A running coupling constant of a hypothetical quantum gravitational field (QGF) supporting a subtype of bimetric gravity theory (BGT) which implies two graviton modes: a super-massive one and a massless one

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* Abstract (with abbreviations)

This paper proposes a running coupling constant of a hypothetical quantum gravitational field (QGF) (in relation to both the strong nuclear field [SNF] and the electromagnetic field [EMF] and based on an interesting logarithmic coincidence relating the running coupling constants of all these three fundamental physical fields: QGF, SNF and EMF) supporting a subtype of bimetric gravity theory (BGT) which implies two graviton modes: a spin-2 super-massive graviton (with rest energy around 1 TeV) and a spin-2 massless graviton; this subtype of BGT is closely related to massive gravity theory (MGT).

This paper continues (from alternative angles of view) the work of other past articles/preprints of the same author [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25] and is actually a separate article dedicated only to “conjecture no.4” of author’s quantum general relativity (QGR) variant [3].

I. A running coupling constant of a hypothetical quantum gravitational field (QGF)

Observation no. 1 (Obs1). Let us start from the following observation:

\[
\alpha_S / \alpha \geq \log_2 (\alpha / \alpha_G) \geq 1/140 \geq \alpha
\]  

(1a),

which is equivalent to (see below)

\[
\alpha / \alpha_G \approx 2^{\alpha_S / \alpha}
\]

(1b)

and

\[
\alpha_G \approx \alpha / 2^{\alpha_S / \alpha}
\]

(1c).

The previous three equations all use the following notations:

a. \(\alpha_S \geq 1\) [URL] is the running coupling constant of the strong nuclear field (SNF)

b. \(\alpha = 1.5E_p \) (the argument of \(\alpha_{SNF} (1.5E_p) \geq (\alpha_S \geq 1) \)) and \(E_e \) (the argument of \(\alpha_{EMF} (E_e) \approx \alpha \)) aren't the same so that \(G_q (E) \) and

\[
\alpha_{SNF} (E) = \frac{12\pi}{(2 \pi) n_f} \ln \left( \frac{E}{E_{QCD}} \right) = \frac{6\pi}{5 \ln \left( \frac{E}{E_{QCD}} \right)}
\]

(a)

formula only valid for \(E \gg E_{QCD} \) at the energy scale of a proton at rest \(E = E_p = m_p c^2 \approx 0.94 GeV \), more precisely \(\alpha_{SNF} (1.5E_p) \approx 1 \) (which is a function of the number of quark flavors \(n_f = 6 \) and the energy scale of quantum chromodynamics [QCD] \(E_{QCD} \approx 0.22 GeV \));

b. \(\alpha = k_e d_e^2 / (\hbar c) \approx 1/137 \) is the running coupling constant of the electromagnetic field [EMF]

\[
\alpha_{EMF} (E) = \left[ \frac{\alpha}{1 - (\alpha / 3\pi) \ln \left( \frac{E^2}{E_e^2} \right)} \right]
\]

(energy scale of an electron at rest \(E = E_e = m_e c^2 \approx 0.51 MeV \) (also known as FSC at rest, valid for scales larger than electron’s Compton wavelength \(E = \lambda_{C(e)} = \hbar c / E_e \approx 2.4 \times 10^{-12} m \) [26]);

c. \(\alpha_G = G m_e^2 / (\hbar c) \approx 1.75 \times 10^{-45} \) is the gravitational coupling constant (GCC), standardly defined as a function of the electron rest mass \(m_e \approx 0.51 MeV / c^2 \) and measuring the strength of the gravitational field (GF).

* Conjecture no. 1 (Conj1). One may easily notice that \(\alpha \) is a “junction”-term in Eq.1a (with \(\alpha \) being present in both left and right parts of Eq.1a): this fact indicates that the running coupling constant \(\alpha \) may actually have a “hybrid”/dual electromagnetic and gravitational significance, acting like a binary logarithmic strength “tuner” between SNF and QGF (through EMF). We consider Obs1 (with its main equation) to NOT be just a simple coincidence and we conjure a generalized equation defining a generalized quantum big G \(G_q (E) \) (varying with the energy scale) and a variable quantum GCC (assigned to a quantum gravitational field [QGF] with variable strength) \(\alpha_{QGF} (E) \) being a function of this \(G_q (E) \), such as:

\[
G_q (E) = \left( \frac{\hbar c / m_e^2}{\alpha_{EMF} (E) / 2^{\alpha_{SNF} (E) / \alpha_{EMF} (E)}} \right)
\]

