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Why the Energy Density of the Universe Is Lower and Upper-Bounded? Relaxing the Need for the Cosmological Constant

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Abstract

Recently, it was argued that the energy density of the supranuclear dense matter inside the cores of massive neutron stars must have reached the $\mathcal{E}^{uni}_{max}$, beyond which supranuclear dense matter becomes incompressible entropy-free gluon-quark superfluid. As this matter is also confined and embedded in flat spacetime, it is Lorentz invariant and could be treated as vacuum. The lower bound of matter in the universe may be derived using the following observational constraints: 1) The average energy density of the observable universe is $\langle\mathcal{E}\rangle^{OU} = \mathcal{O}(10^{-9})$ erg/cc, 2) The observable universe is remarkably flat, and 3) the Hubble constant is a slowly decreasing function of cosmic time. Based thereon, I argue that the energy density in nature should be bounded from below by the average density of our vast and flat parent universe, $\langle\rho\rangle^{\infty}$, which is, in turn, comparable to the vacuum energy density $\langle\rho\rangle^{vac}$, and amounts to $\langle\mathcal{E}\rangle^{OU} = \mathcal{O}(10^{-9})$ erg/cc. When the total energy density is measured relative to $\langle\rho\rangle^{vac}$, then both GR and Newtonian field equations may consistently model the gravitational potential of the parent universe without invoking cosmological constants. Relying on the recently proposed unicentric model of the observable universe, UNIMOUN, the big bang must have warped the initially flat spacetime into a curved one, though the expansion of the fireball doomed the excited energy state to diffuse out and return back to the ground energy state that governs the flat spacetime of our vast parent universe.

Keywords

General Relativity, Big Bang, Black Holes, QSOs, Neutron Stars, QCD, Condensed Matter, Incompressibility, Superfluidity, Super-Conductivity

1. Introduction

During the early years of the nineteenth century, the Milky Way, which was perceived as the content of the whole universe, was considered stationary. In 1917, Einstein applied his field equation to model this universe, and as expected, he found out that his cosmic configurations were dynamically unstable [1]. He invoked then a mathematical constant, called the cosmological constant, Λ, to stabilize his matter-dominated universes mathematically, though its physical origin remained unexplained. While today the name has changed into dark energy and recently found to be a slowly varying function of time [2] [3] [4].

Another obstacle was the realization that the field equations, both in GR and Newtonian gravitation, cannot deal with an infinite universe with constant density. To circumvent this problem, Einstein argued that the universe must be spatially finite but temporarily infinite [1].

Since then, many cosmological models have been invented to explain the dynamics of the observable universe, though ΛCDM cosmology, or similar versions are widely accepted as the standard model of cosmology. Nevertheless, several unresolved problems appear to challenge these models, among others are the flatness and coincidence problem, the invoked inflation [5], the origin of dark matter [6], dark energy and the Hubble tension [2] [7].

Very recently, UNIMOUN—The Unicentric Model of the Observable Universe, was proposed as an alternative model with the following arguments [see [4], and the references therein]:

1) Our big bang (BB) happened to occur in our neighbourhood, thereby endowing the universe the observed homogeneity and isotropy.

2) Prior to BB, the embedding spacetime was a tiny fraction of the infinitely large and flat parent universe.

3) The BB explosion triggered a significant deformation of the embedding spacetime, thereby transforming it into a highly excited energy state, but which through rapid expansion is doomed to diffuse out and disappear into the vast parent universe.

4) The energy density of the universe is upper-bounded by the universal critical density ρ_{cr}^{uni}, beyond which matter becomes purely incompressible.

5) Big bangs are neither singular nor invoked events by external forces, but rather, they are common self-sustaining events of our parent universe. The progenitors of BBs are created through the merger of dark energy objects (DEOs, [see [4] [8], and the references therein]): the ultimate phase of cosmologically dead and inactive neutron stars and/or through the growth of "supermassive black holes" on time scales much longer than the age of our observable universe.

