase could be very small due to accelerated contraction of the emergent spacetime (see Secs. IV B 2, IV C and also next section) before the phase transition. The dynamical justification of such a transition is given in the sequel.

There is no need for an inflation period to generate the flatness, uniformness, and isotropicity of the universe manifested in the CMB. This is because the meta-spacetime is flat to begin with which guarantees the flatness of emergent spacetime at large scale. Uniformness and isotropicity result from the fact that baryonic matter in the superfluid state has anti-gravity tendency at macroscopic level and there is no localized color confinement from gluons due to the fact that the $SU(3)$ color gauge symmetry is spontaneously broken down in the superfluid and gluons become massive and is believed to be dominated by a kind of color Meissner effects, namely they are expelled from the static or slow varying quark matter due to their finite masses. Structures down to nuclear physical length scale, if any, are also dissolved into quark matter and approaches an eventually uniform and isotropic quantum quark soap of superfluid even if the initial state is not anything like that. On top of the ocean of quark matter, there are ripples of massless baryon density fluctuation waves and quantum turbulence. It is from such a state that the current universe becomes what is now.

X. THE POSSIBILITY OF A CYCLIC INTELLIGIBLE UNIVERSE

One of the bigger questions is what is the most likely fate of the Universe given its state observed inside the visible part of it by an observer?

Since there is no real spacetime (meta or emergent one) singularities in the current theory, there is no beginning or end of spacetime at hypothetical singularities. Therefore most of our physical intuition gained from the physics build around singularities of physical spacetime are not expected to be valid ones to rely upon according to the current study.

Because the underlying QFT is translational invariant in meta-time it expected that the dynamical properties of the emergent time has the same symmetry for large enough interval of it. There are two possibilities: the first one is that the interval is infinite, the Universe will continue its current path into the ultimate heat death; the second one is that the interval is finite and these properties could repeat their values periodically. While the repeating behavior

could only happen sequentially in time in classical physics, it could happen as parallel processes in meta-time in a quantum world which make it much more probable to happen¹³.

As a macroscopic law, the second law of thermodynamics does not prevent state recurrence at the microscopic level, it only implies that these recurrences have low probabilities for an outsider observer. Sec. XIII A provides detailed explanations of such a topic. The views of an outsider observer of the Universe is perhaps inaccessible to mere earthlings, but the very fact that internal rational observers (see Sec. XIII C) exist to observe and understand the universe means it (he or she) had already picked, amongst all possibilities in an assemble of quantum states that may or may not contain high epistemological info-entropy in the emergent spacetime, a quantum state and inside a proper meta-time interval that could lead to low info-entropy in the emergent spacetime at the “baryogenesis” stage to collapse into to begin with. It’s only these quantum subsets of the Universe that are intelligible to conscious beings in the emergent spacetime.

In addition, the change in info-entropy during the evolution of universe is less drastic than what is expected from GR based cosmology because pure emergent spacetime expansions or contractions do not change the entropy of a co-expansion or co-contraction regions, like the Hubble event horizon, in the current theory. This is shown in Sec. V.

The recent discovery (currently at $\sigma \sim 2.8$ to 4.2) in the Dark Energy Spectroscopic Instrument (DESI) collaboration that the effects of the so called “dark energy” tends to decrease provide further motivation for the theoretical exploration of the second possibility, under the light of current theory, in the following.

A. The current epoch

Following Sec. V, let’s consider a co-expanding sphere Σ_h , namely the Hubble event horizon, that coincides with the cosmological event horizon Σ_c at a given emergent time t_0 . After t_0 , Σ_h becomes larger in diameter than Σ_c due to the accelerated cosmic expansion. Since the number of baryons in Σ_h is invariant under the expansion, the number of baryons in Σ_c reduces as emergent time goes on. However the dependency of the energy density of the α -phase and the superfluid state of ω -phase on the baryon density is different. The differences can be studied in relatively model independent manner.

From Ref. [10] it’s known that baryonic quasi-particles (namely the light quarks) loses its baryon number in the superfluid phase in which the $U(1)$ symmetry corresponding to baryon number conservation is spontaneously broken down, some of the baryon number is carried away by the massless Goldstone boson of the said symmetry breaking. Therefore, per unit baryon number reduction, the superfluid phase loses more quasi-particles than the α -phase inside Σ_c . It implies that it is quite plausible the energy density of the α -phase decreases slower than that of the ω -phase within Σ_c as the universe expands. It is possible, therefore, the energy density between the α -phase and the ω -phase becomes equal at certain emergent time t_c , which marks the potential beginning of a first order phase transition from the α -phase to the ω -phase.

Note that since the entropy within the Hubble event horizon Σ_h is constant if one assumes the universe is expanding adiabatically according to the current theory (see Sec. V and Eq. 103), the entropy for the universe enclosed by the cosmological event horizon Σ_c will be **decreasing** as it expands at certain time when the density is small enough so that it can be treated as an approximate adiabatic process. This is because $\Sigma_h > \Sigma_c$ and there is a net outflow of baryon number when the expansion is accelerated.

Indeed, the current dark energy survey, baryonic acoustic oscillations (DESI) and other experiments showed that the “cosmological constant” Λ may not be a constant after all but seems to be changing. Albeit a conclusive statement remains to be made after more data is acquired, it’s a trend that encourages the speculative studied in the following to be persued ahead of facts since it opens up the possibility of a more interesting dynamical future of the Universe.

Let’s suppose that the dynamics of the system does has such a critical emergent time t_c for a phase transition and see what could happen then.

B. The superfluid state

At the beginning of the superfluid ω -phase, in which the baryon number density is vanishingly small compared to the stable density at the true minimum of the effective potential V_{eff} in μ at $\pm\mu_{vac}$, the effective emergent spacetime in the ω -phase has the tendency to start contracting in scale uniformly so that the Universe can roll down from a higher energy density position in μ to the minimum one at μ_{vac} (or $-\mu_{vac}$ in an anti-universe) and the dynamics of the

¹³ This is also the mechanism which make it possible that quantum computation machines can in principle be designed and built.

system favors a process in which corresponding baryon number density increases (or decreases in an anti-universe). Let's consider a universe made of baryons in the following.

1. Cosmic and Hubble event horizons

The contraction in emergent spacetime form an spherical event horizon in the emergent spacetime at which the speed of contraction equals that of the causal front or c . Let's call the Hubble event horizon at beginning of the ω -phase the new cosmic event horizon. It defines a new visible universe in the emergent spacetime of the new phase for a hypothetical observer.

If the contraction rate is constant in emergent time, then the cosmic event horizon will be the same as the Hubble event horizon. Since the number density of baryons remains constant inside of the Hubble event horizon according to Seq. V, such a process is not energetically favored. There must be an inward acceleration in contraction rate so that the Hubble event horizon moves further inward than the cosmic one so that there is a influx of baryons at the cosmic event horizon and, as a result, the baryon number density increases as the emergent time goes by. In the mean time, since there is antigravity between baryonic entities here, the structures formed in the previous epoch start to dissolve and spread out evenly leading to the future of a uniform quark matter in the state of superfluidity.

2. The next "big bang"

Following the same mechanism as the one in the previous phase, for each baryon number increase inside of the cosmic event horizon, the increase in energy density of the ω -phase is expected to be greater than that of the α -phase due to the spontaneous breaking of the $U(1)$ baryon number symmetry. There exists a point in the emergent time at which the α -phase is energetically favored again, which marks the beginning of a new first order phase transition or "big bang".

XI. SUPERCRITICAL STATE, BARYON RECYCLING, AND PHENOMENA

At the current stage of discussion, one could have already developed sufficiently fine physical intuition to see more possibilities. Let's consider a more speculative scenario in which the true ground state of the universe is already the superfluid state that has finite baryon density after a certain time since the "big bang". It allows a richer set of cosmological phenomena to be predicted and compared to the observations.

Because of the baryon number conservation, the universe at large scale, which contains near zero baryon density at present epoch, can not change directly into the true ground state, such a global transition is energetically favored only when the energy density in the superfluid state is smaller than the one in the α -phase at the same baryon density, when measured in the metric of the meta-spacetime.

However, such kind of inhibition due to symmetry could be overcome in local regions where baryonic matter concentrates, like inside a densely packed star, inside or surrounding a black hole. Given the right baryon density at which the true ground state is energetically favored, there will be finite possibilities for such kind of regions to locally tunnel and then rolling or falling down to the valley of true ground state of superfluidity. Because the color interactions between quarks becomes short range and the baryonic quantum density waves are massless, the region of the local concentration of nuclei or nuclear matter will first be dissolved in structure on its way of falling and then a portion of them will be sink into the true ground state of superfluidity while the rest will carry away the extra energy via collective quantum excitations on top of the true ground state in the form of density waves and turbulence. The extra baryonic matter is spread out by the density waves in the superfluid. While the density waves leave the central star, their baryonic density will decrease. Their role as part of the dissolved quantum superfluid could only last until the α -phase is favored again in which case the concentrated baryonic matter prefers to reemergence as neutron gas under conversion processes dominated by weak $n \rightarrow p + e^- + \bar{\nu}_e$ transitions leading more stable hydrogen molecule gas in the α -phase, somewhat like water molecules evaporated from a body of boiling water. As a result, the corresponding energy carrying gravitation waves in the α -phase are dissipated during the evaporation processes. This will induces changes of their gravitational effects and optical manifestation.

As it is shown in Eq. 10, the average distance between quarks estimated according to cosmological constant Λ is about $\sim \mathcal{O}(10fm)$, which implies that the above mentioned "right density" could be less than that of the nuclear matter in which the said distance is about $\mathcal{O}(1fm)$. Assuming such an estimate is correct in the following.

The process will stop after a sufficient amount of iterations when all the regions having the right density in the star have already sink into the superfluid phase and the ground state under region of star contains a localized region of true ground state. It could restart only if the star can accrete more baryonic material from surroundings.

