Extra Dimentions, Brane Worlds, and the Vanishing of Axion Contributions to Inflation?

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Abstract: We examine the implications of the 5th Randall Sundrum Brane world dimension in terms of setting initial conditions for chaotic inflationary physics. Our model pre supposes that the inflationary potential pioneered by Guth is equivalent in magnitude in its initial inflationary state to the effective potential presented in the Randall - Sundrum model We also pre suppose an axion contribution to chaotic inflation with a temperature dependence which partly fades out up to the point of chaotic inflation being matched to a Randall – Sundrum effective potential. This is done by use of the Bogomolnyi inequality to re scale and re set initial conditions for the chaotic inflationary potential. One of potential systems embedded in the Ruandal-Sundrum brane world is a model with a phase transition bridge from a tilted washboard potential to the chaotic inflationary model pioneered by Guth which is congruent with the slow roll criteria. If the axion wall contribution is due to Di Quarks, this is equivalent to tying in baryogenesis to the formation of chaotic inflation initial conditions, with the Randall-Sundrum brane world effective potential delineating the end of the dominant role of di quarks, due to baryogenesis, and the beginning of inflation. [Nature and Science. 2006;2(3):45-50].

INTRODUCTION

The 5th dimension of the Randall-Sundrum brane world is of the genre, for $-\pi \le \theta \le \pi$

$$x_5 \equiv R \cdot \theta$$

This lead to an additional embedding structure for typical GR fields, assuming as one may write up a scalar potential 'field 'with $\phi_0(x)$ real valued, and the rest of it complex valued as:

$$\phi(x^\mu, \theta) = \frac{1}{\sqrt{2 \cdot \pi \cdot R}} \cdot \left\{ \phi_0(x) + \sum_{n=1}^{\infty} \left[\phi_n(x) \cdot \exp(i \cdot n \cdot \theta) + C.C. \right] \right\}$$

This scalar field makes its way to an action integral structure which will be discussed later on, which Sundrum used to forming an effective potential. Our claim in this analysis can also be used as a way of embedding a Bogomolyni inequality reduced effective potential in this structure, with the magnitude of the Sundrum potential forming an initial condition for the second potential of the following phase transition .

$$\begin{array}{ll} \widetilde{V}_1 & \to \widetilde{V}_2 \\ \phi(increase) \le 2 \cdot \pi & \to \phi(decrease) \le 2 \cdot \pi \\ t \le t_P & \to t \ge t_P + \delta \cdot t \end{array}$$

The potentials $\widetilde{V}_1$, and $\widetilde{V}_2$ were described in terms of **S-S'** di quark pairs nucleating and then contributing to a chaotic inflationary scalar potential system. Here,

$$m^4 \approx (1/100) \cdot M_P^4 \tag{1}$$

$$\widetilde{V}_1(\phi) = \frac{{M_P}^4}{2} \cdot (1 - \cos(\phi)) + \frac{m^4}{2} \cdot (\phi - \phi^*)^2$$

$$\widetilde{V}_2(\phi) \propto \frac{1}{2} \cdot (\phi - \phi_C)^2 \tag{2}$$

We should keep in mind that ϕ_C in Eqn 3a is an equilibrium value of a true vacuum minimum of Eqn. 3a after tunneling. In the potential system given as Eqn, (3a) we see a steadily rising scalar field value which is consistent with the physics of Figure 1 . In the potential system given by Eqn. (3b) we see a reduction of the 'height of a scalar field which is consistent with the chaotic inflationary potential overshoot phenomena We should note that ϕ^* in Eq (3a)is a measure of the onset of quantum fluctuations. **Appendix I** is a discussion of Axion potentials which we claim is part of the contribution of the potential given in Eqn. (3a) Note that the tilt to the potential given in Eqn. (3a)(3) is due to a quantum fluctuation. As explained by Guth for quadratic potentials[2],

$$\phi^* \equiv \left(\frac{3}{16\cdot\pi}\right)^{\frac{1}{4}} \cdot \frac{M_P^{3/2}}{m^{\frac{1}{2}}} \cdot M_P \rightarrow \left(\frac{3}{16\cdot\pi}\right)^{\frac{1}{4}} \cdot \frac{1}{m^{\frac{1}{2}}}$$

This in the context of the fluctuations having an upper bound of

$$\widetilde{\phi} > \sqrt{\frac{60}{2\cdot\pi}} M_P \approx 3.1 M_P \equiv 3.1$$