6) The progenitors are made up of purely incompressible gluon-quark super-

fluids (SuSu-matter or GQ-condensates), whose material densities equal to ρ_{cr}^{uni}. The incompressibility condition endows these objects giant masses and measurable sizes.

7) Spacetimes embedding incompressible gluon-quark superfluids must be flat, as other topologies would violate the incompressibility and causality conditions.

8) The observed accelerations of high redshift galaxies are consequences of their collisions with the matter from the expanding fireball. With its extraordinary momenta, this matter set the quiet and inactive galaxies into outward accelerating motions (see Figures 5 and 6 in [9]).

9) In UNIMOUN, inflation, dark matter or dark energy are needless.

On the other hand, recently, it was argued that astronomical observations of high redshift galaxies, dark matter-dominated galaxies, the merger of binary neutron stars in GW170817, glitch phenomena in pulsars, cosmic microwave background and experimental data from hadronic colliders might pinpoint the existence of an upper-bound to the energy density in the universe, beyond which supranuclear dense matter with zero entropy becomes purely incompressible [10]. Under these conditions, the natural state of matter is the gluon-quark superfluids embedded by a flat spacetime, though they are confined by powerful tensorial surface tensions that render them invisible to outside observers. The energy state of matter corresponds to zero-point energy and therefore behaves as vacuum. Such fluids are considered to make the cores of massive pulsars and young neutron stars (NSs). The main consequence is that the masses of NSs revealed from observations are underestimated by far.

In this paper, we discuss why the stress-energy tensor (SET) of the normal matter of our expanding universe should converge into the SET of vacuum, which governs energetic of the vast flat parent universe. Also, we show that the field equations can be employed to model the gravitational fields of our infinite and flat universe without invoking a cosmological constant.

2. The Model Equations Governing the Parent Universe

WMAP measurements reveal that the current density in our observable universe is $\langle\rho\rangle^{uni} = \mathcal{O}\left(10^{-30}\right)$ g/cc [11], though this value must decrease as the universe continues to expand. On the other hand, in ΛCDM-cosmologies the vacuum energy density, ρ_{cos}^{vac}, may be obtained from the cosmological and Hubble constants: $\rho_{cos}^{vac} \sim \Lambda_{cos} \sim H_0^2$, which found to coincide with $\langle\rho\rangle^{uni}$ accidentally: hence the origin of the coincidence problem [12] [13] [14].

Invoking the cosmological constant in the field equations gave rise to several unresolved problems in cosmology:

- The spacetime topology of the observable universe is perfectly flat. However, ΛCDM-cosmologies predict the observable universe to expand at an ever-increasing rate: $H \sim \Lambda^2$, thereby giving rise to an unbounded universe.
- Recently revealed Hubble tension implies that H_0 is a slowly varying func-

tion of the cosmic time, which gives rise to a varying ρ^{vac}_{cos}.

- It is not clear why ρ^{vac}_{cos} should coincide with the currently measured value of $\langle\rho\rangle^{uni}_{cos}$ just now?
- Why ρ^{vac}_{cos} differs from those values predicted from QFT by at least 120 orders of magnitudes and whether ρ^{vac}_{cos} should be taken more seriously than ρ^{vac}_{QFT} ?

Another annoying consequence of Λ-cosmology: Vacuum energy, which started dominating the universe only lately, seems now to be capable of increasing the universe's expansion rate indefinitely and reaching infinite expansion speeds. Whether this phenomenon should respect causality or not, the process is thermodynamically inconsistent. One possibility to circumvent these problems is to adopt the scenario of UNIMOUN, in which, accordingly, our observable universe is a tinny fraction of the vast and flat parent universe. The average energy density of the observable universe, $\langle\mathcal{E}\rangle^{OU}$, is bounded from below by the average energy density of the parent universe, $\langle\mathcal{E}\rangle^{\infty}$, which, in turn, is equal to the vacuum energy density, *i.e.*,

