Creating a Universe, a Conceptual Model

James R. Johnson, Email: jrj2222@aol.com

Abstract

Space is something. Space inherently contains *laws of nature*: universal rules (mathematics, space dimensions, types of forces, types of fields, and particle species), laws (relativity, quantum mechanics, thermodynamics, and electromagnetism) and symmetries (Lorentz, Gauge, and symmetry breaking). We have significant knowledge about these laws of nature because all our scientific theories assume their presence. Their existence is critical for developing either a unique theory of our universe or more speculative multiverse theories. Scientists generally ignore the laws of nature because they "are what they are" and because visualizing different laws of nature challenges the imagination. This article defines a conceptual model separating space (laws of nature) from the universe's energy source (initial conditions) and expansion (big bang). By considering the ramifications of changing the laws of nature, initial condition parameters, and two variables in the big bang theory, the model demonstrates that traditional fine tuning is not the whole story when creating a universe. Supporting the model, space and "nothing" are related to the laws of nature, mathematics and multiverse possibilities. Speculation on the beginning of time completes the model.

Introduction

"If you wish to make an apple pie from scratch, you must first invent the universe." - A quote from Carl Sagan's classic book, *Cosmos*. So how would we create a universe? In one approach, initial conditions are established with a recipe: pack 10^{50} tons of matter/energy into a tiny space, possibly a cube 10^{-33} cm on a side. The extreme density and high temperature, possibly 10^{30} K, somehow generates an outward pressure which inflates space reducing the temperature and density. After 13.8 billion years, the "big bang" becomes our universe, with hundreds of billions of galaxies - an expanding space possibly infinite in extent. In this universe there are sentient beings who make apple pies and enjoy eating them.

Quoting Brian Greene, "In broad strokes, then the big bang's instructions for creating a universe like ours, require that we gather a gargantuan amount of mass and compress it to a fantastically small size. But having achieved that, however improbable, we would face another challenge. How do we ignite the bang?" (Greene, 2011, p. 276). The big bang requires an energy source (initial conditions) - something to breath fire into equations and propel the expansion of space itself. Energy density, temperature, entropy, number of particles and their masses were established by initial conditions. Various theories (Inflation the predominant one) propose how initial conditions were established. But all these theories conform to laws of nature which seem to exist inherently in space. In this context, the *laws of nature* include: universal rules, such as mathematics and number of dimensions; theories, such as quantum mechanics and relativity; and symmetry.

The simple recipe above created a universe, but to "invent" a universe from scratch, we must establish the laws of nature, as well as initial conditions for a subsequent big bang expansion. Thus, the conceptual model for creating a universe incorporates three parts (Figure One). The first part, *Space*, establishes the laws of nature inherent in space; the second part, *Energy*, comprises different theories for initial conditions (Inflation, Loop Quantum Gravity, String Theory, and Mathematical Hypothesis); and the last part, *Expansion*, evolves a physical universe via a big bang.

After the model overview, we describe the laws of nature and contemplate the ramifications of their modification, a speculative task. Explaining the assumptions for initial condition theories is followed by defining the big bang variables. Clarifying traditional fine tuning is next. Then, since the model encompasses multiverse possibilities, its relationship to Max Tegmark's Ultimate multiverse, a controversial theory, is reviewed. And last, the model is expanded by exploring a metaphysical topic, the meaning of space and time.

Model Overview

Space and Laws of Nature

We know a lot about the laws of nature (universal rules, laws, and symmetry) occupying space since they establish the foundation for our universe. Laws of nature are prerequisites for both initial condition theories and the subsequent big bang. The universal rules include mathematics, number of space dimensions, types of forces, types of fields, and particle species. The major laws are thermodynamics, relativity, quantum mechanics, and electromagnetism. Two essential symmetries are Lorentz and gauge.

Each of these laws of nature must exist for our universe to exist. If they differ from what we have observed, could we make apple pies? Assume we change just one law of nature; can we predict the resulting universe? For example, if there were no quantum mechanics, the atom would not exist. Since physics, chemistry, and biology require atoms, this is a significant obstacle for creating universes. If more than one law is simultaneously changed, the challenge of predicting results is virtually impossible. By considering options for laws of nature, we will discover that our universe is even more unique than predicted by traditional fine tuning. Changing the laws of nature is rarely discussed. Only speculative multiverse theories (discussed later) entertain different laws, and even then, a vivid imagination is insufficient to visualize the consequences.

Energy, Initial Conditions and Plasma

The energy/mass in a universe results from initial conditions. In order to accommodate different theories, the model defines a plasma which exists a fraction of a second after the bang (ATB). The plasma, a fourth form of matter where particles and radiation coexist in a state before the formation of atoms, is the output of initial conditions and input to expansion (big bang).

For our universe, the four theories summarized (Inflation, Loop Quantum Gravity, String Theory, and Mathematical Hypothesis) have the same goal – create a plasma with the identical characteristics (temperature, energy, entropy, etc.). Although each theory is predicated on our existing laws of nature, each theory is based on unique assumptions. For example, different theories propose various sources for energy - the inflaton field in the inflation theory and colliding branes for string theory. If the plasma had different characteristics, the resulting "universe" would be unrelated to our world, probably a bizarre lifeless place as predicted by traditional fine tuning.