Here, $\widetilde{\phi} > \phi_C$. Also, the fluctuations Guth had in mind were modeled via[3]

$$\phi \equiv \widetilde{\phi} \; - \frac{m}{\sqrt{12\cdot\pi\cdot G}} \cdot t$$

In the potential system given by Eqn. (3b) we see a reduction of the 'height' or magnitude of a scalar field which is consistent with the chaotic inflationary potential overshoot phenomena mentioned just above. This leads us to use the Randal-Sundrum effective potential, in tandem with tying in baryogenesis to the formation of chaotic inflation initial conditions for Eqn. (3b) , with the Randall-Sundrum brane world effective potential delineating the end of the dominant role of di quarks, due to baryogenesis, and the beginning of inflation. The role of the Bogomolnyi inequality is to introduce, from a topoplogical domain wall stand point a mechanism for the introduction of baryogenesis in early universe models, and the combination of that analysis, plus matching conditions with the Randal-Sundrum effective potential sets us up for chaotic inflation.

How to form the Randall-Sundrum effective potential

The consequences of the fifth dimension mentioned in Eqn. (1) above show up in a simple warped compactification involving two branes, i.e. a Planck world brane, and an IR brane. This construction with the physics of this 5 dimensional system allow for solving the hierarchy problem of particle physics, and in addition permits us to investigate the following five dimensional action integral.

$$S_5 = \int d^4x \cdot \int_{-\pi}^{\pi} d\theta \cdot R \cdot \left\{ \frac{1}{2}\cdot(\partial_M \phi)^2 - \frac{m_5^2}{2}\cdot\phi^2 - K\cdot\phi\cdot[\delta(x_5) + \delta(x_5 - \pi\cdot R)] \right\}$$

This integral, will lead to the following equation to solve.

$$-\partial_\mu \partial^\mu \phi + \frac{\partial_\theta^2}{R^2}\phi - m_5^2\phi = K\cdot\frac{\delta(\theta)}{R} + K\cdot\frac{\delta(\theta-\pi)}{R} \quad (3c)$$

Here, what is called m_5^2 can be linked to Kalusa Klein "excitations" via (for $n > 0$)

$$m_n^2 \equiv \frac{n^2}{R^2} + m_5^2 \quad (3d)$$

This is for a compactification scale, for $m_5 << \frac{1}{R}$, and after an ansatz of the following is used: (3e)

$$\phi \equiv A\cdot[\exp(m_5\cdot R\cdot|\theta|) + \exp(m_5\cdot R\cdot(\pi - |\theta|))]$$

We then obtain after a non trivial vacuum averaging

$$\langle \phi(x,\theta) \rangle = \Phi(\theta)$$

$$S_5 = -\int d^4x \cdot V_{eff}(R_{phys}(x))$$

This is leading to an initial formulation of

$$V_{eff}(R_{phys}(x)) = \frac{K^2}{2\cdot m_5} \cdot \frac{1+\exp(m_5\cdot\pi\cdot R_{phys}(x))}{1-\exp(m_5\cdot\pi\cdot R_{phys}(x))}$$

Now , if one is looking at an addition of a 2nd scalar term of opposite sign, but of equal magnitude

$$S_5 = -\int d^4x \cdot V_{eff}(R_{phys}(x)) \rightarrow -\int d^4x \cdot \widetilde{V}_{eff}(R_{phys}(x))$$

This is for when we set up an effective Randall – Sundrum potential looking like

$$\widetilde{V}_{eff}(R_{phys}(x)) = \frac{K^2}{2\cdot m_5}\cdot\frac{1+\exp(m_5\cdot\pi\cdot R_{phys}(x))}{1-\exp(m_5\cdot\pi\cdot R_{phys}(x))} + \frac{\widetilde{K}^2}{2\cdot\widetilde{m}_5}\cdot\frac{1-\exp(\widetilde{m}_5\cdot\pi\cdot R_{phys}(x))}{1+\exp(\widetilde{m}_5\cdot\pi\cdot R_{phys}(x))} \quad (4)$$

This above system has a meta stable vacuum for a given special value of $R_{phys}(x)$ We will from now on use this as a 'minimum' to compare a similar action integral for the potential system given by Eqn. (3) above.

