An extended zero-energy hypothesis: on some possible quantum implications of a zero-energy universe, including the existence of negative-energy spin-1 gravitons (as the main spacetime "creators") and a (macrocosmic) black-hole (bh) Casimir effect (bhCE) which may explain the accelerated expansion of our universe

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1st Motto: „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." (Hawking, Stephen [1998]. "A Brief History of Time". New York: Bantam Books; page 129) [URL1, URL2]

2nd Motto: „"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!" (extract from the book "The Cosmos: Astronomy in the New Millennium" [1st edition, 2001] by Alexei V. Filippenko and Jay M. Pasachoff [URL1, URL2, URL3])

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Abstract

This paper proposes an extended (**e**) zero-energy hypothesis (e**ZEH**) starting from the "classical" speculative zero-energy universe hypothesis (**ZEUH**) firstly proposed by the mathematical physicist 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/fluctuation of the (quantum) vacuum state. ZEUH 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 limits" and emphasizes some new possible quantum implications:

(**1**) the existence of negative-energy spin-1 gravitons and their appearance in (evanescent) photon-graviton pairs defined as the main "creators" of the 4D spacetime;

(**2**) a (macrocosmic) black-hole (**bh**) associated Casimir effect (**bhCE**) which may inhibit Hawking radiation (explaining why it wasn't observed yet) and may explain the accelerated expansion of our universe;

(**3**) a quantum strong gravitational constant (strong quantum big G) defined as a function of a Planck-like gravitational constant which measures the quantum angular momentum of the (negative energy) graviton (which is predicted to nullify the positive energy of a photon at Planck scales, solving the vacuum energy density apparent paradox);

Keywords: the zero-energy universe hypothesis (**ZEUH**); vacuum; quantum fluctuation; gravitational field (**GF**); the energy conservation principle (**ECP**); the extended (**e**) zero-energy hypothesis (e**ZEH**); negative-energy spin-1 graviton; (evanescent) photon-graviton pairs; 4D spacetime; black-hole (**bh**); the black-hole (**bh**) associated Casimir effect (**bhCE**), Hawking radiation inhibition; accelerated expansion of our universe; quantum strong gravitational constant (strong quantum big G); vacuum energy density;

Important note (1). This atypical URL-rich paper (which maximally exploits the layer of hyperlinks in this document), chooses to use Wikipedia links for all the important terms used. The main motivation for this approach was that each Wikipedia web-article contains all the main reference (included as endnotes) on the most important terms used in this paper: it simply the most practical way to cite entire collections of important articles/books without using an overwhelming list of footnote/endnote reference in this paper. The secondary motivation (for using Wikipedia hyperlinks directly included in keywords) was to assure a "click-away" distance to short encyclopedic monographs on all the (important) terms used in this paper, so that the flow of reading to be minimally interrupted.

Important note (2). This paper also exploits the advantages of the hierarchic tree-like model of presenting informational content which is (also) very easy to be kept updated and well organized.

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I. INTRODUCTION

1. **The zero-energy universe hypothesis (ZEUH)**[URL]. 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)**.
   a. ZEUH was firstly proposed by the mathematical physicist 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 [URL].
   b. ZEU theory (**ZEUT**) was independently proposed by Edward Tryon in 1973 (in the "Nature" journal) who speculated that our whole universe (**wu**) (including both the observable and un-observable parts of our universe, no matter if finite or not) may have emerged from a large-scale quantum fluctuation of vacuum energy, resulting in its positive mass-energy being exactly balanced by its negative GF potential energy [URL1, URL2(page 189)]. During the inflation phase of wu, 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 [URL].
   c. **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.*" (Hawking, Stephen [1998]. "A Brief History of Time". New York: Bantam Books; page 129 [URL1, URL2]).
   d. **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.*" (Hawking, Stephen [1998]. "If There's an Edge to the Universe, There Must Be a God" (interview), in Renée Weber, Dialogues With Scientists and Sages: The Search for Unity, 1986; (Also partially reprinted in "God as the Edge of the Universe", in "The Scientist", Vol. 1, No. 7, February 23rd 1987, page 15 [URL]).
   e. **Cite from Alexei V. 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!" (extract from the book "The Cosmos: Astronomy in the New Millennium" [1st edition, 2001] by Alexei V. Filippenko and Jay M. Pasachoff [URL1, URL2, URL3])

f. The negative energy gravitational field (**GF**) and the positive energy matter (and radiation) cancel out only if our universe is completely flat: such a zero-energy flat universe can theoretically last forever.

g. As previously explained, the concept of negative energy is used to describe the gravitational field and attractive quantum fields. For example, in the Casimir effect, two flat plates placed very close together restrict the wavelengths of the virtual PHs (EM field quanta) which can exist between them; this in turn restricts the types and hence number and density of virtual EPs pairs which can form in the intervening vacuum and can result in a negative energy density (this causes an attractive force between the plates, which has been measured).