When the central region of a spiral galaxy, including the black hole, is considered, the reemerged baryonic matter should be a jet + ring like nebulae of reborn hydrogen gas surrounding the center of the galaxy that could be far away¹⁴, providing a ring like region of active star formation, which could be considered as a localized “mini bang”. It has a jet + ring but not a spherical shell like structure due to its original rotation and the existence of the central quantum vortices. Such kind of mechanism have been observed to manifest according to current theory, in the α -phase, in the formation of planetary nebulae (see Sec. VIII B). Besides the ring, if any, the spread out baryonic matter before or after the evaporation is pinched to the central vortices to form jets of GECP current along the vortices similar to those birkeland current in a plasma. It could provide a reasonable explanation for some ring galaxies observed, some of whose formation mechanism still remains to be established base on existing gravitational models in the other literatures. As to how much of the baryonic goes into the jet from a single falling event, it depends on the strength of the central vortices. For example, M94 (NGC 3647) has very large outer rings and almost Newtonian gravitational rotation curve, which, according the current theory, means that it has very small central vorticity. Another example of this kind is perhaps M105. One of other extreme examples with large jet is perhaps the Alcyoneus elliptical galaxy, in which, according to the current theory, there are super strong vortices at its center that can absorb all the spread out baryon density waves of the falling baryonic matter generated under the current scenario and transport them to extremely far regions along the lines of vortices leaving nothing for itself to recreate active star formation regions. The knots of brightness observed in the jets represent, at least partly, the regions in which the baryonic matter in the superfluid pop up into the α -phase to become hydrogen gas causing increased hydrogen density around the jets that act as a portion of the radio emitting GECPs belonging to the galaxy. There is indeed an observed positive correlation between the frequency of occurrence of nova events and their closeness in distances to the jets, which can be interpreted as that the closer a white dwarf, on which the nova events occur, gets to the jets the less time is required for it to absorb enough hydrogen to trigger a fusion reaction on its surface. Therefore these phenomena are explainable and it does not contradict with each other in the current scenario under the current theory.

It’s also interesting to explore what are the consequences regarding outer low density regions of neutron stars where the density has not reached the value for nuclear matter, when the current epoch of the universe is in such a critical state. If a spherical shell of neutrons with finite thickness inside a star has the right baryon density, it has finite probability to fall into superfluid state in a short period of time and redistribute itself as reborn hydrogen gas into the outer space. When that happen, the remaining star will experience star-quakes to readjust its outer low density regions that can release enough energy to emit hard gamma rays. This is supposed to be caused by adjustment of the superstrong surface magnetic field in magnetars in other literatures in which some researchers think there is no natural mechanism to generate sufficient energy via a pure EM process. Therefore, could some of the random gamma ray bursts observed in the sky be created by such kind of events described here?

Provided that the estimate given in Eq. 10 is correct, what happens to center of massive stars that are close but not massive enough to become a neutron star is also an interesting topic to be explored.

Another possibility is that Eq. 10 underestimates the baryon density for the false ground state of superfluidity. If this is the case, the said density must be larger than the normal nuclear matter density since most neutron stars known do not exhibit shrinking behavior due to the falling of its internal nuclear matter into the false ground state of superfluidity. The existence of a mass gap between the heaviest neutron stars ($\sim 2.08M_{\odot}$) and the lightest black hole ($\sim 5M_{\odot}$) could be the result of the existence of a supercritical “false” ground state of superfluidity. This is because the missing neutron stars in the gap are all absorbed by the said “false” ground state and recycled to generate hydrogen atoms elsewhere in the universe due to the fact that they have proper internal baryon density, if the current scenario describes reality.

It’s also interesting to see if the star recycling mechanism discussed here could play a role in solving the so called S8 tension problem in cosmology revealed recently since it can naturally reduce the clumpiness of baryonic matter in the universe against the one inferred from CMB observations.

XII. THE EMERGENT SPACETIME AND QUANTUM MECHANICS

The introduction of meta-spacetime has other advantages at the fundamental level since it provides a new conceptual framework for constructing solutions to long standing fundamental problems in physics, most of which are not directly

¹⁴ It could happen that their distance from the center seems to break classical causality given the time interval the process could taken in the α -phase. But such kind of “teleportation” does not violate physical principles due to the fact that the superfluid is pure quantum mechanical in nature and also the fact that emergent spacetime metric scales are different in the α -phase and the one in the superfluid state (when considered alone). The effects are somewhat akin to what a “wormhole”, fancied upon in the studies of GR, has. Nevertheless the current mechanism has a underlying support from quantum reality.

related to gravity.

A. Measurements in QM

So far the current theory for the emergent spacetime is applied to a description of macroscopic (celestial) objects. Can the emergent spacetime provide certain physical coordination for a quantum packet? Here it will be referred to as microscopic quantum packet or entity in the following, despite the fact it may have a mass or size significantly different from a typical microscopic quantum entity. Or more specifically, whether or not it can also be applied to a consistent description of the physical process in a measurement of microscopic quantum entities using a macroscopic and near thermal (classical) apparatus, following the same logic, is examined in the following.

1. Collapse of wave functions onto the emergent spacetime

Basing QM on the meta-spacetime provides us new leverages to resolve its measurement problem. The collapsing of wave functions during measurements (using a macroscopic apparatus) is not a prediction of the theory if, in the language of the current theory, the meta-spacetime is not distinguished from the emergent one. It is an additional assumption that had been troubling thinkers and researchers on QM for about a century now.

However, when QM is based on meta-spacetime, whether or not there is collapses of wave functions during measurements can be determined following the method of path integration using stable action principle, just like what it is done in the current theory of gravity. Therefore it is no longer an independent assumption but a result that can be derived from many body QM.

The abruptness in the change of the wave function of a quantum packet (of periodic action that is $\sim h$) is due to the existence of large number of participating particles in the apparatus that interact with the said quantum packet to become an assemble of entangled **quantum packet** of $n + 1$ composite object during entering and leaving of the measured carrier of the quantum packet, with n the number of participating “particles” that respond with transient and most likely off-shell and phase distortions of their original states in the apparatus. The non-local entanglement in QM spread the (periodic) action of h of the original quantum packet amongst all participating $n + 1$ “particles” with similar weight (it’s an order of magnitude statement). This leads to a scale down of observed transition time

$$\delta t \sim \frac{1}{\gamma^{-1}n + 1} \delta t_m, \quad (106)$$

where¹⁵ δt , δt_m are the least and equal action duration in emergent, meta- proper time respectively of the measured carrier of the quantum packet to interact with the apparatus and γ^{-1} is the Lorentz length contraction factor (of the apparatus), which, when the speed of the packet is much larger than the temperature dependent average speed of particles in the said apparatus, can be written as

$$\gamma^{-1} = \sqrt{1 - \frac{v^2}{c^2}}$$

with v the velocity of the said packet relative to the apparatus and c the speed of causal front. This is because the apparatus and the measured carrier of the quantum packet contain $n + 1$ particles evolving in emergent spacetime in the classical view but it is also an assemble of entangled quantum state in meta-spacetime in the quantum mechanical view and, in the reference frame of the measured quantum packet, time duration of the measuring apparatus is reduced by a factor of γ . However these two views should be equivalent if the assemble is macroscopic and is at least close to a thermal one so that the concept of emergent time, together with other ones (e.g. the emergent spatial coordinates or spin orientation, etc.) that define the measurement, is one of the relevant classical properties of it.

It can be seen that

$$\delta t \xrightarrow{n \rightarrow \infty} 0 \quad (107)$$

for any massive particles.

¹⁵ The reduction factor could be a monotonic decreasing function of $\gamma^{-1}n$ if one calculate such a factor more rigorously from first principle, Eq. 106 is a simplified but physically sensible version that represents such a qualitative trend.

Before and after entering the measurement spacetime region, since the measured carrier of the quantum packet is a single particle, one has

$$\delta t = \delta t_m \quad (108)$$

when the influences of gravity can be ignored.

Since the emergent spacetime is classical, relativistic causality holds true. Therefore a measurement of a single quantum of a massive particle has manifestation region with a size within

$$\delta r \leq c \delta t \quad (109)$$

with c the speed of causal front and δr the radius of the said region. Therefore each single measurement of a quantum packet of a massive particle at a given emergent time is recorded as a dot, rather than a smeared out region in the 3-D space. It renders the massive quantum packet looks like a “particle”. It means that each measurement of the said particle will cause its wave function in the meta-spacetime to collapse onto a single point (approximate, of cause) in the emergent spacetime despite the fact it is not localized in the meta-spacetime. Albeit this does not imply that a sequence of independent measurements of an assemble of such a particle will reveal a unique, smooth and predictable curve or point, like what classical objects that follows Newtonian dynamics will do.

It is quite interesting to see that for a massless particle, like a quanta of the light, Eq. 107 does not hold since $\gamma^{-1} = 0$ for it, unless it could be absorbed (effectively “stopped”) by a quantum unit (of \hbar) of an atom or molecule inside the detector and passes its energy to it. Therefore, according to Eq. 109, a passthrough quantum of light does not behave like a particle since a “particle” is supposed to be localizable. Instead, it will emerge as a classical wave after collapsing onto its own “light cone”. It is reasonable to expect that an assemble of the said classical waves can be mapped to the EM ones which are governed by the Maxwell’s equations for EM. Sec. XII B 5 explores the subject further.

Now the statistical interpretation of QM in the classical view of macroscopic observers is not an extra assumption, rather it’s a logical consequence of the current theory. While the statistical random nature of an observable can be attributed to the thermal randomness of the parts in a measuring apparatus, the statistical distribution in an observation of an assemble of identical particles as a function of emergent spacetime are related to the amplitude of wave function $|\psi|^2$ for a quantum packet in the meta-spacetime. It, which is inherited from Born’s interpretation of QM, serves as the a priori probability for observables in the emergent spacetime of the current theory. In a measurement using macroscopic apparatus, together with proper state transition represented by an abrupt change in the wave function at recording emergent times, the emergent spatial 3-D hypersurface on which statistical distribution is defined is likely to be also distorted in probability measure (of the meta- to emergent spacetime mapping) according to the principle of stable action¹⁶ for a full description an observation of an assemble of identical particles. This is discussed next.

2. Revisit well known experiments that led to QM

Let’s try to resolve a puzzle concerning two categories of experiments that are amongst the key ones in the establishment of QM: 1) the Stern–Gerlach type of experiments and 2) the double slit experiment. The former exhibits a “classical” one by manifesting a non-wave like behavior of point particles when the measured particle hit the recording apparatus behind while the later display interference patterns instead. While the interference patterns of the later establishes the wave nature of a microscopic quantum packet, the pair of sharp dots observed in the former, which is called *space quantization*, is not that easy to understand base upon the standard statistical interpretation of QM since the time evolution of a microscopic quantum neutral atom having a non-vanishing magnetic dipole moment should imply that there should not be any sharp space quantization on the recording apparatus since the orientation of the magnetic dipole of the neutral atoms are random, just like what one observe the double slit experiments. Why the observed one is not so? It’s easy to see that the essential difference between the two is that the spin up and down states along the direction of the magnetic field in a Stern–Gerlach experiment have different potential energies inside the region where magnetic field strength is not zero while the potential energy required for a particle to pass any of two possible slits in double slit experiment is the same.