How to compare the Randall-Sundrum effective potential minimum with an effective potential minimum involving the potential of Eqn. (3) above

A Randall – Sundrum effective potential, as outlined above would give a structure for embedding an earlier than axion potential structure which would be a primary candidate for an initial configuration of dark energy .This structure would by baryogenesis be shift to dark energy. The Sundrum effective potential at a critical value of $R_{phys}(x)$ would be

$$\widetilde{V}_{eff}\left(R_{phys}(x)\right) \approx \text{ constant } +$$

$$\tfrac{1}{2}\cdot\left(R_{phys}(x) - R_{critical}\right)^2 \propto \widetilde{V}_2\left(\widetilde{\phi}\right) \propto \frac{1}{2}\cdot\left(\widetilde{\phi} - \phi_C\right)^2$$

Let us now view a toy problem involving use of a S-S' pair which we may write as[4]

$$\phi \equiv \pi\cdot\left[\tanh b(x - x_a) + \tanh b(x_b - x)\right]$$

This is for a di quark pair along the lines given when looking at the first potential system.

Now for the question the paper is raising., Does a reduction of axion wall mass for the first potential system due to temperature dependence shed light upon the Wheeler De Witts equations[5] modification by Ashtekar [6] in a early universe quantum bounce ?

Kolb's book also gives a temperature dependence of axions which is [7]

$$m_{axion}(T) \cong .1\cdot m_{axion}(T = 0)\cdot\left(\Lambda_{QCD}/T\right)^{3.7} \qquad (14)$$

We should note that Λ_{QCD} is the enormous value of the cosmological constant which is 10^{120} larger than what it is observed to be today. However, if axions are involved in the formation of instaton physics for early universe nucleation, then Eqn. (14) tells us that as can be expected for very high initial temperatures that axions are without mass but exist as an energy construct. Does this process if it occurs lend then to the regime where there is a bridge between classical applications of the Wheeler De Witt equation to the quantum bounce condition raised by Ashtekar [6] ?

Tie in with di quark potential systems, and the classical Wheeler De-Witt equation

We previously found problems with previous calculations of the cosmological constant as seen in the current QCD calculations[8] which we believe are solved by the inclusion of temperature dependent behavior of the axion wall mass. In doing so, though, we now need to raise the question of a transition from a regime where the classical Wheeler De Witt equation holds, as in n=2 versions of scalar potential as shown by Eqn . (2b) above to where it breaks down, as shown by Abbay Ashtekar's quantum bounce discretized version of the same Wheeler De Witt equation. Let us first review classical De Witt theory which incidently ties in with inflationary n= 2 scalar potential field cosmology.

In the common versions of Wheeler De Witt theory a potential system using a scale radius $R(t)$, with R_0 as a classical turning point value[5] (13)

$$U(R) = \left(\frac{3\cdot\pi\cdot c^3\cdot R_0}{2\cdot G}\right)^2\cdot\left[\left(\frac{R}{R_0}\right)^2 - \left(\frac{R}{R_0}\right)^4\right] \qquad (13a)$$

Here we have that

$$R_0 \sim c\cdot t_0 \equiv l_P \equiv c\cdot\sqrt{\frac{3}{\Lambda}} \sim 7.44\times10^{-36}\, meters$$

As well as

$$\sqrt{\frac{3}{\Lambda}} \equiv t_P \sim 2.48\times10^{-44}\sec$$

This assumes in doing it that one is looking at a Hamiltonian system for a wave functional with $\cdot\Psi(R)$ obeying a Hamiltonian system with energy set equal to zero, so

$$\hat{H}\cdot\Psi(R) = 0 \Rightarrow \left[-\hbar^2\cdot\frac{\partial^2}{\partial\cdot R^2} + U(R)\right]\cdot\Psi(R) = 0$$

Now, Alfredo B. Henriques[9] presents a way in which one can obtain a Wheeler De Witt equation based upon

$$\widetilde{\hat{H}}\cdot\Psi(\phi) = \left[\frac{1}{2}\cdot\left(A_\mu\cdot p_\phi^2 + B_\mu\cdot m^2\cdot\phi^2\right)\cdot\Psi(\phi)\right]$$