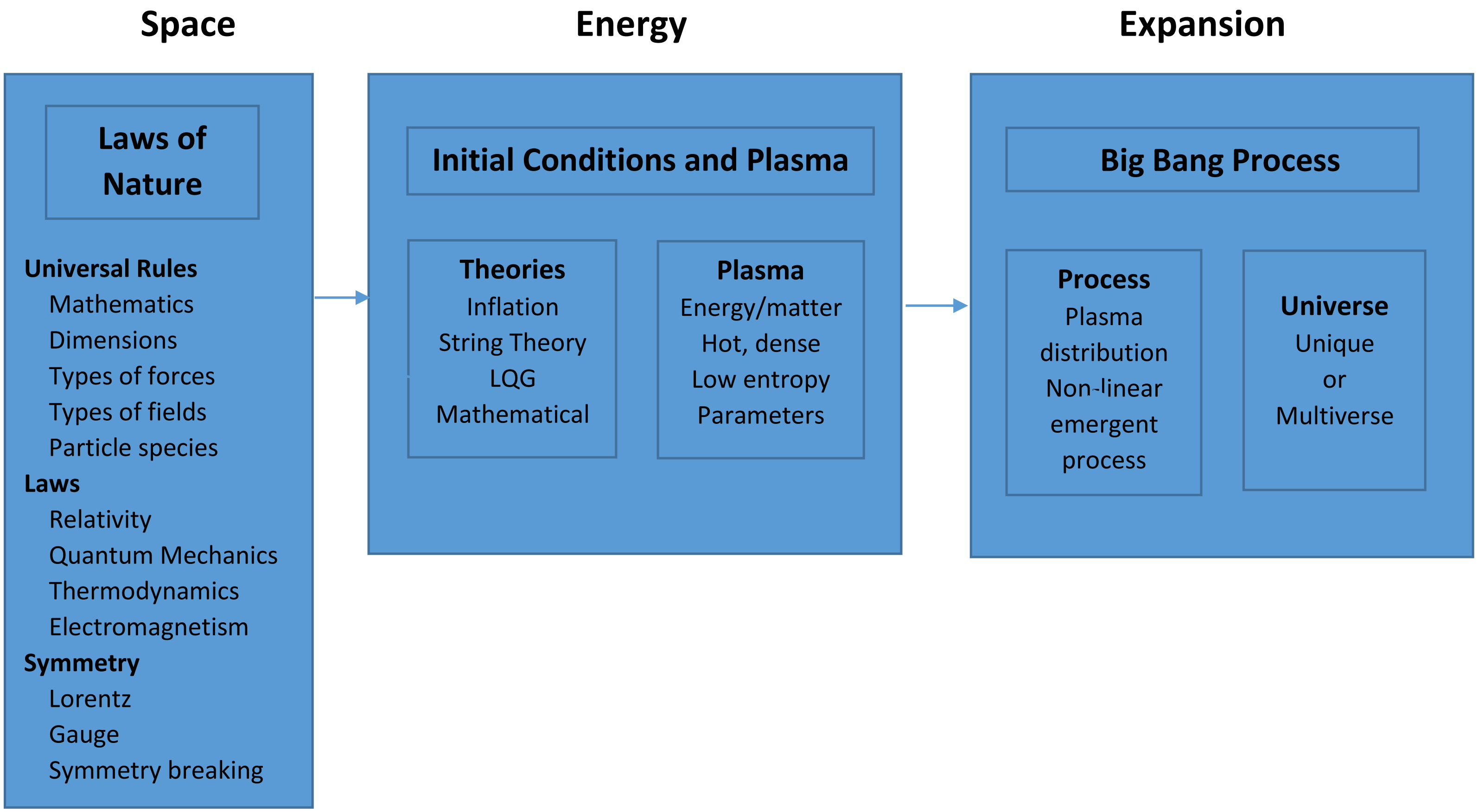

Figure One. Conceptual Model for Creating One Universe or Many Universes

Expansion, Big Bang Process

The plasma created from initial conditions is input to expansion, the big bang process. Cosmologists describe the big bang theory with time lines. In general, nucleons and nuclei form in the first hundred seconds. Atoms form during the next 400,000 years. Then, gravity coalesces matter into stars and galaxies.

All big bangs are constrained by both laws of nature and initial conditions. For our big bang, there are just two variables permitted during expansion: initial distribution of plasma energy; and randomness in the biological evolution. Thus, even with identical plasmas, a universe might have a different history or forms of life. If laws of nature or initial conditions were different, other big bangs processes would vary considerably. Also, as Figure One shows, depending on initial conditions the model may spawn one or more universes. If just one universe, the laws of nature and initial conditions are unique. This would validate a Theory of Everything (TOE) where there is only one possible outcome. However, more than one universe, the multiverse, relies on various initial condition or, as speculated, different laws of nature.

Space - Laws of Nature

Our existing laws of nature in space are fixed and form the basis for all physics. Since the ultimate source of space may always remain unknown, space is considered an abstract reality which just exists (spacetime is addressed later). The laws of nature are listed on the left side of Table One below: universal rules, laws, and symmetry. The right side explores the ramifications of modifying these laws.

Space, Laws of Nature	**Ramifications**
Universal Rules	**for our universe**
Mathematics	Difficult to visualize anything else
Dimensions	Minimum of three effective dimensions required
Type of forces	Four forces and associated fields required
Type of fields	Dark energy and Higgs required, others possible
Particle species	Quarks, leptons, bosons, and hadrons required
Laws	
Thermodynamics	Required in physics
Relativity	Required in cosmology
Quantum Mechanics	Required for atom to exist (chemistry)
Electromagnetism	Required for stable particles
Symmetry	
Lorentz Symmetry	Required for conservation laws
Gauge Symmetry	Required in SMPP
Symmetry breaking	Required selectively: electroweak and matter/anti-matter

Table One. Ramifications of Laws of Nature

Universal Rules

Mathematics. Observed patterns of nature are explained by mathematical equations. These equations define the laws of physics, "…monumental upheavals in physics have emerged time and again from vigorously following mathematics' lead" (Greene 2011, p. 319). The most famous and significant mathematical equations are: Maxwell's electromagnetism (1862); Einstein's special and general relativity (1905, 1915); Friedmann's expanding universe (1922); and Schrödinger's wave equation (quantum mechanics, 1926). From these source equations, physics derives equations for: mechanics, electricity and magnetism, fluid mechanics, thermal physics, nuclear physics, and waves/optics.

Must the laws be mathematical or is there another option? Brian Greene addressed this issue. "I could imagine an alien encounter during which, in response to learning of our scientific theories, the alien remarked, `Oh, math. Yeah, we tried that for a while. At first it seemed promising, but ultimately, it was a dead end. Here, let us show you how it really works.'" Greene continues, "I don't know how the aliens would actually finish the sentence… I'm not even sure what kind of answers wouldn't amount to math" (Greene, 2011, p. 297).

Number of Space Dimensions. There are a number of mathematical structures describing types of space. Typically, we relate to Euclidian three dimensional space (coordinates x, y, and z), but special relativity introduced time, a fourth dimension, for a Minkowski space. Then, general relativity added Riemann space allowing curved spacetime. Then, quantum mechanics defined Hilbert space, an abstract infinitely dimensional space where the wave function lives. For our universe, the number of effective dimensions of space must equal three. With fewer, there's insufficient gravitational attraction. A universe with one or two space dimensions would be bland and lifeless. With more than three dimensions, there are no stable atoms (Tegmark, 2014, p. 149). String theory proposes ten space dimensions with seven compacted and undetectable, leaving three effective dimensions corresponding to what we observe. As portrayed in numerous science fiction movies, one can imagine additional invisible dimensions outside our normal reality.

Forces. The four forces - electromagnetic, weak, strong, and gravitational - are indeed strange. They operate over distance in dissimilar ways. For example, the strong force strength increases with distance but only acts over an extremely short range; the weak force also acts over a short range but decreases with distance, the electromagnetic and gravitational force strenghts decrease inversely with distance squared but have unlimited range. Their relative strengths vary enormously (10^{39} times between electromagnetic and gravitational). How could they be more different? As related to force properties, "The formation and stability of atoms… rely on the properties of the electromagnetic and nuclear forces. If you substantially modify those forces, atoms will fall apart or, more likely not coalesce in the first place. An appreciable change to the properties of particles would thus disrupt the very processes that give our universe its familiar features" (Greene, 2011, 65).

Four bosons, one associated with each force, communicate the force. The photon is the messenger for electromagnetic force and light is the visible evidence. The graviton is theoretically the carrier for the gravitational force but has not experimentally been observed. Both the W and Z bosons convey the weak force and were predicted by theory (1960s) before discovery (1983). Bosons are the only particles following the Pauli Exclusion Principle. If any boson characteristics were changed, forces would have drastically different properties.

In this model, the number and type of forces and how they operate are defined as universal rules; however, the strength of the forces is set by initial conditions. There might exist any number of forces in space, but, if different, the probability of producing stable matter is remote because of the intricate relationship required.

Fields. In addition to fields associated with forces and particles, two other unique fields exist in nature. The Higgs field, permeating all of space, is responsible for particle mass (dictates inertia and kinetic energy). The recent discovery by the LHC, confirmed the existence and establishes the energy value of the Higgs field. It does not dilute as space expands, a characteristic shared with the dark energy field also referred to as the cosmological constant. Balancing the equation energy equation (actual density equals critical density), dark energy provides seventy percent of all the energy in our observable universe.

