On a Quantum Theory of Emergent Spacetime and Gravity

S. Ying[1, *]

[1] *CryptoGateway Software Inc*
Vancouver, BC, Canada

A theory for the emergence of spacetime and gravity 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 constraint 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. 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 a prediction rather than an additional external assumption.

* 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

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

$$R = g^{\mu\nu}R_{\mu\nu} \tag{2}$$

$$\kappa = \frac{8\pi G}{c^4} \tag{3}$$

with G the Newton's gravitation constant, c the speed of causal front (namely the speed of macroscopic light[1] in the absolute vacuum, see Ref. [13]), 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 can 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 current 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. Göde) 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

$$m_P \approx 10^{19} m_B, \tag{4}$$

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.

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[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

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

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.

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

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

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

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 amount 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 effects 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 [13]), 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 one 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

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

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

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

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

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

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

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

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 path[2]!

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 a quantum field theory (QFT) represents a many (infinite) body 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 that it is the amplitude of an excitation coordinated by the point that is physical. Therefore that gravity, if any, should 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 treated as a virtual spacetime point and the gravity, if any, is best to be regarded as an emergent classical phenomena 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 said 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.

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.

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 constants 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 the QFT

$$\Omega \stackrel{\text{def}}{=} \{|S\rangle | \, S \in \mathcal{F}\} \tag{12}$$

that corresponds to a classically localizable[3] 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 $[c\hat{t}, \hat{x}, \hat{y}, \hat{z}]$ and the said entity in a pre-selected reference frame is the set of expectation values

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

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

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 hyper surface 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 $[c\overline{t}, \overline{x}, \overline{y}, \overline{z}]$ 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 $[c\overline{t}, \overline{x}, \overline{y}, \overline{z}]$, 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, see Ref.[13].

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" [4], quantum fluctuation effects that persists even in the thermodynamical limit. See Refs. [7] section II.D and [6, 8] 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, the effects of finite size on observables of a relativistic system need to be carefully investigated to see if there are

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[3] Photons, which is massless and moving on the light cones, are not localizable in the classical limit of $n_\gamma \to \infty$, where n_γ is the number of photons in a random or thermal assemble. It is expected that they converges to least action classical EM waves, governed by suitably adapted Maxwell's equations to the curved emergent spacetime of the current theory, from all possible set of quantum ones, when the assemble average is taken.

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

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. [7])

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

where $\hbar$ is the Planck constant which is one in the natural unit, $\mathbf{J} = \{J_1, J_2, \ldots, J_n\}$ are a collection of external probing fields coupled to the corresponding boson fields $\mathbf{f} = \{f_1, f_2, \ldots, f_n\}$, $\mathcal{L}_B[f]$ is the Lagrangian density for the boson fields $\mathbf{J}$, and η_v, $\overline{\eta}_v$ are external probing Grassmann fields coupled to the fermion fields $\overline{\Psi}$, Ψ. Only one fermion field is shown explicitly here to simplify the notation, there can be more in general. $W[J,\overline{\eta}_v,\eta_v]$ 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. [11, 13]. $\hbar$ 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 $[\eta_v, \overline{\eta}_v]$ 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. [7] section II.D and [6, 8]. In such a case, the propagator for an fermionic quasi–particle can be written as

$$S_F = \frac{i}{\not{p} + \not{\mu} O_3 - \Sigma + i\epsilon}. \tag{15}$$

with O_3 the third of the Pauli matrices, $\not{p}$ the Dirac 4–momentum operator and Σ the "mass" matrix in the 8–component representation for fermions, which is 2DCTR [13] for spin 1/2 particles, has a generic form [7, 13]:

$$\Sigma = \begin{pmatrix} \sigma & D \\ \overline{D} & -\sigma \end{pmatrix} \tag{16}$$

Here, μ^α is the statistical gauge field introduced in [7, 12], 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 $\overline{D}$ 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. [9].