$$\langle\mathcal{E}\rangle^{OU} \xrightarrow[Vol(E)\gg E]{T\to 0} \langle\mathcal{E}\rangle^{\infty} \approx \langle\mathcal{E}\rangle^{vac} = const. > 0, \quad (1)$$

where $Vol(E)$ is the Euclidian volume embedding the total energy of normal matter E^{tot}. Following UNIMOUN, BBs are common events in the parent universe, and our observable universe is one of numerous sub-universes. BB-explosions may merely deform the manifold's topology locally, but as they expand, they are doomed to diffuse out and disappear into the flat spacetime of the parent universe.

As was realized by Einstein in 1917: the gravitational field equations are incompatible with an infinitely large and flat universe governed by a constant energy density $\langle\mathcal{E}\rangle^{\infty}$. Here, a trivial or a constant gravitational potential Φ cannot be a solution to the Poisson equation: $\Delta\Phi = \left(4\pi G/c^2\right)\langle\mathcal{E}\rangle^{\infty} = const$.

However, both GR and the Newtonian treatments may be made consistent, if the induced deformation of spacetime due to BB-explosions is measured relative to a spacetime whose topology is determined by vacuum, as follows:

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} = \frac{8\pi G}{c^4}\left(T_{\mu\nu} - T^{vac}_{\mu\nu}\right), \quad (2)$$

where $R, R_{\mu\nu}$ are the Ricci scalar and Ricci tensor. Unlike earlier formulations, the SET, $T_{\mu\nu}$ includes various contributions due to matter, vacuum, etc. However, under normal conditions the contribution of $T^{vac}_{\mu\nu}$ is negligibly small and may be safely ignored. On the other hand, when our observable universe has expanded and its topology settled down to a complete flat spacetime, then both SETs become comparable, and they ought to cancel each other, *i.e.* the RHS of Equation (2) should converge to zero. In this limiting case, the observable universe becomes an indistinguishable part of the parent universe, namely isotropic, homogeneous and flat. Therefore, the Ricci scalar, *R*, and the Ricci tensor, $R_{\mu\nu}$, ought to vanish equally. This convergence is facilitated through the expansion of the universe, during which the locally deformed manifold re-flattens and causes both the energy density, pressure and temperature to decrease:

$$T_{\mu\nu} \xrightarrow[Vol(E)\gg E]{T\to 0} T_{\mu\nu}^{vac} = \langle \mathcal{E} \rangle^{vac} \eta_{\mu\nu}, \tag{3}$$

where we implicitly replaced $g_{\mu\nu}$ by $\eta_{\mu\nu}$, as the metric governing our vast parent universe must be a Minkowski-type one. In the Newtonian regime, this yields a constant gravitational potential. Here the Christoffel symbols $\Gamma^{\mu}_{\nu\sigma}$, are relatively small, $R_{00} \to -1/2\Delta\Phi$ and T_{00} on the RHS of 2 becomes the dominant term. Under these conditions, Equation (2) reduces to:

$$\Delta\Phi = \frac{4\pi G}{c^2}\left(\langle \mathcal{E} \rangle - \langle \mathcal{E} \rangle^{vac}\right) \xrightarrow[Vol(E)\gg E]{T\to 0} \approx 0. \tag{4}$$

Hence the solution Φ may be either a const. or zero, though the precise value of Φ is not really relevant.

We note that in the reference frame in which the universe is isotropic, the STE reads:

$$T_{\mu\nu}^{tot} = \begin{pmatrix} \mathcal{E} & 0 & 0 & 0 \\ 0 & p & 0 & 0 \\ 0 & 0 & p & 0 \\ 0 & 0 & 0 & p \end{pmatrix}, \tag{5}$$

where p is the pressure and $\mathcal{E}$ is the total energy density, which includes all types of energy densities, and in particular due to vacuum:

$$\mathcal{E}^{tot} = \mathcal{E}^{nm} + \mathcal{E}^{vac} + \cdots, \text{ where } \mathcal{E}^{vac} = \mathcal{E}^{vac}_{ZPE} + \mathcal{E}^{vac}_{GQC} + \mathcal{E}^{vac}_{Higgs} + \cdots \tag{6}$$

The subscripts *nm*, *ZPE*, *GQC* and *Higgs* correspond to normal matter, zero-point energy, gluon-quark condensate, Higgs field, etc., respectively.

