An extended zero-energy hypothesis predicting the existence of negative-energy gravitons and possibly explaining the accelerated expansion of our universe

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Abstract

This paper proposes an extended (**e**) zero-energy hypothesis (**eZEH**) starting from the "classical" speculative zero-energy universe hypothesis (**ZEUH**) (first proposed by physicist Pascual Jordan), which mainly states that the total amount of energy in our universe is exactly zero: its amount of positive energy (in the form of matter and radiation) is exactly canceled out by its negative energy (in the form of gravity). eZEH "pushes" ZEUH "to its quantum limits" and generates some new predictions: (**1**) the existence of multiple types of negative-energy gravitons; (**2**) a strong quantum gravitational field acting at very small subatomic length scales (which is measured by a quantum strong gravitational constant and which is predicted to make Hawking radiation very improbable to form at the first place); (**3**) a (macrocosmic) black hole Casimir effect which may explain the accelerated expansion of our universe etc.

Keywords: the zero-energy universe hypothesis (**ZEUH**); an extended zero-energy hypothesis (**eZEH**); quantum vacuum; negative-energy graviton; quantum strong gravitational constant; Hawking radiation; black hole Casimir effect; accelerated expansion of our universe.

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I. Introduction

The zero-energy universe theory. The zero-energy universe hypothesis (**ZEUH**) states that the total amount of energy in our universe is exactly zero: its amount of positive energy (in the form of matter and radiation) is exactly canceled out by its negative energy (in the form of gravity). ZEUH was first proposed by the mathematical physicist Ernst Pascual Jordan who argued that, in principle, since the positive energy of a star's mass and its (negative energy) gravitational field (**GF**) together may have zero total energy, the energy conservation principle (**ECP**) wouldn't prevent a star being created by starting from a quantum transition of the (quantum) vacuum state [**1**].

ZEU theory (**ZEUT**) was independently proposed by Edward Tryon in 1973 (in the "Nature" journal) who speculated that our universe may have emerged from a large-scale quantum fluctuation of the vacuum energy, resulting in its positive mass-energy being exactly balanced by its negative GF potential energy. ZEUT explains that, during the inflation phase of our universe, energy flows from the (negative energy) GF to the (positive energy) inflation field (**IF**) so that the total (negative) GF-energy decreases (becoming more negative) and the total (positive) IF-energy increases (becoming more positive): however, the respective GF/IF energy densities remain constant and opposite since the region is inflating; consequently, IF explains the cancellation between matter (including radiation) and GF energies on cosmological scales, which is consistent with astronomical observations (concordant with the observable universe being flat) [**2**]. The negative energy GF and the positive energy matter (and radiation) may exactly cancel out only if our universe is completely flat: such a zero-energy flat universe can theoretically last forever. Tryon acknowledged that his ZEUT was inspired by the general relativist Peter Bergmann, who showed (before Tryon) how a universe could come from nothing without contradicting ECP (with the 1st law of thermodynamics being also an ECP version). The first documented mention of ZEUH (1934) (in the context of some possible oscillating models of our universe) belongs to Richard C. Tolman from the California Institute of Technology [**3**]. The well-known physicists Stephen Hawking, Alexei V. Filippenko and Jay M. Pasachoff also appear to agree with ZEUH, at least in part. **Cite no. 1 from Stephen Hawking**: "*The total energy of the universe is exactly zero. The matter in the universe is made out of positive energy. However, the matter is all attracting itself by gravity. Two pieces of matter that are close to each other have less energy than the same two pieces a long way apart, because you have to expend energy to separate them against the gravitational force that is pulling them together. Thus, in a sense, the gravitational field has negative energy. In the case of a universe that is approximately uniform in space, one can show that this negative gravitational energy exactly cancels the positive energy represented by the matter. So the total energy of the universe is zero*." [**4**]. **Cite no. 2 from Stephen Hawking**: "*We might decide that there wasn't any singularity. The point is that the raw material doesn't really have to come from anywhere. When you have strong gravitational fields, they can create matter* [in form of particle-antiparticle pairs: my note]. *It may be that there aren't really any quantities which are constant in time in the universe. The quantity of matter is not constant, because matter can be created or destroyed. But we might say that the energy of the universe would be constant, because when you create matter, you need to use energy. And in a sense the energy of the universe is constant; it is a constant whose value is zero. The positive energy of the matter is exactly balanced by the negative energy of the gravitational field. So the universe can start off with zero energy and still create matter. Obviously, the universe starts off at a certain time. Now you can ask: what sets the universe off. There doesn't really have to be any beginning to the universe. It might be that space and time together are like the surface of the Earth, but with two more dimensions, with degrees of latitude playing the role of time.*" [**5**]. **Cite from Alexei V.**