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 [3, 5, 7]

$$D = \gamma^5 \mathcal{A}_c \chi^c, \qquad \overline{D} = \gamma^5 \mathcal{A}^c \overline{\chi}_c \tag{17}$$

with χ^c and $\overline{\chi}_c$ the pair of order parameters for the scalar color superconducting phase and $(\chi^c)^\dagger = -\overline{\chi}_c$. If the system is in a state of vector superconducting phase [4, 5]

$$D = -\phi^c_\mu \gamma^\mu \gamma^5 \mathcal{A}_c, \qquad \overline{D} = \overline{\phi^\mu_c} \gamma_\mu \gamma^5 \mathcal{A}^c \tag{18}$$

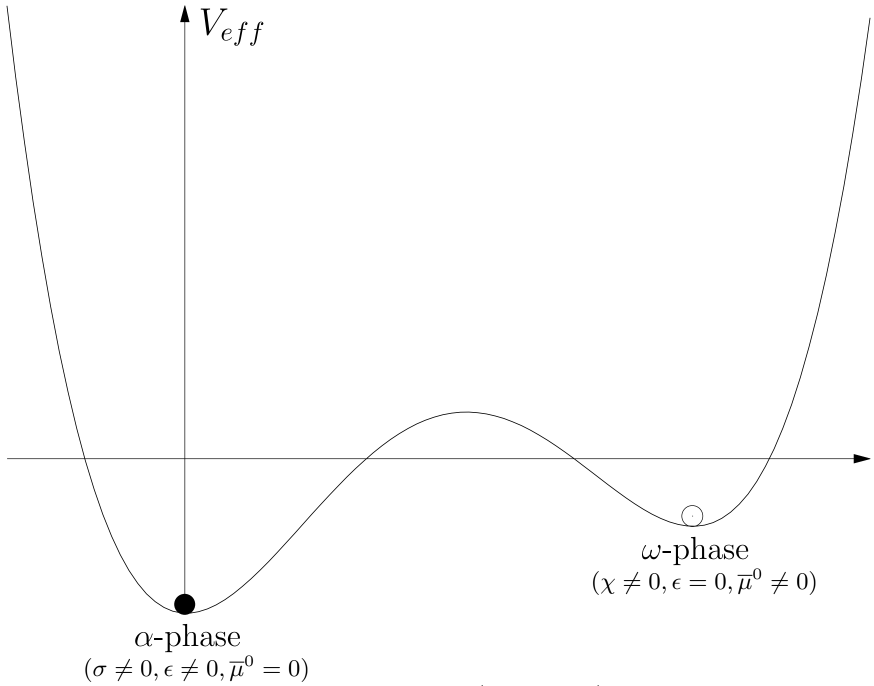

FIG. 1. An illustrative plot of a cross section of the ground state (or vacuum) effective potential V_{eff} across two stable points in its order parameters space. For the light quark system of strong interaction, model studies predicts that there can be two kinds of phases in general: one of them is 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^c_μ and $\overline{\phi^\mu_c}$ the pair of order parameters for the vector color superconducting phase. $\mathcal{A}_c$ is an antisymmetric matrix and $\mathcal{A}_c = -\mathcal{A}^c$.

There is an additional non-perturbative parameter called statistical blocking parameter ϵ, which is introduced in Refs. [7, 8, 10], 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. [7]), 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 $\overline{n} = 0$. Instead it is at a finite value for localized chemical potential (see [7])

$$\mu \stackrel{\text{def}}{=} \overline{\mu}^0, \tag{19}$$

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 hyper surfaces, forming causal unconnected regions of matter ($\mu > 0$) and anti–matter ($\mu < 0$). It constitutes a natural mechanism for spontaneous baryogenesis [3], 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–phase[5] 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 conducted 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 [9] 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 $\overline{\mu}^\alpha$ of the statistical gauge field, namely the

$$\mu'^\alpha = \mu^\alpha - \overline{\mu}^\alpha \tag{20}$$

field (see Refs. [7, 12]), together with the EM, generates EM like hybrid massless excitations that acts **only** between baryonic and leptonic subsystems [9]. 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

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

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

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

$$\mathcal{A}[\Psi] = \frac{1}{2}\int d^4x \overline{\Psi}\left(i\partial\!\!\!/ + \mu\!\!\!/ O_3 - \Sigma\right)\Psi + \ldots . \tag{23}$$

It can be decomposed into

$$\mathcal{A} = \mathcal{A}_0 + \sum_{v\in\mathcal{V}} \mathcal{A}_v \tag{24}$$

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

$$\mathcal{A}_i \sim \hbar \qquad (i = 0\; or\; i \in v)\,. \tag{25}$$

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[5] 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

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

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

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

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

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

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

for a sufficiently large system. Here

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

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:

$$\Delta\varepsilon_v = \Delta\varepsilon_v^0\,(1+\eta_v) \tag{31}$$

$$|p_v\rangle = c_v^0\,|e_v\rangle + \delta c_v\,|l_v\rangle \tag{32}$$

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

$$\eta_v = \delta\varepsilon_v/\Delta\varepsilon_v^0, \tag{33}$$

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

$$|c_v^0| \sim \lambda, \tag{34}$$

$$|\delta c_v| \sim -|d_v|\eta_v + \mathcal{O}\left(\eta_v^2\right) + \ldots \tag{35}$$

where

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

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 $1/\sqrt{N_C}$. 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