In the light of the above discussions using the concept of meta- and emergent spacetime and the interpretation of measurements in QM using the “classical” emergent one, the difference in the behaviors of the two is a predictable

¹⁶ Emergent gravity for celestial entities is derived using the same principle in Sec. IV.

one. This is because the paths of an atom in the emergent spacetime in a Stern–Gerlach type of experiments must be along the classical ones with stable action in an observation involving macroscopic apparatus, namely the path in the emergent spacetime where it experiences the maximum and minimum potential energies. Or the upper or lower spin components of a randomly oriented atom can only be recorded by a macroscopic thermal apparatus involved separately, there is no middle ground in the emergent spacetime, despite the fact that it could points to any direction in the meta–spacetime before its recording by the apparatus. This splits or “collapse” the original randomly originated atoms into two distinct and fixed dots (or thin lines), even for a single quantum packet, on the recording apparatus behind because the non–uniformity of the magnetic field in the paths of the atom deflects the up and down components of its state differently. While on the other hand, there is no such an action based selection mechanism for the preferred paths in the emergent spacetime in a double slit experiment since the two slits are indistinguishable from each other for the particle under observation as far as the action in the emergent spacetime is concerned, resulting in the possibility of manifesting its wave nature in the emergent spacetime by displaying interference pattern on the measuring apparatus behind when the number of particles in the assemble is large enough, albeit any single microscopic quantum packet still manifests itself as a dot on the said apparatus. This validates the standard statistical interpretation of QM. However, this is not sufficient. The emergent 3–space, on which the statistical distribution of the dots corresponding to the assemble of particles in an experiment is defined, needs to be distorted (in probability measure) against the meta– one in a Stern–Gerlach type of experiment to give rise to the so called *space quantization* phenomena, according to the current theory. Without such a collapse of the emergent 3–space, which is an prediction here, it is almost impossible to connect the standard statistical interpretation of QM that is the square of the amplitude of the wave function with what would be observed in a Stern–Gerlach type of experiment without introducing additional assumptions because forcing the wave function into fixed point like dots on the recording apparatus after go through an assemble of atoms requires the existence of large uncertainty in its transverse momentum (the uncertainty relation $\Delta x \Delta p \geq \hbar/2$), but all atoms in the assemble would be seen to be moving in a near straight line, namely from the region of magnetic field to the apparatus, their transverse momentum is also close to zero. That would create contradiction with theoretical expectations without employing the conceptually finer explanatary framework and computational machinery of the current theory.

3. Emergent spacetime “quantization” and “particle” dynamics in continued observations

The most popular observation of the motion of a massive quantum packet of a QFT is using a cloud chamber or the modern version of it in which the quantum packet interacts with the specially prepared surrounding macroscopic “cloud”, weakly and continuously, so that its “particle” nature can manifest in the emergent trojectories within the cloud without much distortion so that they can be revealed and recorded. In order for the emergent trajectories of the particle to proceed in time, the “collapse” events in emergent time (see Eq. 106) must be discrete in the emergent time. As it is discussed above, those events generates a set of dots in emergent spacetime that satisfies

$$p\Delta l = h \quad (110)$$

where h is the Plank constant, the left hand side is the stable periodic Bohr–Sommerfeld classical action¹⁷ corresponding to the single quantum packet under consideration¹⁸, p is the 3–momentum and Δl , which is identical to the de Broglie wave–length for the “particle”, is the minimum spatial interval between the discrete dots in the emergent spacetime on which the collapses occurred. The corresponding emergent time intervals can extracted from the above equation as well. The equation is based on a proposed new universal principle for QM in meta–spacetime, the subject domain of the current theory, that

*Any **periodic**, classical¹⁹ or quantum in nature, stable action, in its meta or emergent manifestation, of a quantum system with a chosen constant total energy, is a possitive multiple of the Planck constant h .*

This is a summary, extension and unification of those existing principles of QM that are supported by empirical results in a variety of areas where these principles were applied to. It is also verifiable starting from the first principle of the current theory from the quantum aspect of the theory, which will be attempted, at least qualitatively, in the following sections.

The “smooth” curves supported by the emergent spacetime dots upon which the collapse events occur, which are expected to be random in nature, correspond to the observed trajectories of the quantum packet. They are governed

¹⁷ It’s a classical action to be minimized or maximized by keeping the total energy constant in the parameter space and letting the time interval or the corresponding spatial interval to be variable in searching for the stable one corresponding to the Newtonian trajectory. While Bohr and Sommerfeld use it to find quantization in electron’s energies of an atom in the early days of QM, it’s also an appropriate kind of action to be used here, if not more.

¹⁸ The classical view is an effective one where the contributions of the macroscopic measuring “cloud” can be ignored after the collapse of the spactime had been taken into account.

¹⁹ For example, the classical motion of a harmonic oscillator or even the classical view of electromagnetic waves.

by the corresponding classical mechanics of the system according to the principle of stable (minimum or maximum) action. Thus classical Newtonian dynamics, including its relativistic extensions, emerges as well from the current theory.

This should not be unexpected since such kind of discreteness in the conjugate variables of emergent spacetime, namely, the energy and (angular) momentum and in the Stern–Gerlach type of experiments discussed above, is empirically wellknown for microscopic systems. On the other hand, albeit the dynamics of QM contains the discreteness of the eigenvalues of observable operators in it, the association of the discreteness of those eigenvalues with corresponding observations is not governed by QM itself, since its dynamics is continuous in time and transition between any kind of quantum states should not be in the manner of “sudden jumps”. To account for the empirical observations, it requires the adoption of added assumptions, mostly referred to as “rules” in text books on QM that are mostly based upon the Copenhagen interpretation of it. Some of the founding fathers of QM know this well, Schrödinger invented his fictional cat to illustrate the problems that QM was facing at the time (and up until now).

The complete theory for the discreteness of observed energy (and momentum) and in their conjugate variable, time (and space), for a quantum packet of a QFT in a measurement can be derived, for the first time, from first principles in the current theoretical framework.

The prediction that a quantum packet emerges as the one that follows smooth trajectories in an observation cloud chamber, like what a classical particle does, had already been shown to be easily verifiable (not the discrete aspects of it) using a home made desktop apparatus, thanks to the advancements in technowledge in current days. Their discreteness or periodicity, however, is harder to discern in observations due to the random nature of the relative phases between individual quantum packets under observation even if their momentum is the same. Here certain masoscopic or even macroscopic quantum coherence need to be establish first. This is discussed in Sec. [XII B 4](#).

4. Accelerated observers and emergent frame dragging effects

The current theory for gravity is derived from particle polymorphism (see Sec. [III B](#)) due to the existence of multiple ground states of the strong interaction and the finiteness of the observable universe. It means that all particles have a small mixing amplitude of order $1/\sqrt{N_B}$ between the two components in the 2DCR of causal time reversal transformation, which constitutes the key mechanism for an explanation of the phenomenon of cosmological acceleration of the universe (see Sec. [IV C](#)), render it non-energy related in nature.

This means that for an observer A , an accelerated observer B gets an additional contribution to the acceleration of his/her emergent spacetime coordinate systems, in addition to whatever classical special relativity (SR) or even GR predicts, of order

$$\delta a = \mathcal{O}\left(1/\sqrt{N_B}\right) a \quad (111)$$

where a is the acceleration of observer B relative to observer A , which is implied by Eq. 21 of Ref. [\[14\]](#). This kind of “global” effect, despite its smallness in value for even celestial objects, has cosmological consequences some of which are discussed in Sec. [IV E](#).

B. Dynamics of quantum packets in a thermal environment and quantum encoherence

Let’s consider the interaction between a thermalized system, which acts as the macroscopic apparatus that is used for continuous observation, and a pure quantum system to be observed, such as a single quantum packet discussed above (Sec. [XII A 3](#)). Suppose the initial state of the observed system can be described by a wave packet sufficiently localized such that it has no spatial overlap with the apparatus, when it enter the apparatus it will entangle with each one of the particles involved in the apparatus. The question is how it affects the quantum state of the apparatus, which in turn give rise to the measured results that obey the classical dynamics in the emerget spacetime?

1. The theoretical framework for off equilibrium quantum thermodynamics

Such a process can in principle be described by Eq. [14](#). Albeit obtaining rigorous solutions to such a problem is beyond the scope of the current study, some qualitative features relevent here can be draw from it nevertheless. Since the current theoretical framework consistently unifies statistical mechanics and realtime dynamics generated by path integral representation of QFT (such as Eq. [14](#)) by allow the meta-time variable analytically continued into its complex

plane²⁰. In such a framework, the Boltzmann entropy in Eq. 100 maps to, after proper canonical transformation, the action A in Eq. 14 on the complex meta-time plane. For example the entropy in Eq. 100 corresponds to the Euclidean Bohr–Sommerfeld action for the QFT on the imaginary meta-time axis, while keeping the total energy of the system constant. Thermodynamics of the system lies on the pure imaginary meta-time axis. The dynamics of the same can be obtained using a meta-time contour in its complex plane off the pure imaginary axis (see Ref. [12]). Only those field configurations around the stable action ones have significant contribution to the corresponding dynamics and thermodynamics. In the classical and large N limit, only the stable ones will survive.

2. Degeneracy and ergodicity hypothesis in complex phase phase space

The behavior of the monitoring cloud chamber mentioned above can be understood using thermodynamics since they are most likely to be prepared in a state of thermal equilibrium at a finite temperature.

The generating function(al) for a classical system in thermal equilibrium can be computed from micro-canonical assemblies using Boltzmann equation 100. It is developed in the context of classical mechanics and can be “derived” based on the hypothesis of ergodicity. Albeit intrinsic ergodicity may be hard to proof, the observational ergodicity (see discussions inside Sec XIII A in the following) for an observer of limited capabilities and localized attention, it could be a very good assumption. Such a hypothesis can also be derived from stable action principle mentioned above when using info-entropy functional. It therefore can also be handled using the same framework developed here.

For a quantum many-body system at sufficient high temperature it is reasonable to assume that in the “views” of other ones each quantum packet in the system behaves, according to the discussions of the above subsection, like a localized classical particle on their discrete emergent spacetime trajectories due to quantum decoherence. However, quantum packets differ from their classical corresponding particles in the fact that they have an associated complex phase factor. Albeit the global complex phase of a system is not relevant in QM, the relative complex phases between particles do matter. The global phase are factored out by introducing the statistical gauge fields (see Refs. [8, 9]), which may have non-trivial topological structures that are highly relevant to a understanding of the quantum behaviors of the corresponding systems, which will be demonstrated in the sequel.

It means that their thermodynamical phase space volume are larger than the corresponding classical ones and may support richer real-time dynamics when probed. Assuming, for a system with sufficient large number of particles that is sufficiently thermalized, ergodicity is also a valid hypothesis in studying the complex phase phase space and, in addition, a de-correlation or dis-entanglement of the kinematical and complex phase phase space, so that they are statistically independent from each other, then the following factorization apply:

$$W_m = W_c * W_q \quad (112)$$

$$S = S_c + S_q \quad (113)$$

where W_m is defined in Eq. 100, W_c is the volume of the kinematical phase space under a given energy and W_q is the volume of the quantum complex phase phase space of the system with S_c the classical observational entropy and S_q the same kind of entropy due to the random and *degenerate* (in energy) relative phases (against the one defined by the statistical gauge field) of each particle, within a system dependent range not necessarily in $[0, 2\pi)$, in the system. Given a large number N of particles, the volume for S_q is expected to be proportional to N .