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Filippenko and Jay M. Pasachoff: "*In the inflationary theory, matter, antimatter, and photons were produced by the energy of the false vacuum, which was released following the phase transition. All of these particles consist of positive energy. This energy, however, is exactly balanced by the negative gravitational energy of everything pulling on everything else. In other words, the total energy of the universe is zero!*" [**6**].

The concept of negative energy is not only used to describe GF, but also other attractive quantum fields (like the electromagnetic field between opposite sign charges).

The concept of negative energy density also explains Casimir effect: when two flat plates are placed very close to each other (at a distance $d \cong 1\mu m$), they restrict the number of virtual photons (**vPHs**) (allowing only vPHs with wavelengths $\lambda \le d$) and particle-antiparticle pairs (**PAPs**) which can exist between them; this results in a negative energy density, which causes an attractive force between the plates, that has been demonstrated and measured.

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II. The extended zero-energy hypothesis (eZEH)

eZEH statement no. 1. The extended zero-energy hypothesis (**eZEH**) (proposed in this paper) states that, when an particle-antiparticle pair (PAP) pops out from the (quantum) vacuum, NOT ONLY the total electromagnetic (EM) charge is conserved (and equals zero in that PAP), BUT also the total energy of that PAP $\left(E_{tot}\right)$ is also conserved and equals zero**.**

$E_{tot}\left(=0\right)$ at non-relativistic speeds (and considering that the inverse square law is preserved or offers a reasonable approximation/prediction in both EM field and GF acting on point-like elementary particles (**EPs**) even at very small length scales, comparable to Planck scale) is defined as the sum between these three energy quantities: (**1**) the rest energy of a PAP $\boxed{E_{PAP} = 2m_{EP}c^2}$; (**2**) the EM attraction (negative) energy between EP and its antiparticle $\boxed{E_{EM} = -k_{e(x)}{q_{EP}}^2 / r_x}$ (with: r_x being the distance between the EPs of that PAP in the exact moment of its "birth", $k_{e(x)}$ being the Coulomb constant at those r_x length scales and q_{EP} being the zero/non-zero EM charge of each EP from that PAP); (**3**) the (negative) gravitational energy between EPs of that PAP $\boxed{E_G = -G_x{m_{EP}}^2 / r_x}$ (with: r_x being the distance between the EPs of that PAP in the exact moment of its "birth", G_x being the Newtonian gravitational constant at those r_x length scales and m_{EP} being the zero/non-zero rest mass of each EP from that PAP);

$$\boxed{\begin{aligned} &E_{tot} = E_{PAp} + \left(E_{EM} + E_G\right) = \\ &= 2m_{EP}c^2 - \left(k_{e(x)}{q_{EP}}^2 + G_x{m_{EP}}^2\right)/r_x = 0 \end{aligned}} \quad \textbf{(Eq.1)}$$

Based on eZEH and Eq.1, a general function measuring the reciprocal distance $\left(r_x\right)$ between any two paired (virtual) EPs (in the exact moment of their "birth" as a PAP) can be defined as:

$$\boxed{r_x\left(k_{e(x)}, q_{EP}, G_x, m_{EP}\right) = \frac{\left(k_{e(x)}{q_{EP}}^2 + G_x{m_{EP}}^2\right)}{2m_{EP}c^2}} \quad \textbf{(Eq.2)}$$