Using a momentum operator as give by

$$\hat{p}_\iota = -i \cdot \hbar \cdot \frac{\partial}{\partial \cdot \phi}$$

This is assuming a real scalar field ϕ as well as a 'scalar mass ' m 'based upon a derivation originally given by Thieumann[10]. The above equation given by Theumann, and secondarily by Henriques[9] lead directly to considering the real scalar field ϕ as leading to a prototype wave functional for the ϕ^2 potential term as given by

$$\psi_\mu(\phi) \equiv \psi_\mu \cdot \exp(\alpha_\mu \cdot \phi^2)$$

As well as an energy term

$$E_\mu = \sqrt{A_\mu \cdot B_\mu} \cdot m \cdot \hbar$$

$$\alpha_\mu = \sqrt{B_\mu / A_\mu} \cdot m \cdot \hbar$$

This is for a 'cosmic' Schrodinger equation as given by

$$\tilde{\hat{H}} \cdot \psi_\mu(\phi) = E_\mu(\phi)$$

This has

$$A_\mu = \frac{4 \cdot m_{pl}}{9 \cdot l_{pl}^9} \cdot \left(V_{\mu+\mu_0}^{1/2} - V_{\mu-\mu_0}^{1/2}\right)^6$$

And

$$B_\mu = \frac{m_{pl}}{l_{pl}^3} \cdot \left(V_\mu\right)$$

Here V_μ is the eignvalue of a so called volume operator[6], and the interested readers are urged to consult with the cited paper to go into the details of this, while at the time noting m_{pl} is for Planck mass, and l_{pl} is for Planck length, and keep in mid that the main point made above, is that a potential operator based upon a quadratic term leads to a Gaussian wavefunctional with an exponential similarly dependent upon a quadratic ϕ^2 exponent. We do approximate solitons via the evolution of Eqn. (9), and so how we reconcile higher order potential terms in this approximation of wave functionals is extremely important.

Now Ashtekar in his arXIV article[11] make reference to a revision of this momentum operation along the lines of basis vectors $|\mu\rangle$ by (18)

$$\hat{p}_\iota |\mu\rangle = \frac{8 \cdot \pi \cdot \gamma \cdot l_{PL}^2}{6} \cdot \mu |\mu\rangle$$

With the advent of this re definition of momentum we are seeing what Ashtekar works with as a sympletic structure with a revision of the differential equation assumed in Wheeler – De Witt theory to a form characterized by[11]

$$\frac{\partial^2}{\partial \phi^2} \cdot \Psi \equiv - \Theta \cdot \Psi \tag{19}$$

Θ in this situation is such that (19a)

$$\Theta \neq \Theta(\phi) \tag{19b}$$

Also, and more importantly this Θ is a difference operator, allowing for a treatment of the scalar field as an 'emergent time' , or 'internal time' so that one can set up a wave functional built about a Gaussian wavefunctional defined via

$$\max \tilde{\Psi}(k) = \tilde{\Psi}(k)\Big|_{k \equiv k^*} \tag{19c}$$

This is for a crucial 'momentum' value

$$p_\phi^* = -\left(\sqrt{16 \cdot \pi \cdot G \cdot \hbar^2 / 3}\right) \cdot k^* \tag{19d}$$

And

$$\phi^* = -\sqrt{3/16 \cdot \pi G} \cdot \ln\left|\mu^*\right| + \phi_0 \tag{19e}$$

Which leads to, for an initial point in 'trajectory space' given by the following relation $\left(\mu^*, \phi_0\right) =$ (initial degrees of freedom [dimensionless number] ~'eignvalue of 'momentum', initial 'emergent time ')

So that if we consider eignfunctions of the De Witt (difference) operator, as contributing toward

$$e_k^s(\mu) = \left(1/\sqrt{2}\right) \cdot \left[e_k(\mu) + e_k(-\mu)\right]$$

With each $e_k(\mu)$ an eignfunction of Eqn. (12a) above, with eignvalues of Eqn. (12a) above given by $\omega(k)$, we have a potentially numerically treatable early universe wave functional data set which can be written as

$$\Psi(\mu,\phi) = \int_{-\infty}^{\infty} dk \cdot \widetilde{\Psi}(k) \cdot e_k^s(\mu) \cdot \exp[i\omega(k)\cdot\phi]$$

This equation above has a 'symmetry' as seen in Figure 1 of Ashtekar's PRL article [6] about ϕ, reflecting upon a quantum bounce for a pre ceding universe prior to the 'big bang' contracting to the singularity and a 'rebirth ' as seen by a different 'branch of Eqn. (28b) emerging for a 'growing' set of values of ϕ.

