Special Issue

Examining the Existence of the Multiverse

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Abstract
Guth's (1997) inflationary universe model has been widely accepted in modern physics. Expanding upon this concept, Linde (1994) introduced the Chaotic and Eternal Inflationary model. The inflationary universe structure allows for multiple universes or various "bubble" universes connected through scalar and tensor fields and making the structure of space self similar on larger scales. In this paper we briefly examine these and other theories - including M-Theory - associated with a multiverse, which consider that our universe and others are created by collisions between membranes in an 11-dimensional space.

Key Words: *:* cosmology, quantum mechanics, multiverse, scalar fields

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1 - Introduction: Why a Multiverse?

Use of the observational data, in the study of CMB and WMAP, indicates that the universe is accelerating its expansion. If this acceleration is caused by a positive energy density of the vacuum (i.e., cosmological constant, $\Lambda>0$), the process could continue forever. With a variety of theories researchers have sought to explain this phenomena including abstract theories of elementary particles, such as M-theory, string theory, supergravity and the standard model (SM). Many of them lead to the conclusion that our known universe is part of a multiverse.

There are numerous ideas of how a multiverse came into existence, including Linde's Bubble Theory, the many worlds interpretation (MWI) of quantum physics, braneworlds predicted by string theory and M-branes, and other models which we examine in this paper.

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There are at least six different classifications of a multiverse: the Quilted Multiverse, Inflationary Multiverse, Brane, Cyclic and Landscape Multiverses, MWI, and the Holographic Universe. In most of these theories—string theory, the inclusion of the cosmological constant and quantum physics—have shown certain mathematical congruities.

According to Rauscher and Hurtak (2012), Jenkins (2010) and others, our ability to exist, that is, for life to form as we know it, depends on a precise set of conditions, physical constants that exist in our universe. Specifically, in this observable universe, the parameters seem to be "fine-tuned" into particular values, including the Planck length, such that if they had other values, known forms of life would not exist.

A critical constant that had been generally overlooked, the cosmological constant, Λ, is now beginning to occupy a major role following the research of Perlmutter (2005) and the High-z Supernova Search Team. Sorkin (2007) examined the data, to provide an explanation of the importance of Λ, stating that based upon observations of supernovas, it is most likely that $\Lambda>0$ but also $\Lambda<1$. According to Steinhardt and Turok (2006) the observed data, 7 x 10^{-30} g/cm^3, is over 120 orders of magnitude smaller than the Planck density of 10^{93} g/cm^3, the density of the universe as it emerges from the big bang.

Einstein formulated the field equation of (Rauscher, 2012):

$$R_{\mu\upsilon} - \frac{1}{2} g_{\mu\upsilon} R_{\mu\mu} + \Lambda g_{\mu\upsilon} = -\frac{8\pi G}{c^4} T_{\mu\upsilon} = -\frac{8\pi}{F} T_{\mu\upsilon} \quad (1)$$

where $T_{\mu\upsilon}$ is the Riemann-Christoffel curvature mass-energy tensor, and $F = c^4/G$ is the Rauscher cosmological acceleration force. Although he never clearly defined Λ (Kofman, 1993), a positive cosmological constant accelerates the universal expansion and this is exactly what Perlmutter (2005) observed in the supernova data. The observable data also reveals that the calculations of the density parameter Ω are closer to: $\Omega_m \approx 0.25$ and $\Omega_\Lambda \approx 0.75$.

The cosmological constant has become an important factor in measuring and understanding the acceleration of the universe, as well as the H_0 (Hubble) = 73.8 ± 7 km/sec/MPC (Rauscher, Hurtak, Hurtak 2012) are also required for its calculation. Specifically, according to Guth's (1997) Inflationary Theory, the initial inflation occurs because of the positive vacuum energy density, and where Λ creates a negative pressure which causes an accelerated expansion measured in the Hubble constant H, of the universe (Dharwadker, 2011).

As before mentioned, our universe seems to have a fine-tuning suitable for life as we know it. In the multiverse theory, one universe has the same temperature and same physical constants, whereas other universes may display other properties. For instance, the constant temperature of the cosmic background radiation throughout space is measured at ~ 2.73° K, as determined by the NASA COBE satellite in 1992. According to Fixsen (2009) specifically, T = 2.725 FIRAS calibration (2.725 ± 0.002 K.) as derived from the WMAP. The temperature "consistency" is key to the consideration of the inflationary model because, for the universe to reach the same temperature throughout, with limited irregularities of only a few millionths of a degree, different regions must exchange heat with every other part. The Big Bang would not alone account for this amount of homogeneity.

The universe, however, is not only homogenous, but is isotropic where its matter is evenly distributed in all directions. Specifically, the cosmic microwave background has shown that space is isotropic in all directions to within one part in 100,000. Guth's (1997) conclusion is that a rapid "inflationary period" took place in approximately the first 10^{-35} seconds of our universe's start of existence. Since the standard model assumes the universe is both homogenous and isotropic, inflation is used to explain the dilemma, known as the "horizon problem", as to how different regions of space, appear to be essentially indistinguishable in nature. Linde's (1994) Chaotic or Eternal Inflation Theory followed in which it was considered that this universe was just a "bubble" that was generated from the "foam" of many other possible universes, during the inflationary period. Linde describes our universe as a "child universe" generation out of a "false vacuum" of quantum fluctuations.

Moreover, in the consideration of Linde's Eternal Inflationary model or other string theorists, Brane models hypothesize that in other universes, universal constants could be different, although some duplication or similar constants may occur. One of the mathematical geometric concepts behind these theories come from the question of a possibly open or closed universe, where in addition to our universe's homogeneous nature, it appears our universe is relatively flat. The present day range of the density parameter is 0.1 <~ Ω <~ 2 (Linde, 2005).

In fact, since the observable data of the energy density, Ω yields a value close to the value of 1, and supports the flatness of the universe hypothesis which, in turn, supports the inflationary model.