eZEH statement no. 2. eZEH additionally states that NOT ONLY fermionic PAPs (with non-zero rest masses) obey eZEH, but also the other bosonic EPs with theoretical zero rest masses (and possessing only relativistic masses) like the photon (**PH**), the gluon and the hypothetical graviton: more specifically, eZEH states that (virtual) PHs also pop up (or can be "extracted" from) the vacuum ONLY in pairs composed from a (spin-1) positive-energy PH $\left(E_{PH} = h\nu\right)$ and a spin-1 negative-energy PH (nePH) $\left(E_{nePH-} = h(-\nu)\right)$ (with negative linear/angular frequency $-\nu$, with nePH travelling backwards in time) so that the total energy of the two-PHs system conserves and remains zero:

$$\boxed{E_{tot(PHs)} = E_{PH} + E_{nePH} = 0} \quad \textbf{(Eq.3)}$$

Notes. nePHs are the negative energy solutions of Maxwell's equations for propagating PH energy. nePHs were first proposed by physicist Paul Dirac in his notorious "Dirac sea" theoretical model (in which vacuum was stated to be a "sea" containing an infinite number of virtual EPs with negative rest energies, including nePHs). Virtual negative energy EPs (including nePHs) can exist for a short time interval: this phenomenon is a part of the mechanism involved in Hawking radiation (**HR**) (by which black holes evaporate and which HR also implies the existence of conjugated PHs and nePHs. nePHs are currently under research [**7**].

eZEH statement no. 3. The r_x distance between PH and its paired nePH (in the exact moment of their "co-birth") is stated by eZEH to have any random finite/infinite value, because the total energy of that PH-nePH pair $\left(E_{tot(PHs)}\right)$ remains zero, no matter the r_x value.

eZEH – statement no. 4. eZEH additionally states that negative energy also implies negative (physical) information, defined by eZEH as that information which decreases the entropy of a physical system (PS) when absorbed by that PS.

eZEH further speculates that positive and negative information may not have perfectly symmetrical mechanisms so that the subtle mechanism of a PS emitting a positive energy/information PH may not be identical with the mechanism of that PS absorbing a negative energy/information PH (although the resulting PS may be the same, after that PH emission or nePH absorption respectively).

Checkpoint conclusion. eZEH is stated to apply to both microcosm and macrocosm, so that it can be considered a unifying-type of hypothesis.

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eZEH predictions. eZEH alone (or combined with other modern theories) generates some interesting predictions: **see next**.

eZEH prediction no. 1A (r_x estimation). For EM-charged EPs and $\boxed{G_x m_{EP}{}^2 << k_{e(x)} q_{EP}{}^2}$ at r_x length scales (like for the case $G_x \cong G$ and $k_{e(x)} \cong k_e$), eZEH predicts:

$$\boxed{r_x \cong \frac{k_{e(x)} q_{EP}{}^2}{2 m_{EP} c^2}} \quad \textbf{(Eq.4a)}$$

eZEH prediction no. 1B (r_x estimation). For EM-charged EPs and $\boxed{G_x m_{EP}{}^2 \cong k_{e(x)} q_{EP}{}^2}$ at r_x length scales, eZEH predicts:

$$\boxed{r_x \cong \frac{k_{e(x)} q_{EP}{}^2}{m_{EP} c^2} \cong \frac{G_x m_{EP}{}^2}{m_{EP} c^2}} \quad \textbf{(Eq.4b)}$$

eZEH prediction no. 1C (r_x estimation). For EM-neutral EPs $\left(q_{EP} = 0\right)$, eZEH predicts:

$$\boxed{r_x = \frac{G_x m_{EP}{}^2}{2 m_{EP} c^2} = \frac{G_x m_{EP}}{2 c^2}} \quad \textbf{(Eq.4c)}$$

r_x estimations for various types of particle-antiparticle pairs. For the special cases $G_x \cong G$ and $k_{e(x)} \cong k_e$ one can approximate various r_x values for various PAPs such as (with proton radius $\boxed{r_p \cong 0.87 \times 10^{-15} m}$, as determined by electron scattering):

Table II-1. **r_x estimations for various types of particle-antiparticle pairs, for the special cases $G_x \cong G$ and $k_{e(x)} \cong k_e$**

