Symmetries in Evolving Space-time and Their Connection to High-Frequency Gravity Wave Production

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Abstract: Linking a shrinking prior universe via a wormhole solution for a pseudo time dependent Wheeler-De Witt equation permits the formation of a short-term quintessence scalar field. We claim that our model and the addition of the wormhole is tied to an initial configuration of the Einstein field equations, allowing for high-frequency gravitational waves (HFGW) at the onset of inflation. This is due to symmetries in space-time, which enable the creation of high-frequency gravitational waves. The duration of a wormhole thermal bridge between prior and present universes is less than Planck's time duration, but has consequences up to our present cosmological era. This also leads to phase transition changes that form a template for graviton production. The initial conditions so created also suggest optimal environmental conditions for advanced spacecraft propulsion systems.

Keywords: Wormhole, High-frequency Gravitational Waves (HFGW), symmetry, causal discontinuity
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INTRODUCTION

We begin first with a restatement of the physics that leads to a wormhole solution for early-universe transferal of vacuum energy from a prior universe to today's expanding universe. The main contention of this paper is that we need to go back to early universe conditions to determine optimal conditions for graviton production. These conditions should be reduplicated in a graviton-based propulsion system. In part, when we do so, we have to appeal to symmetry arguments, which in themselves lend toward a symmetry-breaking phase transition. Due to graviton production, this involves a radical drop in temperature several orders of magnitude, from a very high initial temperature of ten to the 32nd power Kelvin in the process.

Several symmetries present themselves for analysis. The first is inherent in the wormhole from a prior to a present universe. The second is in the thermal discontinuity region inherent in the wormhole, for reasons described in this paper. The third is in a well-known computational universe model presented in part by Seth Lloyd, showing how entropy is maximized in a way that tends toward high-frequency gravity wave production. This with the Seth Lloyd model of the universe as a quantum computing device permits us to specify a shift to high-frequency gravitational waves, as a way of keeping a finite, but large number of computational bits of information for the modeling of how the universe expands, no matter how large the universe becomes in the far future.

HOW A WORMHOLE FORMS

The Friedman equation referenced in this paper allows for determining the rate of cosmological expansion. Mukhanov (2005) provides the easiest derivation of this equation. The usual way is to start with the energy-momentum tensors of cosmic matter-energy and from there go to the Einstein field equation to show how the universe expands. The basics of this are in the observation that the strength of gravitational fields not only depends on energy density, but also pressure. The rescaled "distance term" $a(t)$ is part of an equation that is similar to the Newtonian equations used for the derivative of energy density with respect to time, with additional space-time metrics used to show the interrelationship of space-time components combined by the Einstein version of the stress-energy tensor. By necessity, if we look at the Friedman equation, we need to look at a metric for space-time. And wormholes are used as a way to obtain conditions for sufficient energy to be transferred from a prior to present universe to initiate relic graviton production at the onset of the universe's expansion..

The wormhole picked is the so called Lorentzian Wormhole used by Visser (1996) to form a bridge between two space-time configurations. Lorentzian wormholes have been modeled thoroughly. Visser (1995) states that in the wormhole solution, there is not an event horizon hiding a singularity, i.e., there is no singularity in the wormhole held open by dark energy. resenting a wormhole as a bridge between a prior to a present universe, as Crowell (2005) refers to in his reference on quantum fluctuations of space-time. The equation for thermal/vacuum energy flux that leads to a wormhole uses a pseudo time- like space coordinate in a modified Wheeler-De Witt equation for a bridge between two universes. The wormhole solution is dominated by a huge vacuum energy value.

This paper uses a special metric that is congruent with the Wheeler-De Witt equation, which can be explained as follows. If one rewrites the Friedmann equation using Classical mechanics, we can obtain a Hamiltonian, using typical values of $H = p_a \cdot \dot{a} - L$. Where p_a can be roughly thought of as the "momentum" of the scale factor a(t), and L is the Lagrangian of our modeled system. The most straightforward presentation of this can be seen in Dalarsson (2005). Afterwards, momentum is quantized via $p_a = i\hbar \frac{\partial}{\partial a}$, and then with some rewrite initially, one can come up with a time-independent equation looking like $H \cdot \Psi = 0$. Crowell, among others, found a way to introduce a pseudo-time component that changed the $H \cdot \Psi = 0$ equation to one that has much the same flavor as a pseudo-WKB approximation to the Schrodinger equation. This, with some refinements, constitutes what we used for forming a "wormhole" bridge.