Specifically, measurements, including MAT/TOCO, Boomerang, Maxima and DASI (Sievers, 2003) have shown that the brightest spots within the WMAP are about 1 degree across which demonstrates that we are living in a flat universe.

The flatness, Ω, is defined by the density parameter, ρ/ρ_c, which is the ratio between the actual mass density of the universe (ρ) to the critical density (ρ_c). The flatness is a relative parameter and yet may be sufficient to create an "infinite" universe. The combination of CMB anisotropy, LSS (Large Scale Structure at the Institut Laue-Langevin) and other observations demonstrate the flat universe as $\Omega_K \approx -0.02 \pm 0.02$, where Ω_K is the deviation from flatness, that is curvature which corresponds to a closed, flat, and open universe, or the magnitude of the spatial curvature in our current universe (Souradeep, 2011). According to calculations by NASA scientists, there is only a 5% margin of error in the CMB. This is based on the basic geometrical fact that angular scale subtended in the sky by the acoustic horizon is different in a universe with uniform positive (spherical), negative (hyperbolic), or zero (Euclidean) spatial curvature.

If space is flat, it could be also infinite; we prefer to say "open-ended". An open universe indicates a negative large-scale curvature that the universe would expand forever. If the universe were slightly larger, it would have collapsed in to a big crunch; if the universe were smaller the stars would have disappeared too early in its evolution. Flat space would indicate that space is infinite or "open ended" and keeps expanding forever. Yet regions in our own universe may be "off-limits" due to what is called a Quilted Multiverse, where only our region of the universe is available for observation. So even though space is infinite with a zero largescale curvature there may be additional spaces, some even undergoing additional Big Bangs that we cannot normally observe, hence the limited age of "our" own universe at a mere 13.7 billion years. This is consistent with the "Little Wimper" or multiple bangs of Rauscher (2005).We may all be living in part of a quantum possibility where every possible world manifests as some other universe.

Both flat and open universe models account for our observations of an accelerating universe (Riess, 1998). Thus, Drs. Hurtaks agree with Linde (1994) who claims the initial expansion was caused by the positive vacuum energy and the cosmological constant, $\Lambda > 0$, allowing for the acceleration of the universe to continue forever. On the other hand, this acceleration may stop and the universe may eventually collapse. The flatness of the universe may be simply a temporary phase of expansion. Since it is clear that the average density and the critical density changes with time, three major factors are important to consider. We have already introduced these factors, but now to determine the relationship between Ω_Λ, Ω_m and Ω_K, or what Bahcall (1999) tells us are the three factors needed to assess the state of the universe. Mathematically they can be interpreted as:

$$\Omega_m = \frac{8\pi G \rho_{matter}}{3H^2} \tag{2a}$$

$$\Omega_\Lambda \equiv \frac{8\pi G \rho_\Lambda}{3H^2} = \frac{\Lambda}{3H_0^2} \tag{2b}$$

$$\Omega_\kappa = \frac{-\kappa}{a^2 H^2} \tag{2c}$$

a is the scale value which is taken to be 1 at the present time and G is the gravitational constant. In an open universe $\Omega_K > 0$ and in a closed universe $\Omega_K < 0$. According to Guth's (1997) Inflationary Cosmology, a flat universe is a consequence of the inflationary era, where $\Omega_K = 1 - \Omega_m - \Omega_\Lambda$.

Here we see how Ω_Λ is associated with the density parameter:

$$\Omega \equiv \frac{\rho}{\rho_c} = \frac{8\pi G \rho}{3H^2} \tag{3}$$

By utilizing the observational data (Perlmutter 2005; Sievers 2003), it appears that the universe is flat which agrees with Einstein's theory of general relativity that confirms that the energy density of the universe has a critical value of (Bahcall 1999),

$$\rho_c \equiv \frac{3H^2}{8\pi G} \sim 1.7\ x10^{-29}\, g \cdot cm^{-3} \qquad (4)$$

where:

$$\Omega \equiv \frac{\rho}{\rho_c} \approx 1 \qquad (5)$$

Although one important premise is that temperature is homogenous throughout the universe, there are also small perturbances in the temperature of the universe, as further noted in the CMB which add support to the inflationary theory (Guth, 1997), and the flat spectrum where the scalar spectrum n_s is indexed as 0.963 ± 0.12. Some of these perturbances may also be a clue to observing a previous connection to other universes (Feeney 2011).

Many of the problems with a stand alone Big Bang theory can be found in Amaroso and Rauscher (2009) which details not only flatness and temperature constants, as mentioned here, but also rotations and density fluctuation. However, Rauscher does not consider Inflation, but the concept of the multi-Big Bang or "Little Whimper" model (Rauscher, 2005) which demonstrates the consistency between Einstein's field equations and the Big Bang-like cosmology.

Drs. Hurtak postulate a false vacuum that comes from previous – false vacuum bubbles (or a cyclic-type universe) which connects with Rauscher's fundamental rotation as one of the multi-dimensions in the Rauscher model, but not necessarily full inflation.

Considering the possible existence for other universes and understanding that our universe is flat, there is no reason to consider that all possible universes are flat. All possible geometries may be available for other universes. In terms of geometric structures of the multiverse, Hurtak (1973) considered two versions of the geometry of multiple universes in both 2-D and 3-D structures as shown in Figure 1, as just two of the numerous possibilities.

We also take into account the Calabi-Yau formulations of over 100^{500} possible geometries for the multiverse. Every Calabi-Yau manifold with mirror symmetry or T-duality admits a hierarchical family of supersymmetric toroidal 3-cycles (Amoroso and Rauscher 2009). It is currently unknown whether the attempt to formalize this continuous-state structure should follow a Kaluza-Klein spin tower, logarithmic or golden ratio spiral, cyclotron resonance hierarchy, Genus-1 helicoid 'parking-garage' or some other higher dimensional structure. Considering the idea of the holographic universe, we realize basic complex structures, as detailed in Figure 2 (Amoroso and Rauscher 2009).