Particle-antiparticle pair	r_x (as expressed in r_p units)
electron-positron	$1.6 r_p$
muon-antimuon	$10^{-2} r_p$
tauon-antitauon	$10^{-3.5} r_p$
up quark-antiquark	$10^{-1} r_p$
down quark-antiquark pair	$10^{-2} r_p$
$W^{+/-}$ boson-antiboson	$10^{-5} r_p$
$Z - Z$ boson-antiboson	$10^{-37} r_p$
Higgs boson-antiboson	$10^{-37} r_p$
electron neutrino-antineutrino, for $\boxed{m_{\nu e} \cong 1eV / c^2}$	$10^{-48} r_p$

Important observations. One may remark that, the lighter the EM-charged EP, the larger the empty space volume needed for its correspondent PAP to pop out from the vacuum (and the longer the mean life time of that EM-charged EP). One may also observe that $r_x\left(k_e, q_e, G, m_e\right) \cong 1.62 r_p$ is close to proton radius r_p (for the electron-positron pair [**epp**]), which indicates that epps have sufficiently space to pop out (from vacuum) in any atom at normal temperature and pressure, but the (evanescent) occurrence of epps in large black holes (with very high densities and containing highly compact atoms and atomic nuclei) may be strongly inhibited, so that only heavy PAPs (like muon-antimuon, tauon-antitauon, quark-antiquark pairs etc) are allowed to pop out from the vacuum inside those massive black holes. This aspect will be further discussed in the next sections of this paper.

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eZEH prediction no. 2A (the "photonic graviton"). As GF is assigned negative energy (and obviously has zero EM-charge), eZEH predicts that a GF hypothetical bosonic quanta (aka "graviton") may also have negative energy and negative information (with obviously zero EM-charge), no matter the spin of the graviton. This prediction also identifies the (spin-1) nePH with a (negative-energy) **spin-1 graviton**: nePH may be called a "**photonic graviton**" and it is stated to act on both small and large scales (and thus to mediate gravity at both macrocosmic and microcosmic scales).

eZEH prediction no. 2B (the "gluonic graviton"). eZEH also predicts the existence of a neutral negative energy gluon which is identified by eZEH with **a (zero color charge) second type of spin-1 graviton** acting at nuclear scales only (as the gluon does), which may be called "**gluonic graviton**", because it is predicted to be distinct from the spin-1 nePH previously named "photonic graviton".

eZEH prediction no. 2C (the "dual" spin-2 gravitons). Besides the prediction of two major types of spin-1 gravitons (the "photonic" and "gluonic" gravitons), eZEH also predicts the existence of two possible types of spin-2 gravitons: (**1**) a positive-energy spin-2 graviton (**peS2G**) and a (**2**) negative-energy spin-2 graviton (**neS2G**). eZEH also predicts that virtual spin-2 gravitons act on both macrocosmic and microcosmic scales and may only pop out from the vacuum as peS2G-neS2G virtual pairs.

eZEH prediction no. 2D (the growth of GF strength when decreasing length scale). As the length scale decreases from macroscopic (where only "photonic gravitons" and spin-2 gravitons are predicted to act) to subatomic scales, eZEH predicts that additional "layers" of quantum gravity (the "gluonic gravitons") superpose by coming into action so that the quantum "big G" $\left(G_x\right)$ (measuring GF strength at various r_x length scales) is predicted to increase with the r_x length scale decrease, reaching very high values at the Planck scale. This important eZEH prediction also has the potential to solve the cosmological constant $\left(\Lambda\right)$ problem by offering the possibility of a vacuum energy density ρ_{vac} that varies inverse-proportionally to the length scale $\lambda = r_x$ (and direct-proportionally to the energy scale $E = hc/\lambda$), which may fill the huge "gap" (varying from 40 to more than 100 orders of magnitude) between the observed small ρ_{vac} used by General relativity (**GR**) and the very large ρ_{vac} predicted by the quantum field theory (**QFT**). These aspects were also extensively developed in another paper of the author [**8**].