During the expansion of the universe, the density and temperature must have decreased by at least 45 and 32 orders of magnitude, respectively. This tendency is expected to continue as the universe expands until the lower limit of $\mathcal{E}^{tot}$ is reached. While both $\{T, p\}$ of our observable universe converge to zero, the energy density must still be bounded from below by the ground energy state characterizing the matter content of the parent universe. In this phase:

$$\mathcal{E}^{tot} = \langle \mathcal{E} \rangle^{OU} \approx \mathcal{E}^{vac} \approx \mathcal{E}^{vac}_{ZPE} \approx \mathcal{E}^{vac}_{GQC} \approx \mathcal{E}^{vac}_{Higgs} + \cdots, \tag{7}$$

where $\mathcal{E}^{vac}_{GQC}$ also includes the contribution due to dark energy objects (DEOs), *i.e.* the ultimate phase of dead and inactive massive NSs.

Recalling that under normal astrophysical conditions, the total pressure is positive and upper-bounded by the energy density, *i.e.* $0 \le p^{tot} \le \mathcal{E}^{tot}$, we may assume that this correlation would still hold all the way down to the lower limit, where $\mathcal{E}^{tot} \approx \langle \mathcal{E} \rangle^{\infty}$ and:

$$p^{tot} = \sum_i p_i \xrightarrow[|p_i|\ll \mathcal{E}]{T\to 0} 0. \tag{8}$$

Here p_i is a partial contribution to the pressure, such as from normal matter, vacuum etc. Note that $p^{tot} = 0$ for incompressible GQCs inside massive

NSs [15] [16]. Based thereon, we conclude that the steady expansion of our universe would foster the convergence of the SET as follows:

$$T_{\mu\nu}^{tot} = \begin{pmatrix} \mathcal{E} & 0 & 0 & 0 \\ 0 & p & 0 & 0 \\ 0 & 0 & p & 0 \\ 0 & 0 & 0 & p \end{pmatrix} \xrightarrow[\varepsilon = \frac{p}{\mathcal{E}} \ll 1]{T \to 0} T_{\mu\nu}^{vac} = \langle \mathcal{E} \rangle_{min}^{uni} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \varepsilon & 0 & 0 \\ 0 & 0 & \varepsilon & 0 \\ 0 & 0 & 0 & \varepsilon \end{pmatrix}. \tag{9}$$

Astrophysical and Cosmological Amplification

The glitches are well-studied phenomena of pulsars, and they may be used to study gravity-entropy connections and dynamics of vacuum [17] [18]. Pulsars are considered to be born with embryonic cores that are made of incompressible supranuclear dense superfluids or equivalently of gluon-quark condensates [19]. As pulsars evolve on cosmic times, the enclosed cores ought to grow in mass and dimension (**Figure 1**). Their growths proceed discretely according to the Onsager-Feynman analysis of superfluidity [20] [21]. These discrete transitions have been identified as prompt spin-up events that were found to accompany their cosmic evolution of pulsars. Once the difference of the rotational frequencies between the core and the ambient compressible and dissipative medium has exceeded a critical value, *i.e.* $\Delta\Omega = \Omega_{core} - \Omega_{pulsar}^{obs} \geq \Omega_{cr}$, then the core undergoes a prompt transition into the next lower energy state, thereby ejecting a certain amount of energy into the ambient medium, where it set to diffuse throughout the entire shell, triggering herewith the observed spin up.