Rauscher, however, further points out that if we cannot measure or observe details that constitute a multiverse its existence may never be able to be proven. Although in science many proposals appear well in advance of observations, for example, the Higgs particle. At the same time, there may be ways of observing the previous existence of other universes as proposed by WMAP data, which may show signs of a parent or sister universes (Feeney, 2011). There is also the possibility that other universes may not be completely unique, and share similar constants and could be cosmic duplicates of our realm (Greene, 2011).

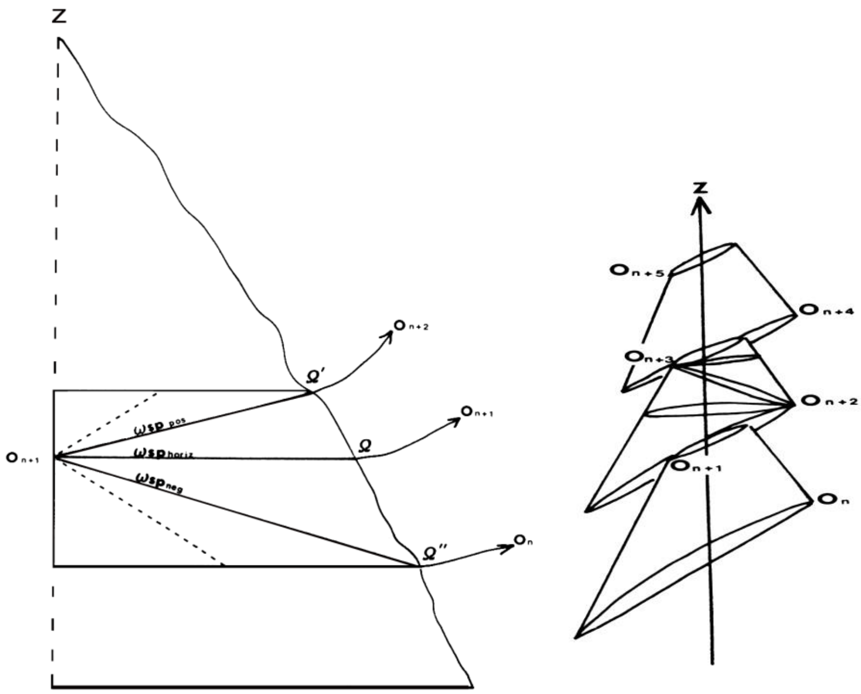

Figure 1. 2-dimensional (left) and 3-dimensional (right) Geometric Structures of our universe and other pocket universes generated by "false vacuum"(Courtesy of J. Hurtak)

2 - Guth's Inflationary Theory

Alan Guth hypothesized that the early universe grew exponentially, driven by vacuum energy pressure expanding many times faster than the velocity of light. The universe generated from a hot Big Bang would not allow for the observable even temperatures of the current universe. In the Big Bang, space would be flying apart faster than light, so all parts of the universe would not have been in touch with each other.

To solve this dilemma in the early 1980s, Guth (1997) introduced his inflationary cosmology with the hypothesis that started with the fabric of space exploding by the stupendous factor of roughly a factor of 10^{40}-10^{100}, during the very initial moments after the space-time foam and the initial Planck epoch ($t = 0$ to $t=10^{-43}$), probably at $t=10^{-37}$ to 10^{-34}s, and then "inflation" came to a halt. He further postulated that during the "inflaton field", the preliminary time would have permitted matter/energy to interact throughout all of space. The inflaton field is a scalar field, which causes the universe to expand exponentially. Additionally, the flatness is due to the enormous size of the universe at the initial period of exponential inflation. Inflation ended when the cosmological constant dropped to a value similar to what we have today ($\Lambda>0$ and $\Lambda<1$) (Guth, 1997). The energy perturbations became frozen into the fabric of spacetime and lead to the formation of galaxies. Matter began to dominate the universe with gravity coalescing it around areas of greater density.

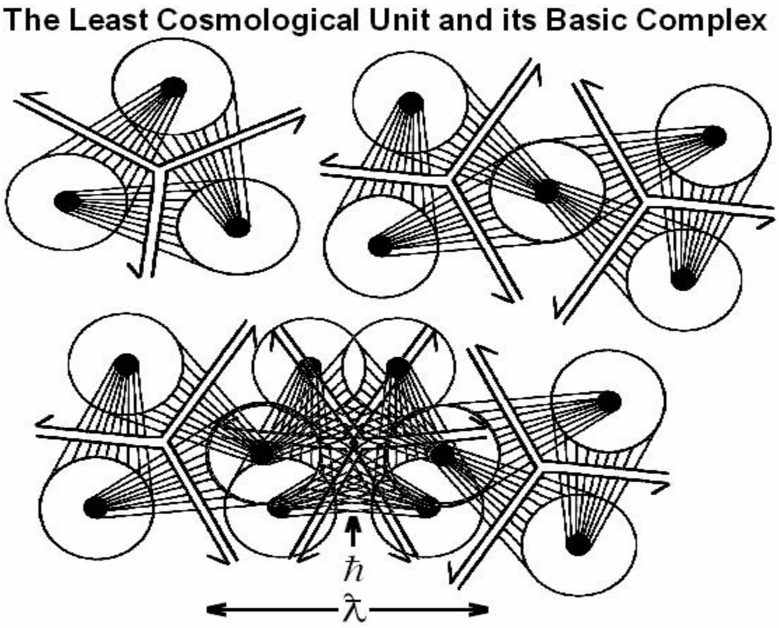

Figure 2 According to Amoroso and Rauscher the basic configuration for the Holographic universe can conceptualize the triune nature of an isolated least-unit not existing in nature. This illustrations how there is the coupling of two isolated least-units along an *x* coordinate. The central portion denoted by $\hbar$ represents the realization of one virtual Euclidean point which oscillates harmonically to ~ the Larmour radius of a hydrogen atom here denoted as $\lambda\!\!\!^{-}$ which represents the new *Stoney* representation of $\hbar$ plus string tension, *Ts*. This model can be considered a Cramer transaction. (Courtesy of Amoroso and Rauscher 2009).

