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A Standard Model of Everything

4th of July Summary Version

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Abstract

To complete the standard model 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 Kerr (Schwarzschild) core object of size L_{Planck}. The core replaces the general relativity singularity of the black hole. A simple phenomenological model is presented for the core. In the high curvature $t \sim 0$ universe cores were created in the false vacuum. Subsequently they tunneled into the true vacuum causing the inflationary expansion of the universe. Gravitons condensate around the cores to form primordial black holes which evolve into dark matter in the big bang together with the standard model particles.

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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 big bang 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, 2, 3] I made two assumptions

(**1**) Inside any black hole there is a 3D integral part core, a Kerr (Scwarzschild) mini black hole core of spin $\frac{1}{2}(0)$, or higher. 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 field. The core is the very cause of inflation and later point of condensation of gravitons in the formation of primordial black holes. Einstein equations hold outside the hole, but in the inner region of the hole a new quantum picture of a core in a false vacuum is proposed. For the Starobinsky model action renormalization group (RG) equation methods are used.

Gravons are formed at $t \sim 0$ in a tiny high curvature spacetime with a relatively long lifetime on the inflation time scale. Gravons are at the same time a candidate for dark matter by being a condensation point for bosons, gravitons in this case. The gravon couples to gravitons and to the Higgs. On the other hand, it may be easier to see the gravon to be the $T = 0$ limit remnant of a thermally end-radiated black hole (possibly without a horizon) [5].

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 clear signal of the models of this type.

In this note I concentrate to a physical motivation and qualitative description of the model which is based on particle approach rather than geometrical. The model details with ample references are given in [3]. In section 2 I discuss the gravon model for quantum black holes. Section 3 is devoted to inflation. The Bose-Einstein condensate model is described in section 4. We finish in section 5 with conclusions. What is not discussed here much is the horizon, which has been extensively treated in the literature after the AMPS paper [4]. [2] Dark energy is left for future considerations.

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

2 The Black Hole Core

This phenomenological model of the black hole core gives reasonable quantitative answers to some important problems in astro-particle physics. Apart from the assumption of the existense of the core the model is based on concrete physical processes and is largely under the control of present day technology. Properties of the model include

(**1**) at $t \sim 0$ in the tiny very early spacetime the curvature value R is very high producing a $T = 0$ black hole gravon of size L_{Planck} and immediately a myriad more during time intervals of the order $\Delta t \sim 10^{42-37}$ seconds,

(**2**) the gravons are in a false vacuum with energy much higher than the true vacuum energy [6]. The decay of the false vacuum is a nucleation processes associated with first order phase transitions. The decay is initiated by the materialization of a bubble of true vacuum within the false vacuum by quantum tunneling leading an explosive inflationary expansion. The "Schrödinger equation" is not known exactly at the moment in the literature, but this process can be studied by computer simulations. The Higgs VEV can cause the same physics for inflation, but not for black holes.

(**3**) the gravon is a remnant, either stable or with long lifetime, of a thermally end-radiated black hole. Remnants have no singularity or information loss problems, see eg. the recent review [7],

(**4**) the model works well together with inflation with the cores, black holes, gravitons and the Higgs creating a universe with substantial amount of dark matter together with the standard model matter,

(**5**) there are no problems with unitarity of the present model, and

(**6**) the model gives a physically real interpretation to the nature of thermal Hawking radiation: bosons emitted from the black hole.

(**7**) when the core wave functions do not over lap any more substantially the core thin wall interacts with gravitons causing the phase transition and building a graviton condensate and the horizon around the black hole. The basic attractive force of gravity operates now.

(**8**) black hole formation slows down inflation to a graceful exit.

3 Inflation

Inflation [8, 9, 10] is perhaps one of the most natural way to stretch the initial quantum vacuum fluctuations to the size of the current Hubble patch, seeding the initial perturbations for the cosmic microwave background (CMB) radiation and large scale structure in the universe [11] (for a theoretical treatment, see [12]). 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, i.e. the standard model degrees of freedom together with dark matter (for a review on pre- and post-inflationary dynamics, see [13]). The most economical, with no new degrees of freedom, way to achieve this would be via the vacuum energy density stored within the SM Higgs, or as in the present model, the vacuum energy is inside the gravon.

