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A Standard Model at Planck Scale

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Abstract

To extend the standard model to Planck scale energies I propose a phenomenological model of quantum black holes and dark matter. I assume that at the center of any black hole there is a core object of length scale L_{Planck}. The core replaces the singularity of general relativity. A simple phenomenological model is presented for the core. In the high curvature $t \sim 0$ universe a core is spontaneously created in a false vacuum. Subsequently it tunnels into the true vacuum causing an inflationary process in the universe. Possible conformity with the string world is briefly mentioned.

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1 Introduction and Summary

The motivation behind the model described here is to find an economic way to go beyond the standard model (BSM), including mini black holes, inflation and the model of renormalization group improved quantum gravity. This short note is hoped to be a step forward in exploring the role of Planck scale gravity in particle physics and inflationary universe while a complete theory of quantum gravity remains beyond the scope of this note.

I made earlier a gedanken experiment of what might happen when exploring a mini black hole deep inside with a probe. In [1] I made two assumptions

(**1**) Inside any black hole there is a three dimensional integral part core of spin 0 ($\frac{1}{2}$). The core has an associated length scale of the order L_{Planck}. The core is called here the gravon, and gravion if its a fermion.

(**2**) The black hole singularity of general relativity is replaced by the core.

Einstein equations hold outside black holes, but in the inner region of the hole a different picture for the core is proposed. At $t \sim 0$ the core is a field of large amount of energy that is spontaneously created in a false vacuum from where it tunnels to the true vacuum. Next it goes through an inflationary process leading to black holes and dark matter. For the tunneling a single bubble inflationary model is assumed. The core has an applicable lifetime on the inflation time scale (between 10^{-33} and 10^{-32} sec). The gravon has no horizon and it decays to gravitons which couple to classical objects like black holes and the Higgs. From the high temperature side, the core can be seen as the $T = 0$ limit remnant of a thermally end-radiated black hole [2].

As to cosmic microwave background (CMB) measurements, this model is not designed to give new predictions - many current models compare very well with all available data. The purpose of the model is to take a new look inside black holes. An illustrative comparison might be to see the core as the hydrogen atom nucleus and a black hole as the whole atom.

With the Planck scale having its the conventional value 10^{19} GeV finding a gravon is hard. Gamma-ray signals from the sky may be a promising way. A gamma-ray, or particle, with energy half the Planck mass would be a favorable signal for the model.

In this note I disclose the physical motivation and description of the model. In section 2 I discuss the core qualitatively and in 2.2 its modeling for quantum black holes. Section 3 is devoted to inflation mechanisms and the Starobinsky model of gravity. In 4 I consider issues of conformity in extra dimensions and string theory. I finish in section 5 with a short conclusions. What is not discussed here is the horizon, which has been extensively treated in the literature after the AMPS paper [3]. [2] Dark energy is left for future considerations.

2 The Black Hole Core

2.1 Qualitative Properties

Apart from the assumption of the existence the core model is based on known physical processes, supported by calculations, and is largely under the control of present day technology.

Properties of the gravon model include

[2] Their paper introduced the field to this author.

(**1**) at $t \sim 0$ in the tiny very early spacetime the curvature value R was very high, near singular, and a quantum fluctuation produced a gravon field of an associated length scale of the order L_{Planck},
(**2**) the created gravon is in a false vacuum with energy higher than the true vacuum energy. The subsequent processes started the inflationary phase of the universe. [3]
(**3**) the gravon is a horizonless remnant, either stable or with some lifetime, of a thermally end-radiated black hole. Remnants have no singularity or information loss problems, see the recent review [4],
(**4**) dark matter consists of neutral matter around a core, i.e. black holes.

2.2 Modeling the Core

The core is a finite lifetime bunch of energy, originating from some vacuum and obeying approximately the Klein-Gordon equation. When enough matter falls into the core it makes a transition to a black hole and the wave function collapses into a classical state of general relativity outside the hole.

I consider a few different model cases below which might give insight into the quantum nature of the core. There is an enormous amount of models and calculations in the literature on the general title of quantum gravity, and it may not be too optimistic that a selective synthesis of progress can be made in the near future. The modern view is that general relativity forms a quantum effective field theory at low energies upon which models can be built. The point of view advocated in this note gives an extremely minimal time interval before the big bang for any major effect of quantum gravity.