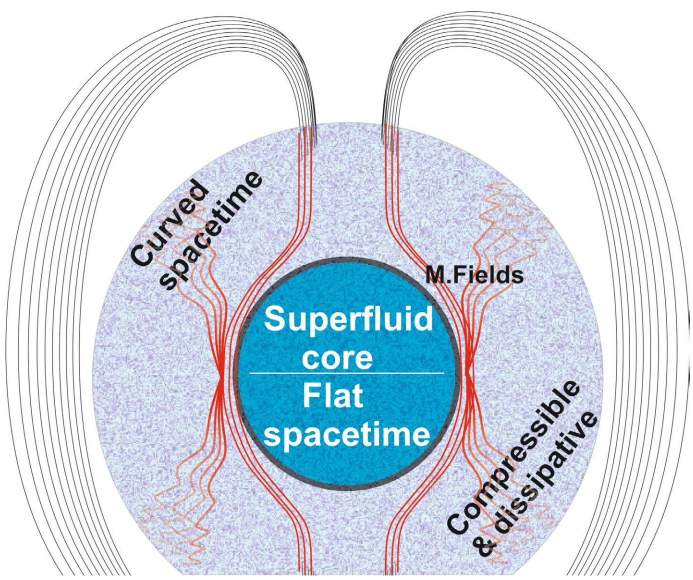

Figure 1. A schematic description of the internal structure of a massive pulsar: the core, which is embedded in flat spacetime, is made of an incompressible supranuclear dense gluon-quark superfluid. The ambient medium is a compressible and dissipative medium embedded in curved spacetime. The dynamo-action is believed to operate in the geometrically thin boundary layer between these two regions, where ejected energy starts diffusing outwards throughout the entire shell.

Following [16], it was argued that pulsars undergo billions of glitches during their luminous lifetime before they turn into invisible dark energy objects: the ultimate phase of dead and inactive NSs. Unlike BHs, NSs are in hydrostatic equilibrium and therefore, inside these objects, there are neither particles nor observers that could accelerate their relative motions to generate thermal baths or induce Hawking radiation as predicated by the Unruh, and Hawking [22] [23]. Moreover, in the absence of tensorial surface tension, the force balance normal to the interface between the gluon-quark-superfluid core and the ambient medium can be found using the TOV equation (**Figure 1**):

$$\frac{\mathrm{d}P}{\mathrm{d}r} = \mathcal{E}a = -\mathcal{E}\frac{GM(r)}{c^4 r^2}\left[\frac{(1+p/\mathcal{E})\left(1+\left(4\pi r^3 p/M(r)\right)\right)}{1-r_s/r}\right] \tag{10}$$

where $a, M(r), r_s$ denote the acceleration, the enclosed mass and the corresponding Schwarzschild radius, respectively.

The sound speed inside the supranuclear dense GQ-superfluid (GQ-superfluids) is of the order of the speed of light and the width of the boundary layer (BL) between the core and the ambient medium is predicated to be of order the width of the confining membrane, which is of order the Planck length scale, ℓ_p. This yields $a \approx c^2/\ell_P \approx 10^{53}\ \mathrm{cm/s^2}$, which is an unreasonably high value, as, according to the Unruh effect, this would induce thermal baths with temperatures of order 10^{34} K. Consequently, the force-balance normal to the interface enclosing the GQ-superfluid core should be ruled out.

Also, as BLs are generally highly dissipative regions, they are unsuited for storing the deposited information from the core in bits-format in accord with the holographic principle [24] [25]. Here all types of ejected energies, including entropy, would diffuse out throughout the entire ambient medium, rendering the process irreversible and the reconstruction of information impossible. The process includes annihilating old and creating new viscous BLs, whose spatial and temporal variations evolve sequentially as dictated by the Onsager-Feynman equation of superfluidity.