The Starobinsky action is [14]

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

with the dimensionless coupling $b = 6M^2/M_{\text{Planck}}^2$, where M is a constant of mass dimension one, $M_{\text{Planck}} = G^{-1/2}$, G is the Newton's constant with scale dependence and g is the determinant of the metric. The R^2 term is important to the present model for providing high curvature conditions in the very early universe.

Another important property of the Starobinsky action is that making a non-perturbative renormalization group (RG) analysis it leads to asymptotically safe (AS) gravity. There exists a non-trivial, or non-Gaussian, UV fixed point, where G is asymptotically safe and the R^2 coupling b vanishes. This vanishing of the coupling b in the UV turns out to be of great importance for a succesful inflationary behavior.

Asymptotic safety was first introduced by Weinberg [15] and it states that a UV complete theory for gravity is obtained by assuming that gravity is non-perturbatively renormalizable through the existence of a non-trivial interacting fixed point under the RG. The starting point for RG calculations is an exact renormalization group equation (ERGE) in Wilsonian context [16].

The aim of [17] 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 The BEC Model for Black Holes

A Bose-Einstein condensation model has been studied by Dvali and Gomez [18], see also [19]. Gravitons can self-condense into black holes. To see this let us localize as many soft gravitons as possible around a core within a region of space of size L. We try to form a condensate of gravitons of characteristic wave length L by gradually increasing the occupation number N. For small N the gravitons behave like photons, and the condensate requires external binding forces. As one increasess N the effects of the graviton interaction become large. Individual gravitons feel strong collective binding potential and for the critical occupation number using the graviton-graviton interaction dimensionless coupling constant α

$$N = N_c = \frac{1}{\alpha} \tag{2}$$

the graviton condensate becomes self-sustained.

The concept of maximal packing is that the system is so densely packed that its defining characteristics becomes simply N. In particular

$$L = \sqrt{N}L_{\text{Planck}}, \quad \alpha = \frac{1}{N}. \tag{3}$$

For gravitons being in an overpacked point means that further increase of N without increasing L becomes impossible. Any further increase of N results in the increase of the wave length in such a way that the system stays at the maximal packing point (3). The self-sustained condition equation indicates that the critical point (3) can be achieved for arbitrary N, but decrease of L beyond $L < \sqrt{N} L_{\text{Planck}}$ would result into an even stronger bound system. This collapse of L can happen but it cannot take the system out of the critical point (3). The reason is that the decrease of L is balanced by the decrease of N due to quantum depletion and leakage of the condensate. The condensate slowly collapses and it looses gravitons at the same rate. So the systems always stays at the critical point (3).

The reason for the leakage is that due to the interaction with the other gravitons some of the gravitons get excited above the ground state. The ground state energy is within $1/N$ from the escape level and the gravitons gaining energies above this tiny gap leave the condensate for the continuum. The condensate starts to leak with a depletion rate essentially given by

$$\Gamma_{leakage} = \frac{1}{\sqrt{N} L_{\text{Planck}}} + L_{\text{Planck}}^{-1} \mathcal{O}(N^{-3/2}) \tag{4}$$

This can be understood from the following. Since the graviton-graviton coupling in the condensate is $1/N$ the probability for any pair of gravitons to scatter is suppressed by the factor $1/N^2$, but this suppression is compensated by a combinatoric factor $\sim N^2$ counting the number of available graviton pairs.

The quantum depletion rate translates into the following leakage law

$$\dot{N} = -\frac{1}{\sqrt{N} L_{\text{Planck}}} + L_{\text{Planck}}^{-1} \mathcal{O}(N^{-3/2}) \tag{5}$$

where the dot means time derivative. This quantum leakage of the graviton condensate becomes Hawking radiation in the semi-classical limit, which is defined as the following double scaling limit

$$N \to \infty, \quad L_{\text{Planck}} \to 0, \quad L = \sqrt{N} L_{\text{Planck}} = \text{finite}, \quad \hbar = \text{finite} \tag{6}$$

Thus the semi-classical limit is the limit in which all the quantum physics of the condensate decouples as $1/N \to 0$ and becomes impossible to resolve. The condensate becomes now a collection of infinite number of infinitely soft non-interacting bosons.