Two critical components behind this theory should be understood: 1) the "inflation field" and 2) the concept of a "false" vacuum. The "inflaton field" has an energy density (ρ) and also pressure (p) considered to be negative or repulsive. We define density of the early universe as:

$$(\Omega^{-1}-1)\rho a^2 = -\frac{-3kc^2}{8\pi G} \qquad (6)$$

The energy density, ρa^2, remains roughly constant because of being dominated by the inflaton field. Hence, the expansion of the universe directly relates to one of Friedmann's equation,

$$H^2 = \left(\frac{\dot{r}}{r}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} \qquad (7a)$$

and the closer H^2 gets to $\frac{8\pi G}{3}\rho$, the flatter the universe becomes.

This continues to a second Friedmann equation, which is introduced to show how a universe has been dominated with both energy density ρ and pressure p:

$$\left(\frac{\ddot{r}}{r}\right) = -\frac{4\pi G}{3}(\rho + 3p) \qquad (7b)$$

At the end of the inflationary era essentially all of the energy of the universe is contained in this one, nearly homogeneous field. We find this also defined in the acceleration equation:

$$\left(\frac{\dot{r}}{r}\right) = -\frac{4\pi\ G}{3c^2}(\varepsilon + 3p) \qquad (7c)$$

The "false vacuum" (Guth, 2004), in quantum mechanics is considered as a metastable spacetime that is a teeming foam of particles and antiparticles that are coming into existence from virtual space and then annihilating each other. Unlike in a true vacuum, a false vacuum, is a combination of energy states with a nonzero value. A standard vacuum state (i.e, lowest energy state), devoid of any matter or radiation, does have some energy associated with it. The value, however, of this energy is given by Λ which in a "false vacuum" becomes a condition for an elevated or metastable vacuum energy density.

The question is how does the particle from the vacuum come into this universe, or how do virtual particles become real? Quantum fluctuations, in the form of virtual particle pairs of borrowed energy ΔE, get separated during the interval $\Delta t \leq \hbar/\Delta E$. If during Δt, the physical size Δx leaves the event horizon (Lineweaver 2003), the virtual particles cannot reconnect, they become real and the energy debt is paid by the driving mechanism of inflation, the energy of the false vacuum, the Λ_{inf} associated with the inflaton potential $V(\phi)$.

This concept, in general, was recently confirmed by Wilson (2011) who demonstrated how virtual particles that constantly appear and disappear in the vacuum become real particles. What Wilson and colleagues confirmed is the *Dynamical Casimir Effect,* where virtual photons, after leaving their virtual state, become real photons of light in matter. The Casimir effect was predicted more than 40 years ago by Gerald Moore, who said that if photons (as virtual particles) bounce off a mirror moving at nearly the speed of light, they could become real.

The theory of the vacuum is based on the concept of quantum energy fluctuations of zero-point energy (ZPE), which is what makes it impossible to reach absolute zero degrees Kelvin. The quantum vacuum is not empty but is seething with virtual particle creation and annihilation in a Dirac-Fermi Sea model. Another area of consideration is in plasma at considerably higher temperatures. Rauscher (1968) developed a detailed theoretical formalism of the effect of vacuum state energy states in a polarization on the properties of fully ionized plasma gas, the conductivity and other electrical properties are demonstrated to be modified by the vacuum state polarization of the plasma media, that is, the measured values of the plasma's electrical and magnetic properties are consistent between theory and experiment only when we include the effects of a Dirac-Fermi vacuum of virtual particle states.

Casimir and Polder (1948) considered that the vacuum virtual particles could induce a short-lived electrical current between two parallel smooth conducting metallic plates. In turn, the induced current will create a magnetic field, which could either pull the plates together or push them apart. The direction of the force between the plates on the respective current flows and forms fields.

Sparnaay (1958) conducted an experiment and came within 15% of the theoetrical value and later Steve Lamoreaux (1997) designed and conducted an experiment, which was more sensitive, the results of which were within 5% of experimental value.

In current experiments by Wilson and colleagues (2011), to create a dynamic Casimir effect, a mirror was used to simulate movement at the speed of light as in the early universe, by varying the physical distance to the mirror. More specifically, the "mirror" consisted of a SQUID magnetometer. By changing the direction of the magnetic field several billion times a second, with the use of the SQUID, the mirror moved slightly causing a 'wiggle' at around 25% the speed of light, which was sufficient to cause photons to be extracted from the vacuum.

The result was that photons appeared in pairs from the vacuum, which were able to be measured in the form of microwave radiation. It is believed that other particles (e.g., electrons, positrons, protons, etc.) might also be extracted from a vacuum, but photons are the easiest as they require less energy to extract. Now that virtual particles from a vacuum can become real particles, we can ask the question; where do the virtual particles come from? Does the vacuum pair production and Big Bang Nucleogenesis (BBN) come from empty space, that is, out of nothing, or are the vacuum particles from our connection to other dimensions or parallel universes?

3 - Linde's Chaotic or Eternal Inflation

The question of quantum fluctuations is addressed by Albrecht (2004), Steinhardt (2007), and Linde (1994), and expanded upon Guth's Inflationary Theory. According to Linde (1994), our universe is one of an infinite number of universes. In addressing the question of where do virtual particles come from, Linde described the universe as a bubble emerging from the quantum foam of a "parent universe." On very small scales, the foam is dynamic and frothing due to energy fluctuations (Wheeler, 1962). Fluctuations in the foam create tiny bubbles and wormholes. Small energy fluctuations establish a small bubble universe, which expands, but then contracts and goes out of existence. If the energy fluctuation is greater than a particular critical value, a bubble universe forms from the parent universe, and long-term expansion continues, permitting matter and large-scale galactic structures formation.