We referenced the Reissner-Nordstrom metric. This is a metric that is similar to the space-time metric used for black hole physics, i.e., black holes with a charge. With some modifications, this is the metric that Crowell (2005) used to form his version of the Wheeler-De Witt equation with a wave functional, similar to the WKB equation (i.e. it is still semiclassical), to form the wave functional solution. Crowell (2005) used this solution as a model of a bridge between a prior universe and our own. To show this, one can use results from Crowell (2005) on quantum fluctuations in space-time, which provides a model from a pseudo time component version of the Wheeler De Witt equation, using the Reinssner-Nordstrom metric to help obtain a solution that passes through a thin shell separating two space-times. The radius of the shell, $r_0(t)$ separating the two space-times is of length l_P in approximate magnitude, leading to a multiplication of the time component for the Reissner-Nordstrom metric:

$$dS^2 = -F(r) \cdot dt^2 + \frac{dr^2}{F(r)} + d\Omega^2 \quad . \tag{1}$$

This has:

$$F(r) = 1 - \frac{2M}{r} + \frac{Q^2}{r^2} - \frac{\Lambda}{3} \cdot r^2 \xrightarrow[T \to 10^{32}\,Kelvin \sim \infty]{} -\frac{\Lambda}{3} \cdot (r = l_P)^2 \quad . \tag{2}$$

Note that Equation (2) referenced above is a way to link this metric to space-times via the following model of energy density equation, linked to a so called "membrane" model of two universes separated by a small "rescaled distance" $r_0(t)$. In practical modeling, $r_0(t)$ is usually of the order of magnitude of the smallest possible unit of space-time, the Planck distance, $l_P \sim 10^{-35} cm$, za quantum approximation put into general relativity.. The equation linking Eqn.(2) to energy density ρ is of the form:

$$\rho = \frac{1}{2\pi \cdot r_0} \cdot \sqrt{F(r_0) - r_0^2} \quad . \tag{3}$$

Frequently, this is simplified with the term, $\dot{r}_0(t) \cong 0$. In addition, following temperature dependence of this parameter, as outlined by Park (2003) leads to

$$\frac{\partial F}{\partial r} \sim -2 \cdot \frac{\Lambda}{3} \cdot \left(r \approx l_P\right) \equiv \eta(T) \cdot \left(r \approx l_P\right) \quad . \tag{4}$$

This is a wave functional solution to a Wheeler De Witt equation bridging two space-times. The solution bridging two space-times is similar to one made by Crowell (2005) between these two space-times with “instantaneous” transfer of thermal heat:)

$$\Psi(T) \propto -A \cdot \left\{\eta^2 \cdot C_1\right\} + A \cdot \eta \cdot \omega^2 \cdot C_2 \quad . \tag{5}$$

This equation has $C_1 = C_1(\omega, t, r)$ as a cyclic and evolving function of frequency, time, and spatial function, also applicable to $C_2 = C_2(\omega, t, r)$ with, $C_1 = C_1(\omega, t, r) \neq C_2(\omega, t, r)$

It is asserted here that a thermal bridge in wormhole form exists as a bridge between a prior and present universe. Furthermore, it is asserted that the existence of this bridge is part of a necessary condition for thermal energy transfer between a prior and present universe. The prior universe shrinks to a singularity at the time that thermal energy is transferred to our present universe, thereby helping to initiate cosmological inflation. dominated This is due in part to the absolute value of the five-dimensional “vacuum state” parameter varying with temperature T, as Beckwith (2007) writes:

$$\left|\Lambda_{5-\dim}\right| \approx c_1 \cdot \left(1/T^{\alpha}\right) \quad . \tag{6}$$