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

where $Z = |C_0|^2$. Only the interference terms between quasi particle states around the true ground state and the locale 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 $\overline{O}$ 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 $\hat{O} = \hat{t}_m$. According to Eq. 37, one gets,

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

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

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

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

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

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

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 $\delta\overline{O}_{loc}$ is the contributions from false ground states due to matter concentration and $\delta\overline{O}_{vac}$ is the one from energy density difference between the true ground state and the false one(s). All dependencies of $\overline{O}$ 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

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

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

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. [11]) is using the 2DCTR representation of quantum fields [13]:

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

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

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–hyper surface at t_m on which the 3–integration is performed.

For a single particle state

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

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

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:

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

$$x^i[s,t_m] = \overline{\mathbf{x}}^i[s,t_m],\ \{\, i=1,2,3\,\}. \tag{49}$$

As it is discussed in Ref. [13] 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 [11])

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

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

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

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

Here $p^\alpha_\pm = \{p^0 \pm \mu,\ \mathbf{p}\}$, 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 $\overline{\chi}_c$

$$\epsilon_{\mathbf{p}} = \pm\left(E_{\mathbf{p}} \mp \mu\right) \tag{53}$$

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

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

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

$$\epsilon_{\mathbf{p}} = \sqrt{\mathbf{p}^2+\sigma^2} \tag{55}$$

$$U = \begin{pmatrix} u_1 \\ 0 \end{pmatrix} \quad \mathit{or} \quad \begin{pmatrix} 0 \\ u_2 \end{pmatrix} \tag{56}$$

$$\epsilon_{\mathbf{p}} = -\sqrt{\mathbf{p}^2+\sigma^2} \tag{57}$$

$$V = \begin{pmatrix} v_1 \\ 0 \end{pmatrix} \quad \mathit{or} \quad \begin{pmatrix} 0 \\ v_2 \end{pmatrix} \tag{58}$$

$(u_1,\, u_2)$ 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 $\overline{\chi}_c$, then there are four solutions

$$\epsilon_{\mathbf{p}} = \pm|\mathbf{p}| \mp \mu \tag{59}$$

and solution is also of the form

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

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. [11]. The energy of the rest of the two quarks with different colors are

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

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

$$U = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \tag{62}$$

with u_1 related to u_2

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

$$\gamma^5 \mathcal{A}^c \overline{\chi}_c u_1 + \not{p}_- u_2 = 0. \tag{64}$$

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

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

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 $\mu \to 0$ 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

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

where $\delta\overline{t}_0$ is the emergent time difference when $N_C \to \infty$, 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

$$\sqrt{g^{00}} = Z + \frac{\delta\overline{t}_{loc} + \delta\overline{t}_{vac}}{\delta\overline{t}_0} \tag{67}$$

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

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

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,

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

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

$$\sqrt{g^{00}} < 1, \tag{70}$$

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

$$\overline{U}_0(\mathbf{p})U_0(\mathbf{p} \ll \overline{U}_v(\mathbf{p})U_v(\mathbf{p}) \tag{71}$$

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

$$\sqrt{g^{00}} > 1, \tag{72}$$

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

C. Emergent spacetime acceleration and cosmological constant

According to Ref.[11], quantum fields in the 2DCTR representation transforms as

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

in an accelerated coordinate system with $\widehat{\phi}_{1,2}$ 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

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

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

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

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

with the cosmological constant given by

$$\Lambda = \frac{\lambda^2 c_\Lambda}{N_B} \tag{76}$$

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

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

$\delta\varepsilon_v$ is the deformation of the energy density difference $\Delta\varepsilon_v$ in the presence of matter which can be computed, at lease in principle, from the underlying dynamics of the system using a real time relativistic quantum field theory at finite density and temperature [11] where the energy density ε can be identified with the value of one of the minima of the effective potential V_{eff} (see Ref. [7, 8] 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 Ref. [7, 8] 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,

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

where a_1 is the (functional) Taylor expansion coefficient of $f[n_B]$ at $f[0]$. a_1 is not zero since is related to the differences in the discontinuous finite jump in μ across the $n_B = 0$ surface. This is because either the present 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 cress section), which is relevant to the current epoch of the universe.