The dark energy field is assumed constant with a precise value. If the value were different (one decimal place after 120 zeros), the expansion rate of our universe would not have been conducive to creating stars or galaxies. It is conceivable that the value of dark energy might vary over time. If so, the ultimate fate of our universe could be a "big rip" or a "big crunch" depending on how the field changes value. Also, a few scientists propose that gravity acts differently over large distances imitating the effects of dark energy, if so, there would be no dark energy, but a modification to general relativity (Riess, 2016). The model accommodates either situation. Since complex atoms are made by stars and since the universe expansion provides time for stars to evolve, there is no apple pie without a precise value for the dark energy field.

Particle species. In addition to bosons (force carriers) previously discussed with forces, twelve elementary particle species exist in our laws of nature, six quarks and six leptons - the electron, muon, tau, and three neutrinos. (Virtual particles result from quantum field fluctuations and rapidly annihilate repaying borrowed energy so are not considered separate particle species.) Bosons, electrons and two neutrinos are stable and do not decay. All baryons (protons and neutrons) consist of combinations of three "up" and "down" quarks. When electrons, following the laws of quantum mechanics, "surround" a proton or combination of protons and neutrons, atoms are formed. For our apple pie we need bosons, atoms, electrons, and neutrinos which are integral to nuclear reactions. But, are the other quarks and leptons required?

Laws

Laws of Thermodynamics and Entropy. There are four laws of thermodynamics: zero - heat always diffuses from hot to cold; first - energy is always conserved; second - entropy increases; and third - at absolute zero, energy is minimal. Each law impacts how matter and energy interact, but the second law, the tendency of physical systems to evolve toward higher states of entropy, plays a critical role in the evolution of a universe because it dictates a low entropy (more order) at the start of the big bang (Note 1). A high temperature corresponds to more symmetry and a simpler system with low entropy. Thus, as time proceeds, entropy increases, and the universe becomes more disordered. In some fundamental sense, all systems are trying to obtain thermodynamic equilibrium. Thus, initial condition theories must explain how the universe started with low entropy.

Einstein's Relativity. Special relativity limits the velocity of light and establishes a maximum speed limit for matter and energy. An equivalence between energy and mass ($E=mc^2$), a key equation in physics defined by Einstein in 1905, would not be possible without this speed limit. Picture a universe where energy and mass are not related. Particle physics, and specifically particle collisions, as defined by quantum mechanics, would be restricted to mass to mass conversions with no energy exchange possible, a concept totally foreign to our world. If any law is eliminated, say energy is directly proportional to mass ($E = mc^2$), the impact is virtually impossible to predict. If the law exists, but the equation changes, say energy is proportional to the reciprocal of mass ($E= 1/mc^2$), physics would again be dramatically different.

Equating the force of gravity and the force of acceleration was not discovered until 1915. This surprising relationship was proven by general relativity; Einstein's equations unified space, time, energy, and gravity. As John Wheeler once said, "Matter tells spacetime how to curve, and spacetime tells matter how to move." There is no way to hide from gravity.

Quantum Mechanics. Quantum mechanics, a completely non intuitive concept, entertains bizarre principles, specifically: the uncertainty principle (based on Planck's constant); Pauli Exclusion Principle; probability waves (wave particle duality); and, entanglement or non-locality. However, SMPP theories (QED and QCD) both successfully predict particle and force interactions to extreme precision.

Quantum mechanics is required to construct atoms, "little particles that move around in perpetual motion" (Feynman description). In Newtonian physics, an accelerating electron loses energy; thus, an electron traveling at about one tenth the speed of light spirals into the nucleus. Quantum mechanics solves this problem by providing: probability waves to replace electron circular orbits; Pauli exclusion principle to assure discrete electron orbits (particles cannot occupy the same energy state with the same quantum numbers: principal, orbital, magnetic, and spin) and discrete energy states (reflecting multiples of Planck's constant). These clever concepts allow elements, molecules, and subsequently biological life. Generating or absorbing photons as electrons move from one energy state to another is an innovative and also required notion. How about entanglement? Does transcending space and time (non-locality) provide an integral function? It might be expendable for our universe, but are we sure?

Electromagnetism. The four laws of electromagnetism are: Gauss's Law - electric charges act as sources for generating electric fields and electric fields exert forces that accelerate electric charges; Ampere's Law - moving electric charges constitute electric currents which act as sources for generating magnetic fields; Faraday's law and Maxwell's law - time varying electric fields induce magnetic fields, and conversely, time varying magnetic fields induce electric fields; and last - light consists of time-varying electric and magnetic fields that propagate as a wave and interacts with matter by accelerating charged particles and, in turn, accelerating charged particles emit electromagnetic radiation. The first three laws are defined by Maxwell's equations. What would happen if any of these laws were modified or replaced? Atoms required for our apple pie need these laws precisely as they are.

Electromagnetism, the unification of electricity, magnetism and light, explain all of chemistry and biology. Fortunately, positive and negative charges of the electron and proton are always identical, exist in equal numbers, and attract each other. If this were not true, and matter were not electrically neutral, the electromagnetic force, would produce clouds of charged masses completely dominating the gravitational attraction. What processes might occur in these charged concentration of matter?

Symmetry

Symmetry (Conservation Laws). "Symmetries are the foundation from which laws spring" (Greene, 2004, p. 225). If a transformation on a physical system has no effect on a law, then a symmetry is at work. Frank Wilczek emphasizes this point, "Study of Maxwell's equations brought out an essentially new idea that had not played a role in science before. That is, the idea that *equations,* like objects, can have symmetry, and that the equations Nature likes to use in her fundamental laws have enormous amounts of symmetry" (Wilczek, 2015, p. 136).

The laws of physics didn't have to operate this way. Although strange, we can imagine a universe in which physical laws vary by location, for example, forces acting differently in New York than in Los Angeles. In that world, experimental results would not be repeatable because they would depend on where they were performed.

For time, space, and motion the conservation laws associated with symmetries are: time symmetry - conservation of mass/energy; rotation symmetry - conservation of angular momentum; and translation symmetry - conservation of linear momentum. These spacetime symmetries are called Lorentz symmetries. The existence of time relies on the absence of a particular symmetry. If time were symmetric there could be no change.

In special relativity, symmetry dictates that motion among observers moving relative to one another has no effect on laws. Einstein extended this symmetry by including the speed of light among the observations that would be unaffected by the observer's motion or the motion of the light's source - the constant velocity of light is a law of nature. Symmetry also applies to accelerated vantage points; general relativity is based on the equivalence principle (symmetry) which equates the force of acceleration to the force of gravity.

Symmetry (Gauge). The standard model of particle physics includes more abstract "gauge" symmetries denoted by mathematicians as *SU*(3) x *SU*(2) x *U* (1), where *SU*(3) produces quark color conservation laws, *SU*(2) defines isospin or weak force conservation, and *U*(1) preserves electric charge. To illustrate how charge is conserved, consider the radioactive decay of a neutron (zero charge) into a proton (positive charge), an electron (negative charge) and an antineutrino (zero charge). This simple rule forbids decay processes that violate this symmetry. For perspective on conservation laws, consider the following, "Before Emmy Noether [in 1915], no one had really understood why any of these quantities are conserved. What Noether realized was as simple as it was profound: the conservation laws are mathematical consequences of the symmetries of space and time and other basic ingredients in the laws of physics" (Turok, 2012, p. 178).