This contrasts with the more traditional four-dimensional version of the same, without the minus sign of the brane world theory version (i.e., the four-dimensional cosmological constant grows large and is a positive valued expression at the same time that the five- dimensional vacuum energy expression shrinks in value and has a negative value). The five-dimensional version is based on brane theory and higher dimensions, whereas the four-dimensional version is linked to more traditional De Sitter space-time geometry, as given by Park (2002):

$$\Lambda_{4-\dim} \approx c_2 \cdot T^{\beta}. \qquad (7$$

Looking at the range of allowed upper bounds of the cosmological constant, one can note the difference between what Park (2002) predicted (a nearly infinite four-dimensional cosmological constant) and Barvinsky (2006), who specified an upper limit of 360 times the square of Planck’s mass m. This indicates that a phase transition is occurring within a Planck interval of time.. This allows for a brief interlude of quintessence. This assumes that a release ofgravitons occurs, which leads to a removal of graviton energy stored contributions to this cosmological parameter, with m_P as the Planck mass, i.e. the mass of a black hole of “radius” on the order of magnitude of Planck length $l_P \sim 10^{-35}$ m. This leads to Planck’s mass $m_P \approx 2.17645 \times 10^{-8}$ kilograms, as alluded to by Barvinsky (2006).

$$\Lambda_{4-\dim} \propto c_2 \cdot T \xrightarrow[\text{graviton-production}]{} 360 \cdot m_P^2 << c_2 \cdot \left[T \approx 10^{32} K\right] \quad . \tag{8}$$

Right after the gravitons are released, there is still a drop off of temperature contributions to the cosmological constant. For a small time value, $t \approx \delta^1 \cdot t_P$,where $0 < \delta^1 \leq 1$ and for temperatures sharply lower than= 10 to the 32nd power Kelvin, this difference is the ratio of the value of the four-dimensional version of the cosmological constant divided by the absolute value of the five dimensional cosmological constant, which is equal to 1 plus 1/n, where n is a positive integer. This assumes Beckwith's (2007) result, where the four-dimensional cosmological constant parameter sharply decreases in value with decreasing temperature, while the absolute value of the five-dimensional cosmological parameter grows, leading to n growing far larger. Eventually, with an increase of time to about the Planck time interval , the 1/n values goes to zero, and the values of the ratio of the cosmological parameters remains in the same relative magnitude. (The five-dimensional cosmological parameter in absolute magnitude is a very large vacuum energy value.)

The absolute value of the brane world vacuum energy expression becomes identical in value to the four-dimensional cosmological constant at time t (Planck) interval when the matter-energy exits the wormhole. In other words, t

(Planck), or 10 to the minus 44 seconds after exiting the wormhole mouth, there are approximately equal values of the four- and five-dimensional cosmological parameters, i.e., the magnitude of the brane world vacuum energy increases as the four-dimensional cosmological constant shrinks with decreasing temperature.

This huge drop in temperature occurs because energy is removed due to the release of relic gravitons during a phase transition from a nearly infinite thermally based Park value of the cosmological constant to Barvinsky's much smaller value of the cosmological constant. . The initial temperature is in the range of needed thermal excitation levels required for quantum gravity processes to be initiated at the onset of a new universe nucleation. Energy is removed due to the release of relic gravitons during a phase transition from a nearly infinite thermally based Park value of the cosmological constant to Barvinsky's much smaller value.

$$\frac{\Lambda_{4-\dim}}{\left|\Lambda_{5-\dim}\right|} - 1 \approx \frac{1}{n} \quad . \tag{9}$$

The transition outlined in Eqn. (7) above has a starting point with extremely high temperatures given by a vacuum energy transferal between a prior universe and our present universe, as outlined by Eqn. (3) and Eqn. (4) above; whereas the regime where there is an upper bound to vacuum energy in four dimensions is outlined in Eqn. (9) above. So eventually, we can model the behavior of scalar fields as transformed from cyclic behavior, with an imaginary component, to a purely real-valued scalar equation, as given by the argument in the next sections. The paper concludes with a proof of the short-term behavior of this quintessence scalar field, making reference to both Eqn. (7) and Eqn (8) above. This wormhole solution is a necessary and sufficient condition for thermal transfer of heat from that prior universe to allow for graviton production under relic inflationary conditions.