2. Quantum fluctuation (definition). A quantum fluctuation (**QF**) is defined as the a very short lived appearance (a so-called "pop out") of an elementary (quantum) particle (**EP**)-anti-EP (**aEP**) pair out of the vacuum (empty space), as allowed by Heisenberg's uncertainty principle (**HUP**): HUP states that it is impossible precisely determine the values for a pair of conjugate variables (such as position[**x**]-momentum[**p**] or energy[**E**]-time[**t**]) at the same time. In scalar terms, HUP states that $\sigma_x \sigma_p \geq \hbar/2$ or $\sigma_E \sigma_t \geq \hbar/2$ with: σ_x, σ_p, σ_E, σ_t all being the standard deviations (of position, momentum, energy and time respectively) and $\hbar = h/(2\pi)$ being the reduced Planck constant (h). **Proofs and effects**. The spontaneous EP-aEP pairs (virtual particles pairs) production from the vacuum was demonstrated by the (measurable) vacuum polarization effect (generated by any point-like charge localized in empty space), which explains, for example, why the effective (electromagnetic [EM]) charge of the electron is smaller than its true/"naked" EM charge. QFs existence and interactions between EPs and virtual EP-aEP pairs (generated by the fluctuations of the quantum fields of EPs) are also demonstrated by the Casimir effect, the ~0.1% deviation of the intrinsic magnetic moment of the electron from the Bohr magneton (the so-called anomalous magnetic moment) etc. QFs existence also explain the apparent paradox of a point-like particle like the electron having both intrinsic angular momentum and magnetic moment: the electrons causes the pop-out of virtual photons (in the electric field generated by the electron), which cause the electron to shift about in a jittery fashion (known as zitterbewegung), causing electrons to move in a net circular motion with precession (which motion produces both the spin and the magnetic moment of the electron); in atoms, this induced creation of virtual photons explains the Lamb shift observed in spectral lines.

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II. THE EXTENDED ZERO-ENERGY (UNIVERSE) HYPOTHESIS (eZEH) proposed in this paper

1. The extended zero-energy hypothesis (eZEH). eZEH states that, when an EP-aEP pair pops out from the vacuum, not only the total EM charge is conserved (and equal to zero), BUT also the total energy of the EP-aEP pair (E_{tot}) is also conserved and equals zero. $E_{tot}(=0)$ at non-relativistic speeds (and considering that the inverse square law is preserved or offers a reasonable approximation/prediction in both EM and gravitational forces even at very small length scales, comparable to Planck length scale) is defined as the sum between the rest energies of EP and aEP (which are equal to each other so that $E_{EPs} = 2m_{EP}c^2$) plus the (negative) EM attraction energy between EP and aEP (defined as $E_{EM} = k_{e(x)} {q_{EP}}^2 / r_x$, with: r_x being the distance between those