The thermality of Hawking radiation follows from the leakage law. Rewriting N in terms of the black hole mass one gets the Stefan-Boltzmann law for a black hole with Hawking temperature $T = \hbar/L$

$$\dot{M} = -\frac{\hbar}{L^2}. \tag{7}$$

The exponential suppression of higher frequencies, usually attributed to the thermality of the source, follows from the combinatorics of the quantum depletion. The underlying quantum physics of this thermal-like spectrum has nothing to do with the thermality of the source, since condensate is in fact cold, but with the underlying quantum physics of BEC being at the overpacked critical point.

In [18] a prototype model, based on standard theory of Bogoliubov-de Gennes equation, is considered, which captures the key features of the phenomenon.

5 Discussion and Conclusions

The present note contains a definite model, and references elsewhere, how to go a short but important step beyond the standard model towards a theory 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 calculation results concerning Planck mass region black holes are in consensus. And a key idea is still missing. On the other hand, ERGE based calculations provide rather solid results for $f(R)$ gravity [20].

The scheme I propose here can be summarized as having the gravon and the graviton the fundamental elementary particles of quantum gravity, to be considered in the standard model. The gravon, going through gravitational inflation and Bose-Einstein graviton condensation, is a natural candidate for non-singular black holes, dark matter and the standard model matter in the universe. The model can most obviously be extended or generalized to more sophisticated mathematical disciplines.

References

[1] R. Raitio, Deep Inelastic Gedanken Scattering off Black Holes, [viXra:1401.0006].

[2] R. Raitio, Black Holes without Singularity? [viXra:15050051v3].

[3] R. Raitio, The Standard Model for Everything [viXra:1506.0212v2].

[4] A. Almheiri, D. Marolf, J. Polchinski, and J. Sully, "Black holes: complementarity or firewalls?". Journal of High Energy Physics 2013 (2) [arXiv:1207.3123].

[5] S. Giddings, Phys.Rev. D46 (1992) 1347-1352, [arXiv:hep-th/9203059].

[6] S. Coleman and F. De Luccia, Gravitational effects on and of vacuum decay, Phys.Rev. D21, 12 (1980).

[7] P. Chen, Y. Ong and D-h Yeom, Black Hole Remnants and the Information Loss Paradox, [arXiv:1412.8366v2].

[8] A. Guth, Phys.Rev. D23, 347 (1981).

[9] A. Linde, Phys.Lett. B108, 389 (1982).

[10] A. Albrecht and P. Steinhardt, Phys.Rev.Lett. 48, 1220 (1982).

[11] P. A. R. Ade *et al.* [Planck Collaboration], "Planck 2015 results. XIII. Cosmological parameters," [arXiv:1502.01589].

P. A. R. Ade *et al.* [Planck Collaboration], "Planck 2015 results. XX. Constraints on inflation," [arXiv:1502.02114].

[12] V. F. Mukhanov, H. A. Feldman and R. H. Brandenberger, Theory of cosmological perturbations. Part 1. Classical perturbations. Part 2. Quantum theory of perturbations. Part 3. Extensions, Phys.Rept. 215, 203 (1992).

[13] A. Mazumdar and J. Rocher, Particle physics models of inflation and curvaton scenarios, Phys.Rept. 497, 85 (2011) [arXiv:1001.0993].

[14] A. Starobinsky, Phys.Lett. B91, 99 (1980).

[15] S. Weinberg, Critical Phenomena for Field Theorists, Erice School for Subnuclear Physics (1976).

[16] E. J. Copeland, C. Rahmede, and I. D. Saltas, Asymptotically Safe Starobinsky Inflation, [arXiv:1311.0881v3] 8 Jun 2015.

[17] A. Salvio 1 and A. Mazumdar, Classical and Quantum Initial Conditions for Higgs Inflation, [arXiv:1506.07520v1].

[18] G. Dvali and C. Gomez, Black Holes as Critical Point of Quantum Phase Transition, arXiv:1207.4059v1 [hep-th].

[19] V. Foit and N. Wintergerst, Self-similar Evaporation and Collapse in the Quantum Portrait of Black Holes, arXiv:1504.04384v1 [hep-th].

[20] T. Sotiriou and F. Faraoni, Rev.Mod.Phys. 82:451-497, 2010 [arXiv:0805.1726v4, gr-qc].