CLAIM 1: The following are equivalent (In a space-time evolution sense? Definitely yes)

1. There exists a Reisnner-Nordstrom Metric with -F(r) dt^2 dominated by a cosmological vacuum energy term, $(-\Lambda/3)$ times dt^2, for early universe conditions in the time range less than or equal to Planck's time t_P.
2. A solution for a pseudo-time dependent version of the Wheeler De Witt equation exists, with a wave function $\Psi(r,t,T)$ forming a wormhole bridge between two universe domains, with $\Psi(r,t,T) = \Psi(r,-t,T)$ for a region of space-time before signal causality discontinuity for times $|t| < t_P$.
3. The heat flux-dominated vacuum energy value given by $\Psi(r,t,T)$ contributes to a relic graviton burst, in a region of time less than or equal to Planck's time t_P.

The proof of claim 1 is referenced via an article in arXIV, Beckwith (2007). This claim establishes the structure outlined in this paper as to the causal discontinuity approach to wormholes. The wormhole solution to the Wheeler De Witt equation implies evidence for causal discontinuity due to the transferal of thermally based vacuum energy..

Begin first by presenting a version of the Friedmann equation given by Frampton (2007). The scale factor evolution equation as referenced here, is based on a derivative of the energy density with respect to time, and the combination of terms seen from the energy stress tensor used in General Relativity. The ρ_{rel} ~ energy density terms due to high velocity (near the speed of light) contributions to states of matter energy--taking into account the known effects of how matter/energy states--are altered at the ultra-relativistic physics scale. The ρ_{matter} ~ baryonic (ordinary matter, which is thought now to comprise 3 to 5% of matter-energy in the universe today). Where Λ is the vacuum energy, initially transferred from a prior universe to our own. This paper argues that when Λ is initially enormous, the following evolution equation creates a discontinuity regime of space-time at the mouth of the wormhole:

$$(\dot{a}/a)^2 = \frac{8\pi G}{3} \cdot \left[\rho_{rel} + \rho_{matter}\right] + \frac{\Lambda}{3} \quad . \tag{10}$$

The existence of such a nonlinear equation for early universe scale factor evolution introduces a de facto "information" barrier between a prior universe, which can only include thermal bounce input to the new nucleation phase of our present universe. To see this, refer to Dr. Dowker's (2005) paper on causal sets. These require the following ordering with a relation $\prec$, where we assume that initial relic space-time is replaced by an assembly of discrete elements, so as to create, initially, a partially ordered set C:

(1) If $x \prec y$, and $y \prec z$, then $x \prec z$

(2) If $x \prec y$, and $y \prec x$, then $x = y$ for $x, y \ \varepsilon \ C$

(3) For any pair of fixed elements x and z of elements in C, the set $\{y \mid x \prec y \prec z\}$ of elements lying in between x and z is always assumed to be a finite valued set.

Items (1) and (2) show that C is a partially ordered set, and the third statement permits local finiteness. Stated as a model for how the universe evolves via a scale factor equation permits us to write, after we substitute $a(t^*) < l_P$ for $t^* < t_P =$ Planck time, and $a_0 \equiv l_P$, and $a_0 / a(t^*) \equiv 10^{\alpha}$ for $\alpha >> 0$ into a discrete equation model of Eqn (5) leads to the existence of a de facto causal discontinuity in the arrow of time and blockage of information flow, once the scale factor evolution leads to a break in the causal set construction written above .