eZEH prediction no. 2E (the minimum value of the quantum big G in the present epoch of the observable universe). Based on its previous prediction, eZEH proposes a variable Planck length $\left(l_{Pl(x)}\right)$ (defined as a function of the variable quantum G_x) defined as $\boxed{l_{Pl(x)} = \sqrt{\hbar G_x / c^3}}$. eZEH also predicts that G_x depends on the additive volumic density of both "photonic gravitons" and spin-2 gravitons: this volumic density may decrease with the (accelerated) inflation of our universe, so that the G_x minimum $G_{x(\min)}$ (which may be reached in the distant future of our expanding universe) may be much smaller than the present measured Newtonian gravitational constant $G\left(\cong 6.7\times 10^{-11} m^3 kg^{-1} s^{-2}\right)$. A minimum Planck length (which may also reach an infinitesimal value if the expansion of our universe will continue forever), may be defined as $\boxed{l_{Pl(\min)} = \sqrt{\hbar G_{x(\min)} / c^3}}$. eZEH predicts that, in the present epoch of our universe, $\boxed{G_{x(\min)(pres)} \cong G}$ (a G_x "temporary" minimum that covers all the observable universe in the present epoch), so that $\boxed{l_{Pl(\min)(pres)} = \sqrt{\hbar G / c^3} \cong l_{Pl}}$. Furthermore, the Coulomb constant at Planck scale $k_{e(Pl)}$ can be exactly estimated by using the running coupling constant of the EM field $\boxed{\alpha_f\left(E\right) \cong \frac{\alpha}{1-\left(\alpha/3\pi\right)\ln\left[\left(E/E_e\right)^2\right]}}$ (as determined in quantum electrodynamics by using the beta function computed in perturbation theory, as a function of a variable energy scale $E >> E_e\left(= m_e c^2 \cong 0.51 MeV\right)$ starting from the fine-structure constant (**FSC**) value at rest $\boxed{\alpha \cong 137^{-1}\left[= k_e q_e{}^2 / \left(\hbar c\right)\right]}$ experimentally determined by using quantum Hall effect **[9, 10]**). FSC at Planck (length/energy) scales can be estimated as $\boxed{\alpha_{Pl} = \alpha_f\left(E_{Pl}\right) \cong 126^{-1}}$ resulting an estimated Coulomb constant at Planck scale $\boxed{k_{e(Pl)} = \alpha_{Pl}\hbar c / q_e{}^2 \cong 1.087 k_e \cong 8.99\times m^3 kg A^{-2} s^{-4}}$.

Comments. Multiple spin (0,1,2) gravitons are not a theoretical novelty per se, as there also alternative gravity theories predicting more types of GF perturbations than Einstein's General relativity theory (which only allows the spin-2 modes in vacuum): two spin-0 modes, two spin-1 modes and two spin-2 modes, which modes are the result of all the possible decompositions of a rank-2 symmetric tensor (the metric perturbation) into different irreducible representations of Wigner's little group E(2).

Checkpoint conclusion. eZEH essentially revalues the "Dirac sea" theory by applying it as a quantum gravity hypothesis, resulting a kind of "Dirac sea"-like "multi-layered quantum gravity sea/foam". this type of negative energy "quantum gravity foam" was extensively developed by the author in another article describing a toy-model of a "digital" vacuum composed of positive-energy space voxels with quantized energetic states suspended in a "gravitonic fluid" with negative energy [**11**]. It's worth mentioning that "Dirac sea" original concept was also recently revived as an important "ingredient" of the causal fermion systems theory

(**CFST**) (first introduced by Felix Finster and collaborators), which is essentially a unified physical theory proposal based on the causal action principle (and claiming to have quantum mechanics, general relativity and quantum field theory as limiting cases): CFST defines spacetime (and all structures therein) as the result of the collective reciprocal interaction of the sea states and the interactions of these sea states with the additional particles and "holes" from Dirac's sea [**12**].