(2a)

\[
\alpha_{QGF} (E) = G_q (E) m_e^2 / (\hbar c) = \alpha_{EMF} (E) / 2^{\alpha_{SNF} (E) / \alpha_{EMF} (E)}
\]

(2b)

Note that \(1.5E_p \) (the argument of \(\alpha_{SNF} (1.5E_p) \geq (\alpha_S \geq 1) \)) and \(E_e \) (the argument of \(\alpha_{EMF} (E_e) \approx \alpha \)) aren't the same so that \(G_q (E) \) and

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\( \alpha_{QGF}(E) \) aren't quite exact, but only reasonably approximations. A more exact form of the two previous definitions (Eq.2a and Eq.2b) would be

\[
G_q(E) = \left( \frac{\hbar c}{m_e^2} \right) \alpha_{EMF}(E) \left( \frac{2}{\alpha_{SNF}(1.5\beta E/\alpha_{EMF}(E))} \right)
\]

and

\[
\alpha_{QGF}(E) = \frac{G_q(E) m_e^2}{\hbar c} = \frac{\alpha_{EMF}(E)}{2 \alpha_{SNF}(1.5\beta E/\alpha_{EMF}(E))},
\]

with

\[
\beta = \frac{E_p}{E_e} \quad \text{being the ratio between the rest energies/masses of the proton and the electron.}
\]

b. Conjl actually proposes a smooth transition from

\[
G_q^{\text{(min)}} \rightarrow G^{\text{estim.}} \rightarrow G_q^{\text{(max)}} = G_q(E_{pl}) \approx 10^{41} G
\]

by using this E-dependent variable \( G_q(E) \) with variable energy scale \( E \) taking values up to Planck energy \( E_{pl} \approx 1.96 \times 10^9 J \). Interestingly enough, the \( G_q^{\text{(max)}} / G_q^{\text{(min)}} \approx 1.2 \times 10^{41} \) ratio has the same order of magnitude as the ratio

\[
m_{pl}^2 / (m_p, m_n, m_e) \approx 3.1 \times 10^{41}
\]

(with \( m_{pl} = \sqrt{\hbar c / G} \approx 10^{-8} \text{kg} \) being the Planck mass and \( m_p, m_n, m_e \) being the rest masses of the proton, the neutron and the electron respectively). The logarithmized graph of \( p(E) = \log_{10} \left[ G_q(E) / G \right] \) is presented next:

Image 1: The graph of \( p(E) = \log_{10} \left[ G_q(E) / G \right] \) for \( E = 10^x \text{MeV} \) and \( x \in [y, z] \), with

\[
y = \log_{10}(E_{QCD} / 1 \text{MeV}) + 1 \approx 3
\]

and

\[
z = \log_{10}(E_{pl} / 1 \text{MeV}) + 1 \approx 23
\]

c. Very interestingly, the (next) graph of \( \alpha_{QGF}(E) \) (which is the predicted running coupling constant of the quantum gravitational field \( QGF \)) has a growth pattern similar to the graph of the (previously explained) running coupling constant of WNF

\[
\alpha_{WNF}(E) = \frac{E_w G_F / (\hbar c)^3}{e^{E_{pl}/E}}
\]

(with a pattern of unification between QGF and WNF around Planck energy scale \( E_{pl} \approx 1.96 \times 10^9 J \), which is another argument for QGF and WNF being unifiable at those sufficiently large energy scales).

Image 2: The comparative graph of both \( r_{WNF}(E) = \log_{10} \left[ \alpha_{WNF}(E) \right] \) and \( r_{QGF}(E) = \log_{10} \left[ \alpha_{QGF}(E) \right] \) for \( E = 10^x \text{MeV} \) and \( x \in [y, z] \) (see the 1st image of this paper).

d. Important note (1). From the previous image, one may easily notice that \( \alpha_{QGF}(E) \) grows rapidly with the energy scale (being however negligible at atomic size scale \( l_a \approx 10^{-10} m \) corresponding to an energy scale \( E_a = \hbar c / l_a \approx 10^{-2} \text{MeV} \)) up to an inflexion (i) point (ip) (from which \( \alpha_{QGF}(E) \) grows much slower with the increasing energy scale), which ip corresponds to an energy scale \( E_{QGF(i)} \approx 10^6 \text{MeV} \) and to a subnuclear (Compton) length scale \( l_{QGF(i)} = \hbar c / E_{QGF(i)} \approx 10^{-18} m \approx r_p / 10^3 \) (with \( r_p \approx 0.87 \times 10^{-15} m \) being the radius of the proton and \( d_p = 2r_p = 1.64 \times 10^{-15} m \)). Even more interestingly, \( E_{QGF(i)} \approx 10^6 \text{MeV} \) is approximately one order of magnitude larger than the rest energies (E) of the Higgs boson (Hb) \( E_{Hb} \) and top quark (tq) \( E_{tq} \) (which are the heaviest known elementary particles) so
that $E_{QGF(i)}/E_{Hb}\approx 8$ and $E_{QGF(i)}/E_{eqi} \approx 5.7$; it is also interesting that the length-ratio $d_{p}/l_{QGF(i)} (\approx 1403)$ is relatively close to the mass-ratio $m_{p}/m_{e} (\approx 1836)$.