2.2.1 Einstein-Dirac Cosmology

The singularity of general relativity is a property independent of the size of the system, whether the whole universe or a mini black hole. We start with an example from the large scales. The work of ref. [6] gives indication of singularity avoidance in Friedmann-Robertson-Walker (FRW) cosmology. Their analysis leads to the formation of a fermion condensate, instead of the singularity, and a bouncing scale function. I summarize [6] as follows.

The authors study Einstein-Dirac (ED) equations

$$R^i_j - \frac{1}{2}R\delta^i_j = 8\pi\kappa T^i_j \tag{1}$$

$$(\mathcal{D} - m)\Psi = 0 \tag{2}$$

where T^i_j is the energy-momentum tensor of the Dirac particles, κ is the gravitational constant, $\mathcal{D}$ is the Dirac operator and Ψ the wave function. For metric the closed Friedmann-Robertson-Walker is chosen

$$ds^2 = dt^2 - R^2(t)d\sigma^2 \tag{3}$$

[3] The common multiverse picture of bubbles as universes is not excluded but it does not change conclusions for this model. The bubble collision rate can be made small by the vacuum tunneling potential height.

where R is the scale function and $d\sigma^2$ is the line element on the unit 3-sphere

$$d\sigma^2 = \frac{dr^2}{1-r^2} + r^2 d\theta^2 + r^2 sin^2\theta d\phi^2 \tag{4}$$

where r, θ and ϕ are the standard polar coordinates. The Dirac operator in this metric is written as

$$\mathcal{D} = i\gamma^0 \left(\partial_t + \frac{3\dot{R}(t)}{2R(t)} \right) + \frac{1}{R(t)} \begin{pmatrix} 0 & \mathcal{D}_{S^3} \\ -\mathcal{D}_{S^3} & 0 \end{pmatrix}, \tag{5}$$

where γ^0 is the standard Dirac matrix, and D_{S^3} is the Dirac operator on the unit 3-sphere. The operator D_{S^3} has discrete eigenvalues $\lambda = \pm\frac{3}{2}, \pm\frac{5}{2}, \ldots$, corresponding to quantization of momenta of the particles. The Dirac equation is separate with the ansatz

$$\Psi_\lambda = R(t)^{-\frac{3}{2}} \left[\frac{8\pi\kappa}{3} \left(\lambda^2 - \frac{1}{4} \right) \right]^{-\frac{1}{2}} \begin{pmatrix} \alpha(t)\, \psi_\lambda(r,\vartheta,\varphi) \\ \beta(t)\, \psi_\lambda(r,\vartheta,\varphi) \end{pmatrix}, \tag{6}$$

where α and β are complex functions. For a homogenous system the components of the energy-momentum tensor simplify and the time component is

$$8\pi\kappa T^t_t = \left[m\Big(|\alpha|^2 - |\beta|^2 \Big) - \frac{2\lambda}{R}\, \mathrm{Re}(\alpha\overline{\beta}) \right]. \tag{7}$$

Substituting ψ and T^j_i into the Einstein-Dirac equation one gets

$$i\frac{d}{dt}\begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} m & -\lambda/R \\ -\lambda/R & -m \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} \tag{8}$$

$$\dot{R}^2 + 1 = \frac{m}{R}\left(|\alpha|^2 - |\beta|^2 \right) - \frac{\lambda}{R^2}\left(\overline{\beta}\alpha + \overline{\alpha}\beta \right). \tag{9}$$

With the ansatz (6) all single particle wave functions have the same time dependence thus they form a coherent macroscopic quantum state. The fermionic many-particle state is a spin condensate.

The ED equations further reduce to ordinary differential equations involving the scale function $R(t)$ and the complex functions $\alpha(t)$ and $\beta(t)$. In the limits $\lambda = 0$ and $m = 0$ the equations reduce to the Friedmann equations for dust and radiation universes, respectively. For large R the universe behaves classically as in the dust case. But near the singularities big bang and big crunch quantum effects change the situation. Under certain conditions $\dot{R}$ can become zero and change sign even for small values of R. Thus the formation of a big bang or big crunch is prevented. This effect is called the bouncing scale function.

2.2.2 Asymptotically Free Quantum Gravity

Building on higher derivative terms in the Einstein-Hilbert action, super-renormalizable and asymptotically free theories of gravity have been discussed in the literature [7], see also [8]. Asymptotic freedom removes the singularity. Secondly, asymptotic freedom due to higher derivative form factor causes an effective negative pressure. Repulsive gravity at high density produces a bounce of a black hole. Black holes in fact never form. A distant observer sees a long lifetime for the trapped surface and interprets it as a black hole. The bounce is not given by Heisenberg uncertainty but follows from the dynamics of the system.