Similar to the bag model of gluon-quark plasma in QCD, the work needed for confining the gluon-quark-superfluid inside the core should be proportional to the surface area of the core:

$$\mathrm{d}W = \vec{\sigma}\cdot\mathrm{d}\mathbf{A} = \sigma_0\left(\frac{\mathbf{n}}{\nabla\cdot\mathbf{n}}\right)\mathrm{d}\mathbf{A}, \tag{11}$$

where σ_0 and $\mathbf{n}$ are the surface tension coefficient and the normal unit vector to the surface $\mathbf{A}$, respectively. Recalling that the confining energy of the GQ-cloud inside single baryons is approximately one-third of its rest and that $\nabla\cdot\mathbf{n} = 2/R$ for spheres, we may then set the confining energy of the incompressible GQ-superfluids, in general, to be upper-limited by one-third the core's rest energy $E = M_{core}c^2$. In this case, we obtain a radius-independent value for the coefficient: $\sigma_0 = 2\times10^{20}\rho$, which is of order 1, 10^{56}, 10^{80} GeV for a single isolated baryon, DEO of $1\times M_\odot$ and the progenitor of the BB, respectively.

Thus the formation of macroscopic incompressible GQ-superfluid cores inside massive NSs requires an extraordinarily powerful surface tension to confine the GQ-condensates and keep them hidden from outside observers. Due to the incompressibility condition, the enclosed GQ-superfluid is homogeneous and isotropic, and therefore the SET should have the following form:

$$T_{\mu\nu}^{GQC} = \frac{8\pi G}{c^4} \mathcal{E}_{max}^{Uni} g_{\mu\nu}^{GQC}, \tag{12}$$

which coincides with the usual form of the SET of vacuum.

To study the amplification of this scenario in cosmology, we propose the following "Gedanken-" experiment: Assume the observable universe is a tinny fraction of the vast flat parent universe, which is isotropic and homogeneous (**Figure 2**). The parent universe consists of all types of astrophysical objects, gas clouds and galaxies etc., that are uniformly distributed with an average density ρ^{∞}.

Recalling that the BB-progenitor is made of a GQ-condensate embedded in a flat manifold that was a tinny fraction of the parent universe, then the BB-explosion has merely warped the manifold and set it into an expansion mode. The effect of expansion here is to re-flatten the curvature and alter its thermodynamical conditions, so to match those of the parent universe. However, as the observable universe is revealed to be extraordinarily flat, we conclude that the current densities of the observable universe and the parent universe are indeed comparable, *i.e.* $\rho^{OU} \approx \rho^{\infty} \approx \mathcal{O}\left(10^{-30}\right)$ g/cc, which in turn comparable to the ρ^{vac}.

Let us further assume that at a certain instance of time, we empty the tinny region of the parent universe, $\mathcal{D}$, out of all types of matter abruptly. This action is predicted to have no consequence whatsoever on the energetics inside $\mathcal{D}$, as removing matter will be instantly replaced by vacuum. However, wave-matter duality combined with unitarity ensures that the corresponding information about the system before the removal of matter is not lost but even extractable. In the present case, this information should be optimally encoded on the surface $\partial\mathcal{D}$ in bit-like format, each occupying a Planck-area ℓ_p^2, to yield a total number $N = A/\ell_p^2$ bits that are stored in a δ-like function on $\partial\mathcal{D}$.

Associating these information with entropy [26], S, and using the first law of

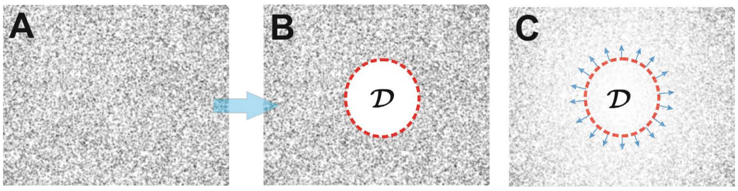

Figure 2. A schematic description of the infinite flat, isotropic and homogeneous universe (A). In panel (B), a spherical region of the volume D is removed abruptly, whereas, in panel (C), the region D is replaced by a fireball, from which ultra-relativistic particles are set to propagate throughout the surrounding vacuum.