If any of these symmetries are eliminated or modified, "we'll end up with… different kinds of particles and forces, where quarks, electrons and photons are replaced with other entities with novel properties" (Tegmark, 2014, p. 324). In a more pessimistic view, if positive and negative charges were not equal, the electromagnetic force might disrupt gravitational attraction and mass would not aggregate but stay dispersed with no structures. Thus, if we want to make an apple pie, the symmetries in space must include all those we observe and possibly others like supersymmetry (Note 2).

Symmetry Breaking. Strange as it may seem, selective symmetry breaking is allowed. At least two of the four forces, the electromagnetic force and the weak force, are subject to symmetry breaking at extremely high energy densities, temperature about $10^{15.5}$ K. Above this temperature the forces function as one, the electroweak force, demonstrating greater symmetry. At higher temperature, it is possible that the strong force, also joins the electroweak force forming a more basic force. There is additional speculation that the gravitational force, which decreases magnitude identical to the electromagnetic force, might combine to form a single force at a still higher temperature.

One of the unsolved puzzles of cosmology is the asymmetry or violation of baryon number symmetry between baryons and anti-baryons. Baryon number symmetry states that baryons and antibaryons are created and destroyed in pairs. If perfect symmetry prevailed, only radiation would exist; without this minor violation of symmetry, there would be no matter. So selected laws of nature are not always absolute; it appears they occasionally allow discrepancies (Wilczek, 1980).

Ramification of laws of nature. The left side of Table One summarizes the ramifications of the laws of nature in our universe. As discussed, visualizing a universe not based on mathematics or visualizing one with more (or less) than three space dimensions challenges the imagination. The balance among the four forces is astonishing, for example, the lifetime of stars measured in billions of years. If we add or subtract forces, would this magical balance exist? Probably not. The Higgs and dark energy fields are both critical to our concept of physics and cosmology. Although some particle species appear superfluous, predicting physics without them may be problematic. The laws of thermodynamics, relativity, quantum mechanics and electromagnetism comprise the foundation of physics and cosmology. They appear intuitive and logical, but delete one or more and the result is unpredictable. Conservation laws regulate particle physics and relativity. Symmetry breaking creates matter and separates forces. Would a change to any law of nature allow an apple pie?

Energy - Initial Conditions Theories, Plasma, and Parameters

Assuming the laws of nature previously defined, we now will discuss initial condition theories required to create *our* universe from an energy source. The assumptions for generating energy vary by theory, for example, inflaton field, colliding branes or previous cycles. Also, each competing theory must establish both Standard Model of Particle Physics (SMPP) and Standard Model of Cosmology (SMC) variables exactly as contained in the plasma.

Plasma

Defining the Plasma. The SMC generally defines plasma as a hot, dense energy with low entropy and specific attributes. This plasma is the basis for our universe and possible similar universes. Since the plasma exists at a specific time/temperature, it provides a common output for initial condition theories. The problem is how to select a time/temperature that accommodates all theories. It could be based on observational evidence, experimental evidence or theory. Telescopes can look back to the Cosmic Microwave Background (CMB) radiation or 400,000 years ATB when the temperature was 3,000 K. The LHC experiments achieve temperatures approaching 10^{16} K where quarks and other elementary particles reside in a plasma state. This corresponds to a theoretical time of 10^{-12} seconds ATB. Selective theories contain a Planck time limit; this time is exceedingly short, 10^{-43} seconds and has an associated temperature of 10^{32} K.

Our model's only requirement is that all initial condition theories produce identical plasma. The time/temperature decision is not completely arbitrary because physicists and cosmologists are confident their predictions are accurate into the sub-second range. Changing the selected time does not invalidate the approach. The more time ATB has for plasma definition, the less activity there is in the big bang part of the model; conversely, if the time ATB is less, more activities occur in initial conditions. For this paper the selection of 10^{-12} seconds is primarily based on theoretical considerations (Note 3). This quark-gluon soup of fundamental particles had a temperature of 10^{16} K, a diameter of 10 cm, a mass/energy exceeding 10^{56} gm, and a density over 10^{53} gm/cm^{3}. When diameter is specified, it implies an observable universe; however, the universe may also be infinite in extent. Significant unknowns exist concerning the plasma content. For example, dark energy and dark matter are scientific mysteries, although they have one commonality – no interaction with electromagnetism. We cannot "see" them.

SMPP and SMC parameters. Now that the laws of nature are established, is there significant work remaining for initial conditions and the supporting theories? Yes, so much so that no one has been able to define a theory that does not require parameter input to equations, parameters that appear to have random values. Many scientific articles have addressed how miraculously these parameters work together to create our universe. As the literature concludes, the universe appears to be fine-tuned for life. (Note 4) Traditional fine tuning is the improbable coincidence that a random collection of about thirty-two dimensionless input parameters, from the SMPP and the SMC, would produce a universe like ours. For example, if the cosmological constant were slightly larger or smaller, galaxies could not have formed. If force strengths or particle masses were to vary by a few percent, no atoms, stars or planets would exist; our life-friendly universe is a rare combination of input parameters. Other parameter permutations might exist in different universes, but the vast majority would be devoid of life.

Physicists have attempted without success to mathematically calculate input parameters values from first principals. Even string theory physicists have failed at predicting correct values. Possible explanations proposed for fine-tuned parameters in our universe are: just an accident; designed for life; and, one out of many universes, a multiverse. Our model embraces all explanations although acknowledging options for the laws of nature and SMPP and SMC parameters implies a multiverse.

Before surveying four initial condition theories, it is appropriate to define plasma values which cannot be computed from theory principles. Our discussion starts with eight parameters in the SMPP as shown in Table Two, basically, particle mass and the strength of forces. (Fundamental constants c, ħ, and G are not listed but assumed.) Each of these were derived from 25 dimensionless (and one dimensional) input parameters to the Lagrangian equation (Note 5). The force strength values, via complex interaction, amazingly produce stable particles.

One consequence of different particle mass, "If the electron mass … were a few times larger than it is here, electrons and protons would tend to merge, forming neutrons and thus preventing the widespread production of hydrogen" (Greene, 2011, p. 64). Dark matter, although it may integrate with the SMPP, is still a mystery as mentioned when discussing types of fields.

Within the SMC, all observations can be explained by six parameters, five densities and a measure of homogeneity (Tegmark *et al*., 2006). (There is a slight modification from the reference because photon density is isolated rather than expressed as ratios with the four other densities). The densities inputs are for photons, baryons, cold dark matter, neutrinos, and dark energy. Of course, the density values diminish as the space expands, that is, except for dark energy which is constant or non-diluting. For our universe, the actual energy density (a sum of all densities), fortunately matches critical density allowing the expansion of space to extend over billions of years. The measure of homogeneity represents the proportion of galaxy rest mass needed to disperse galaxies, a ratio of about one in one hundred thousand. However, plasma has an additional property of low entropy (high structure). Low entropy is puzzling, a challenge for initial condition theories.

Initial Condition Parameters SMPP	**Initial Condition Parameters SMC**
Electromagnetic Force Strength	Photon Density
Strong Force Strength	Baryon Density
Weak Force Strength	Cold Dark Matter Density
Higgs Field's Strength	Neutrino Density
Mass of Quarks	Dark Energy Density or Cosmological Constant
Mass of Electrons	Measure of Homogeneity
Mass of Neutrinos	Low Entropy
Dark Matter (?)	