3. Quantum encoherence

The introduction of a pure quantum packet to be observed into the system, which only interacts weakly with the particles of the system but entangles fully with all of them, causes pure quantum disturbances to the particles in the thermalized system, rendering certain complex phases in the otherwise fully random set to be more important to stabilize the action along the chosen contour in the complex meta-time plane corresponding to the dynamics of the off equilibrium system. The observing system thus acquires an increase in quantum coherence from the observed pure quantum packet as a result, which in turn provides the mechanism on the QM meta-spacetime side for the emergence of Newtonian dynamics for the quantum packet on a smooth but discrete trajectories in the emergent spacetime discussed in the previous subsection. Without the said coherence, the emergence of Newtonian dynamics in the emergent spacetime (on trajectories discrete in nature) is not possible.

²⁰ Plenty of other related works using conventional QFT approaches exist in literature. But they were not able to do so consistently due to the existence of non-cancellable, but dropped, divergencies. These divergencies are eliminated under the current theoretical framework.

Such a mechanism is termed *quantum encoherence* in the following.

It can also be used to explain how a laser device works at lower microscopic quantum level. Contemporary explanations are semiclassical in nature where the EM fields are treated classically, and only the atoms or molecules (AoMs) involved are regarded as quantum entities. Since even the classical EM fields that represent radiations are waves as well, it is easy to mix the classical wave nature of the EM fields, which also has the concept of coherence, and the wave nature of the quantum packets, namely the photons, that give rise to the emergent EM fields. Here, like the emergence of Newtonian dynamics for massive “particles” discussed above, the classical EM fields governed by Maxwell equations should emerge from quantum behaviors of photons in the meta-spacetime (see Sec. XII F). It is not sufficient to discern quantum effects in a semiclassical view, because a given emergent classical EM field configuration may correspond to different underlying microscopic quantum states that are distinguishable in empirical observations.

The reflection mirrors in a laser device set the boundaries that regulate, not only the classical phases that are not of interest here, but also the complex quantum phases of the subset of photons traveling in between, which significantly reduce the randomness of their quantum phases and turn them into a near pure quantum system of EM radiation. The otherwise random emission and absorption processes of these photons by the AoMs in the device also get regulated due to the coupling to the photonic system because all the stimulated AoMs and the stimulating system (of input photons) that are out of phases have off balance contributes to action than the ones in phases with the configurations around a stable action, and thus get suppressed. Such differences in action are further amplified in a N body system where N is large, resulting in their faster suppression. It turns the coupled system of photons, including the stimulating ones, and AoMs involved into a highly quantum coherent one which behaves quantum mechanically that can continuously emit large number of coherent photons in abrupt single- or multi- AoMs synchronous quantum jumps (in the emergent spacetime, of course) resulting in superradiant.

The claim that photons in a laser beam are in quantum coherent states can easily be verified experimentally. It had been demonstrated, in a desktop experimental settings, that photons emitted by a laser of certain wavelength can excite AoMs in targeting outside materials to energy levels that are beyond the maximum energy of a single photon in the said beam. This is an effect that seems to be against the well known *photoelectric effect*, which was one of the crucial experimental facts that led to the establishment of QM. Does that implies certain problems? No, it does not. The seemingly contradiction is not hard to resolve if one assume that photons emitted by a laser is in a coherent quantum state that can be absorb by the targeting AoMs in multiples in a single quantum transition. The photoelectric effects were discovered at times that there were no means to create photons in a quantum coherent state and the likelihood of absorbing multiple thermal photons by the targeting AoMs in multiple steps in a stochastic temporal sequence that is “just right” is statistically suppressed in probability, if possible at all. It’s most likely not possible because it requires near identical energy gaps in the target AoMs that match that of the photons emitted by the laser. But energy levels of known AoMs are highly non uniform in their mutual separation.

The recent discovery, published on the Aug. 4, 2025 in ScienceAdvances titled “Violation of Bell inequality with unentangled photons”, is hard to explain in contemporary semiclassical understanding of how lasers works. But if one assumes that some photons in a laser beam are already entangled, then the experimental results are a natural consequence of the fact that the researchers in the experiment were using lasers as their light sources. Their presumption of using “unentangled photons” does not hold within the context of the current theory. Their results, however, in turn, does provide a direct empirical support for the current full quantum level mechanism for lasers and thus *quantum encoherence*.

One may find, following the same reasoning, that even microwaves in a microwave oven are in quantum coherence to certain degree, because it could heat up materials to much high temperature than the (effective) one corresponding to the average energy of a single photon in the microwaves themselves. If the photons in a microwave oven has no quantum correlations what so ever or are of blackbody radiation, then it can not heat up anything beyond a few Kelvin (like in the CMB), no matter what power is pumped into it, because of the photoelectric effect in which it’s the energy not the number of thermal photons that matters.

4. Time crystal

Many of the so called “time crystal” effects are observed in masoscopic or even macroscopic systems so far (Oct. 2025). Most of the theoretical mechanism for them in literatures are based upon semiclassical pictures. Here they can be explained, like the one for lasers, pure quantum mechanically based on the discreteness of emergent spacetime predicted in Sec. XII A 3 and on the mechanism for quantum encoherence effects discussed above.

Here, any masoscopic and macroscopic system that is quantum encoherenced around a narrow range of finite momentum and relative QM phases should manifest periodicity in time, according to Eq. 110, with sharp dots in emergent time broaden by the randomness in the said phases between the constituents of the sample under observation.

5. Beyond the classical expectation – quantum overlays

Let’s consider the case of laser further. The relation between the energy and *observable frequency or color* of quantum packets in light contained in it can be written as

$$\epsilon = n\hbar\omega \quad (n = 1, 2, \dots) \quad (114)$$

where n is the number of photons in *a coherent quantum packet* in the laser beam and only $n = 1$, found by Planck in the early days before the establishment of QM²¹, is present in an blackbody radiator. The effects of those $n > 2$ componets are not visible in pure “classical” observations, such as a measurement of the frequency or wavelength of the light emitted, but do have indirect observable physical manifestations, as discussed above.

Such kind of additional structures ($n > 1$ ones) are termed *quantum overlays* in the following.

While lasers are one of the simplest systems having quantum overlays, it is expected that the same kind of structures exist in any quantum encoherented manybody systems, like atomic molecules, masoscopic systems, etc.. These overlays have large combinatory space that can support much richer yet volatile variety of “virtual” structures when compared with their classical localizable and rigid substrates, namely the observable localized structure (see Sec. XII A 3) of its constituents that can be described in terms of emergent spacetime, such as the structure of a molecule, the organization of the lattice of atoms in a solid, etc.. These non-local entangled quantum states could play essential roles in supporting the most sophisticated physical process in the universe, namely life, to be discussed in Sec. XIII.

C. The foundation of contemporary QFT framework can be solid

There are ultraviolet and infrared divergencies in the perturbation theories of QFTs, putting the foundation for the QFT framework potentially questionable, despite the fact that it is largely ignored.

The current work could resolve such an issue, at least some of, the ultraviolet divergencies found in the said perturbation theories which take only a few “particles” into account at each order of their expansion. Non-perturbative QFTs at short distances (relative to the scale of interest) contain a large number of “virtual particles” due to vacuum fluctuation and interactions between the “particles” in them, these “particles” are effectively observational cloud environments. The simple few “particle” truncation in perturbation theories could be supplemented by an mapped spacetime from the meta one with increasing clumpiness, fragmentation and possible fractalization in its measure leading to the ultimate classical emergent one as the distances becoming smaller and smaller. Here, for a given 4-momentum p^μ , instead of the volume of 4-dimensional emergent spacetime continuum required by the Heisenberg Uncertainty Principle in the traditional understanding of QM, only a discrete set of 0-dimensional points supporting a 1-dimensional classical Newtonian trajectory in it are required to be accounted for. More specifically, given the distance scale of interest, the shorter the relative distance scales of the contributing quantum “trajectories” (in path integral sense), the farther away from the said “on-shell” 0-dimensional discrete trajectory mentioned above. It leads to an exponential suppression of their contributions as the number of particles in the above mentioned “virtual particle cloud” increases. The discreteness and dimensional reduction in the emergent spacetime at much shorter distances, relative to the scale of interest, could remove any related divergencies otherwise. It remains to be studied in quantitative details in the future. If it is found to be true, basing QFTs on meta-spacetime, as suggested in the current theoretical framework, provides a more solid foundation for them. It also provides a foundation for renormalization group theories about QFTs.

Some of those infrared divergencies are also expected to be removable using similar argumentation.

D. Weak interaction, chirality, neutrinos and neutrons

Retro-causality in the meta-spacetime was introduced in Refs. [12, 14] in the form of 2DCTR representation for relativistic quantum fields in order to realize a consistent unification of special relativity and QM. And it is also a necessary assumption for a unification of Gravity with the Standard Model of physics in the current theory. Retro-causality can be represented by an exchange of the initial and final states in an scattering amplitude (see Ref. [14]). Is there direct observable effects of retro-causality in the meta-spacetime at the Quantum level? The answer is yes, they are contained in the weak interaction sector of the Standard Model. Such effects could manifest in physical

²¹ Note that Planck used the same equation for multiple stochastical independent photons in doing statistics. The current equation is for a single quantum packet of multiple photons.

processes involving neutrinos, which have fixed chirality (to a good approximation at the energy scale of interest even if neutrinos are not massless) that lead to the well known phenomena of parity violation deduced from chirality or polarization agnostic observations in which the said violation is inferred from asymmetry in angular distributions of the nuclei β -decay products. Without such an intrinsic chirality, the physical effects of meta-retro-causality in the meta-spacetime are cancelled early at the scattering amplitude or Feynman diagram level. With neutrinos and antineutrinos having intrinsic chirality, the said effects could not be cancelled at the same level in the same way.

The strength of weak interaction, despite its weakness and short range in the Standard Model, is still overwhelmingly strong in strength compared to that of Gravity. The intrinsic chirality in the weak interaction formulated using contemporary QFT should leave traces in cosmic nucleosynthesis processes since almost each one of the primordial hydrogen is generated, in the current theory of baryogenesis where neutrons are evaporated from the false ground state of superfluidity of the strong interaction first, via the $n \rightarrow p + e^- + \bar{\nu}_e$ β -decay process after the “big bang”. Should there be any of the dominating weak interaction effects of net primordial chiralities left to be observed in reality? Maybe not according to the current theory because it is more “chiral symmetric” in the sense that it prevents such a weak interaction induced native chirality from happening due to the introduction of the retro-causal component for neutrinos or antineutrinos, which have *effectively* opposite chirality compared to its corresponding causal component for emergent observables or at classical apparatuses. Therefore the current theory is able to provide a neutralization mechanism for any possible direct coupling of interactions in the Standard Model of physics with the gravitational one via chiral charge.