e. Important prediction. The similitude between $\alpha_{WNF}(E)$ and $\alpha_{QGF}(E)$ graphs (with $\alpha_{WNF}(E)$ variation graph also having an inflexion point corresponding to the rest energy of the W boson $E_{W} \approx 80\, \text{GeV}$ and to $x = \log_{10}\left(\frac{E_{W}}{1\, \text{MeV}}\right) \approx 4.9$, as also visible in the previous graph) actually suggests that the massive graviton mode of at least one bimetric gravity theory (BGT) could be actually a heavy spin-2 boson with non-zero rest energy $E_{gr}$ close to $E_{QGF(i)} (\approx 8E_{Hb} \approx 1\, \text{TeV})$ (indifferentified with the quantum of QGF): furthermore, all elementary particles (EPs) with non-zero rest masses could be actually composed from preons interchanging this kind of virtual super-massive hypothetical gravitons (which quantize QGF). We also consider these two possibilities: (1) EITHER what we measure as macroscopic/macrocosmic gravity is only a “residual” force/field (residual QGF) generated by exchange of heavy gravitons at subnuclear scales; (2) OR there are actually two types of spin-2 gravitons (a heavy one mediating gravity at subnuclear scales [QGF] AND a massless one mediating QG at supra-nuclear atomic, microscopic and macroscopic/macrocosmic scales). Note. The predicted rest energy of this heavy spin-2 graviton (mediating QGR at subnuclear scales up to Planck scales) $E_{gr} (\approx E_{QGF(i)} \approx 1\, \text{TeV})$ is almost one order of magnitude larger than the lower bound (lb) energy $E_{lb} \approx 170\, \text{GeV}$ established by quantum electrodynamics (QED) to be assignable to any possible (super-heavy) subcomponent of the electron (that may exist and act inside a composite electron with a hypothetical non-zero volume), with $E_{lb} (\approx 170\, \text{GeV})$ being actually deducted from the very small difference $|\delta q| (\approx 8.3 \times 10^{-12})$ between the value of the electron magnetic moment that we measure in Bohr magnetons (called g/2) and the value of g/2 as predicted by QED as a function of FSC ($\alpha$) at rest (called g/2(\alpha)) [URL].

f. Conclusion (with additional graph). All known fundamental forces/fields can be comparatively represented on the same graph, showing a unifying pattern close to Planck energy scale: see the next image (containing a graph which clearly shows that the strength of QGF approaches very closely the strength magnitudes of the other three fundamental physical fields [FFPs] at energy scales $E \in \left[10^{14}, 10^{15}\, \text{MeV}\right] (<< E_{PI})$ (corresponding to a length scale interval $l \in \left[10^{8}l_{Pl}, 10^{9}l_{Pl}\right] (>> l_{Pl})$ which is approximately 4 orders of magnitude lower than the upper limit [UL] of the electron diameter $d_{e} (\approx 10^{-22}\, m (>> l_{Pl})$, as estimated by using electrons trapped in Penning traps [URL]) (suggested that the electron could actually have a non-zero volume and could be composed from preons interchanging these kind of super-massive gravitons), a fact that raises a great hope for all known FFPs to be actually unifiable at energy scales much lower than $E_{Pl}$ which are hypothetically achievable in other large hadron colliders (LHCs) potentially constructible in the distant future.

Image 3. The comparative graph (with a pattern of unification around Planck energy scale) of $r_{SNF}(E) = \log_{10}\left[\alpha_{SNF}(E)\right]$, $r_{EMF}(E) = \log_{10}\left[\alpha_{EMF}(E)\right]$, $r_{WNF}(E) = \log_{10}\left[\alpha_{WNF}(E)\right]$ and $r_{QGF}(E) = \log_{10}\left[\alpha_{QGF}(E)\right]$ for $E = 10^{x}\, \text{MeV}$ and $x \in \{y, z\}$ (see the 1st image of this paper).

II. References (see also the Wikipedia URLs)


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