Table Two. Initial Condition Parameter Values Established

Since each parameter might have any value, “numerous” plasmas are contemplated. Thus, a plasma with significantly different attributes is not only plausible but more probable than the fine-tuned plasma that produced our world.

Initial Condition Theories

For our universe, a brief overview of selected theories illustrates diverse sources for creating energy during initial conditions. One of these theories may someday prove the “real” theory, but there may always be doubt. As Martin Harwit contends, “Only when even the most far-sighted observations and laboratory experiments yield results fully anticipated by theoretical predictions are we likely to gain assurance that we are close to fully comprehending the complexities of the cosmos, and that our theories may be more than just social constructs [theories]” (Harwit, 2013, p. 321).

Popular initial condition theories are: inflation, string theory, loop quantum gravity, and the mathematical (universe) hypothesis. The original theory proposed in the 1920's by Alexander Friedmann preceded these theories. He showed that a variety of expanding, contracting, or oscillating universes were compatible with Einstein's General Theory of Relativity. At about the same time, George Lemaitre predicted that our universe began with a “big bang”; everything we *observe* originated in a hot, dense, and rapidly expanding space. However, a few major issues, were not explained; thus in 1979, Alan Guth proposed inflation to resolve open issues.

Inflation. Inflationary cosmology is not one unique theory; rather it provides a framework containing many versions differing in details, such as number of inflaton fields (spelled differently than inflation) and their potential-energy curves. However, in general, the basic inflation concept precedes the big bang theory by inserting an extremely brief burst of astoundingly rapid expansion during the universe's earliest existence. This stupendous growth explains the uniformity of the CMB temperature, predicts that the universe is flat, and addresses other problems associated with the original Big Bang.

The source of the brief burst is a hypothetical "scalar inflaton field," a field similar to the scalar Higgs field. The inflaton field contains a high amount of potential energy, exists uniformly throughout space, and does not dilute as space expands. The field is subject to random quantum fluctuations that can cause the energy value to vary, and if the energy drops too far, the overall superfast expansion of space stops and inflation starts. In one popular version, the inflation process is astonishingly short, lasting about 10^{-35} seconds. During this brief period, space expands by at least 10^{30} times. To appreciate the full scale of this process, consider Brian Greene's re-phasing, "the size of the universe increased by a factor larger than a million trillion trillion in less than a millionth of a trillionth of a trillionth of a second" (Greene 2004, p. 15). As expansion ends, the *field's energy is converted into particles*, thus creating a universe. Some scientists have challenged the inflation theories; Paul Steinhardt, one of the original authors of inflation, has had second thoughts about the reasonableness of the assumptions and now supports a version of string theory (Steinhardt, 2011).

String Theory. In the first version of superstring theory (1984), now referred to as string theory, tiny strings or vibrating filaments, replace electrons and quarks as nature's building blocks. Strings are so minute they may never be observed (Planck distance of 10^{-33} cm). The string vibration pattern dictates intrinsic features that may represent an electron or a quark or more importantly a graviton (massless, chargeless, and having a spin-2 quantum property). Thus, without contradicting previous theories, string theory bridged the gap between general relativity and quantum mechanics. However, the mathematics, as defined in five unique theories, required nine rather than three dimensions for space. The extra dimensions are curled up into Calabi-Yau shapes, shapes that dictate particle properties. Combining string theory and eternal inflation is another version of initial conditions consisting of nine space dimensions. *Inflation provides the energy* in this scenario.

In 1995, physicist Ed Witten started the second revolution of string theory by employing refined calculations. He showed that the five previously unique string theories were encompassed in one overriding theory, M-theory. The old calculations missed one dimension; there were actually ten space dimensions. M-theory generates “n-dimensional” braneworlds, where n has values from one to nine. A "one" brane corresponds to a one-dimensional string and a "three" brane corresponds to a three-dimensional space. Thus, our universe could exist on a 3-brane (one of many) with large or infinite extent. Different branes reside in different dimensions, not necessarily separated by vast distances in space, and possibly hovering in close proximity to each other. All strings are attached to the brane except for gravitons, which are unattached loops that can leave and re-enter the 3-brane (Greene 2011, p. 118).

Some theorists predict periodic collisions between two branes separated by a fourth dimension. This produces a collision scenario for the *creation of matter and radiation* identical to a big bang. The proposed cycle, occurring over a trillion years, is: collision, expansion, cooling, dispersion and then another collision. The process excludes a dramatic "inflation" type of expansion. This theory not only addresses the fine-tuning issue but also the “infinite regress enigma” (Steinhardt, 2011). Gravitational waves disrupting the CMB would discredit this theory because they are not anticipated with colliding branes.

Loop Quantum Gravity. Another alternative to inflation, Loop Quantum Gravity (LQG), predicts the existence of spacetime atoms each with a volume of 10^{-99} cm^3. Particles and fields are described as spin networks. Spacetime is spin foam with discrete time. Loop quantum gravity suggests that the atomic structure of spacetime changes the nature of gravity at very high energy densities. Loop-based scenarios are founded on general principles of quantum theory and relativity theory and therefore avoid introducing new ad hoc assumptions (as with inflation). When a preexisting universe collapses under the attractive force of gravity, the density grows so high that gravity switches to repulsive and the universe starts expanding again. It bounces **(**Bojowald, 2008; Smolin, 2004; Veneziano, 2004). In this scenario *energy is recycled* from the previous universe.

Mathematical Hypothesis. This is a speculative proposal from Max Tegmark for initial conditions: The External Reality Hypothesis (ERH) and the Mathematical Universe Hypothesis (MUH). As implied from their descriptions, all reality is described mathematically; in fact, physical existence equals mathematical relationships and all defined mathematical relationships are real. Since every imaginable universe may not have a mathematical definition, some would not exist. In the MUH, the passage of time is not fundamental - a time-dependent process is not required and the flow of time is an illusion. Thus, existence is like a movie DVD that just exists, not physically but as mathematical equations (Tegmark 2014, p. 318). A baking analogy underscores the concept of MUH; the mathematical relationships exist just as the recipe for a cake exists. According to the hypothesis, because the recipe contains the relationships, it is as real as the physical cake. The explanation for the source of *energy is rather nebulous; it just exists*. This sounds implausible but remember the competition is the inflaton field, strings, branes and discrete spacetime “atoms”.

Expansion - Our Big Bang

Our Universe Characteristics/Time Line

For our universe, science provides convincing evidence of a big bang process unwinding events back to the first three minutes and even minuscule fractions of seconds. The Lambda Cold Dark Matter (ΛCDM) cosmological paradigm uses Einstein’s equations to accurately describe our observable universe. It is generally referred to as the SMC. The *energy source*, an initial singularity, is in the form of a hot, dense “fireball” of energetic radiation similar to the plasma produced by initial conditions at 10^{-12} seconds. Our model’s big bang process starts by “acting on” the plasma provided by initial conditions.

In the SMC scenario, radiation and particles exist as a plasma up to 380,000 years ATB. At this time, atoms form allowing radiation to travel virtually unimpeded - the origin of the CMB. Over the next 13.8 billion years, matter concentrated in clumps, stars and galaxies formed, and life evolved. More specifically, fundamental changes were: entropy from low to high; diameter from 10 cm to 10^{28} cm; quarks combined into protons and neutrons; energy density from 10^{50} gm/cm^3 to 8.5×10^{-30} gm/cm^3; energy percent of ordinary matter from 15 to 4.8; energy percent of dark matter from 85 to 26.8; and, energy density of dark energy from less than 1 percent to 68.3 percent. The changes in energy density highlight the transition from a radiation dominated universe (before 50,000 years) to matter dominated universe (after 50,000 years) to dark energy dominated universe (after 5 billion years).