The universe is thus neutral, to any force effects in the Standard Model, in any “charge” contained in the Standard Model at celestial scales under the current theory so that gravity has a chance to emerge beyond macroscopic scales where thermodynamics provides a valid description of nature.

For chiral charge however, such a cancellation is incomplete, down to order of $1/\sqrt{N_B}$ or the strength of gravity, due to the spontaneous time reversal violation that underlies the mechanism for baryogenesis under the current theory (see Sec. IX A), which also plays essential role in understanding the origin and evolution of life (see Sec. XIII C 7).

The counterintuitive retro-causalities in meta-time are inevitable (according to the current theory) intrinsic relativistic quantum phenomena. Like the quantum entanglement ones on space like hypersurfaces in the meta-spacetime that a reader is more used to at the current stage of our understanding of QM, it’s kind of relativistic meta-temporal quantum non-locality or entanglement.

It should be mentioned that the direction of time and causality in the emergent spacetime is governed by the second law of thermodynamics, namely, by the direction of an increase of entropy. More specifically, despite the fact that there is a symmetry in causality and retro-causality at the quantum meta-spacetime level and they occur in parallel in the meta-time in any quantum processes, what emerges from a measurement using a macroscopic apparatus may not reflect that underlying symmetry. This is because a measurement is a process of projecting the quantum system under investigation onto “classical localizable properties” pertaining to the apparatus which are then mapped and attributed to the said quantum system, it is reasonable to assume that the sensitivity of said apparatus in detecting the quantum causal component and the corresponding retro-causal component to be different since the retro-causal component could appear to be either harder to detect or probabilistically less likely to happen even for the detection of a non-localized single quantum packet using the classically localized macroscopic apparatus. Sec. XIII C 3 explores the subject further.

That is one of the microscopic reasons why there appears to be a direction in the emergent time. In most situations, due to Eq. 106, in a relativistic high energy process, the more massive or lower energetic of the measured quantum packet is, the more classical the quantum packet looks like in which case it is expected that the difference between causal component and retro-causal component to be more pronounced. Such differences will be enhanced for a macroscopic number of such quantum packets, which, together with other mechanisms already discussed in the standard statistical mechanics, is expected to contribute to the existence of an unidirection or arrow in the emergent time. It’s one of the microscopic foundations for the second law of thermodynamics.

1. Had retro-causality in the meta-spacetime already been observed?

A recent antarctic impulsive transient antenna (ANITA) experiment is designed to observe ultra-high energy ($\sim 10^{18}$ eV) cosmic neutrinos. They were performed above the south pole using radio antenna on high altitude balloons that point to the center of the Earth to detect effects of these cosmic neutrinos. High energy neutrinos will generate radio flashes of some fixed chiralities corresponding to the neutrinos that triggered them when they interact with the Earth material near the surface due to Askaryan effect. The experiment detected a few radio flash events with “unexpected” chirality related shapes. Such shapes are not expected because for them to be possible in the contemporary theories in use, they must be caused by cosmic neutrinos that had passed through the entire Earth from below (relative to the radio antenna). But since the neutrinos involved in the ANITA experiment have energies so high that they have

very high probability to be absorbed by the denser matter inside the Earth on their way to the south pole, they are therefore unexpected without going beyond the contemporary theoretical frameworks for the Standard Model.

The current framework provides an explanation of the observation because it is symmetric in causality and retro-causality at the meta-spacetime level as discussed in Ref. [14]. The “unexpected” events are manifestations of the existence of retro-causality in the meta-spacetime (see also Sec. XIII C 3).

Admitted that the results of said experiment are inconclusive due to the small number of such unexpected events observed, it is certainly a worthwhile research direction to be further pursued.

2. Neutrino oscillation and the nature of “sterile neutrinos”

LSND and MiniBoone experiments provide hints at a 6.1σ confidence level that the Standard Model under the contemporary theoretical frameworks, in which neutrinos are left-handed and antineutrinos are right-handed, does not provide a complete picture to explain the experimental findings. The initial hypothesis is that there exists opposite handed neutrinos called sterile neutrinos that could provide a mechanism for solving the discrepancies between theoretical predictions and the corresponding experimental observation. However, sterile neutrinos can not participate in any interactions in the Standard Model, because otherwise it would potentially break well established observations, like those chirality or spin agnostic parity violation experiments of early times. Instead of being completely invisible or decoupled from reality as certain existing entities, they could have indirect physical effects since neutrinos can mix with each other. Related experiments implies that sterile neutrinos, if exist, are much heavier than their counterpart neutrinos. The current limit for their masses are above 2–3 GeV.

Sterile neutrinos are also been speculated to be a candidate for the so called cosmological “dark matter” and for matter genesis in the early universe. But these are no longer problems to be solved within the current theory any more.

Given that, some of the *effects* of the “sterile neutrinos” can be also realized by the retro-causal component of the neutrinos and antineutrinos without assuming different masses for them in the current theory. Here, neutrinos are still left-handed and antineutrinos are still right-handed, however, they are causally reversed in meta-time. Their existence does not conflict with the well know experimental results in weak interactions, as it give rise to formally equivalent expression of elementary weak scattering vertices, which was established in Ref. [12]. There is no need for additional hypothesis or parameters because they are already part of the theory.

The 2DCTR for fermions has in it a more general mass matrix of the form Eq. 16, which provides more allowed modes for mixing between neutrino flavors. This could be investigated in more details in the future.

3. Neutron lifetime puzzle and it’s possible solution

A neutron in free space decays into a proton in a β -decay process: $n \rightarrow p + e^- + \bar{\nu}_e$.

There is a $\sim 1\%$ persistent discrepancy in high accurate measurements of the lifetime of a neutron using two type of experiments: the first one monitors the decrease in number per unit of time of ultracold neutrons in a “bottle” and the second one measures the increase of protons originated from such a decay per unit of time in a relatively high speed “beam”.

The difference has an explanation in the current theory. According to which, it’s easier to capture both the causal and retro-causal components of a neutron in an ultracold “bottle” (since they are essentially static) than to capture the retro-causal component of a high speed proton in a “beam”. Therefore, given the same time period, it appear that the percentage of neutrons that disappear is greater than the percentage of protoms that appear in a “beam” experiment since some of the retro-causal components are not able to be captured. That is why the lifetime of neutron appears to be shorter when it is measured in a “bottle” type of experiment than the one measured in a “beam” type of experiment. It remains to see if improved detectors that are more sensitive to the retro-causal components of a proton could decrease the discrepancy.

E. Condensed matter and low energy physics

Here, some of the potentially relevent experiments that could be interpreted as providing empirical support for the theoretical (or analytical) necessity, as discussed in Ref. [14], of an inclusion of the companion “retro-causal”

component for any quantum entity²², which is realized by adopting the 2DCTR representation of QFTs, in any attempt of unifying QM and relativistic spacetime, are discussed. Mathematically, the nature of retro-causal contributions could be mapped from the causal ones by an exchange of the initial states and final states in scattering amplitudes involved in the physical process under consideration (see the quantum field Eq. 6 of Ref. [14]) and the relative strength or amplitude in the quantum packets involved in an experimental observation is determined by boundary conditions²³ (see Sec. XIII C 3 for details), dynamics and particular experimental settings and sensor capabilities.

1. Differential photon traveling time in an atomic cloud

A recently disclosed (Sep. 2024) experiment led by Daniela Angulo of University of Toronto found effects that some photons in an experimentally prepared group “spend less time” traveling in a cold atomic cloud when they are absorbed and re-emitted by certain atoms in the cloud when compared to the ones in the same group that pass straight through without any interaction.

It could be interpreted as that atoms can jump into an excited state and “re-emit” photons “before” they absorb the “incoming” photons that drives the experiment. If it is proven to be a true effect, the finding seems to be an isolated observation that is paradoxical in classical causal logic and very counterintuitive to have a straightforward explanation in the context of contemporary physics. However, as discussed above, this is a “required” retro-causal effect derivable from the 2DCTR representation of QFTs that plays the key role in interpreting a vast amount of phenomena from high energy neutrino physics at the elementary particle level, to the emergence of macroscopic gravity and associated astrophysical and cosmological ones using the current theoretical explanatory framework.

F. Completing the classical equivalence principle

Whether or not a static charged particle in an inertial frame will be observed to emitting EM waves by an observer who is accelerating relative to the said inertial frame is a question that must be answered by any consistent theory on classical GR. Einstein’s GR, which is originated from incorporating equivalence principle for classically localizable particles certainly has not been consistently unified with classical EM, partly because the non-locality of the classical EM governed by Maxwell equations, which is discussed in Ref. [14], when there is no conceptual separation between the meta-spacetime and the emergent one.

According to the current theory, the quanta of quantum electrodynamics (QED) observed by the accelerating observer acquires a rotation in its upper and lower component space given by Eqs. 73 and 74 so the stable action emergent spacetime of the observer is also an accelerating coordinate that cancel the said rotation as much as possible (see Sec. IV C) in the emergence of Maxwell equations for classical EM waves (with macroscopic number of photons) in the accelerating coordinate. So there are plenty of rooms to implement the equivalence principle which, in the current case requires that the observer sees no EM radiations no matter what an accelerating frame the observer joins, or put it in another way, it also requires that an accelerating observer in a reference frame that accelerates with an accelerating charged particle will emit observable EM radiations despite the fact that the charged particle is at rest relative to the observer.

The emergence of classical EM waves governed by the Maxwell’s equations from macroscopic number of non localizable photons of QED and how they behaves in the emergent spacetime will be explored in future studies.

XIII. BOUNDARY CONDITIONS, ENTROPY AND THE PHYSICAL ORIGIN OF LIFE

Let’s turn our attention to the study of non-relativistic masoscopic scales using the current theory. A preliminary reductionists’ theory for protoconsciousness and life is proposed.

A. Observational entropy

The concept of entropy is an emergent one since it is associated with a corresponding observer who has only limited information acquisition capabilities.

²² Including the ones in more accessible (and more relevant for some application oriented minds) non-relativistic low energy physical processes. It’s one of the very few, if not the only, situations in which SR, which is only relevant to high energy processes in the realm of classical physics, plays a role at low energies when quantum mechanical effects are of interest.

²³ At a “future moment” in contrast to the subjective time reference frame in our conscious mind or, simply, at the detectors!

In classical physics with time reversal invariance, a chosen phase space volume in system remains constant due to Liouville's Theorem so there is no intrinsic or objective increase of intrinsic entropy during the dynamical evolution of the system, especially for a single particle system. However for a multiple particle with an observer who has only local sensing capabilities is involved, and when the system starts from an ordered or localized state which is known relatively well by the observer, the observational entropy increases despite the above mentioned mathematical theorem. This is because less and less of the total phase space volume involved could be tracked by the observer as time goes by, especially when the number of the particles is large, since the phase spaces of the particles of the system are separated farther and farther from each other and from the attention based “localized” sensing apparatus of the observer.