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eZEH prediction no. 3A (a new interpretation of Planck length). As the electron-neutrino (ν_e) is the lightest known EP (with non-zero rest mass) from the Standard model, its eZEH-imposed $\nu_e - \overline{\nu_e}$ pair inter-distance (at their "co-birth") $\boxed{r_x\left(k_{e(Pl)}, q_e, G, m_{\nu e}\right) \cong 10^{-28} l_{Pl}}$ (for the special case $k_{e(x)} = k_{e(Pl)}$ and $G_x = G$) also seems the shortest known r_x length in our universe. eZEH predicts that Planck length $\boxed{\left(l_{Pl} = l_{Pl(\min)(pres)}\right) \cong 1.62 \times 10^{-35} m}$ could be in fact the minimal (empty-space) micro-cavity diameter needed by the lightest known EPs (the electron neutrino-antineutrino pair for example) to pop out from the vacuum in virtual PAPs. This prediction offers a new interpretation of Planck length, interconnecting l_{Pl} with the lightest known EP (the electron neutrino).

eZEH prediction no. 3B (the prediction of a strong gravity constant associated with Planck length scale). Given the ratio $\boxed{X_{\nu e} = l_{Pl} / r_x\left(k_{e(Pl)}, q_e, G, m_{\nu e}\right) \cong 10^{28}}$, if one imposes the Planck length $\left(l_{Pl} = l_{Pl(\min)(pres)}\right)$ as the minimal conceivable distance in our universe (as predicted by Loop quantum gravity theories) and constraints $r_x\left(k_{e(Pl)}, q_e, G_{Pl}, m_{\nu e}\right)$ to equal l_{Pl}, then: $\boxed{r_x\left(k_{e(Pl)}, q_e, G, m_{\nu e}\right) = l_{Pl}}$ implies a quantum big G at Planck length scale equal to (at least) $\boxed{G_{Pl} = X_{\nu e} G \cong 10^{28} G}$ which approaches the previously predicted strong gravitational constant (**SGC**) (Γ) and which G_{Pl} can be considered a low bound value for SGC, as our universe may contain (still undiscovered) EPs (with non-zero rest masses) even lighter than the electron neutrino. In the literature, SGC is estimated to have a value between $\boxed{\Gamma_{\inf} \cong 10^{35} G}$ up to $\boxed{\Gamma_{\sup} \cong 10^{47} G}$ (Fisenko et al. [**13**]; Recami et al. [**14**]; Stone [**15**]; Mongan [**16**] etc).

eZEH prediction no. 3C (a Planck-like gravitational constant measuring the quantum momentum of the predicted spin-1 "photonic" graviton). Based on the predicted $\boxed{G_{Pl} = 10^{28} G}$ and modeling the (negative energy) graviton (wave) scalar analogously to the photon (such as $\boxed{E_g(\lambda) = -h_g \lambda / c}$, with h_g being a predicted Planck-like gravitational constant, λ being the frequency of that graviton and c being the speed of light in vacuum, currently considered a good approximation to the speed of gravity in vacuum), eZEH predicts that G_{Pl} can be written as a function of $h_{g(Pl)}$ (h_g minimum value at Planck scale) and electron mass m_e such as $\boxed{G_{Pl} = \left(c / m_e^{\,2}\right) \cdot h_{g(Pl)}}$ (analogously to Coulomb constant being a function of $\hbar$: $\boxed{k_e = \left(\alpha c / q_e^{\,2}\right) \cdot \hbar}$), so that $h_{g(Pl)}$ can be inversely deduced as $\boxed{h_{g(Pl)} = 2\pi G_{Pl} m_e^{\,2} / c \cong 10^{-16} h}$ (based on the fact that h_g can be inversely written as a function of the gravitational coupling constant arbitrary defined as $\boxed{\alpha_G = G m_e^{\,2} / (\hbar c)}$, so that $\boxed{h_g \overset{def.}{=} 2\pi\hbar\alpha_G = 2\pi G m_e^{\,2} / c}$) which suggests that h_g may approach the magnitude of h at Planck scales, so that GF strength may approach EM field strength at those Planck scales. For $\boxed{\Gamma_{\inf} \cong 10^{35} G}$ and $\boxed{\Gamma_{\sup} \cong 10^{47} G}$ predictions from the literature, one may calculate $\boxed{h_{g(\inf)} = \Gamma_{\inf} m_e^{\,2} / c \cong 10^{-10} h}$ and $\boxed{h_{g(\sup)} = \Gamma_{\sup} m_e^{\,2} / c \cong 10^{2} h}$. For $h_{g(Pl)}$ and h to be exactly equal at Planck scale $\left(h_{g(Pl)} = h\right)$, one may obtain:

$$\boxed{\begin{aligned} &G_{Pl(2)} = \left(c / m_e^{\,2}\right) \cdot h_{g(Pl)} = \left(c / m_e^{\,2}\right) \cdot h \\ &\cong 10^{45} G \in \left[\Gamma_{\inf}, \Gamma_{\sup}\right] \end{aligned}} \quad \textbf{(Eq.5)}$$

Based on $G_{Pl(2)}$, eZEH predicts a vacuum (positive) energy density at Planck scale $\boxed{\rho_{vac(Pl)} = \dfrac{\Lambda c^2}{8\pi G_{Pl(2)}} = \dfrac{\Lambda c m_e^{\,2}}{8\pi h}}$ which is in congruence with the vacuum (positive) energy density offered by QFT,

In a checkpoint conclusion, the negative energy ("new born") (spin-1) photonic graviton may exactly nullify the positive energy ("new born") photon when (spontaneously) emerging in pairs at Planck scale so that the total energy of a "new-born" photon-graviton pair to be always exactly zero

(as eZEH predicts). Generally, eZEH regards the evanescent (positive energy) bosons-graviton virtual pairs as the main "creators" and "bricks" of the 4D spacetime (4D-ST) continuum "scene" (as modeled by GR), which 4D-ST can be regarded as a zero-energy fluid/matrix, with all (positive) energy EPs and all types of gravitons being actually perturbations of this zero-energy 4D-ST matrix**.**

Some notes on the Higgs boson (Hb) in the context of eZEH. eZEH is very limited in predicting additional facts about Hb, as there are many uncertainties which need to be clarified theoretically and experimentally in the future: mainly, it is not known for sure if other types of charged/non-charged (scalar/non-scalar) Hbs also exist, as many extensions of the Standard Model (**SM**) predict (the so-called extended Higgs sector with additional Hb doublets or triplets). The known Hb is a (very unstable) zero-spin, zero-(electromagnetic) charge and zero-color charge (scalar) boson, with a relatively large non-zero rest mass: the zero-charge also implies that Hb is its own antiparticle (Hb=antiHb) (as stated in SM). eZEH predicts that Hbs may spontaneously pop out from the vacuum in ("evanescent") Hb-(anti)Hb pairs, "needing" an eZEH-predicted linear space inter-distance (between the two paired neutral Hbs) estimated as: $\boxed{r_x = \frac{G_x {m_{Hb}}^2}{2m_{Hb}c^2} = \frac{G_x m_{Hb}}{2c^2}}$. For the special case $\boxed{G_x = G}$, the estimation is $\boxed{r_x \cong 10^{-37} r_p \cong 10^{-17} l_{Pl}}$, which is unrealistic from the point of view of eZEH. Based on the (previously predicted) strong gravitational constant and its minimum value $\boxed{G_{Pl} = X_{\nu e} G \cong 10^{28} G}$ (at scales comparable to Planck length scale), eZEH predicts a (much more realistic) minimum $r_{x(\min)}$ for the Hb-Hb pair, such as:

$$\boxed{r_{x(\min)} = \frac{G_{Pl} m_{Hb}}{2c^2} \cong 10^{-9} r_p \cong 10^{10} l_{Pl}} \quad \textbf{(Eq.6)}$$

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eZEH prediction no. 4A (the black hole Casimir effect). eZEH predicts that local regions of our universe with very high (positive) matter/energy volumic density (mainly black holes) may significantly inhibit some types of virtual PAPs spontaneous "birth" inside them (given their high degree of spatial "filling", implying a significant reduction in the number of "vacant" linear spaces with minimal specific r_x values on many directions): this PAPs "birth-blocking" phenomenon from inside a black hole (**bh**) may create a huge gradient/ratio between the virtual PAPs outside-over-inside volumic density (and the outside-versus-inside rate of PAPs-"birth"); this gradient is predicted to generate the bh Casimir effect (**bhCE**) which implies an additional bh Casimir force/field (**bhCF**).