However around a finite background baryon density, one has

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

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

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

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

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

where

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

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

Note that, from the formulation of finite density and temperature QFT (see [11]), $\delta\varepsilon_v$ 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 that 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

$$M^{\alpha\beta} = \rho_B u^\alpha u^\beta + U^{\alpha\beta} \tag{83}$$

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

$$U^{\alpha\beta} = aT^{\alpha\beta} + bL^{\alpha\beta}, \tag{84}$$

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, $\overline{n}_B \approx 0$, where $\overline{n}_B$ is the background baryon number density. The minimum of V_{eff} along the constant μ (and therefore $\overline{n}_B$) 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 $\pm\overline{n}_B$), see Ref. [7, 12]. 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 $\overline{n}_B \approx 0$ 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 its ability to absorb the longitudinal massless Goldstone boson of the spontaneous local $U(1)$ symmetry breaking (the Higgs mechanism, see Ref. [9]), 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 $\delta\varepsilon_v$ 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 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

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

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

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 leptonic

As it is shown in Ref. [9], 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. [7]), there are topological constraints, namely

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

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

$$\boldsymbol{\mu} \propto \frac{1}{r_m} \tag{88}$$

where r_m is the radius of $\partial\Sigma_m$ when it is a circle with it 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

$$\delta\varepsilon_v \propto -|\boldsymbol{\mu}|. \tag{89}$$

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

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

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

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

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

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

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

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

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

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

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

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 momentum' (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 onw 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 $\overline{n}_B = 0$, see Ref. [7, 12]. Decreasing $\overline{n}_B$ 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, $\overline{n}_B > 0$) and for anti-baryons in anti-baryon concentrated regions (namely, $\overline{n}_B < 0$). Also for anti-baryons in baryon concentrated regions and baryons in anti-baryon concentrated regions, there is gravity.

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 quantum field theory given in Ref. [11], 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 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 a 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 (and vice versa), which could be small or irrelevant, but also on the metric of it, which render the correct form of laws of thermodynamics in the emergent spacetime 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

$$S = k_B \ln W_m \tag{95}$$

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 increase function of the spatial volume of the microscopic quantum system in the meta–spacetime, e.g. for free particles,

$$W_m \propto V_m^N \tag{96}$$

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

$$V = \zeta_m^3 V_m = \zeta^3 V_0 \tag{97}$$

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. 95 can be written as

$$S = k_B \ln W \left(\frac{V}{\zeta^3}\right) + \dots \tag{98}$$

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 region included by the Hubble event horizon, does not alter its entropy, energy, etc., in 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. 96. This is quite different from the old views, in which entropy can be counter intuitively generated from 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 Zwichy'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 its central quantum vortices (mostly) stripped away during intergalactic interaction according to the current theory.

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 $\kappa\, M$ of Eq. 81 are proportional to each other, independent of the galaxy under investigation, namely

$$\frac{\kappa_L\, V}{\kappa\, M} = const \tag{99}$$

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.

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 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.

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. [9]). This condition is not satisfied in the Standard Model since quarks carry fractional charges and leptons have integral charges. It was shown in Ref. [9] 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 (see below) in the ocean of quantum liquid of superfluid and turbulence of the false ground state, pre- "big bang" remnants, etc..

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 vortices[6] 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. III B, 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 amd 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 simulation of 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 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.

[6] 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-supper conducting phase.

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. [9]. If the charge of a light quarks is written as

$$q = q_s + \sigma_3 q_v \tag{100}$$

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 charged[7] 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. [9]). 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 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)[8].

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

[7] Or positively charged for antimatter dominated universes.

[8] 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.

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 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 enough far apart. 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 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 that 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

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 the one predicted Planck's blackbody radiation. The observed surface features of the Sun also indicate its non gaseous, condense matter behavior when the possibility of plasma state is excluded (Unzicker). The only 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 $32.938K$, can a liquid state of hydrogen atoms be reached at temperature above $6000K$ near the surface solely due to the gravitational pressure requires new physical mechanisms which are yet to be discovered.

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 be 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 a factor of $1/\sqrt{N_B}$ reduced. 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**[9] plasma like behavior without the need of any ad hoc mechanism and fittings. 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.

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 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 the current theory in which the 2DCTR representation is used (see Ref. [11] 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 the 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 lease 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 effective electric dipole moments 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.

Also 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 interactions of the same nature which are those in addition to the 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

[9] 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.

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 obits 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 frame dragging effects 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.

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 and UHZ1 in the early universe, both 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 reduce 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.