The time line for key events in the big bang process is shown in Table Three. Prior to 10^{-12} seconds, the electroweak and strong forces may have been a single force that experienced spontaneous symmetry breaking similar to the symmetry breaking of the electroweak force. Still earlier at higher temperature (energy density), the strong and gravitational force may have disengaged from a single super force. If this happened, initial condition theories should provide mathematical validation.

Big Bang Time Line	Time ATB	T (K)	R (m)	Description/Activity
Quark-gluon plasma	10^{-12} sec	10^{16}	0.1	Contents of plasma*
Electroweak unification	10^{-11} sec	$10^{15.5}$	1	Spontaneous symmetry breaking of force
Nucleons form	10^{-4} sec	10^{12}	1000	Quarks form protons and neutrons
Nuclei form	10^{2} sec	10^{9}	10^{10}	Protons and neutrons form atomic nuclei**
Atoms form, radiation free (CMB)	3.8×10^{5} yrs	3000	10^{21}	Atoms form, dark ages follow - no stars
First stars and galaxies form	3.0×10^{8} yrs	30	10^{24}	Gravity clumps matter, stars/galaxies form
Current time, universe expansion	13.8×10^{9} yrs	2.7	10^{26}	Six billion years ATB expansion accelerated

* Quark, electron, neutrino, muon, tau, gluon, photon, W, Z

** Helium, deuterium, lithium

Table Three. Big Bang Time Line

Big Bang Variables

All big bangs are constrained by both laws and initial conditions. For our big bang, there are just two variables allowed during expansion: initial distribution of plasma energy and randomness in the biological evolution. These seemingly minor independent influences have significant impact resulting in different histories or possibly universes containing no intelligent life (or life at all). Their influence would also be considerable with different plasmas.

The first influencing factor is simply matter distribution; with all else being equal, history would vary because different plasma contents (radiation and particles), although homogeneous like a gas, are not symmetric. Thus, clustering of matter would vary for each big bang. Consider a simplistic example of planetary orbits around the sun as described by Caleb Scharf, "The equations describing them [orbits] exhibit an inability to contain and control tiny computational uncertainties … that [strains] our ability to predict anything. Nature itself is also full of real variations, and the web of interactions in a planetary system can make it extremely sensitive to these changes. This sensitivity of a system is often called non-linearity; since there is no simple one-to-one correspondence between changes to a system and how it responses. … And non-linear systems are special, because they can behave in a way that's chaotic" (Scharf, 2014, p. 102).

Secondly, the evolution of biological life is also a random, non-linear process. As with the planet orbit example, the sensitivity for biological life is immensely dependent on uncertainties at the microscopic level as well as the macroscopic level. "Any general principle of biology is what it is because of the fundamental principles of physics together with historical accidents, which by definition can never be explained. … Physicist who study fluids or solids often cite examples of "emergence," the appearance in the description of macroscopic phenomena of concepts like heat or phase transition that have no counterpart in elementary particle physics, and that do not depend on the details of elementary particles" (Weinberg, 2015, p. 267). "A biological organism therefore encapsulates the products of a complex and convoluted history. To sum it in a phase, life as we observe it today is one percent physics and ninety-nine percent history" (Davies, 2008, p. 233).

Thus, there is no assurance of duplicating our form of life. What we can safely predict from identical plasmas are the physical attributes of a universe: atoms, gas clouds, stars, black holes and galaxies. This is because the laws of nature treat two identical plasmas the same.

Conceptual Model with Different Laws, Initial Conditions and Big Bang

A detailed version of the conceptual model, Figure Two, relates various scenarios where laws of nature, initial conditions, and big bang variables change universe characteristics. With multiple options, it embraces one universe or many universes (multiverse). If the top path creates our energy plasma as predicted by the SMC, the result is our unique universe or one similar with different histories, histories dictated by the two big bang variables, initial distribution of energy and randomness in evolution. This assumes "our" spacetime with identical constants of nature as those we observe.

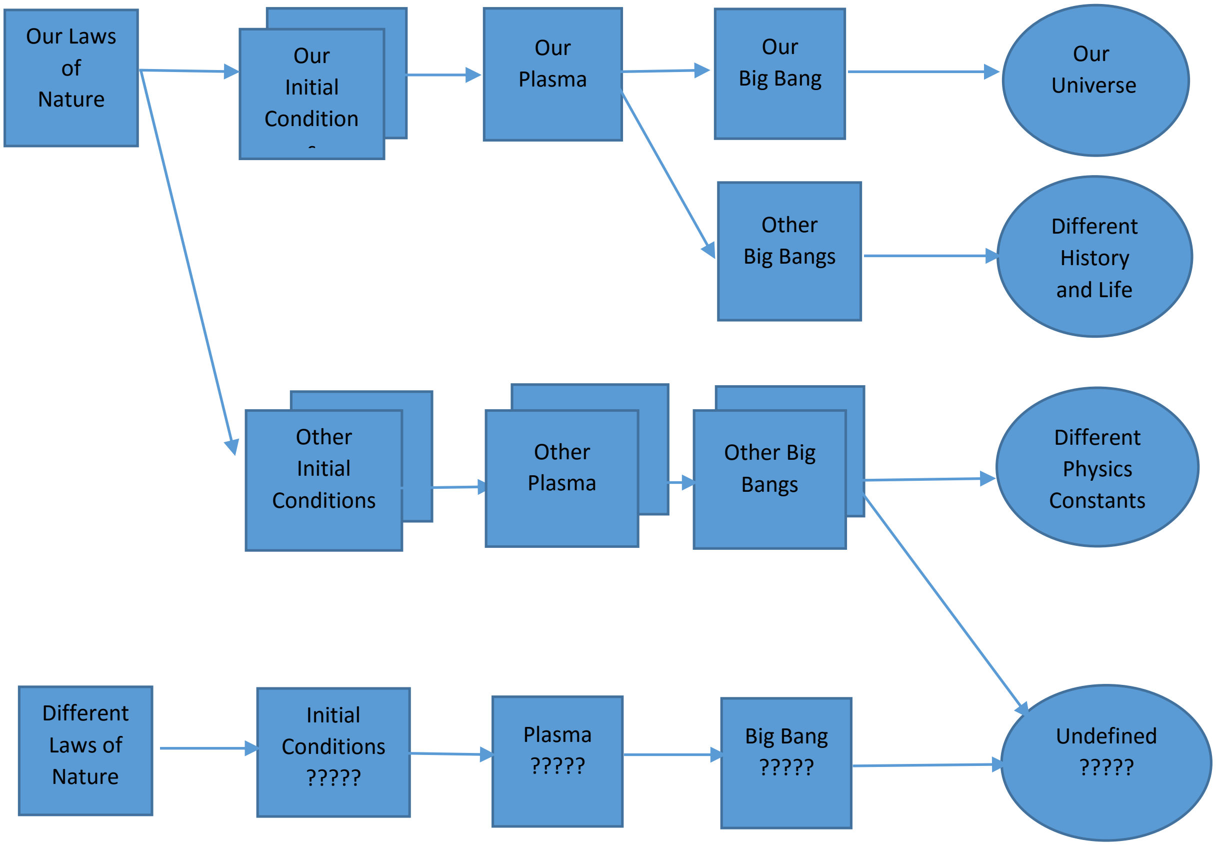

Figure Two. Conceptual Model Detail

The next scenario also assumes "our" spacetime but produces a different plasma via other initial conditions. Even though constrained by the same laws, other theories produce diverse types of plasma with distinct values for parameters. In string theory, for example, dimensions can be geometrically compacted in 10^{500} different ways, each option juggling parameters and plasma specifications. Plasma with dissimilar characteristics would consequently sustain a universe with different physics. Thus, the subsequent big bang may produce a physical universe with different physics or it may produce something bizarre, an undefined universe or many undefined universes.