EPs in the exact moment of their "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 the pair) plus the (negative) gravitational energy between EP and aEP (defined as $\boxed{E_G = G_x {m_{EP}}^2 / r_x}$ with: r_x being the distance between those EPs in the exact moment of their "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 the pair): $\boxed{E_{tot} = E_{EPs} - (E_{EM} + E_G) = 2m_{EP}c^2 - \left(k_{e(x)}{q_{EP}}^2 + G_x {m_{EP}}^2\right)/r_x = 0}$, which is equivalent to $\boxed{2m_{EP}c^2 = \left(k_{e(x)}{q_{EP}}^2 + G_x {m_{EP}}^2\right)/r_x}$, with $\boxed{r_x = \left(k_{e(x)}{q_{EP}}^2 + G_x {m_{EP}}^2\right)/\left(2m_{EP}c^2\right)}$. eZEH additionally states that not only fermionic EP-aEP pairs with non-zero rest masses obey eZEH, but also the other bosonic EPs with theoretical zero rest mass (and possessing only relativistic mass) like the photon, the gluon and the hypothetical (spin-2)graviton: more specifically, eZEH states that virtual photons (vPHs) also pop up from (or can be "extracted" from) the vacuum ONLY in pairs composed from a positive-energy photon $E_{ph} = h\nu$ and a negative-energy photon $E_{ph-} = h(-\nu)$ (with negative linear/angular frequency) so that the total energy of the two-vPHs system conserves and remains zero: $\boxed{E_{tot(vPHs)} = E_{ph} + E_{ph-} = 0}$, which is equivalent to $\boxed{E_{ph-} = -E_{ph}}$. The distance between nePH and its paired PH (in the exact moment of their "birth") is considered arbitrary and not a specific r_x, because the total energy $E_{tot(vPHs)}$ of the PH-nePH pair remains zero, no matter the distance between them in the exact moment of their "birth".

- **a. Definition**. The negative energy photon (**nePH**) is defined by eZEH as PH with negative linear/angular frequency and which travels backwards in time (from the future to the past). nePHs are stated to generate an attraction force between the EPs that interchange them. When absorbing a nePH (with frequency matching its energy level) an excited bound electron (defining a excited state of the atom containing that electron) would collapse back to its ground level in that atom. **Note**. nePHs are the negative energy solutions of Maxwell's equations for propagating EM photon energy. nePHs are not a theoretical novelty, as they were first proposed by physicist Paul Dirac in his notorious "Dirac sea" theoretical model (in which vacuum is 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 existences of conjugated PHs and nePHs [URL]). nePHs are currently under research: see the article "The dark side of light: negative frequency photons" published in "Ars Technica" [URL1, URL2].
- **b. Additional statement of eZEH**. As the gravitational field has negative energy, its hypothetical quanta, the predicted spin-2 boson called "graviton", is also hypothesized to have negative energy. Furthermore, eZEH additionally states that the graviton can have at least three forms (a spin-0 [scalar] graviton, a spin-1 graviton and a spin-2 graviton) and that the spin-1 graviton is actually a nePH. Spin-1 graviton is not a theoretical novelty per se either, as there also alternative gravity theories that also predict more types of perturbations than in General relativity theory (**GRT**) (which only allows the spin-2 modes in vacuum, as GRT states that GF is only attractive which implies a certain kind of symmetry based on an even positive integer, in which the value of graviton's spin has to be 2, which 2 is the smallest non-zero positive even integer): 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).

c. **Note**. eZEH is state to apply to both micro-universe (microcosm) and macro-universe (macrocosm), so that it can be considered a unifying hypothesis, a common "denominator" of both microcosm and macrocosm.

d. **Definition**. Let us define a **general function** $\boxed{\boxed{r_x\left(k_{e(x)},q_{EP},G_x,m_{EP}\right)=\left(k_{e(x)}{q_{EP}}^2+G_x{m_{EP}}^2\right)/\left(2m_{EP}c^2\right)}}$ **which measures the reciprocal distance** r_x **between any two paired virtual EP-aEP (in their exact moment of "birth").**

e. **Approximations**. One may easily notice that:

i. **For non-zero EM-charged EPs:** $\boxed{\boxed{r_x\left(k_{e(x)},q_{EP},G_x,m_{EP}\right)\cong k_{e(x)}{q_{EP}}^2/\left(2m_{EP}c^2\right)}}$ for $\boxed{G_x{m_{EP}}^2\ll k_{e(x)}{q_{EP}}^2}$**, as in the case** of $\left(G_x\cong G\right)\wedge\left(k_{e(x)}\cong k_e\right)$

1. **(and)** $\boxed{\boxed{r_x\left(k_{e(x)},q_{EP},G_x,m_{EP}\right)\cong k_{e(x)}{q_{EP}}^2/\left(m_{EP}c^2\right)}}$ for $\boxed{G_x{m_{EP}}^2\cong k_{e(x)}{q_{EP}}^2}\Leftrightarrow\boxed{\left(k_{e(x)}{q_{EP}}^2+G_x{m_{EP}}^2\right)\cong\left(2k_{e(x)}{q_{EP}}^2\right)}$.

