July 12, 2015

A Standard Model of Everything

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Abstract

To extend the standard model at 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 Schwarzschild core object of size 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.

PACS 04.60.Bc

Keywords: Quantum Black Hole, Singularity, Dark Matter, Standard Model

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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. This model does not apparently unify gravity with the SM gauge theories, but on closer look, gravity and the Higgs set up the universe from the vacuum as described below.

I made earlier a gedanken experiment of what might happen when exploring a mini black hole deep inside with a probe. In [1, 2, 3] I made two assumptions

(**1**) Inside any black hole there is a 3D integral part core, a Scwarzschild (Kerr) mini black hole core of spin 0 ($\frac{1}{2}$). The core has a length scale of the order L_{Planck}. The core is called here the gravon.

(**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. Quantum corrections to general relativity are expected to be important in the early universe. A false vacuum tunneling single bubble inflationary model is introduced. Renormalization group (RG) equation methods are used to support the non-perturbative renormalizability of the gravity model.

Gravons are formed at $t \sim 0$ in a tiny high curvature spacetime "point" with an applicable lifetime on the inflation time scale (between 10^{-33} and 10^{-32} sec). A $T = 0$ quantum gravon decays to gravitons which couple to classical objects like black holes and the Higgs. On the other hand, the gravon can be seen as the $T = 0$ limit remnant of a thermally end-radiated black hole (possibly without a horizon) [4].

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 qualitative description of the model. The model details and ample references to calculations in the literature are given in [3]. In section 2 I discuss the gravon model for quantum black holes. Section 3 is devoted to inflation mechanisms and the Starobinsky model of modified gravity. I finish in section 4 with conclusions. What is not discussed here is the horizon, which has been extensively treated in the literature after the AMPS paper [5]. [2] Dark energy is left for future considerations.

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

2 The Black Hole Core

This phenomenological model gives a general picture of and quantitative answers to important problems in astro-particle physics. Apart from the assumptions of the existence and properties of the core the model is based on at least previously calculated known physical processes and is largely under the control of present day technology.

Properties of the gravon model include

(**1**) at $t \sim 0$ in the tiny very early spacetime the curvature value R is very high, near singular, producing by a quantum fluctuation a $T = 0$ mini black hole core, the gravon, of size of the order L_{Planck},

(**2**) the gravon is in a false vacuum with energy higher than the true vacuum energy [13]. The subsequent inflationary processes are described in the next section, [3]

(**3**) the gravon is a 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 [6],

(**4**) dark matter consists of neutral matter around a core, i.e. black holes.

3 Inflation

Inflation [7, 8, 9] is the current theory to stretch the initial quantum vacuum fluctuations to the size of the present Hubble patch, seeding the initial perturbations for the cosmic microwave background (CMB) radiation and large scale structure in the universe [10]. For a theoretical review, see [11]. 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 [12].

The decay of the initial false vacuum is a nucleation process in a first order phase transitions [13]. 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 [14].

I assume the tunneling of gravon takes place from a de Sitter vacuum finally to a flat vacuum by the one bubble inflationary scenario [15, 16]. Slow roll inflation, by the Higgs field, follows after the tunneling to true vacuum in the standard way. The gravon decays produce primordial black holes. Black hole formation slows down inflation. Black holes are described by general relativity in the usual way. Dark matter and SM matter can be differently distributed in the universe in this model.

[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 is small due to the vacuum tunneling potential height.

The Higgs inflation action is [17, 18]

$$S = \int d^4x\sqrt{-g}\left[\mathcal{L}_{\rm SM} - \left(\frac{\bar{M}^2_{\rm Planck}}{2} + \xi|\mathcal{H}|^2\right)R\right] \tag{1}$$

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

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

where $V = \lambda(|\mathcal{H}|^2 - v^2/2)^2$ is the Higgs potential and v is the electroweak Higgs vacuum expectation value. In [18] a sizable non-minimal coupling is taken, $\xi > 1$, because it is required by inflation.

Starobinsky has noted that quantum corrections to general relativity should be important in the early universe. The Starobinsky model action is [19]

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{16\pi G}R + \frac{1}{b}R^2\right) \tag{3}$$

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 may remove the early singularity).

An important property of the Starobinsky action is that, by making a non-perturbative renormalization group (RG) analysis, it leads to asymptotically safe (AS) gravity [20]. 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 [21]. The aim of [18] will be 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 Conclusions

The present note contains an outline of a model, and references to literature, and takes a short but important 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 of quantum gravity to study. Unfortunately not all existing calculational results concerning Planck mass region black holes are in consensus. On the other hand, ERGE based calculations provide rather solid results for $f(R)$ type gravity [22].

The scheme I propose here can be summarized as having the gravon the 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 black hole and dark matter. One might classify the gravon and the Higgs as the "arsenal" sector and the traditional SM as the "customer" sector of the standard model of everything (SMoE). While some tuning must be needed for the details of the model we believe a simple model deserves attention until experimental evidence is found for models of more complicated structure.

Acknowledgment

I thank Prof. G. Volovik for useful correspondence.

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