Universes are generated from one dS (de Sitter) vacuum, to another due to the formation of bubbles. A dS universe is spatially flat and neglects ordinary matter, but has a positive cosmological constant, which sets the expansion rate (Linde, 2006). Thus, each bubble contains a new dS vacuum. If gravity is very strong in an alternative universe, no expansion may occur and the universe will never develop. If, on the other hand, gravity is weaker, the expansion will be so fast that no stars or galaxies develop.

Each new universe will have its own life cycle, like our own, depending on the physical constants that constrain it. As a universe could have different laws of physics, this may further mean that any intelligent life forms may only be capable of exploring their own universe, making full observation of other universes difficult, if not impossible.

Linde *et. al.* (2006) hypothesizes that only a "small bang" or something like Rauscher's "Little Wimper" (2005) would be required. Linde considers that the Eternal Chaotic universe becomes more like a growing fractal in that from the false vacuum several pocket universes can be formed and a universe can continue to produce excessive landscape realms. A similar structure is described by Hurtak in Figure 1, where universes generate other universes.

The inflation from the quantum fluctuations is unstoppable and because of this there will always be regions of space somewhere that continue to inflate (Davies, 2008) creating other universes with *ad infinitum* possibilities. In the presence of scalar fields, the fields begin to oscillate, they lose energy, and form elementary particles. This can be observed in the vibrational resonance patterns of the universe as "quantum jitters". Linde calls his theory >chaotic eternal inflation= indicating that it has no end and which may have no beginning. Chaotic inflation requires $\phi > M_p$ where ϕ is the potential density of the inflating scalar field and M_p is the Planck mass.

Inflation can be formulated as $P(\phi, t)\, d\phi$ where t = time and $d\phi$ represents an interval. Here the scalar field is represented by a continuous function, $\phi(x, t)$, which can be real or complex. Inflation occurs when scale factor growth, i.e., $d^2x/dt^2 > 0$ revealing that the universe is accelerating.

Linde (1999) theorized that in the simplest chaotic inflation model, eternal inflation begins at the Planck density of 10^{93} g/cm^3 (Rauscher, 2012), if the potential energy is greater than the kinetic and gradient energy in a smallest possible domain of a Planckian size. The potential of the field as $V(\phi)$ yields both the energy density ρ, and the pressure p, which are crucial to understand the expansion of the universe. In the following equations we define the potential scalar fields dynamics according to Liddle and Scherrer (1998),

$$H^2 = \frac{8\pi G}{3} = [V(\phi) + \frac{1}{2}\dot{\phi}^2 + \rho] \qquad (8)$$

From equation 8, we can derive the more complete scalar fields connected to both density and pressure as:

$$\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi) + \frac{1}{2}(\nabla\phi)^2 \quad (9a)$$

$$p_\phi = \frac{1}{2}\dot{\phi}^2 - V(\phi) - \frac{1}{6}(\nabla\phi)^2 \quad (9b)$$

If $1/2\dot{\phi}^2$ is the kinetic energy and $\frac{1}{n}(\nabla\phi)^2$ the potential energy, this leads to the simplified energy density of $\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi)$.

Domains of the inflationary universe with sufficiently large energy density continuously produce new inflationary domains, due to stochastic processes of generation of the long-wave perturbations of the scalar field (Linde, 1994). Inflation creates an infinite set of cosmic regions, each with "initial boundary conditions" and subsequently evolving properties that are characterized by a statistical distribution that is independent of the choice of region.

In Davies (2008) and Linde's (1999) inflationary universe theory is what we have been calling 'the universe' and is a very small part of a single bubble, also called "pocket universe", in amidst of an infinite number of universes of a "multiverse" which itself is embedded in a continuously inflating space. The exponential growth of simple quadratic potential energy, V, in its most simplified form is:

$$V = \frac{m^2}{2}\phi^2 \quad (10a)$$

or, as Linde (1999) demonstrates, the manner in which an exponential growth of volume becomes maximal for the same quadratic potential is:

$$V = Vo + \frac{m^2}{2}\phi^2 \quad (10b)$$

Large amplitude low frequency oscillations are required to continue the process. Nevertheless, as the scalar waves become frozen, each scenario has different estimated lifetimes and dimensions, so according to Liddle (1999) we have the Higgs potential,

$$V(\phi) = \lambda(\phi^4 - M^2)^2 \quad (11a)$$

the massive scalar field,

$$V(\phi) = \frac{1}{2}m^2\phi^2 \quad (11b)$$

and the self-interacting scalar field:

$$V(\phi) = \lambda\phi^4 \quad (11c)$$

In Linde's bubble universe, each of the bubbles may contain any possible value of the inflaton field. The bubbles contain no particles unless this process of their creation ends by a stage of a "slow-roll" inflation. In Linde's model, instead of tunneling out of a false vacuum state as Guth hypothesized, Linde considered that inflation occurred by a scalar field, where the field rolls very slowly compared to the expansion of the universe. "Slow-roll" inflation is essentially controlled by two parameters defined as: $0 \equiv -\dot{H}/H^2$ and $\delta \equiv -\dot{\epsilon}/(2H0) + 0$, where H is the Hubble rate (Martin, 2000). This agrees with the observation data (Perlmutter, 2005; Sievers, 2003), that the universe is flat and the particles and galaxies which are produced allow the universe to be stabilized sufficiently for creation to occur. There are other explanations, such as that by Lineweaver (2003) who considers that inflation may not be due to a scalar field and its potential V (ϕ), but more to do with extra-dimensions?

4 - Many-Worlds Interpretation (MWI)

Linde's Bubble Theory posits an infinite number of open multiverses, each with different physical constants generating from a cosmic foam, but it does not necessarily rely on the notions of the observer and the environment, two important properties of quantum mechanics. Hugh Everett, in 1957, established what now appears to be an acceptable alternative theory, the many-worlds interpretation (MWI). His theory yields a real multi-world approach to quantum mechanics, with a shared time parameter. The MWI has a quantum wave state $\psi\rangle$ associated with the collapse of the wave form and decoherence based on both the observer and the environment (De Witt, 1993).