The scenario with different laws of nature implies multiple versions of space, each with its own assortment of laws of nature, assuredly inconsistent with our observed laws of nature. In the model, laws of nature may be transformed, added or eliminated; for example, space might contain three rather than four laws of thermodynamics. As discussed, predicting the impact of one modified law of nature on a subsequent big bang process is challenging; predicting the impact when more than one law changes is very problematic. Also, defining innovative plasmas challenges the imagination. So predicting the characteristic of alternative plasma's and the subsequent big bang is purely speculation. Thus, if either laws or initial conditions differ, all bets are off for a stable universe required for an apple pie; rather, an undefined universe (or universes) is the likely result.

Max Tegmark and the Ultimate Multiverse

Max Tegmark believes that our physical world is a mathematical structure, "…our physical world not only is described by mathematics, but that it is mathematical, making us self-aware parts of a giant mathematical object" (Tegmark, 2014, p. 271). In his theory (the Ultimate Multiverse), everything that can be defined by mathematics exists somewhere, although "in some mathematical structures, there's no light. In others, there's no gravity" (Tegmark, 2014, p. 324) Going still more radical, there are many mathematical structures that do away with space and time altogether, so there is no meaningful sense in which anything is happening in them" (Tegmark, 2014, 325). It is highly unlikely that one of these universes would provide the ingredients for an apple pie.

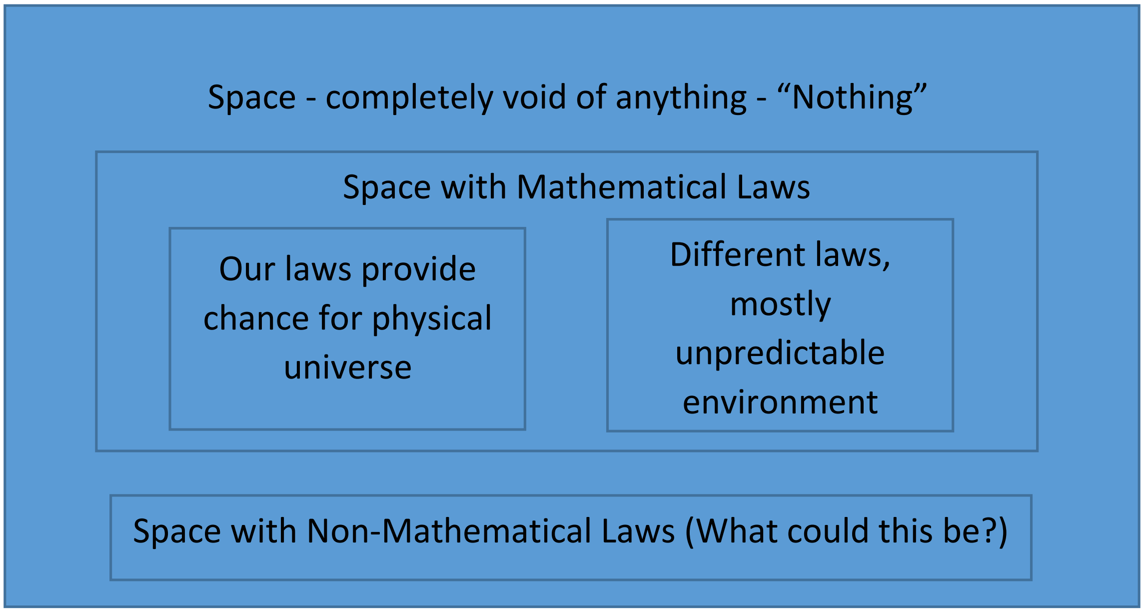

Figure Three. Space and Nothing

An overview including this concept is depicted in Figure Three. Space with our laws is a subset of space with mathematical laws which is a subset of a complete void or "Nothing." As previously stated different mathematical laws produce an unpredictable environment, possibly a universe of some sort. The non-mathematical box is the most difficult to define. Could it be represented by a dream in nonphysical space? In the ultimate set of possibilities, space contains "Nothing", no space, no time, no anything - a complete void. This option raises the question why is there something rather than nothing? Frank Wilczek provided a way of thinking about this question by stating "Nothing is unstable" (Wilczek, 1980).

It is beyond our scope to delve further into this metaphysics topic except to say, it is certainly possible to define a different space, but visualizing the resulting universe is problematic.

Spacetime Speculation

The theory of relativity links space and time to form a unified spacetime. Explaining the existence of space and time is metaphysics - an interesting idea which cannot be proven right or wrong. For our model, space exists in an abstract reality, a platonic realm, “Empty space does not have a physical reality” (Davis, 2010). However, science has discovered two specific fields inherently existing in space: dark energy/cosmological constant and the Higgs field. (Also, the inflaton field if the Inflation theory is validated.) Thus, our space is not nothing; it is something. In our model, space contains even more specific laws of nature - how nature “acts”.

Why is time a mysterious concept? A series of quotes (some paraphrased) provide perspective on the mysterious notion of time (from Scientific American special edition, *A Matter of Time*, 2014). For a definition of time consider the following: if no one asks me, I know; if someone does ask me, I do not know. (Aristotle); time prevents cause and effect from being hopelessly jumbled; and, time is the master of everything we do. On the existence and flow of time, explanations are: nothing other than a conscious observer registers the flow of time; many believe time fundamentally does not exist; all eternity is laid out in a four-dimensional block; and, the past present and future are only illusions, even if stubborn ones. (Einstein)

In summary, quoting Paul Davies, “To be perfectly honest, neither scientist nor philosophers really know what time is or why it exists” (Davies, 2002). So time instills an overall mystery to any conceptual model. But, additional insight is provided by Brian Greene, “To paraphrase John Wheeler, time is nature’s way of keeping everything – all change that is - from happening at once. The existence of time thus relies on the *absence* of a particular symmetry: things in the universe must change from moment to moment… If there were perfect symmetry… time as we normally conceive it wouldn’t exist” (Greene, 2004, p. 226). Thus, our model assumes that time symmetry in space is spontaneously broken allowing change to occur creating spacetime. The concept of spacetime creation is shown in Figure Four. This symmetry breaking is analogous to electroweak symmetry breaking within particle physics.