In QM, the increase of entropy is build-in at the very start even for a single non-free “particle” in the contemporary theoretical framework of QM even if the underlying dynamics is time reversal invariant. More specifically, let's do a high level walk through of single particle non-relativistic QM. The wave function $|\Psi\rangle$ of a non-relativistic “particle” follows, of course, the Schrödinger's differential equation. But differential equation hide certain aspects of the wave nature of “particle” in QM that are of physical relevance. Instead, the integral form of Lippmann-Schwinger equation used in studies scattering states of a “particle” in a non-vanishing potential V on top of Hamiltonian H_0 that governs its “free” propagation can be used to illustrate the points

$$|\Psi^{(\pm)}\rangle = |\phi\rangle + \frac{1}{E - H_0 \pm i\epsilon} V |\Psi^{(\pm)}\rangle \quad (115)$$

where $|\phi\rangle$ is the solution of the Schrödinger's equation when V is turned off and E is the energy of the “particle”. The presence of $\pm i\epsilon$ on the right hand side is because the operator

$$\frac{1}{E - H_0} \quad (116)$$

is singular in E and such a singularity can be consistently handled using complex analysis via a complex continuation of E into its complex plane on which the above mentioned operator can be show to contain a branch cut on real axis from 0 all the way to infinity (the extended scattering states). One has to make a choice which branch to take. $\pm i\epsilon$ is there to explicitly separate two kinds of solutions present in the scattering state the Schrödinger's equation on real E axis. One have to make A choice which one to use. Mixing both of them together in a solution would lead to mathematical inconsistencies down the way. One kind of the $|\Psi\rangle$ is called outgoing waves and the other one incoming waves. The choice in observational physics is obvious, namely one should choose the outgoing ones or the causal ones in which the incoming asymptotically free wave $|\phi\rangle$ can be prepared by an observer in a localized spatial region with low observational entropy and the outgoing (asymptotically) wave is spreaded out with high observational entropy since the local observer is incapable of providing a coherent observation of it in a spatial region on a 2-d distorted (due to phase shifts) surface that can be best mapped to a sphere with radius approaching infinity. The incoming waves, which can be referred to as retro causal ones, are not accessible to local observers since they are states that can be obtained from the outgoing ones by interchange the initial and final boundary conditions. To prepare such states, an agent has to coherently produce such waves on the distorted sphere mentioned above at initial time so that these waves will end up in locally observable regions at the observation time. It's impossible for local observers without godlike capabilities. However, ontologically, these incoming waves are there despite the fact they are not **directly** observable in **final** observations. However it does not preclude them from mixing into the physical processes via dynamics or other means so they could have indirect observational effects. Sec. [XIII C 3](#) contains a further exploration of the subject.

Thus the observational entropy already follow the direction of a monotonic increase of time even in single “particle” non-relativistic QM. These mandatory choices lead to the so called “pseudo time violation” phenomena, a term initially coined and further studied in Ref. [\[3\]](#), in observations of possible intrinsic time reversal violations that are supposed to happen in the underlying dynamics.

The above conclusions are also applicable to relativistic QM, in which, amongst others, the energy of a particle can be both possitive and negative and there are more branch cuts and poles as far as its complex plane is concerned. The way how to get around the branch cuts involves not only a consideration of causality, but also proper particle content interpretation in which, according to Feynman, the negative energy states that moves backward in time have to be selected to be re-interpreted as “anti-particles” moving forward in time. Such an approach is found to still lead to inconsistencies. It is shown in Refs. [\[12, 14\]](#) that the retro-causal components are required to be ontologically relevant. They have to be included in a consistent theory that truely unifies QM and SR in a 2DCTR form so that the analytical properties of the S-matrix is well behaved. It also leads to a consistent complex continuation of the real meta-time variable into its complex plane. The result, amongst other relative minor technical improvements, is a successful unification of the frameworks for statistical mechanics (in imaginary time) and the corresponding off thermal equilibrium real-time dynamical systems at finite densities and temperatures, see Ref. [\[12\]](#) and the prior works referenced therein for more details.

B. The hardness of the “problem of consciousness” in the old spacetime

While one can intuitively talk about the concept of time as a godlike observer outside of the system being observed since it is believed that every living entity experiences the passage of time, at least sub-consciously, because Darwinian evolution depends upon it. Time is something qualitatively different from spatial dimensions when the observer together with any apparatus used in the observation, which will be simply referred to as the observer in the sequel, is part of the system being observed, like in the study of the universe. For spatial dimensions, an observer can always choose a fixed reference point at which it is located and using such a point as reference one to objectively describe the position of other objects, which means that spatial dimensions can be used as a coordination system. However, in the contemporary physical theories, the same observer can not choose a fixed reference point in time using which to describe the time of other objects in the system since it's part of the same system and every objects, including the observer, progress in the same pace (in a given reference frame when SR is taken into account) and has the same time, namely the PRESENT or NOW. Time is therefore not a proper dimension in the coordination system for an internal observer. This is because the observer “moves and **changes** in time” in the same pace and direction as other objects being observed, there is neither internal anchor of time nor external reference time for the drifting observer in the “river of time” to stop so that it can establish an objective standard, derived from properties of apparatus to be used at the same fixed time, for what exactly are “changed” and in what “order” (for establishing causality). One may argue that the memory functionality of living entities can serving the said purpose, at least part of it. But the development of full fledged memory functionality, which is needed here, is the result of having protoconscious and then become conscious, emerged long after the awakening of its protoconscious when primitive intelligence is developed, not the cause of it. When the observer flows in time in the same way as its surrounding objects, there shouldn't be any qualia of flowing time, similar to a person who is put in a closed and moving train can not experience and describe the motion of the train. So everything involving providing an operationally meaningful analytical definition of time that describes the intuitively obvious phenomenon of the passage of time experienced by a conscious being end up in circular argumentation in the contemporary theories. For example, the term time is used circularly, it plays the roles both as the measure and measured in the above statements, despite the fact that most readers could intuitively “understand” them because they have the quala, with the flow of time part of it, already to refer to. Still it is hard to talk about these self-referential and possibly paradoxical subjects to a listener with sufficient analytical capabilities. But what if they are the so called philosophical zombies, like a mechanical computer programed using the latest art of logical AI systems, or would be conscious entities in the early stages of their Darwinian evolution?. They will be in the state of “lost” or falling into an unstoppable recursion whenever time is referred to. The parallel progress in time (again) of themselves and the objects being observed around them will corrupt their (primitive) logic, knowledges derived from temporal causality and resulting intelligence, if they have any, leading to thermal death due to the inevitable increase of entropy firmly established by thermodynamics. Therefore it is almost impossible to envision an intelligible mechanism in which the essential ingredience and ab initio condition for consciousness, namely the quala of the unidirectional flow of time, which forms the basis for its ability to detect changes in the environment, establish causal awareness of and between event sequences, and having the **innate drive** to consistently optimize its response strategy for the wellbeing of the conscious being to learn, structually mutate, and evolve to survive the Darwinian fitness competition, can emerge from physical entities based upon the contemporary physical theories. The task of providing a reductionist's mechanism for bootstrapping life out of nothing but the known elementary constituents in material universe, like atoms and molecules seems to be a mission impossible. If consciousness pre-exists due to certain mythitcal process, it is almost impossible to sustain because the entropy of a potential observer increases in the same way as other objects in the system so that it will become less and less intelligent as the system evolves. This is against the observed facts that the biological system in the current conditions on the Earth evolves in the direction of an increase of its intelligence.

Where and how quala emerges is commonly referred to as the “hard problem of consciousness”. It's the opinion of the current author that an understanding of the mechanism for the “qualia of flowing time” is an essential obstacle, if not the only one, in constructing a solution to the “hard problem”. Most of other aspects of qualia of a life form follows during the emergence and upward recursive evolution (see below) in which more intelligence is accumulated. Each layer requires its own representation, namely quala, of its surrounding world suitable for their structural characteristics and evolution path to respond intelligently to survive, which in part should be “derived” from the ones from lower layers. The development of language and computational capabilities depends upon quala which in turn further promotes them to become an essential part of life.

C. Emergence of anchors of time, self, free-will and a preliminary theory for life

The conceptual difficulties, illustrated above, in trying to constructing a consistent, non-self-referential, and reductionists' explanatory framework for the phenomenon of conscious and eventually life can be removed, at least partially, by the current theoretical framework that is based upon meta-spacetime, in addition to what is done to the unification of the Standard Model of physics and Gravity presented in the previous sections.

1. Basic premise

Suppose that matter at scale at or beyond that of a typical molecule and under the one for a typical living cell, which forms a (non-relativistic) quantum subsystem, can enter into a mostly pure quantum state ε whose emergent time introduced in Eq. 13 is small and negative, namely

$$\tau_a = \sum_{s \in \Omega} w(s) \langle s | \hat{t} | s \rangle < 0 \sim 0, \quad (117)$$

under favorit environmental conditions **due to underlying dynamics**, with Ω including the possible sub- Fock space states that span the said subsystem. Then the emergence of life is possible.

Let's denote such kind of a subsystems as ε -element. It will be shown in the following that it can be the building block of conscious on which life depends.

Here τ_a for the right subsystems (namely $\tau_a \sim 0$) is called the *anchor of time*, which provides the temporal basis that give rise to their protoconsciousness. It could exists inside the framework of the current theory, which, assuming QM should be unified with relativistic spacetime (in meta space), requires taking into account states not only the causal ones but also the retro-causal ones (see, e.g. Eq. 115) in a way that respect analysity (in mathematics). If the underlying dynamics is such that the most favorit states (in, e.g. energy) requires a coherent mixing of these two kind of states, then the emergent time for these favored states are less than the "normal" ones since the expectation of time for the said two kind of states are opposite (see Eq. 7 of Ref. [14]). As it is explicited in the previous sections, the emergence of gravity and accelerated universal scale expansion phenomenon contemporarily associated with the so called "dark energy" rely on such a property as well despite the fact that mixing states that give rise to gravity for cosmological scale hadronic matter is determined to be extremely small ($\sim 10^{-40}$). If, however, the mixing is near perfect for certain state of matter at the said masoscopic scales, then $\tau_a \sim 0$ is the result.