The quantum effects constantly split the universe into multiple diverging copies (Deutsch, 1986). This establishes an ongoing "branching" effect as opposed to the continuous bubble. In this case, time becomes more pronounced, as the longer ago a split occurs the more the universes diverge. So for every possible scenario of reality we have universes that continually split into multi-millions of branches.

Everett=s hypothesis (Tegmark, 1998) is that all isolated systems evolve according to the Schrödinger equation and the pure quantum state $|\psi\rangle$ in Dirac notation,

$$\frac{d\,|\Psi\rangle}{dt} = -\hbar H\,|\Psi\rangle \qquad (12)$$

Most formulations of the MWI consider that the "constituent universes" are structurally identical to each other, but can no longer be in communication. Although they have the same physical laws and values for the fundamental constants, they may exist in different states, and thus, no information can pass between them.

The "split" starts with a decohered wave function superposition of two or more outcomes $|\psi\rangle$, as observed by an experimenter. The multiple potential states exist before an observer collapses them into a single state. To track these universes, at least theoretically, one should be able to trace the evolution of the wave function in order to find the numerous branches of the state. This is because the state of the entire multiverse is related to the states of the constituent universes by quantum superposition, and is described by a single universal wave function (Rauscher, 2010).

This provides the possibility that the wave-function of the universe is predominant or at least preliminarily, evolving according to the Schrödinger equation. However, at the same time this theory provides a complete and consistent theory of quantum mechanics which agrees with various experimental results. Aguirre, Tegmark and Layzar (2010) describe the cosmic wavefunction where each of the "many worlds" are the same world, where "world" in this context refers to the state of an infinite space. They establish a real collection rather than fictitious "ensemble" for a statistical interpretation of quantum mechanics.

Superficially, the MWI model becomes a manner of explaining probability and hypothetical statements. David Deutsch (2001) and others state that all possible worlds exist in reality, and are just as real as the actual world, which is a position known as modal realism. So although Schrödinger's cat might be dead in our universe, in Everett's theory it is not. This interpretation is garnishing more and more support among scientists, particularly theorists researching M-theory.

5 - Nonlinear Quantum Theory and the Detection of Other Universes

Just as the Heisenberg Uncertainly Principle, $\sigma_x\sigma_p \geq \frac{\hbar}{2}$, is a fundamental property of the quantum domain, so is quantum entanglement and non-locality. From our consideration of the MWI multi-universe model, or what is also called the EMW [Everett Many World] model, we contemplate the possibility that entanglement may occupy a role in the possible interconnection between universes. Parity validations in weak interactions may also relate to an asymmetry caused by entanglement with other multiverses, as well as other symmetry breaking processes. Time sequence of emergencies of the possible into the actual is one of the key enigmas of quantum formulism.

We conclude the MWI model is useful only if the quantum formulism contains a non-linear component. This allows the weighted states to remain entangled in such a manner that future effects of other “break off” wave functions, at each time junctions, has interactions with the state that we observe in our universe. In the non-linear model, where the non-linear term is small, we would be able to detect properties of existences of other parallel universes. Hence, the multiverse model could become a testable one (Rauscher, 2010).

In the non-linear quantum theory, linearity becomes only an approximation. In the splitting universe model of EMW, each new set of wave functions Ψ_n has a different weight or probability $\Psi_n^* \Psi_n = |\Psi_n|^2$, where the probability gives the number of possible states available to the system.

Rauscher and Amoroso (2008) explore the formulation of the Schrödinger equation with a small but effective non-linear term in the potential energy of the Hamiltonian for time dependent and time independent solutions. In this formulation, for the time dependent case, we obtain non-local, coherent soliton solutions to the Schrödinger equation with long distance coherence.

Figure 3 yields a mechanism for non-local entanglement, and a possible description that allows the detection, by small non-linear effects in our universe, of other universes. Small anomalies in the cosmic background radiation may act as an indicator of the effects from other universes. This may lead to an explanation, at least in part, of dark matter and the missing mass problem (Rauscher, 2005) and also dark energy (Perlmutter, 2005; Riess, 1998), which may be part of the effect of other universes (Amoroso and Rauscher, 2009).

Eugene Wigner (1967) in his classic book discusses the implications of a nonlinear quantum theory and the role of an active observer and for the nature of life itself. He expands the vector space to include a matrix form that allows a method to analyze the effect of one or more observers (i.e. perhaps, a human and a cat) and/or multiple humans as in the case of the Cat’s Paradox (Amoroso and Rauscher, 2009). Wigner also discusses the role of parity and other symmetries in the quantum theory. Van Bise further discusses the implications of Wigner’s work in his research on low intensity, electromagnetic effects of microwaves, on the human brain (electro-encephalograph). Essentially, this discourse relates to all effects of or by human (and possibly other) consciousness.