ii. **For zero EM-charge EPs**: $\boxed{\boxed{r_x\left(k_{e(x)},q_{EP},G_x,m_{EP}\right)=G_x{m_{EP}}^2/\left(2m_{EP}c^2\right)}}$

f. **Estimations**. For the special cases $G_x\cong G$ and $k_{e(x)}\cong k_e$ one can approximate various r_x values for various EP-aEP pairs such as (with Planck length $\boxed{l_{Pl}\cong1.62\times10^{-35}m}$, classical electron radius $\boxed{r_e=k_e{q_e}^2/\left(m_ec^2\right)\cong2.82\times10^{-15}m}$ and the proton radius $\boxed{r_p\cong0.87\times10^{-15}m}$ as determined by electron scattering [URL]: see next):

i. **For the electron(e)-positron pair:**

$$\boxed{r_x\left(k_e,q_e,G,m_e\right)\begin{cases}\cong1.41\times10^{-15}m\cong8.72\times10^{19}l_{Pl}\\\cong r_e/2\cong1.62r_p\end{cases}};$$

ii. **For the muon(μ)-antimuon pair:**

$$\boxed{r_x\left(k_e,q_e,G,m_\mu\right)\begin{cases}\cong6.81\times10^{-18}m\cong4.22\times10^{17}l_{Pl}\\\cong2.42\times10^{-3}r_e\cong7.83\times10^{-3}r_p\end{cases}};$$

iii. **For the tauon(τ)-antitauon pair:**

$$\boxed{r_x\left(k_e,q_e,G,m_\tau\right)\begin{cases}\cong4.05\times10^{-19}m\cong2.51\times10^{16}l_{Pl}\\\cong1.44\times10^{-4}r_e\cong4.66\times10^{-4}r_p\end{cases}};$$

iv. **For the up-quark(u)-anti-up-quark pair:**

$$\boxed{r_x\left(k_e,2q_e/3,G,m_u\right)\begin{cases}\cong1.39\times10^{-16}m\cong8.61\times10^{18}l_{Pl}\\\cong0.05r_e\cong0.16r_p\end{cases}};$$

v. **For the down-quark(d)-anti-down-quark pair:**

$$\boxed{r_x\left(k_e,-q_e/3,G,m_d\right)\begin{cases}\cong1.67\times10^{-17}m\cong1.03\times10^{18}l_{Pl}\\\cong5.91\times10^{-3}r_e\cong0.02r_p\end{cases}};$$

vi. **For the electron-neutrino(ν_e)-anti-electron-neutrino pair with a non-zero rest mass estimated as $m_{\nu e} \cong 1eV/c^2$:**

$$r_x\left(k_e, q_e, G, m_{\nu e}\right)\begin{cases}\cong 1.2\times10^{-63} m \cong 7.58\times10^{-29} l_{Pl} \\ \cong 4.35\times10^{-49} r_e \cong 1.41\times10^{-48} r_p\end{cases};$$