bhCF vectors are stated to be distributed radially around a bh and to point towards the (geometrical) center (**C**) of bh inner space: bhCF vectors have the same orientation as the GF vectors (associated to that same bh). The bhCF vector magnitude in any point P outside that bh is stated to vary inverse-proportionally to the squared C-to-P distance. bhCF is thus predicted to further compresses that bh or to just slow its "evaporation" rate. A (possible) bh compression implies a progressive increase of bh density which may further increase the outside-versus-inside virtual PAPs density gradient, which may further increase the strength of bhCF (thus compressing bh even more) and so on.

eZEH prediction no. 4B (the prevention. inhibition and "filtering" of the Hawking radiation). By predicting a (very) strong GF at subatomic scales and Planck scales (measured by a very large quantum big G $G_{Pl} = 10^{28} G$ aka "strong gravitational constant"), eZEH also predicts that it is very improbable for a (very) short-lived virtual PAP (with very strong GF acting between the paired EPs at subatomic r_x scales to be splitted by any bh at its horizon surface: in this way, eZEH predicts that Hawking radiation (**HR**) (produced from hypothetical PAPs splitting at bh horizon) is very improbable and thus explains why HR hasn't been recorded yet in the observable universe.

eZEH additionally predicts that bhCF may also act as a HR inhibitor or preventer.

eZEH additionally predicts that, if they truly exist, (hypothetical) micro-black holes (aka "Planck particles", with huge densities equal to Planck density) may totally block virtual PAPs "birth" inside them or may allow the "birth" of only neutrino-antineutrino pairs. eZEH also predicts that, if ever proved to emit HR, bhs may predominantly emit neutrinos (and/or antineutrinos) HR, which is an additional explanation why HR hasn't been observed yet.

eZEH prediction no. 4C (the expansion of our universe possibly explained by bhCF). bhCF exerted on all bhs of our universe may generate an (inverse) reaction-force (based on the third Newton's law of motion): this reactional bhCF (**rbhCF**) is defined to act on all virtual PAPs outside bh ("repelling" them from that bh) and so to dilate the 3D space around bhs. rbhCF is also stated to have the same magnitude as bhCF, but opposite sign. rbhCF may lead to an accelerated expansion/inflation of our universe (at least in the cases where bhCF progressively compresses bhs). **In a checkpoint conclusion**, bhs and rbhCF may actually drive the cosmic accelerated inflation. In this view, eZEH actually avoids (and is essentially and alternative to) the dark energy hypothesis (**DEH**), by explaining the cosmic inflation as caused by bhCE and driven by a cumulated (global) rbhCF.

Important note. The fact that white matter from our universe has a relative uniform distribution at the (global) scale of the observable universe may be actually an indirect proof that the spatial distribution of bhs (which are predicted

to drive the inflation of our universe by bhCF-reaction) is also relatively uniform at this global scale.

Because bhCF-reaction probably acts slowly and uniformly, eZEH also predicts that the so-called "Big Bang" may not had been an explosion, but an initially slow expansion which progressively accelerated, as driven by bhCF-reaction.

THE CONCLUSIONS OF THIS PAPER. eZEH has the potential to be a valid patch of ZEUT, as it expands the horizons of ZEUT predictions such as: (**1**) the existence of multiple types of negative-energy gravitons; (**2**) a strong quantum gravitational field acting at very small subatomic length scales (which is measured by a quantum strong gravitational constant); (**3**) a (macrocosmic) black hole Casimir effect which may explain the accelerated expansion of our universe; (**4**) a low probability for Hawking radiation (HR) to actually exist (as explained by the strong gravitational field at very small length scales, which may prevent the any PAP splitting at those scales); (**5**) (if HR actually exists, although predicted by eZEH as highly improbable), HR would be composed from neutrinos and/or antineutrinos only (which makes HR unobservable with our current astronomical tools).

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III. End references
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