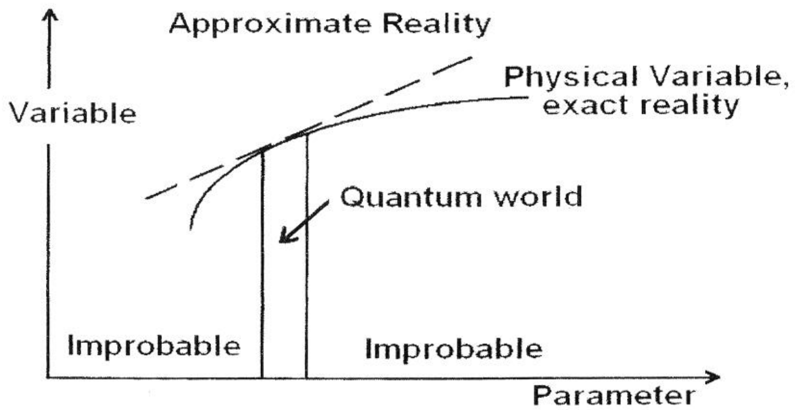

Figure 3. We approximate the quantum domain as a linear variable dependent on a parameter. The full “space” of exact reality is nonlinear (Courtesy of Rauscher and Amoroso, 2009)

The arguments used in Wigner’s essay on ‘The Mind-Body Question’, evolved in the language of quantum mechanics in which he pointed out that physicists possibly learned 'that the principle problem was no longer the fight with the adversities of nature, but the difficulties of understanding ourselves if we want to survive.' If more than one conscious observer enters into a system of measurement this joint system cannot be described by a wave function Ψ *after* the interaction since the result of an observation modifies the wave function of the system by another observer. A proper description of their quantum state is a mixture of states. The wave function is: (Ψ_1 x χ_1) with a probability $|\alpha|^2$; it is (Ψ_2 x χ_2) with a probability of $|\beta|^2$ where Ψ_1 and Ψ_2 are non-simple wave functions.

To quote Van Bise (1978): "Philosophically, this implies that if an observer of one group of experiments asks another observer of the same experiments about his feeling *before* he observed the results, his answer, whether or not it agrees with the questioning observer's conclusions, shows that the question was already decided in his mind before he was asked". In order to avoid this difficulty, it is necessary to postulate that the equations of motion of quantum mechanics are grossly non-linear when conscious beings with opinions enter into the equations. Here again is a paradox in scientific research as seen in Figure 4.

Complete objectivity in the real world is only approachable–not attainable. Even the most stubborn scientific attitudes and the most carefully contrived and controlled experiments suffer from subtle biases within each of us–in other words, we are subject to human emotions. And if any of us are not human in any way, then the conclusions from non-humans about humans are not applicable to humans.

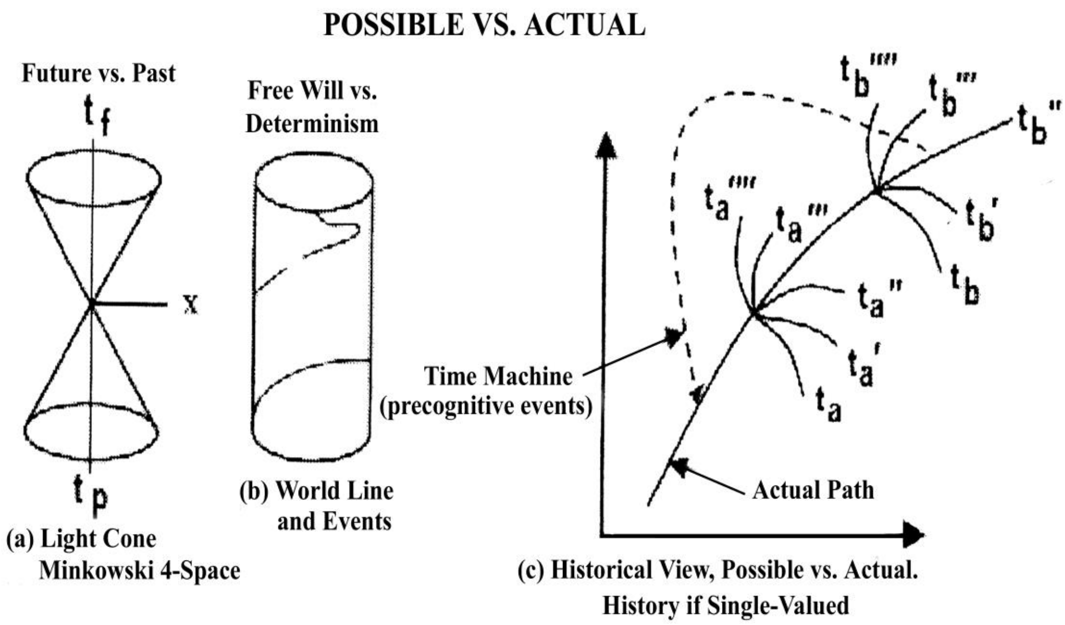

Figure 4. Possible versus actual. Several types of world lines are depicted here. Figure 2a depicts a worldline with a single-valued "now", but Figures 2b and 2c depict a multi-valued present. There is a dual world: constancy and change, absolute versus relativistic and Mach's principles, and certainty versus uncertainty in terms of Einstein and Bohr (Courtesy of Rauscher and Amoroso 2011).

6 - String Theory and M-theory

String Theory and its 11-D structure M-Theory provides another explanation for a multiverse. These theories are an attempt to unify the forces and particles of physics at the Planck scale of energy, $(\hbar c^5/G)^{1/2}$ (Davies, 2004). One impetus for string theory in extra dimensions (D>4) is the work of Kaluza and Klein formulation that gravity and EM could be integrated by introducing a 5^{th} dimension that represents the electromagnetic field (Amoroso and Rauscher, 2009).

In M-theory, our universe and others are created by collisions between membranes (or branes) in an 11-dimensional space and may even share some of the fine-tuning of the universal constants.

Steinhardt and Turok introduced a ekpyrotic model that demonstrates how the collision of branes within a four-dimensional space, creates a big bang type phenomena. Each brane constitutes its own universe (Davies, 2004). When branes collide the tension energy heats up and the universe begins to start the hot big bang allowing strings of all sizes and types to be generated during the collision (Tye, 2006).

At the same time, these universes can have completely different laws of physics. It has been postulated (Greene, 2011) that there are approximately over 10^{500} combinations of strings and therefore if all possibilities are to be taken into account, the same number of possible universes could exist. Specifically, this number permits a cosmic landscape of over 10^{500} different states of the quantum vacuum characterized by different fundamental constants. In these different states each could acquire different universal constants, and may emerge with different spatial and temporal dimensions depending on the outcome of symmetry breaking.