CLAIM 2: The Friedmann equation for the evolution of a scale factor $a(t)$, suggests a non partially ordered set evolution of the scale factor with evolving time, thereby implying a causal discontinuity**.** The validity of this formalism is established by rewriting the Friedman equation as follows:

$$\left[\frac{a(t^* + \delta t)}{a(t^*)}\right] - 1 < \frac{\left(\delta t \cdot l_P\right)}{\sqrt{\Lambda/3}} \cdot \left[1 + \frac{8\pi}{\Lambda} \cdot \left[(\rho_{rel})_0 \cdot 10^{4\alpha} + (\rho_m)_0 \cdot 10^{3\alpha}\right]\right]^{1/2} \xrightarrow[\Lambda \to \infty]{} 0 \quad . \tag{11}$$

So in the initial phases of the big bang, with a very large vacuum energy, the following relation, which violates (signal) causality, is obtained for any given fluctuation of time in the "positive" direction:

$$\left[\frac{a(t^* + \delta t)}{a(t^*)}\right] < 1 \quad . \tag{12}$$

The existence of such a violation of a causal set arrangement in the evolution of a scale factor argues for a break in information propagation from a prior universe to our present universe. This has just proved non-partially ordered set evolution, by deriving a contradiction from the partially ordered set assumption. The easiest way to show this discontinuity is to use Eqn. (12) to show that in the evolution of the scale factor is in certain time steps either partly reversed, or in a chaotic mode. This shows up in a breakage in causal evolution of "information" transmitted via the medium, where Eqn. (12) shows an information exchange/flow with a linear progression in time. There is a causal break, since information flow is not linear in time if the scale factor is unexpectedly made chaotic in its time evolution.

One valid area of inquiry that will be investigated in the future is the following: Is this argument valid if there is some third choice of set structure (for instance, do self-referential sets fall into one category or another?)? The answer to this, it is suggested, lies in (entangled?) vortex structure of space-time, along the lines of structure similar to that generated in the laboratory by Ruutu (1996). Self-referential sets may be part of the generated vortex structure, and the author will endeavor to find if this can be experimentally investigated. If the causal set argument and its violation via this procedure holds, we what we see is a space-time "drum" effect. The causal discontinuity forms the head of a "drum" for a region of about 10^{10} bits of "information" before our present universe, up to the instant of the big bang itself, for a time region less than $t \sim 10^{-44}$ seconds in duration, with a region of increasing bits of "information" going up to 10^{120} due to vortex filament condensed matter forming through a symmetry breaking phase transition.

SETH LLOYD'S UNIVERSE AS A MODIFIED QUANTUM COMPUTER MODEL

Many people would not understand why computational models of the universe would be important to either cosmology or to propulsion. What we establish though this model is a way to explain why the dominant contribution to gravity waves from a wormhole transferal of vacuum energy to our present universe is tilted toward a dominant high-frequency spectrum. This allows us to understand what sort of initial conditions would be favored for graviton production, which it is claimed, is the way to go for an advanced propulsion system in spacecraft design.

One can make use of the formula given by Seth Lloyd (2002), which relates the number of operations the "Universe" can "compute" during its evolution. Lloyd (2002) uses the idea, which he attributed to Landauer, to the effect that the universe is a physical system that has information being processed over its evolutionary history. Lloyd also makes reference to a prior paper where he attributes an upper bound to the permitted speed a physical system can have in performing operations in lieu of the Margolis/Levitin theorem, with a quantum mechanically given upper limit value (assuming E is the average energy of the system above a ground state value), obtaining a *first limit* of a quantum mechanical average energy bound value, if $\# operations/\sec = \tilde{N}$:

$$\tilde{N} \leq 2E/\pi\hbar \quad . \tag{13}$$

tThe second limit is the number of operations, which is linked to entropy, due to limits to memory space, as Lloyd writes:

$$\tilde{N} \cdot \sec \leq S(entropy)/\left(k_B \cdot \ln 2\right) \quad . \tag{14}$$

The *third limit*, based on a matter-dominated universe, relates the number of allowed computations/operations within a volume for the alleged space of a universe. This makes the identification of this space-time volume as $c^3 \cdot t^3$, with c the speed of light, and t an alleged time or age for the universe. Energy $E \sim \rho \cdot c^2$, with ρ as the density of matter, and $\rho \cdot c^2$ as the energy density/ unit volume. This leads to:

$$\tilde{N} \leq \rho \cdot c^2 \times c^3 \cdot t^3 \quad . \tag{15}$$

If $\rho \sim 10^{-27} kil/meter^3$ and time is approximately $t \sim 10^{10}$ years, this leads to a present upper bound of:

$$\tilde{N} \cdot \sec \approx \rho \cdot c^5 \cdot t^4 \leq 10^{120} \quad . \tag{16}$$