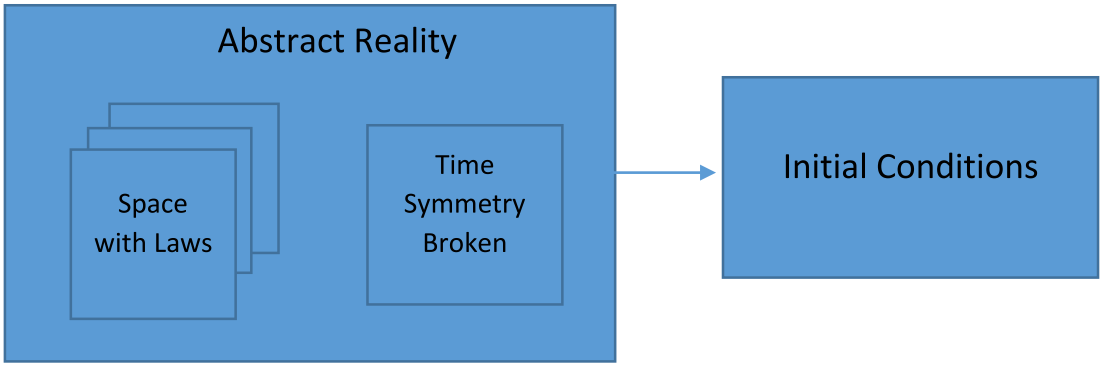

Figure Four. Hypothetical Framework for Spacetime

Although there is logic to this speculation, it is obviously controversial. Many would consider this modification to the model another level of speculation beyond the multiverse. An alternative to time symmetry breaking as the source of spacetime might be that time starts with initial conditions when quantum fluctuations of an energy field, such as the inflaton field, create energy within pre-existing spacetime, but this is also speculation.

Summary

This article defines a conceptual model separating the laws of nature from the universe's energy source and its expansion. From the model, the recipe for inventing our universe is to select a spacetime identical to our observed spacetime, find initial conditions that contribute energy and a plasma with both SMPP and SMC parameters almost identical to ours and then, hope that random actions, during the big bang expansion, primarily biological, create a world with apples and intelligent beings. Other options produce one or many, mostly bizarre, universes defying description.

In our scenario, there may be little or no choice in defining the "laws of nature" just as there may be few choices for dimensionless parameter values and subsequently two big bang variables. Quoting from *A Brief History of Time* "Einstein once asked the question: "How much choice did God have in constructing the universe?" … he had no choice at all to choose initial conditions. He would, of course, still have the freedom to choose the laws that the universe obeyed. This, however, may not really have been all that much of a choice; there may well be only one or a small number, of complete unified theories … that allow the existence of structures as complicated as human beings …" (Hawking, 1988, p. 174).

This model does not attempt to prove or disprove the controversial multiverse theories. It is a conceptual analysis identifying all possibilities. It supports a unique theory for our universe (one mathematical solution) or multiverse theories, and hopefully, provides a perspective on physics, fine tuning, the multiverse, and spacetime. Modifying the laws of nature is ignored by physicists for good reason; there is no practical value or financial reward for research into areas beyond our known laws of physics. Thus, motivation is driven by human curiosity. Predicting different worlds is a mental challenge that tests an individual's technical expertise and imagination. The author's analysis may motivate others to pursue a deeper understanding of nature and our reality.

End Notes

1. The equation for calculating entropy, S, is: S = k log (W), where W = number of rearrangements possible and k is Boltzmann's constant.

2. Another symmetry option is Supersymmetry. "It relates particles of different quantum spin, establishing a deep mathematical kinship between particles that communicate forces and particles that make up matter" (Greene, 2011, p. 331). Supersymmetry may or may not be part of the SMPP; thus its impact is unknown. However, soon the LHC may verify its existence.

3. Discussion of possible time/temperature options for initial condition plasma follow:
a. Inflation ends between 10^{-39} seconds and 10^{-12} seconds. At 10^{-12} seconds, the temperature is 10^{16} K, the density approximates 10^{53} gm/cm^3 and the observable universe would have a diameter of ten cm. Selecting this time implies that electroweak unification (spontaneous symmetry breaking) has not occurred - it is predicted at a later time ($\approx 10^{-11}$ sec) and lower temperature ($\approx 10^{-15.5}$ K). Thus, all initial condition theories assume three forces. Consequently, the big bang process includes the symmetry breaking based on the laws of nature, that is, the electroweak force splitting to the weak and electromagnetic forces.
b. At 10^{-10} sec (10^{15} K), the issue of electroweak unification is avoided and only elementary particles (quarks, electrons, neutrinos) and bosons (force carriers: gluon, photon, and W) exist in the plasma. Also, the density is extremely high, 10^{26} gm/cm^3, enough to accommodate the bounce and cyclic theories. Thus, a plasma at this time/temperature is reasonable although it is beyond the time inflation ends.
c. At 10^{-4} sec, quarks were forming neutrons and protons. The universe's density was 10^{13} gm/cm^3 and its diameter a macro value of approximately one thousand meters. Since quarks were not free and since the density may not have been adequate for the cyclic and bounce theories, this may be too much elapsed time.
d. Nucleosynthesis occurs at 100 seconds ATB. The characteristics are: a temperature of 10^9 K; a density of forty times water (40 gm/cm^3); a diameter of about 10^{10} meters for the observable universe; and a combination of helium, deuterium, and lithium nuclei plus elementary particles. Since inflation theories are predicted to end prior to 10^{-12} seconds, smaller time scales are favored.

4. In Martin Rees' book, *Just Six Numbers*, fine tuning is based on parameters critical to the formation of stars and galaxies. The first two are basic forces: N - the ratio of gravitation and electromagnetic forces (10^{39}) and ε -the percent of energy released in hydrogen to helium conversion (0.7%). The second two relate to energy and expansion: Ω - the ratio of actual density to critical density (0.3) and Ω(λ) -the cosmological constant (0.7). The last two are properties of space: Q - proportion of galaxy rest mass needed to disperse galaxies (10^{-5}) and D - the number of space dimensions (3). Rees says that changing any one of these independently would not produce stars as we know them (Rees, 2000, p. 4).

5. The SMPP contains 25 dimension**less** (and one dimensional) "input physical parameters" relating to particles and forces. Their values cannot be calculated from more fundamental constants because there is nothing more fundamental in SMPP. They are summarized below:

    A. Particle parameters (22 dimensionless plus 1 dimensional)

        1. Coupling constants (G) - twelve (6 quarks, 3 neutrinos, electron, muon and tau)

    2. Matrix/Part angles - eight (4 quarks and 4 neutrinos)
    3. Other - two (CP vacuum part, Quartic Higgs coefficient)
    4. Other - one (Quadratic Higgs coefficient which is dimensional with units of energy)

B. Force parameters (3)

    1. Weinberg angle (θ_W)
    2. Weak coupling constant (g)
    3. Strong coupling constant (g_s)

The force values are dimensionless numbers, but because the Higgs coefficient has energy units, elementary particles also have energy units (mass). It is possible to derive both dimensional “physical parameters", which are primarily masses and forces, and numerous dimensionless constants from these 26 fundamental constants. To avoid arbitrary unit scales, ratios are used to cancel units when establishing dimensionless numbers for mass and density, for example, the Tegmark referenced 2006 article divides particle mass by Planck mass (Johnson, 2015). Using the above parameters, the calculation for the mass of an electron is as follows: $m_e = (vG_e)/2^{1/2} = 0.51$ MeV; where v = Quadratic Higgs coefficient, 247 GeV; and G_e = electron coupling constant, 2.9×10^{-6}. It is possible to derive both dimensional “physical parameters" and also thousands of dimensionless constants (primarily ratios) in physics which can, in principle, be calculated using the laws of physics and the 26 input parameters. The gravitational coupling constant is calculated from fundamental constants ($Gm_p^2/\hbar c$) where G must be experimentally measured (Tegmark, 2014, p. 252).

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