2. Awakening of protoconsciousness and self awareness

Now the ε -element can be separated, at least logically for the time being, from its environment. It, as a would be observer, "sees" two kind of times:

1. **Self:** Due to its quantum nature and masoscopic in sizes, it feels, holistically and, if $\tau_a = 0$ eternally, the whole. The second law of thermodynamics does not apply to itself. If $\tau_a \sim 0 < 0$, a reversal of the said law applies to its evolution in time. Namely, it aquires the dynamical potential or drive to create epistemological order. In addition, it acquires the transcendental anchor of time discussed above. A new dimension, namely, the subjective time, and the associated 4-dimension coordination system, is opened up for it to make it possible to "experience", "understand" and make usage of its surrounding environment. It is possible because it is now physically separates from the rest of world discussed below as an *observer*.
2. **World:** Which includes other ε -elements and surrounding material of itself that help to maintain order. All objects in the world, as seen by the observer, acts normal. Namely, their retro-causal components, if any, are not visible or dark. This is because the retro-causal components are statistically suppressed in local observations (see Sec. XIII A). Therefore the emergent times for them as seen by the observer run in normal paces and in the direction of monotonic increase of entropy. They become differentiable properties that can be placed or recorded in its 4-dimensional coordination system.

Due to the clear seperation of an ε -element and its environment in terms of physical boundary and behaviors, a kind of proto- self awareness, subjectivity and objectivity emerges. Albeit these ε -elements in the current form are not life yet, when a condition is present such that $\tau_a < 0$, the fundamental driving force or dynamical tendency to create life through a slow process of Darwinian evolution is also created.

3. Free will, teleology, Darwinian evolution and the emergence of life

Whether or not there is free will for human beings is discussed in philosophy, religion and certain kind of scientific literatures for centuries. One intuitively know there obviously is because there does not seem to be any force of natural origin against any choice one makes that respects (local) physical laws. But it is also apparent that some will intellectually don't understand it because the universe is supposed to be governed by physical laws, which when the initial boundary conditions are set, runs in deterministic manner. The absence of free will also seems to be in conflict with Darwin's theory of evolution. Some went as far as declaring that there is no free will.

The current new theory for spacetime, despite of its deterministicness, allows free will. This is because here the universe, as we know it, is fundamentally random, albeit it does not seem to be. As it is discussed in Sec. XIII A, the retro-causal components of the quantum world is ontologically relevant for the current theory. It is also known that the observable universe start from a state with minimum entropy. It follows that the retro-causal mirror of the observable universe, albeit invisible to intelligent life forms, start with maximum entropy due to the fact it is a time reversed mapping image of the observable one, which means that the retro-causal universe tends to be becoming a state with minimum entropy or maximum order in the remote future. As to which low entropy state it ends up to, it is not predetermined, due to the thermal randomness and also non-observability (see Sec. XIII A) of the initial boundary conditions, which make them not recordable to become part of epistemological history and knowledge that constitutes a target to be "erased" by future choices. The history modification paradox that is used to against retro-causality exists only in conventional theories, not here. The retro-causal components belong to the realm governed by teleology that give rise to "meaning" or "purpose" for life forms that have enough intelligence.

Therefore ε -elements, the would-be beings with protoconscious, are free to choose their destinies on their way to become a kind of life form and to become better ones. It means that Darwinian evolution for them is possible. A biosystem of life family tree with greater random variety is the result.

Consider the case $\tau_a \sim 0 < 0$, in which the retro-causal components of it dominates ever so slightly, an ε -element will try to reduce entropy to become more ordered despite the fact that most of other non ε -elements are going the opposite direction (in time). A long dynamical journey of trying to reach the perfectly ordered states with minimum entropy in the future, whatever they are, starts in regions of the universe with suitable environmental conditions. If a favorite condition exists that there are other ε -elements present in the vicinity with sufficient density, they will attract each other to increase their density. This is because that way their entropy can be further reduced, which is driven by underlying dynamics. At the same time, their distribution amongst themselves will become more and more regular with structures that benefit further reduction of their entropy or gain in order. Given enough time a cell like structure emerged and a new layer of order creation circle begin. At certain stage, conflict of interest in creating their own order start to occur to these protolife objects, Darwinian mechanism kicks in. In the process of competition, the ones with more capabilities to create order or more intelligent in collecting information and make use of them win, and the sense of "self" enhanced. Destruction or death to a conscious entity means decrease of order, therefore it must be avoided at all cost. After another period of time, life emerges. In which the drive to create order passes, recursively, to higher and higher layers of the life carrying organization at which new kind of qualia emerges to "express" or "represent" the sense of order and knowledge of the world around it that are essential for its survival at that layer. The sense of "self" also recursively expands in the process. Eventually, nested life and cross life order, like inter-life societies and larger "self", appear. More sophisticated qualia experiences emerges because they provide summarizations or abstraction of the result of lower level interactions with others. It also provides a pre-condition for primitive naming systems that are required by the development of higher level intelligent functionality, like the use of languages to communicate, the ability to compute, etc., to develop. External tools and languages are invented to help the reaching the goal of order creation. Objective and quantitative standards for qualia, time in particular, are then developed. As a member of homo sapiens, most of us experience the joy and internal drive of performing actions that ultimately lead to the goal of order creation. Current generation of our species are also witnessing the rapid development, within our life time, in our means of gathering information and creating order with the help of external tools. With advent of artificial intelligent (AI) systems in current days, which can do even better at specific tasks, we are getting ever better at going after our ultimate destiny, a world of "perfect order", whatever it could be, despite that fact any of them may never be eventually reached.

Proponents of *intelligent design theories* argue that natural creation of order as complex as even the most primitive life form is mathematically impossible, they must be initially designed. To the opinion of the present author, their argumentations are a mis-application of information theories to dynamical processes. In ordered structures or configurations created by a underlying dynamics, all the digital "bits" that representing the order are flipped in parallel in ways that obey the said law, they are not flipped, against the said law, bit by bit sequentially. Further, the bits needed to represent a particular dynamical configuration and their statistical distribution depend upon the coordinate or parameter chosen to represent the configuration, they are arbitrary in this sense. Those correct combinations of "bits" minimize the action for the dynamics. Only the initial conditions has to be "designed", if needed, for a system

having known dynamics. But life can start from almost no order, as it is discussed above, apart from the initial one encoded in the ε -elements, which could be explained by normal chemistry, the burden of a designer, if needed, is greatly reduced.

A widely asked question is that is any AI system, in its current implementation, namely a computational system designed using principles of classical physics and only simulate the functionality of high level neural networks in life forms, be self-sustainable in terms of intelligence or become so called “artificial general intelligent” (AGI), where their human ancestors are no longer needed. The present author think no in the context of current work. This is because such kind of “AGI” system has no fundamental innate drive and quala needs, from bottom to up, to define and increase order, they are classical machines and information systems that obey the second law of thermodynamics, which will eventually decay to decrease their intelligence without the drive and maintenance of its real conscious living developers and users, who have and know what their “good” root needs²⁴ are. The obvious difference in the growth rate in the energy consumption between the maintenance and building up of biological intelligence and in those artificial ones, which is currently on the not so clever track of bankrupting a small nation, is a testimony of the qualitatively difference in the underlying mechanism for them. According to the current theory, biological intelligence “gains” energy at its core (see Eq. 117) in the processes of acquiring more intelligence, the net energy needed for life forms to be living is for the supporting normal materials that maintains their physical structures.

4. A preliminary exploration of what and how

A natural question is what the ε -elements are? And, how the quantum states in a ε -element can be maintained inside the quite noisy thermal environment of a living cell?

The first candidate for ε -elements one could conjecture is DNA molecules because it can carry robust superconducting states inside due to its long double helical structure. The following explains how it can be possible.

One can notice that Eq. 110 for quantized states does not consider any kind of non-trivial gauge fields that alter the definition of the phase of a quantum packet. Such kind of gauge field effects exists even if there is no external gauge field present. This kind of effects are related to geometric phase (or Berry phase) in condensed matter physics, which is expressed canonically using statistical gauge field [8, 13] in the current theoretical framework, that represent certain dynamically generated collective topological background context that the quantum packet is in. The double helix of a DNA molecule that is under investigation here is something just like that. In the presence of a topologically non-trivial statistical gauge configuration with finite vorticity, a more general expression is

$$(p \mp \hbar k_0)\lambda = 0 \text{ or } h, \quad (118)$$

where λ is the wavelength, k_0 is the spatial period of the background context that winds in or against the direction of motion of the quantum packet. The 0-mode is allowed here because a state with finite p has finite density of states around and is also a non trivial state. For non 0-modes, the above equation can be rewritten as

$$\begin{aligned} p\Delta l &= h^*, \\ h^* &= \frac{p}{p \mp \hbar k_0} h. \end{aligned} \quad (119)$$

h^* is regarded as effective Planck constant. It can become larger or smaller depending upon which direction the quantum packet is travelling. The effective strength of quantum effects can therefore be modified in a helical statistical gauge environment. The distances in energy between various excited states are scaled by the Planck constant. Given a temperature, the larger the said distances, the harder for the coherent state of a quantum packet to be destroyed by its thermal environment.

The 0-mode, which corresponds to $h^* \rightarrow \infty$, is of particular interest here, because besides the 0-mode, there is no other higher quantum excitations on top available. It can be destroyed by a thermal environment only at much higher temperatures at which the molecular structure of the hosting DNA can no longer be sustained.

Let’s further assume that, like in a normal superconductor, electrons in a DNA can be paired to form lower energy states, which is most likely because the double helix structure that bound two components together by inter-molecular force is known to be stable. Then a Bose-Einstein condensation of such pairs in the 0-mode discussed above become a robust state against thermal environment in a cell. Namely:

A long enough DNA molecule, or other material of similar structure, could be a super high temperature superconductor.

²⁴ The needs that are generated independently due to the innate drive to create order that has no dependency on other ones.

Eq. 117 holds true for a superconducting state, as it can be deduced from discussions about the emergence of gravity given in the previous sections (see e.g. Eq. 65). Whether or not the conjecture and assumption made in the current subsection are true remains to be studied in the future.

It's hoped the current theoretical discussion could also provide insights into how high temperature superconducting material, quantum computation systems or even artificial life forms, which are hot but less understood topics in condensed matter physics and life science and of high economical values, could be designed or searched for.

5. Quantum overlays in biosystems

Contemporary mainstream chemistry and biology are all based mostly on semiclassical structures of the targets of their study. For molecules in chemistry, this might be sufficient for simple understanding and applications. However, a living biosystem is obviously much more than the dull classical structures of its constituents in the emergent spacetime that can be directly observed using macroscopic sensors or apparatus. The needs for an exploration of the quantum aspects of biosystems can also be derived from direct observations. One of the more obvious examples is the photosynthesis process of plants. The speed and efficiency of absorbing and utilizing the energy provided by the Sun, via photons, by plants can not be satisfactorily explained in terms of classical stochastic modeling of the process.

According to the current theory, the root reason for the appearance of life is due to the quantum encoherence provided by the robust source of quantum coherence contained in ε -element or DNA molecules. A biosystem at given layer is thus expected to be characterized not only by its classical structure but also by the quantum non-local and entangle overlay structures (see Sec. XIIB5) on top of it with structures imprints that can be ultimately traced back to the structure of the DNS molecules. These non-local structures can not be directly described in terms of emergent spacetime but are essential for the maintenance of the living status of the biosystem.