In [7] the following non-polynomial extension of the quadratic gravitational action of [9] has been considered

$$\mathcal{S} = \int d^4x \frac{2\sqrt{|g|}}{\kappa^2}\left[R - G_{\mu\nu}\frac{V(-\Box/\Lambda^2)^{-1} - 1}{\Box}R^{\mu\nu}\right], \tag{10}$$

where $\kappa^2 = 32\pi G_N$ and Λ is the Lorentz invariant energy scale. Its value is of the order of Planck mass. The form factor, an entire function V contains the non-polynomial property of the theory. V cannot have poles in the complex plane to ensure unitarity and it must have at least logarithmic behavior in the UV to give super-renormalizability at the quantum level. The theory reduces to general relativity in the low energy limit since all the corrections to the Einstein-Hilbert action are suppressed by the factor Λ^{-1}.

The form factor is related to the propagator and to the effective potential of the theory. An example of a form factor is

$$V(z)^{-1} = exp(z^n) \tag{11}$$

where $z = -\Box/\Lambda^2$ and n is a positive integer. String theory suggests n = 1. These theories have only the graviton pole. There are no ghosts or tachyons. The UV is dominated by the bare action, counterterms are negligible. Further details of these theories are discussed in [7].

It is known that if one adds all quadratic curvature invariants to the Einstein-Hilbert action the resulting theory is renormalizable at the price of ghost modes [9]. In string theory the Einstein-Hilbert action is the first term of an infinite series containing powers of the curvature tensor and its derivatives.

According to Narain and Anishetty [10] the behavior of running coupling constant in the coupled system of higher derivative gravity and gauge fields is renormalizable to all order loops. The leading contribution to the gauge coupling beta function comes entirely from quantum gravity effects and it vanishes to all order loops.

In [10] the authors study fourth order higher derivative gravity which is claimed to be renormalizable to all loops [9] and unitary [11]. The motivation for their study came from the realization that at one loop four kinds of divergences appear $\sqrt{-g}$, $\sqrt{-g}R$, $\sqrt{-g}R_{\mu\nu}R^{\mu\nu}$ and $\sqrt{-g}R^2$. They consider the following higher derivative gravity action in dimensions $2 \leq d \leq 4$

$$S = \int \frac{d^4x\sqrt{-g}}{16\pi G}\left[-R - \frac{1}{M^2}\left(R_{\mu\nu}R^{\mu\nu} - \frac{d}{4(d-1)}R^2\right) + \frac{(d-2)\omega}{4(d-1)M^2}R^2\right] \tag{12}$$

where M has dimension of mass and ω is dimensionless. There are negative norm states, the propagator of the spin 2 massive mode appears with wrong sign violating unitarity at tree level. It was found though that in a certain domain of coupling parameter space, large enough to include known physics, the one loop running of gravitational parameters makes the mass of spin 2 massive mode behave in such a way that it is always above the energy scale being studied.

For our scheme asymptotically free quantum gravity is very interesting but there may not be at the moment general consensus whether it works as hoped.

2.2.3 Asymptotic Safety

Asymptotic safety was proposed by Weinberg [12] in 1976 as a condition of renormalizability. It is based on a nontrivial, or non-Gaussian, fixed point (NGFP) of the underlying renormalization group (RG) flow for gravity. It is nonperturbative in character and it guarantees finite results for measurable quantities. The method for investigation of this scenario is functional renormalization group equation (FRGE) for gravity. The FRGE defines a Wilsonian RG flow on a theory space which consists of all diffeomorphism invariant functionals of the metric $g_{\mu\nu}$ of the type occuring in the action of general relatvity. From this construction emerges a theory called Quantum Einstein Gravity (QEG). QEG is not a quantization of classical general relativity, but it is consistent and predictive theory within the framework of quantum field theory.