thermodynamics, we obtain:

$$\mathrm{d}S = \frac{\mathrm{d}E}{T} \approx \frac{c^2}{T}\mathrm{d}M \xrightarrow[T\to 0]{} \infty, \quad (13)$$

where M denotes the constant mass of matter removed. This divergent behaviour of entropy indicates that under here-given conditions, the process is non-thermal due to the absence of appropriate mechanisms that could lead to effective thermal processes. The removal of matter here would fail to create an inward-accelerating front, rendering the Unruh effect ineffective.

On the other hand, the vacuum energy density in ΛCDM-cosmologies is determined from the correlation $\rho^{vac}_{cos} \sim \Lambda_{cos} \sim H_0^2$. However, the recently revealed Hubble tension shows that H_0, is not constant, but it is a slowly varying function of cosmic time: it increases from 67.5 ± 0.5 km/s/Mpc in the early universe 73.5 ± 1.0 km/s/Mpc in late times. Hence ρ^{vac} is not an invariant physical quantity but depends on cosmic time and location.

Let us consider the second possibility, in which the region $\mathcal{D}$ is filled with an expanding fireball, where hadrons are set to thread and penetrate throughout the surrounding vacuum with ultra-relativistic velocities. This situation mimics the moment when the membrane confining the GQ-superfluid of the entire progenitor is removed abruptly. In this case, the gradient of the pressure would accelerate the newly created hadrons into an outward-oriented motion at the rate: $a \approx \Delta V/\Delta t \approx V_s/\delta t_p \approx c/(\ell_p/c) = c^2/\ell_p \approx 10^{53}$ cm/s^2, where V_s and δt_p denote the sound speed and the Planck time, respectively. Hence, for stationary observers inside $\mathcal{D}$, this acceleration of particles is unrealistically high, as according to Unruh effect [23] it is capable of generating thermal baths with temperatures of order $T \sim 10^{-19} a \sim 10^{34}$ K, which is sufficiently powerful to break vacuum's symmetry and set particle creation into operation. This process should be ruled out, as every newly created baryon would generate 10^3 additional baryons in each ℓ_p, *i.e.*, at least 50 times more than necessary to make the universe matter-dominated, thereby changing the topology of spacetime from a flat into a closed one. Moreover, noting that the propagation of the expansion front of spacetime is the fastest, it may alter the ground energy state of vacuum, e.g. maintaining the symmetry between the creation and annihilation of vacuum's virtual particles.

3. Summary & Conclusions

In this paper, I argued that the GR field equations may consistently describe the dynamics of our expanding observable universe as a tinny fraction of our vast and flat parent universe. Based on the UNIMOUN scenario, the BB-progenitor was made of a GQ-condensate embedded in a flat manifold. The subsequent BB-explosion warped the manifold and set it into an expansion mode. The effect of expansion here is to re-flatten the curvature and alter its thermodynamical conditions, so that it can spread, diffuse out and return to the ground energy state, $\langle \mathcal{E} \rangle^{\infty}$, which prevails the parent universe. Yet, after 13.8 Gyr, the observable universe is revealed to be extraordinarily flat, which implies that the excited energy state triggered by the BB, has returned back to the ground energy state of the parent universe (**Figure 3**). However, according to WMAP-measurements: $\langle\mathcal{E}\rangle^{OU} = \mathcal{O}\left(10^{-30}\right)c^2$ g/cc, which means that $\langle\mathcal{E}\rangle^{\infty}$ and therefore both $\langle\mathcal{E}\rangle^{vac}$ are of order $\mathcal{O}\left(10^{-30}\right)c^2$. The vacuum energy density $\langle\mathcal{E}\rangle^{vac}$ may be composed of various components, e.g. zero-point energy, GQ-condensates, Higgs fields and etc. DEOs, which are considered as the relics of old and dead massive NSs, are natural contributors to the cosmological vacuum prevailing the parent universe.