vii. **Etc.**

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

h. eZEH prediction no. 1. As the electron-neutrino (ν_e) is the lightest known EP (with non-zero rest mass) from the Standard model of particle physics (**SM**), its eZEH-imposed $\nu_e - \overline{\nu_e}$ pair inter-distance (at "birth") $r_x\left(k_e, q_e, G, m_{\nu e}\right) \cong 7.58\times10^{-29} l_{Pl}$ is also the shortest known r_x length in wu with ratio $X_{\nu e} = r_x\left(k_e, q_e, G, m_{\nu e}\right)/l_{Pl} \cong 1.32\times10^{28}$. If one imposes the Planck length $l_{Pl} \cong 1.62\times10^{-35} m$ as the minimal conceivable distance in wu (as predicted by Loop quantum gravity theories [**LQGTs**]) and constraints $r_x\left(k_e, q_e, G_x, m_{\nu e}\right)$ to equal l_{Pl}, then: $r_x\left(k_e, q_e, G_x, m_{\nu e}\right) = l_{Pl}$ implies a quantum big G at Planck length scale equal to (at least) $G_{Pl} = X_{\nu e} G \cong 10^{28} G \cong 10^{18} m^3 s^{-2} kg^{-1}$ which approaches the predicted strong gravitational constant (**SGC**) (Γ) and which G_x can be considered a low bound value for SGC, as wu 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 $\Gamma_{\text{inf}} \cong 10^{35} G$ up to $\Gamma_{\text{sup}} \cong 10^{47} G$ (Fisenko et al. [**1**]; Recami et al. [**2**]; Stone [**3**]; Mongan [**4**] etc): if ever confirmed experimentally (directly or, most probably, indirectly) Γ_{inf} and Γ_{sup} may further predict (based on eZEH) the existence of additional EPs much lighter than the electron-neutrino (ν_e), which may also lead to indirect proof for Supersymmetry (SUSY) theory (which SUSY also predicts spin-0 [possibly super-light] "superpartner particles" [aka "sparticles"] for each known EP from SM). **Potential refinement of eZEH prediction no.1**. For more precision in Coulomb constant $k_{e(x)}$ estimation at Planck scale $k_{e(Pl)}$, one may use the running coupling constant of the electromagnetic field (**EMF**) $\alpha_f(E) \cong \dfrac{\alpha}{1-(\alpha/3\pi)\ln\left[(E/E_e)^2\right]}$ (as determined in quantum electrodynamics by using the beta function computed in perturbation theory, as a function of a variable energy scale $E \gg E_e\left(=m_e c^2 \cong 0.51MeV\right)$ starting from the experimental fine-structure constant (**FSC**) value at rest $\alpha = k_e q_e{}^2/(\hbar c) \cong 137^{-1}$ **[5, 6]**). FSC at Planck (length/energy) scales can be estimated as $\alpha_{Pl} = \alpha_f\left(E_{Pl}\right) \cong 126^{-1}$ resulting an estimated Coulomb constant at Planck

scale $\boxed{k_{e(Pl)} \cong 1.087 k_e \cong 8.99 \times m^3 kgA^{-2} s^{-4}}$, which keeps the initial estimation $\boxed{G_{Pl} = 10^{28} G \cong 10^{18} m^3 s^{-2} kg^{-1}}$ at the same order of magnitude.

i. **Prediction no. 2A**. Based on the predicted minimum value for the quantum big G at Planck scale $\boxed{G_{Pl(\min)} = G_{Pl} = 10^{28} G}$ and modelling 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, predicted to give a good approximation to the speed of gravity in vacuum c_g) eZEH predicts that $G_{Pl(\min)}$ can be written as a function of $h_{g(Pl)(\min)}$ (h_g minimum value at Planck scale) and m_e such as $\boxed{G_{Pl(\min)} = (c / m_e^2) \cdot h_{g(Pl)(\min)}}$ (analogously to Coulomb constant being a function of $\hbar$: $\boxed{k_e = (\alpha c / q_e^2) \cdot \hbar}$), so that $h_{g(Pl)(\min)}$ can be inversely deduced as $\boxed{h_{g(Pl)(\min)} = 2\pi G_{Pl(\min)} m_e^2 / c \cong 10^{-16} h}$ (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 (measured by quantum angular momentum interchange when interchanging gravitons between two EPs) may approach EMF 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 scales $(h_{g(Pl)} = h)$, one may obtain $\boxed{G_{Pl} = (c / m_e^2) \cdot h_{g(Pl)} = (c / m_e^2) \cdot h \cong 10^{45} G}$. **In conclusion**, the negative energy ("new born") graviton may nullify the positive energy ("new born") photon when (spontaneously) emerging in pairs at Planck scales so that the total energy of a "new-born" photon-graviton pair to be always exactly zero (as eZEH "bosonic variant" predicts). In other words, **eZEH predicts a negative energy graviton which should have equal but opposite energy to the (positive) energy of a (paired) photon at Planck scales.**

j. **Prediction no. 2B**. eZEH also proposes the replacement of big G in Einstein's Field Equation (**EFE**) with the quantum G function $\boxed{G_{Pl} = (c / m_e^2) \cdot h_{g(Pl)} = (c / m_e^2) \cdot h \cong 10^{45} G}$. In this way, the compact EFE based on the predefined (symmetric second-rank) Einstein tensor $\boxed{G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu}}$ (function of the metric tensor $g_{\mu\nu}$) $\boxed{G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}}$ becomes a unifying equation for both quantum mechanics and general relativity, describing a quantum GF mediated by negative energy gravitons: $\boxed{\boxed{G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G_{Pl}}{c^4} T_{\mu\nu} = \frac{8\pi h}{c^3 m_e^2} T_{\mu\nu}}}$.This approach also has the potential to solve the cosmological constant problem by offering the possibility of a vacuum energy density ρ_{vac} that varies inverse-proportionally to the length scale λ (and direct-proportionally to the energy scale E), 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 and the very large ρ_{vac} predicted by the quantum field theory: $\boxed{\rho_{vac(Pl)} = \frac{\Lambda c^2}{8\pi G_{Pl}} = \frac{\Lambda c m_e^{\ 2}}{8\pi h}}$. These aspects were also extensively developed in another paper of the author [**7**].