The method of ref. [13] uses the effective average action Γ_k, which is background independent. The RG scale dependence is governed by the FRGE of ref. [14]

$$k\partial_k\Gamma_k[\Phi,\bar{\Phi}] = \frac{1}{2}\mathrm{Str}\left[\left(\frac{\delta^2\Gamma_k}{\delta\Phi^A\delta\Phi^B} + R_k\right)^{-1} k\partial_k R_k\right] . \tag{13}$$

where Φ^A is the collection of all dynamical fields and $\bar{\Phi}^A$ denotes their background counterparts. R_k is an infrared cutoff which vanishes for $p^2 \gg k^2$ and provides a k-dependent mass term for fluctuations with momenta $p^2 \ll k^2$. Solutions of the FRGE give families of effective field theories $\Gamma_k[g_{\mu\nu}], 0 \le k < \infty$, labeled by the coarse graining scale k. The solution Γ_k interpolates between the microscopic action at $k \to \infty$ and the effective action $\Gamma_{k\to 0}$.

Suppose there is a set of basic functionals $P_\alpha[\cdot]$. Any functional can be written as a linear combination of the P_α's. The the solutions Γ_k of the FRGE have expansions of the form

$$A[\Phi,\bar{\Phi}] = \sum_{\alpha=1}^{\infty} \bar{u}_\alpha\, P_\alpha[\Phi,\bar{\Phi}] . \tag{14}$$

The basis $P_\alpha[\cdot]$ may include local field monomials and non-local invariants. The generalized couplings $\bar{u}_\alpha$ are used as local coordinates. Or use a subset of couplings, so called essential couplings, which cannot be absorbed by a field reparametrization. The method is nonperturbative but truncations have to be made to the expansions of solutions.

Expanding Γ_k as above and inserting into FRGE we obtain a system of infinitely many coupled differential equations for the $\bar{u}_\alpha$'s

$$k\partial_k\, \bar{u}_\alpha(k) = \overline{\beta}_\alpha(\bar{u}_1, \bar{u}_2, \cdots ; k) , \quad \alpha = 1, 2, \cdots . \tag{15}$$

which can be solved using analytical or numerical methods.

A simple ansatz for action is the Einstein-Hilbert action where Newton's constant G_k and the cosmological constant Λ_k depend on the RG scale k. Let $g_{\mu\nu}$ and $\bar{g}_{\mu\nu}$ denote the dynamical and background metric, respectively. The effective action then satisfies in arbitrary spacetime dimension d

$$\Gamma_k[g,\bar{g},\xi,\bar{\xi}] = \frac{1}{16\pi G_k}\int d^dx\sqrt{g}\Big(-R(g)+2\Lambda_k\Big)+\Gamma_k^{gf}[g,\bar{g}]+\Gamma_k^{gh}[g,\bar{g},\xi,\bar{\xi}] \tag{16}$$

where $R(g)$ is the scalar curvature from metric $g_{\mu\nu}$, Γ_k^{gf} denotes the gauge fixing action and Γ_k^{gh} the ghost action with the ghost fields ξ and $\bar{\xi}$.

The corresponding β-functions describing the evolution of the dimensionless Newton constant $g_k = k^{d-2}G_k$ and dimensionless cosmological constant $\lambda_k = k^{-2}\Lambda_k$, were derived the first time in [13] for any value of the spacetime dimensionality. The most important result is the existence of a non-Gaussian fixed point suitable for asymptotic safety. It is UV-attractive both in g- and λ-directions (roughly $\lambda \approx .35$ and $g \approx .4$).

In the study of [15] it was shown that for $r \to 0$ the RG improved black hole metric approaches that of de Sitter space. This means that the quantum corrected spacetime is completely regular, free from any curvature singularity. The improved regularity comes because the 1/r-behavior of $f_{class} = 1 - 2G_0M/r$ is tamed by very rapidly vanishing of the Newton constant at small distances.

A heavy black hole obeys the classical relation $T_{BH} \sim 1/M$. The mass of the hole is reduced by the radiation the temperature increases. This tendency is opposed by quantum effects. Once the mass is as small as $M_{cr} \sim M_{Planck}$ the temperature reaches its maximum value $T_{BH}(M_{cr})$ [15]. For even smaller masses it drops very rapidly and vanishes at or below the M_{Planck}. In the present model the microscopic black hole is supposed have a remnant which does not Hawking radiate any more.

Asymptotic safety is an important theoretical tool for quantum gravity. The methods used to derive the result are relevant to our scheme, even though the analysis does not support asymptotic freedom. On the other hand, the FRGE analysis necessitates approximations, like series truncations with unknown accuracy, and contains a number of field theory subtleties.