Lloyd further refines this to read as follows:

$$\tilde{N} \cdot \sec = \frac{4E}{\hbar} \cdot \left(t_1 - \sqrt{t_1 t_0}\right) \approx \left(t_{Final}/t_P\right) \leq 10^{120} \quad . \tag{17}$$

It is assumed that $t_1 =$ final time of physical evolution, whereas $t_0 = t_P \sim 10^{-43}$ seconds and also one sets an energy input by assuming in early universe conditions that $N^+ \neq \varepsilon^+ << 1$, and $0 < N^+ < 1$. So the graviton burst supplied energy value is:

$$E = (V_{4-Dim}) \cdot \left[\rho_{Vac} = \frac{\Lambda}{8\pi G}\right] \sim N^+ \cdot \left[\rho_{graviton} \cdot V_{4-vol} \approx \hbar \cdot \omega_{graviton}\right] \quad . \tag{18}$$

Furthermore, if based on the assumption that the temperature is within the given range of $T \approx 10^{32} - 10^{29}$ Kelvin initially, a Hubble parameter is defined as specified by Seth Lloyd. This is in lieu of time $t = 1/H$, a horizon distance defined as $\approx c/H$, and a total energy value within the horizon as:

$$\text{Energy (within the horizon)} \approx \rho_C \cdot c^3 \Big/ \left(H^4 \cdot \hbar\right) \approx 1/\left(t_P^2 \cdot H\right) \quad . \tag{19}$$

Lloyd (2002) defines a horizon parameter as:

$$H = \sqrt{8\pi G \cdot [\rho_{crit}] / 3 \cdot c^2} \quad . \tag{20}$$

And an early universe:

$$\rho_{crit} \sim \rho_{graviton} \sim \hbar \cdot \omega_{graviton} \Big/ V_{4-Vol} \quad . \tag{21}$$

Then:

$$\begin{aligned} \tilde{N} \cdot \sec &\approx 1\Big/\left[t_P^2 \cdot H\right] \approx \sqrt{V_{4-Vol}} \cdot t_P^{-2} \Big/ \sqrt{\left[8\pi G \hbar \omega_{graviton} \Big/ 3c^2\right]}, \\ &\approx \left[3 \ln 2/4\right]^{4/3} \cdot \left[S_{Entropy} \Big/ k_B \ln 2\right]^{4/3}. \end{aligned} \tag{22}$$

CLAIM 3: The number of allowed operations in the evolution of the universe specifies a relationship between an evaluated volume for space-time, and upper limits of released relic graviton frequencies. This is proved by appealing to Eqn. (22) above. Next, the existence of certain symmetries in the scalar field itself are examined.

CLAIM 4**:** Without the frequency in Eqn. (21) becoming large, the number of operations could effectively go to 10^{1000} or higher. How can this be shown? One would need to have a very large gravitational frequency range, with high-frequency gravity waves, in order to brake the effects of a tiny Planck time interval $t_P^{-2} \sim 10^{86} \sec^{-2}$ in the number of operations. So that instead of Eqn. (22) bounded by 10^{120}, as the volume increased, one could have the number of degrees of operations become almost infinite.

This last claim combined with the discussion right after Eqn. (11) above (the initial “drum head “ model for a bounded region of space bracketed by causal discontinuity regions) constitutes a working model of an information-based model of cosmology that the author expects will yield falsifiable experimental criteria.

SMOOT’S INFORMATION THEORY/COSMOLOGY CONCLUSIONS

At the “D.Chalonge” school presentation Dr. Smoot (2007) stated the following information theory processing bits levels, which are due to different physical processes. The following are Dr. Smoot’s preliminary analysis of information content in the observable universe:

1) Physically observable bits of information possibly generated in the Universe: 10^{180}.
2) Holographic principle allowed bits (states) in the evolution / development of the Universe: 10^{120}.
3) Initially available bits (states) given to us to work with at the onset of the inflationary era: 10^{10}.
4) Observable bits of information present due to quantum / statistical fluctuations: 10^{8}.