Does the formation of temperature dependence of axion walls help delineate a regime where the Wheeler De Witt equation holds classically ?

How does this relate to what was done in our earlier di quark modeling of dark energy? The following claim is made that a vanishing of the axion wall mass $m_{axion}(T) \cong .1 \cdot m_{axion}(T=0)\cdot(\Lambda_{QCD}/T)^{3.7} \xrightarrow[T\to\infty]{} \varepsilon^+ \Rightarrow$ transition from the 1st to the 2nd potentials as given by Eqn. (3a) and Eqn. (3b) that one is seeing a collapse of the di quark contributions to the 1st potential in a transition given by Eqn. (3) to a potential scheme which is in some respects similar to the quadratic inflationary potential referred to by Henrique's, which has a Gaussian wave functional. as given by Eqn. (9) In terms of phase evolution and change of potentials this would be similar to Eqn. (1) above. This would be in tandem with a cancellation of di quark contributions to Eqn. (2a) in which ϕ_F is for the 'false vacuum' value of the scalar potential given in Eqn. (2a), and ϕ_T is for finding the true minimum value of Eqn. (2a) so that[6] as seen in the condensed matter template given earlier where the change in a least action integral

$$\Psi \propto \exp(-\int dx_{space} d\tau_{Euclidian} L_E)$$

$$L_E \geq |Q| + \frac{1}{2}\cdot(\phi-\phi_0)^2\{\ \} \xrightarrow[Q\longrightarrow 0]{} \frac{1}{2}\cdot(\phi-\phi_0)^2\cdot\{\ \}$$

Where

$$\{\ \} = 2\cdot\Delta\cdot E_{gap}$$

This leads, if done correctly to the quadratic sort of potential contribution as given by $\psi_\mu(\phi) \equiv \psi_\mu \cdot \exp(\alpha_\mu \cdot \phi^2)$ in, At the same time it raises the question of if or not when there is a change from the 1st to the 2nd potential system, if or not we can still work with $\psi_\mu(\phi) \equiv \psi_\mu \cdot \exp(\alpha_\mu \cdot \phi^2)$ in a general sense in the regime of quantum bounces. (22b)

Conclusion

We are presenting a question which may be of relevance to JDEM research. Namely if Ashtekar is correct in his quantum geometry[6], and the break down of early universe conditions not permitting the typical application of the Wheeler De Witt equation, then what do we have to verify it experimentally? The axion wall dependence so indicated above may provide an answer to that, and may be experimentally measurable via Kadotas pixel reconstructive scheme.[12]

Furthermore, we also argue that the semi classical analysis of the initial potential system as given by Eqn (**2**) above and its subsequent collapse is de facto evidence for a phase transition to conditions allowing for dark energy to be created at the beginning of inflationary cosmology..[13,14].This builds upon an earlier paper done by Kolb in minimum conditions for reconstructing scalar potentials[15,16,17,18].It also will necessitate reviewing other recent derivation bound to the cosmological constant in cosmology model in a more sophisticated manner than has been presently done[19,20]. In doing so, it may be appropriate to try to reconcile A. Ashtekar's approach involving a discretization of the Wheeler De Witt equation with the bounce calculations in general cosmology pioneered by Hackworth and Weinberg[21]..

APPENDIX I.

Forming an axion potential term as part of the contribution to Equation 2A

Kolb's book[7] has a discussion of an Axion potential given in his Eqn. (10.27) (23)

$$V(a) = m_a^2 \cdot (f_{PQ}/N)^2 \cdot (1-\cos[a/(f_{PQ}/N]) \qquad (23a)$$

Here, he has the mass of the Axion potential as given by m_a as well as a discussion of symmetry breaking which occurs with a temperature $T \approx f_{PQ}$. (23b) Furthermore, he states that the Axion goes to a massless regime for high temperatures, and becomes massive as the temperature drops. Due to the fact that Axions were cited by Zhitinisky in his QCD ball formation[22], this is worth considering, and this potential is part of Eqn. (6a) with the added term giving a tilt to this potential system, due to the role quantum fluctuations play in inflation. Here, N>1 leads to tipping of the wine bottle potential, and N degenerate CP-conserving minimal values. The interested reader is urged to consult section 10.3 of Kolb's Early universe book for details[7].

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PACS numbers: 03.75.Lm, 11.27.+d, 98.65.Dx, 98.80.Cq, 98.80.-k

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