3 Inflation

We assume that the universe originated from a primordial quantum fluctuation in vacuum, creation of a gravon field in a false vacuum. That lead in the next phase to inflation where gravity and the Higgs play major roles. In the heart of quantum gravitation, in the present model, is the black hole core.

3.1 False Vacuum and Higgs Inflation

Inflation [16, 36, 18] stretches the initial quantum vacuum fluctuations to the size of the present Hubble patch, seeding the initial perturbations for the cosmic microwave background radiation and large scale structure in the universe [19]. For a theoretical review, see [20]. Since inflation dilutes all matter it is pertinent that after the end of inflation the universe is filled with the right thermal degrees of freedom: the standard model particles together with dark matter. For a review on pre- and post-inflationary dynamics, see [21].

The decay of the initial false vacuum is a nucleation process in a first order phase transitions [22]. It is initiated by the materialization of a bubble of true vacuum within the false vacuum by quantum tunneling causing a change in the cosmological constant [23].

I assume the tunneling of the scalar gravon takes place from a de Sitter vacuum to a lower energy vacuum, de Sitter or flat, by the one bubble inflationary scenario [24, 25]. Slow roll inflation, by the scalar field potential, follows after the gravon tunneling to the true vacuum in the standard inflationary way. The gravon decay produces primordial black holes which slow down inflation towards exit.

The Higgs scalar field inflation action is [26, 27]

$$S = \int d^4x\sqrt{-g}\left[\mathcal{L}_{\rm SM} - \left(\frac{\bar{M}^2_{\rm Planck}}{2} + \xi|\mathcal{H}|^2\right)R\right] \tag{17}$$

where $\mathcal{L}_{\rm SM}$ is the SM Lagrangian minimally coupled to gravity, ξ is the parameter that determines the non-minimal coupling between the Higgs and the Ricci scalar R, $\mathcal{H}$ is the Higgs doublet and, as a consequence of such large non-minimal coupling, there is a new scale in the theory, $\bar{M}_{\rm Pl}/\sqrt{\xi}$, lower than the standard reduced Planck mass, $\bar{M}_{\rm Pl} \approx 2.43 \times 10^{18}$ GeV. The part of the action that depends on the metric and the Higgs field only (the scalar-tensor part) is

$$S_{\rm st} = \int d^4x\sqrt{-g}\left[|\partial\mathcal{H}|^2 - V - \left(\frac{\bar{M}^2_{\rm Planck}}{2} + \xi|\mathcal{H}|^2\right)R\right], \tag{18}$$

where $V = \lambda(|\mathcal{H}|^2 - v^2/2)^2$ is the Higgs potential and v is the electroweak Higgs vacuum expectation value. In [27] a sizable non-minimal coupling is taken, $\xi > 1$, because it is required by inflation.

3.2 Starobinsky Model

Starobinsky has pointed out that quantum corrections to general relativity should be important in the early universe. The Starobinsky model action is [28]

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{16\pi G}R + \frac{1}{b}R^2\right) \tag{19}$$

with the dimensionless coupling $b = 6M^2/M^2_{\rm Planck}$, where M is a constant of mass dimension one, $M_{\rm Planck} = G^{-1/2}$, G is the Newton's constant with scale dependence and g is the determinant of the metric. This action creates de Sitter expansion phase in the early universe and removes the early singularity.

Usually the Einstein term is regarded as the fundamental term, and the other terms (higher powers in R) are secondary in the sense that they are originate from quantum corrections. But one can take the view that the fundamental term is the one-loop second term R^2 rather than the linear term R.

A non-perturbative renormalization group (RG) analysis the Starobinsky action leads to asymptotically safe (AS) gravity [12]. There exists a non-trivial, or non-Gaussian, UV fixed point, where G is asymptotically safe and the R^2 coupling vanishes. The starting point for RG calculations is an exact renormalization group equation (ERGE) in Wilsonian context, for details see [29]. The aim of [27] is to address both the classical and quantum issues. The latter issue is more of a challenge, but the authors have performed both of them carefully.

4 Theoretical Directions

Assuming scalar and fermion fields a scheme for dynamic generation of the Planck scale with inflation seems possible as discussed in [30]. The authors aim at a model independent analysis and make the interesting proposal that a complete theory of quantum gravity may not even be needed because inflation is described by Einstein gravity at energies below the Planck scale. This is supported by the model of the present note, the quantum era of gravity occurs only extremely briefly before the big bang.