The author’s speculation is that the thermal flux implied by the existence of a wormhole accounts for perhaps 10^{10} bits of information. These bits could be transferred via a wormhole solution from a prior universe to our present, as alluded to by Eqn. (4) above, and that there could be perhaps 10^{120} minus 10^{10} bits of information temporarily suppressed during the initial bozonification phase of matter right at the onset of the big bang itself.

Then, the degrees of freedom dramatically dropped during the beginning of the descent of temperature from about $T \approx 10^{32}\,Kelvin$ by at least three orders of magnitude.

OPEN QUESTIONS

If there is a non-infinite but huge negative value of the cosmological vacuum energy in the wormhole, then there are 10^{10} bits of computing information. When we leave the wormhole, we have 10^{120} bits of computing information.

There is a transition between the two regions in terms of chaotic behavior of the a(t) scale factor. This chaotic behavior of the scale factor creates a measured causal discontinuity between the region of space measurable by increasing a(t) before and after the causal discontinuity regime of space time. The discontinuity regime is induced by a huge thermal flux as shown by the initially enormous Park (2002) value of the cosmological constant. After traversing the cosmological discontinuity regime, the four-dimensional cosmological constant is at the much lower Barvinsky value of 360 times the square of Planck's mass.

More details are needed to bridge this transition to the problem of structure formation and a drop of temperature. In Ruutu's (1996) ground-breaking experiment, vortex line filaments are seen rapidly forming. Here are a few open questions that should be asked:

1) Do the filaments in any shape or form have an analogy to the cosmic strings hypothesized by string theorists? The author's guess is yes, but one cannot be certain of this. If the filaments have an analogy to cosmic strings, then what is the phase transition from a maximally entangled space-time continuum (with a soliton type behavior for temperatures of the order of $T \sim 10^{32}\,Kelvin$) to the formation of these stringy structures?
2) What is the mechanism for the actual transition from the initial "soliton" at high temperatures to the symmetry-breaking phase transition? This is trickier than people think. Many theorists consider that, in tandem with Ruutu's (1996) experiment that axion super partners, saxions, actually are heated up and decay to release entropy. Are there structures in initial space-time analogous to super fluids, allowing for such a transformation? Do axion/saxion super partner pairs exist in the onset of thermal transition from a prior universe to our present universe? How could this be experimentally determined with rigorous falsifiable experimental analysis?
3) One of the models considered as a super fluid candidate for this model has been the di quark one. This however was advanced by Zhitinisky (2002) in terms of "cold dark matter." Could some analogy to di quarks be used for initial states of matter that are thermally impacted by a transfer of thermal energy via a wormhole to form a cosmic "bubble" in line with the initial plasma state given in Ruutu's (1996) experiment?
4) Does the formation of such initial conditions allow optimal conditions for graviton production? If so, can this be transferred to engineering prototypes? How can this be modeled appropriately?

CONCLUSIONS

So far, this paper has established a working information theory-based model of cosmological evolution with a lot of symmetry arguments thrown in. The approach is novel, leading to a new way of looking at why, for example, CMBR space/volume is what it is, relative to bits of "information" computed during the course of cosmological evolution. For future research one should delineate in more detail what would be transferred, possibly by entanglement information transfer from a prior universe, to our own, as well as understand how additional bits of information came to be in the present Universe. It would be valuable, partly using the rich lore from liquid helium as outlined by Kopik (1993), to see if there is a way to experimentally determine if the growth and the relative increase in structure and bits of "information," is in some sense connected with a cosmological equivalent to the vortex reconnection process outlined in liquid helium experiments. One guess is that there is actually a symmetry-breaking transition equivalent in early universe cosmology that could be experimentally duplicated. In particular, the author is convinced that the fourth claim given above is fundamental physics, and that as there is a growing volume during inflation, this needs to be investigated.

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