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 that is 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 plasm 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 ($\sim 10^{38}$) 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 or 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 is another problem since it is not energetically favored and stable state.

The effective gravitational plasma generated by the GECPs and celestial scale EM like behavior generated by 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 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.

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.

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. 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" needs no more 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 "baryongenesis 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. [3]. 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 meta-space-like hyper surface during the phase transition. The "collapse" chooses a corresponding matter or anti–matter region for a future observer, which can be anything smaller than the whole that has the rational capabilities to define what itself is made of, e.g. a human being, 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. [7, 8, 10] 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. 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 metaphysical belief than a scientific requirement.

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 cosmic microwave background (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 because they are massive. Structures down to nuclear physical length scale, if any, are also dissolved into quark matter and approaches an eventually uniform and isotropic 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 happen[10].

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. The views of an outsider observer of the Universe is perhaps inaccessible to mere earthlings, but the very fact that internal rational observers 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 info–entropy in the emergent spacetime, a quantum state 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 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.

In the following sub-sections, the second possibility is explored further.

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

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. [9] 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 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. 98), 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.

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 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 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 "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 charge 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 overcame 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 down 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 nucleus gases dominated by neutron $\rightarrow$ proton + e or hydrogen molecule 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 away[11], 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

[11] 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 the studies of GR, has. Nevertheless the current mechanism has a underlying support from microscopic quantum reality.

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?

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. 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 quarks in the Standard Model of physics using a relativistic real time finite density and temperature QFT, which is constructed to be consistent with special relativity, 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 quantum mechanics 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.

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 microscopic quantum ones having action of a single quantum, inside a logically consistent and parameter reduced (or at least free) framework. A satisfactory match with a selected set of observations in astronomy or cosmology is found on an order of magnitude 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.

Namely, 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.

XIII. FINAL REMARKS

The introduction of meta–spacetime has other advantages since it provides a new conceptual framework for constructing solutions to long standing problems in physics most of which are not directly 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 particle 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 mate–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 integral using least action principle, just like what it is done in the current study. 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 action that is $\sim \hbar$) 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 distortions of their original states in the apparatus, leading to a scale down of observed transition time

$$\delta t \sim \frac{1}{\gamma^{-1} n + 1} \delta t_m, \tag{101}$$

where[12] 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

$$\delta t \xrightarrow[n\to\infty]{} 0 \tag{102}$$

for any massive particles.

[12] 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. 101 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

$$\delta t = \delta t_m$$

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

$$\delta r \leq c\delta t \tag{103}$$

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 particle 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 measurements using an assemble of such a particle at different emergent time will trace out 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. 102 does not hold since $\gamma^{-1} = 0$ for it. Therefore, according to Eq. 103, a quantum of light does not behave like a particle since a "particle" is supposed to be localizable.

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 identical particles as a function of emergent spacetime are related to the amplitude of wave function $|\psi|^2$ for a quantum particle in the meta–spacetime. In a measurement using macroscopic apparatus, together with proper state transition represented by a abrupt change in the wave function at recording emergent times, the emergent spatial 3–D hyper–surface on which statistical distribution is defined could also be distorted in probability measure (of the meta– to emergent spacetime mapping) according to the principle of stable action[13] for a full description an observation of an assemble of identical quantum 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 particle, 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 spacetimes and the interpretation of measurements in QM using the "classical" emergent one, the difference in the behaviors of the two is a predictable 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

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[13] Emergent gravity is derived using the same principle for celestial entities in Sec. IV.

atoms into two distinct and fixed dots, 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 particle 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 introding 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.

B. Weak interaction, chirality and neutrinos

Retro–causality in the meta–spacetime was introduced in Refs. [11, 13] 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. [13]). 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 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 $n \to p + e^- + \overline{\nu}_e$ β–decay process after the "big bang". Should there be any of the dominating weak interaction effects of primordial chiralities 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 in any "charge" contained in the Standard Model at celestial scales under the current theory.

It should be mentioned that the emergent causality in the emergent spacetime is governed by the second law of thermodynamics, namely, by the direction of an increase of entropy. The counterintuitive retro–causalities in meta–time are 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.

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 sourth pole using radio antenna on high attitude baloons that point to the center of the Earch 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 matterial 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 said 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. [13]. The "unexpected" events are manifestations of the existence of retro–causality in the meta–spacetime.

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 persued.

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 oppsite 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 thier conterpart 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 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. [11]. 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.

C. 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. [13], 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 joints, or put it in another way, it also requires that an accelerating observer in an 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.

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