In [31] the Starobinsky model is studied from the point of view of extra dimensions, usually taking six extra dimensions. The authors take the view that the main term is the R^2 term. The pure R^2 theory does not contain any dimensional constant and is therefore scale invariant. Scale symmetry may be spontaneously broken, eg. by coupling to matter sector, leading to a scale Λ. The authors give an estimate of the lower limit of scale $\Lambda \sim 5 \times 10^{15}$ GeV. This is very close to the grand unified theory (GUT) value and the authors suggest associating higher dimensional theory with GUT.

In ten dimensional theories, originally in 5D Kaluza-Klein theory, a dilaton comes always with gravity. If the Newton's constant, or Planck mass, is promoted to a dynamical field the result is the dilaton. The dilaton field has been considered as a model of dark energy in [32].

In the light of present LHC results research based on non-supersymmetric vacua is becoming more important. In non-supersymmetric vacua almost all the moduli are lifted up perturbatively, contrary to the supersymmetric ones which typically possess tens or even hundreds of flat directions that cannot be raised perturbatively. An interesting analysis of non-supersymmetric SO(16) $\times$ SO(16) heterotic string theory is presented in [33]. It is based on the observation that there is a triple coincidence with the Higgs potential

$$V = m^2|\mathcal{H}|^2 + \lambda|\mathcal{H}|^4 \tag{20}$$

(with $m^2 \sim -(90GeV)^2$ and $\lambda \simeq 0.13$) namely: quartic coupling λ, its running, and the bare Higgs mass can all be accidentally small at around the Planck scale. This is a direct hint for Planck scale physics in the context of superstring theory. The vanishing bare Higgs mass implies that the supersymmetry is restored at the Planck scale and that the Higgs field resides in a massless string state. The smallness of both λ and its beta function is consistent with the Higgs potential being very flat around the string scale. Such a flat potential opens up the possibility that the Higgs field plays the role of inflaton in the early universe.

In [33] the authors study the concrete model: the $SO(16) \times SO(16)$ heterotic string theory [34, 35]. This model breaks supersymmetry at the string scale but, unlike the bosonic string theory in 26 dimensions, the tachyonic modes are projected out as in the ordinary heterotic superstring theories. In the fermionic construction, the modular invariance of the partition function restricts the allowed set of the fermion numbers in Neveu-Schwarz (NS) and Ramond (R) sectors. The $SO(16) \times SO(16)$ model is the only one that has neither a tachyon nor supersymmetry in ten dimensions.

There are two possibilities for the potential beyond the maximum: (i) the potential smoothly becomes runaway (ii) the potential has another local minimum

In the latter case, the false vacuum gives a mechanism of eternal inflation. This situation is similar to the idea of the inflation being a first order phase transition. In the medium of the false vacuum, there appears a bubble of the electroweak vacuum due to the tunneling. This eternal inflation in the false vacuum has caused the so-called the graceful exit problem in the old inflation scenario [36]. However in the case (ii) there is a down hill, slow roll and a down hill structure. The space inside the bubble experiences the second stage of inflation hence this problem is ameliorated as we do not need let bubbles collide.

The above described inflation scheme is close to one considered in sec. 3.1, for both the Higgs and the gravon. May be the gravon and gravion are superpartners. Further details should be checked out and there are a lot of subtleties to resolve.

5 Conclusions

The present note contains an definition of a model, and references to literature for more details with calculations and a hint of tests. It takes a step beyond the standard model of particles towards a model of Planck scale phenomena, assuming the standard model is valid up to that scale. At the Planck scale black holes are the key objects to study. Unfortunately not all existing calculational results concerning Planck mass region black holes are in consensus. ERGE based calculations provide rather solid results for $f(R)$ type gravity [37].

The scheme I propose here can be summarized as having the gravon a fundamental elementary particle of quantum gravity, which should be included in the standard model and the modified theory of Einstein-Hilbert gravity. The gravon is a candidate for non-singular blacks hole and dark matter. The Higgs has been considered in [33] to be a string state. The gravon in turn may behave like a massless black string state. It remains open at this stage whether it is stable enough or suitably unstable. One might classify the gravon and the Higgs as the "arsenal" sector and the traditional SM as the "customer" sector of the standard model at Planck scale (SM@P). While tuning will be needed for the details of the model we believe a simple toy model is a useful tool until experimental evidence is found for theories of more mathematical structure. Somewhat unexpectedly, this model seems to conform to a ten dimensional theory, Planck scale supersymmetry and perhaps string theory.

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