It is quite interesting to see how these rich structures within those overlays be utilized to explain various mysteries of life form. For example, the mechanism for photosynthesis mentioned above could be explain based on the existence of these layers that can perform single step synchronized quantum jump involving multiple entangled particles separated by relatively great distances, similar to what happens when a laser beam hit a target material (Sec. XIIB3).

Could these layers be used to provide a physical basis for the mechanism behind the capabilities related to memory that an intelligent life form, including those primitive ones, is believed to has?

Intelligence of a life form also manifests in its ability to cause changes to itself or to its environment incrementally in a way that increases order or decreases entropy without violating physical laws. However, when such a process is represented digitally, it involves flipping of multiple bits each of which would violates classical physical laws so that it is highly suppressed due the principle of stable action when the flipping is done in a temporal sequence. For a humam that are known to be intelligent, it is known how to make an useful object, like a machine, by designing the object virtually on papers and put all the parts (or bits) together so that physical laws could eventually be obeyed before actually utilizing it. The evolution process of life forms is much more complicated, especially when the changes involve the structure of the life form itself. Here flipping a wrong bit directly in a tempral sequence could cause fatal damage to the life form leading to self destruction. So evolution is almost impossible base solely on classical structure of a life form. However, the structures in quantum overlays could be used as the virtual "paper" by a biosystem for a single step in the direction of order increase to be structually completed.

The ability of certain primitive life form to recover severely damaged or mangled body parts to their intended position or form is empirically observed (search vidoes of Michael Levin). It seems that a life form knows what its short term best physical destiny is, which was learned during its evolution, and makes great effort to not be distracted by others, even in the absense of its complete physical body or when severe obstacles are present. Where does the information needed to perform the recovery is stored has a natural explanation, namely they are stored and distributed, redundantly and non-locally, in the quantum overlays as "blue prints" or "digital twins". When the said "invisible" layers are not completely destroyed, the recovery is always possible.

It is possible that evolution in life forms proceeds in two stages: stage one, suitable structural modification are performed in the more volatile quantum overlays in response to the environmental pressure. And, when the change is favorable, then continue to stage two that take much long time, in which the changes are back propagated and persisted to the micro classical structure and eventually condensed into DNS specific to the life form to make them permanent and transferable to the next generation.

Namely, living biosystems, primitive or not, could also be, in part, a kind of programmable quantum computer, in addition to its conscious and self drives due to Eq. 117.

6. Biosystems and the upward propagation of quantum coherence

An ε -element in the core layer of a life form acts as the source of quantum encoherence discussed in Sec. XII B 3 for its peers and upper layers that have chances to entangle with it without losing its own quantum characteristics because of its quantum mechanical robustness. The process could recursively be repeated upward. Therefore all living life forms at all layers could acquire certain ingredience of quantum coherence that render them distinct from non-living materials or dead counter parts. Of course, it is expected that the higher the layer goes, it is more likely the weaker such kind of coherence becomes.

7. Cosmos, the fundamental driving force that give rise to life

Under the current theory, life is possible to evolve only if τ_a in Eq. 117 is less than zero. But that violate the intrinsic time reversal invariance.

One of the candidate for the origin of such kind of violation is the CP violation discovered in the weak interaction sector of the Standard Model because it can be translated into time reversal violation using the CPT theorem. But such kind of possibility is not viable under the current theory because, like the cancellation of chiral charge generated in parity violating processes in weak interaction discussed in Sec. XI D, its effects could also be cancelled under the current theory. In addition, even if such a cancellation is not complete, its effects will be way too large, as discussed below, for a life form that contains masoscopic number of particles to evolve according the known pace that spans ~ 4 billions of years on Earth.

The current theory provides another possibility, name the spontaneous time reversal violation in the false ground state of strong interaction²⁵ which plays the key role in constructing a mechanism for solving the Baryogenesis problem (details are given in Sec. IX A), It provides the reason why the material universe experienced by us exists at all in the first place according to the current theory. Here the magnitude for τ_a , being originated from the false ground state of superfluidity of the strong interaction and measured in the QCD time scale of $1 \text{ GeV}^{-1} \sim 6.6 \times 10^{-25}$ secods, is suppressed by a factor $\sim 1/\sqrt{N_B} \sim 10^{-40}$. Is it too small? No, because the effects of gravity has the same magnitude, yet we are all obviously affected by it.

It is well known that proteins in all life forms are left handed in chirality and this implies that all DNAs and RNAs are right handed. Does such a fact consistent with the current theory?

According to Eq. 61, there are two kinds of solutions for either possitive or negative energies for “free” quarks, the fundamental building blocks of a DNA molecule. For matter, as usual, possitive solutions should be chosen. The first kind of solution, which has larger causal contribution in amplitude, has positive \bar{t} for small μ (see Eq. 65) and the second one, which contains larger retro-causal contributions, has negative \bar{t} . It is reasonable to assume that such a conclusion to be also true for the anchor of time τ_a of Eq. 117. Since the selection of $\bar{t} < 0$ solutions for the component of a quark in the false ground state of superfluidity of strong interaction sets the full quark, the baryon containing it and eventually the hosting DNA molecule to also contain more retro causal contributions in amplitude. It means that helical background context for the electrons in 0-mode and finally the condensed pair in that mode are also slightly dominated by the retro-causal one, and thus $\tau_a < 0$ for the electron subsystem as well. Because almost all protons in a DNA molecule were directly or indirectly generated from the $n \rightarrow p + e^- + \bar{\nu}_e$ β -decay processes in the early universe and an antineutrino $\bar{\nu}_e$ in the retro-causal mode is left-handed (opposite to the causal one), the protons in a DNA molecule are therefore most likely to be eventually right handed on QM average due to the fact that QCD is approximately chiral symmetric and the chirality, which is 0 for the primordial neutrons, is approximately conserved. So the ε -elements identified with DNA molecules that are made out of right handled protons are right handed in chirality. Those left handed DNA molecules will not give rise to life according to the current theory, since they lead to molecules with $\tau_a > 0$, which means that they can not drive order increasing and the Darwinian evolution processes needed for the development of complex life forms of matter (see Sec. XIII C 2).

Therefore the theoretical assertion that the driving force for the evolution of life forms is cosmological in nature associated with the mechanism for baryogenesis in the early universe does not contradicts with reality.

XIV. SUMMARY

It is shown that it's possible to construct a realistic theory for gravity that connects the largest entity, namely the totality of baryons in the visible universe, and the smallest one, namely a quantum packets of excitations of light

²⁵ Due to the fact the false ground state has minimum energy density only when the time component of the statistical gauge field $\mu^0 = \mu_{vac}$ is non-vanishing. It violates intrinsic time reversal invariance spontaneously.

quarks in the Standard Model of physics using a relativistic real time finite density and temperature QFT, which is constructed to be consistent with SR, based on a new layer of conceptual abstraction called meta-spacetime that is assumed to be flat. Gravity is generated by the curvature of the spacetime emerged from the meta- one after the later is combined with the wave functions in a statistical assemble of quantum excitations that is macroscopic in number. Instead of treating spacetime as an independent fundamental physical entity that is assumed/implied in classical GR, the emergent spacetime is a derived concept from other fundamental physical entities involved. It means that the effects corresponding to gravity is not a fundamental one. Therefore there exists one less fundamental interactions in nature. The long sought unification between gravity and QM is achieved in the sense that the former can be consistently derived from the quantum dynamics of the Standard Model of physics within the newly proposed conceptual and theoretical framework. An expression of the gravitation constant G that relates the mass of baryons, the location of them in the universe and the speed of causal front (c) is obtained.

The current theory joins various known theories of modern physics, which are well tested experimentally, into a single consistent unity with little increased theoretical complexity. It has a large enough base information volume to accommodate most of the physical phenomena considered, ranging from the behavior of celestial/cosmological entities, to the motion of quantum ones having action of a single quantum, and even to a self-consistent theory for consciousness and life that is ultimately connected to baryogenesis (of the current theory), inside a logically consistent and parameter reduced (or at least free) framework. The construction of a grand unifying realistic physical theory for a self-observing, intelligible universe that are created from “nothing” is successfully realized. A satisfactory order of magnitude match with a selected set of observations in astronomy or cosmology is found at the fundamental level and qualitative at phenomenological level for a wide range of phenomena, from life cycle of stars to that of the universe. Can it still describe the reality when more detailed computations based on the current theoretical framework are performed remains a topic to be further studied.

Whether or not its unique predictions, like the different dependency of the curvature tensor on the matter properties and type, the nature of gravitational waves, background quantum turbulence inside the false ground state of the universe, the behavior of the dual emergent spacetime, etc., can quantitatively explain the observed life cycle of stars, galaxies and galactic clusters and super clusters, cosmological filaments, inter-galactic magnetic fields, and other astrophysical observations, remains to be further explored.

The hypothesis that classical spacetime emerges from quantum meta-spacetime is also applied, within the same theoretical framework, to solving long standing problems in QM. It makes it possible for removing many of the ad hoc, yet fundamental and century old assumptions in the interpretation of measurements in QM needed before, rendering them, instead, logical predictions of the current theory that are potentially computable quantitatively in mathematics starting from first principles of the theory. These predictions offer finer grained and quantitative description of the measurement processes in which the metric of emergent spacetime plays an important role that are in principle experimentally testable. The term and mechanism for quantum decoherence is put forth to extend the domain of studies and applications of quantum coherence and entanglement phenomena beyond the contemporary highly restricted area of ultra low temperatures, which opens up new arena for the study of quantum entanglement catalyzed single step many particle reactions in (quantum) chemistry and biology.

The concept of emergent spacetime is also applied to creating a theory on the physical origin of biological life. The “hard problem of consciousness” in philosophy is solved, recursively, by applying the newly created conceptual framework (and the accommodating language) for spacetime, base upon known physical laws and facts. According to the new theory, a reductionist’s primitive or “atom” for life is found to be the ε -elements, identifiable with the DNA molecules, which acquire their anchor of time due to favorable environmental physical and chemical conditions. It is believed that the existence of an anchor of time that transcends all layers of consciousness is a pre-condition for the emergence of protoconsciousness that initiates the Darwinian evolution processes for life.

It is found that the Universe is neutral not only in the charges of the Standard Model of particle physics (Sec. [XI D](#)) but also in the “charge of gravity” of the current theory²⁶, namely the mass when one goes beyond the cosmic event horizon (Sec. [IV E](#)).

In certain sense, the current theory is also about observers, subjective (conscious beings) or objective (apparatus), ones which are part of the observed system and the fundamental nature of observation.

²⁶ Since energy is not conserved in GR, such kind of statement is hard to reach there.

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