It should be noted that the negative pressure in FLRW-universe mimics the pressure in incompressible fluids in Schwarzschild spacetime: both pressures are thermodynamically inconsistent and violate the Lorentz invariancy. In the former case, the pressure diverges when approaching the cosmic horizon, whereas the latter diverges at the centre, if the Schwarzschild radius exceeds 8/9 the actual radius of the object.

Finally, the analysis presented here raises two additional open questions. Firstly, apart from the coincidence problem, why do the rules of nature choose to set a non-vanishing lower-bound to the energy density in the universe [27] [28]? Secondly, how do the topologies of different spacetimes, e.g., GQ-condensates and cosmological vacuum (**Figure 4**), match each other on the surface of ultra-thin membranes confining GQ-superfluids and keep them hidden from the outside world?

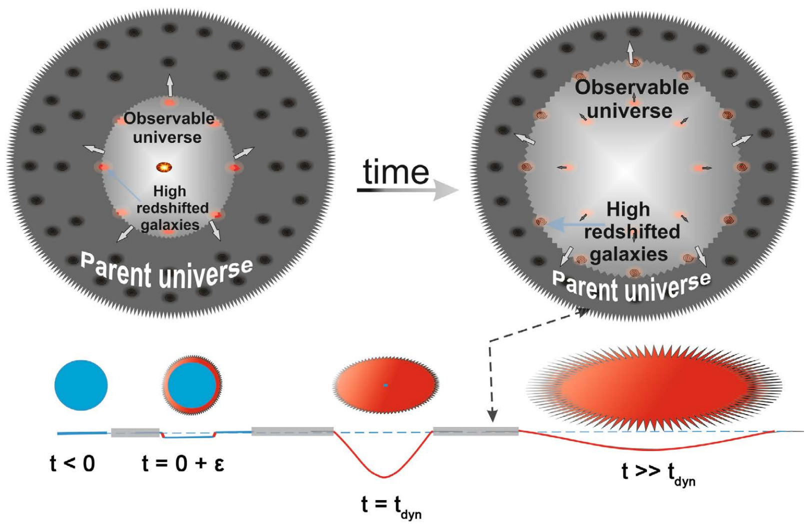

Figure 3. A schematic description of the expansion of the observable universe and its diffusing out into the parent universe (upper panel). In the lower panel we show the evolution of the spacetime embedding the progenitor of the BB: prior to explosion, $t < 0$, the spacetime embedded the progenitor was a tinny fraction of the infinitely large flat parent universe. During the hadronization phase and thereafter, the spacetime started curving and attained its maximum gravitational redshift when hadronization was completed, *i.e.* after one dynamical time scale, t_{dyn}. In the following expansion phases, the spacetime embedded the fireball started flattening to attain the current almost complete flatness.

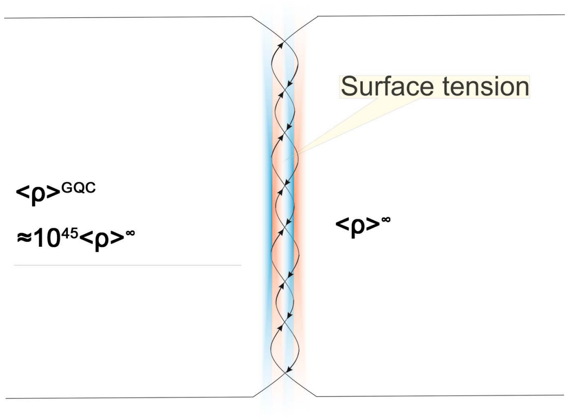

Figure 4. The interaction of the GQ-condensate vacuum with a cosmological vacuum: this configuration is expected to govern the progenitor prior to BB. The structure of spacetime separating these two vacua should also embed the surface tension responsible for confining the GQ-superfluid.

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Conflicts of Interest

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

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