The additional discovery of the KKLT mechanism (Kachru, 2003) provides string theory with an explanation of how various universes can have different stabilized vacua states including those with a negative cosmological constant in anti de Sitter (AdS) space which establishes a positive-cosmological-constant of the de Sitter (dS) vacua. The KKLT mechanism can lead to 10^{500} different states of different vacua, corresponding to different local minima of energy within the string theory landscape. Various anthropic-related string theory structures are also included in the KKLT mechanism which indicates the manner in which the initial fields either roll down to the state where life of our type is impossible (AdS, 10D Minkowski space), or enters the state of eternal inflation.

One can also conjoin M-theory with inflationary cosmology, by expanding the false vacuum, to produce different bubble universes, in which vacuum fluctuations of each particle contribute to Λ. Just as there are 10^{500} different states of the quantum field, so also if we consider $\Lambda \approx 0.4 \times 10^{-123}$ there are perhaps 10^{-121} - 10^{-123} possible states of the cosmological constant. These are just two of the elements that are needed to fine-tune each universe. This leads to an infinity of worlds, where each combination is repeated, in an infinite number of realities.

7 - The Holographic Universe and the Multiverse

An additional model worth citing is that of the 'holographic universe.' Using Hawking radiation, we know that the surface of a black hole is just as significant as the volume. The edge of the area is a type of 2-dimensional surface. The holographic principle suggests that this surface contains enough information to perfectly represent everything that takes place within it volume. At the same time the volume within the space has the same information, but it is like a hologram of what we are able to measure on the surface area (Greene, 2011).

Amoroso and Rauscher (2009) have further developed this theory into a Continuous-State Holographic Anthropic Multiverse (HAM) cosmology. Their HAM cosmology is based primarily on a fundamental least cosmological unit tiling the spacetime backcloth of its 12D superspace that makes correspondence with the SUSY parameters of M-Theory, and introduces the origin of complexity in self-organization, refining the role and nature of the observer in physical theory.

The paradigm has been developed by extending the Wheeler-Feynman-Cramer radiation/transactional interpretation models (Cramer, 985, Kafatos, 2000) and the de Broglie-Bohm ontological models to an higher dimensional regime commensurate with our version of SUSY-M-Theory parameters, but not interpreting Everett's many worlds condition as a duplicate parallelism, but as additional and unique in their own right.

For the HAM, 'our' whole *relational* Hubble sphere, *HR* can be a subspace of an absolute 12 dimensional hyperspace without dimensionality. That is, these are additional dimensions that are not compact, but 'open' and of infinite size (Kafatos, 2000) undergoing a process of 'continuous compactification and dimensional reduction'. To the earthly observer, it appears as a 'standing wave' of the present, continuously created and recreated by future-past advanced-retarded SUSY breaking dynamics.

Here the Hubble radius, *HR* remains an observational limit in Continuous-State Anthropic Multiverse (HAM) cosmology also but is not caused by the Doppler effect. It is due to a minute non-zero rest mass for the photon (Amoroso, 2006). As a photon propagates it couples to the polarized Dirac vacuum and loses energy also attenuating to zero observability; but if one were able to travel to the Hubble limit, observation would extend for another Hubble radius ad infinitum. Thus a critical difference in interpretation of the redshift is a physical limit for the Big Bang and an observational illusion in HAM cosmology.

Therefore, instead of a rigid impenetrable, Planck barrier covered by a stochastic foam of particle creation and annihilation of the vacuum, HAM cosmology has a periodic ordered spacetime with a complex hyperstructure that is closed and finite in time for fermions, but open and infinite atemporally for bosons. In the HAM model, stochasticity, i.e. for zero-point string or brane dynamics, arises in the wake of unitary graviton propagation guiding the dynamics of the continuous-state.

8 - Possible observations

Although it may be impossible to make observations of a universe with different universal constants, Feeney (2011) has developed a specific computer algorithm to search for the signatures of collisions between bubble universes in the expectation that they may have some effect within our universe, proving the existence of the multiverse. Feeney's premise is that if the collisions produce inhomogeneities in the inner-bubble cosmology, it raises the possibility that their effects are imprinted in the cosmic microwave background (CMB). This followed the research of Aguirre, Johnson, Kleban (Feeney, 2011) and others suggesting that a collision of our expanding bubble with another bubble in the multiverse would produce an imprint in the cosmic background radiation as a round spot of higher or lower radiation intensity. These can be relics of heat radiation left over from the Big Bang. Physicists are now searching the data using Feeney's unique algorithm and are looking for disk-like patterns in the midst of the cosmic microwave background (CMB) radiation.

Specifically, in order to verify whether a significant feature is well-modeled as a bubble collision, Feeney, *et.al.* (2011) perform Bayesian model selection for the bubble template. The Bayesian model selection uses the rules of probability theory to select among different hypotheses. Prior probability distributions are used to describe the uncertainty surrounding all unknowns. The Bayesian model works in the form of trees which are visited by each run of the algorithm, then a method is devised to identify those trees which are of most interest. Although no specific data has been cited, the search is underway to determine the possibility of the collision or prior existence of a false vacuum in the myriad points of the CMB. Analysis is being done on the cold spot in the CMB map with more details with the Planck satellite. Mathematics is also being worked on by Czech (2011), which seeks to differentiate between random Gaussian fluctuations and what may occur from a bubble collision and a polarization pattern consistent with various angular power spectra.

Conclusion

Numerous theories have been developed leading many physicists to favor the concept that we exist in one of many universes, or a multiverse. We have examined some of the current multiverse worlds. These models describe a new cosmology that can include both the observer and the non-observer, taking into account all quantum possibilities. Although these theories may also be impossible to prove, they seem to be becoming impossible to disprove as they acknowledge many formulations of, for example Friedmann and Einstein. It is on the notion of the latter that we claim the universe, as we know it, is probably not the end of creation, but one of a seemingly infinite at 100^{500+} possibilities of different quantum states.

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