k. **Prediction no. 2C**. Based on the newly defined type of graviton (as a spin-1 negative energy photon $\boxed{E_g(\lambda) = -h_g \lambda / c}$ with h_g value tending to h [when length scale decreases] and $h_{g(Pl)} = h$ at Planck scale so that $\boxed{E_{ph}(\lambda) + E_{g(Pl)}(\lambda) = h\lambda / c - h_{g(Pl)}\lambda / c = 0}$), eZEH also predicts 4D space to be actually a negative energy perfect fluid-like entity composed from the total number of (negative energy) gravitons formed per time unit (and then vanished, after a various time interval): in other (more plastic) words, **the evanescent photon-graviton pairs are predicted to be the main "creators" of the 4D spacetime "scene"**; this prediction/hypothesis was extensively developed by the author in another article describing a toy-model of a "digital" vacuum composed of space voxels with quantized energetic states suspended in a 3D/4D perfect fluid with negative energy [**8**] (this toy model also predicts that even photons and gluons [who are assigned zero rest masses in SM] actually have very small but non-zero and non-infinitesimal rest masses).

l. **eZEH reformulation (as checkpoint conclusion)**. In other more plastic words, eZEH essentially states (and predicts) that fermionic EP-aEPs pairs need very specific linear space (EP-aEP inter-distance measured as $\boxed{r_x\left(k_{e(x)}, q_{EP}, G_x, m_{EP}\right) = \left(k_{e(x)} q_{EP}^{\ 2} + G_x m_{EP}^{\ 2}\right) / \left(2 m_{EP} c^2\right)}$) to be "born" by the vacuum itself. eZEH conjectures that $r_x\left(k_{e(x)}, q_{EP}, G_x, m_{EP}\right)$ can only have finite and non-infinitesimal values (which also implies that GF cannot reach infinite negative energy density) r_x, which values correspond to a minimal set of spatial (linear) lengths that can be considered a set of spatial length quanta: this may also imply that all known/unknown EPs may have non-zero radii and volumes (**prediction**) and not actually be 0D point-like entities, but 3D entities: this "3D EPs" hypothesis was extensively developed by the author in another article describing a preonic toy model [**9**].

m. **eZEH prediction no. 3 -- the (macrocosmic) black-hole Casimir effect (bhCE)** . eZEH predicts that the regions of wu with very high matter-energy (including radiation) volumic density (like the black holes [**bhs**] for example) may almost totally prevent EP-aEP spontaneous "birth" inside them (given their high level of matter-energy and spatial compression which may not permit specific r_x values): this (internal) EP-aEP "birth-blocking" phenomenon from bhs may create huge gradients/ratios between the EP-aEP outside-over-inside volumic densities; these gradients are predicted to generate the (macrocosmic) black-hole (**bh**) Casimir effect (**bhCE**) which implies an additional bh Casimir field/force (**bhCF**) which further compresses a bh or slows down its evaporation. bhCF is predicted to may strongly inhibit Hawking radiation (**HR**) of bhs and so to potentially explain why HR hasn't been observed yet in the studied bhs from our accessible surrounding macrocosm. eZEH additionally predicts that micro-black holes (**mbhs**) (aka Planck particles) with Planck densities may totally block EP-aEP inside them or may allow the birth of neutrino-antineutrino pairs only. eZEH also predicts that bhs in general may also predominantly emit neutrinos as HR, which is an additional explanation why HR hasn't been observed yet. bhCF exerted on all bhs of wu may generate an (inverse) reaction force (based on the third Newton's law of motion) which may lead to an accelerated expansion/inflation of wu (which is confirmed by the

recent astronomical observations and studies). **In conclusion**, bhs and reaction bhCF may actually drive the cosmic accelerated inflation.

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