An Alternative Paradigm for the Universe

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Abstract

Information is corruptible and subject to erroneous interpretation, whereas reality is synonymous with “truth”; bit from it. Here we propose an alternative reality, the beginning and evolution of the universe based upon a new paradigm, the Zero Kelvin Big Bang (ZKBB). Grounded in basic demonstrable physics, simple logic, and extrapolation, ZKBB proposes a past-eternal cosmic fabric of mutually repulsive, spin-oriented atomic hydrogen, at zero kelvin. Condensation into a Bose-Einstein condensate (BEC) results in Georges Lemaitre’s Primeval Atom, the concentrated mass of the entire universe in a single quantum, with zero energy and zero entropy; finally, a concrete universe-quantum connection. A quantum event, a single electron spin-flip, precipitates an implosion-explosion; a thermonuclear Big Bang and a universe, and the ultimate “bit to it” event. Using energy stoichiometry, we discuss how the ZKBB model accurately describes the cosmic microwave background (CMB), both conceptually and quantitatively. This model provides a realistic explanation for dark energy, and obviates the horizon problem and the flatness problem. Perhaps this logical, coherent model for the universe will partially fulfill Wheeler’s dream; “Surely someday, we can believe, we will grasp the central idea of it all as so simple, so beautiful, so compelling that we will all say to each other, ‘Oh, how could it have been otherwise! How could we all have been so blind for so long!’. I don’t know whether it will be one year or a decade, but I think we can and will understand. That’s the central thing I would like to stand for. We can and will understand”.

“It from Bit”

John Archibald Wheeler was an exemplary physicist for the 20th century, leaving his mark not only with his ideas and accomplishments, but also with his engaging nomenclature: geons, black holes, wormholes, quantum foam. Late in his life (he died in 2008 at age 96) he turned more philosophical, asking if there was a connection between information theory and reality. He provocatively asked if everything in the universe existed due to the apparatus-elicited answers to yes-or-no questions; believing that all things physical are information-theoretic in origin, and that this is a participatory universe. This was summarized as the “it from bit” conjecture (Wheeler, 1990). In other words, it is only the act of human measurement which reveals the answer to each yes-or-no question, and thus defines reality.

While this position tends towards the metaphysical, the underlying concept is still worthy of consideration. But what about the opposite conjecture, where reality is paramount and nature only reveals itself when we ask the correct questions. Could “bit from it” be more realistic? What is the relationship between human consciousness and reality? How does quantum theory and the concept of probability apply to the universe; could the universe have originated in a series of binary steps: 0 or 1, yes or no, spin-up or spin-down?

The essay theme asks the question, “what is information, and what is its relation to ‘reality’?” Is it from bit or bit from it? I tend towards the “bit from it” school. Reality is all of the processes and events which took place from a defined “origin” to now. Despite quantum theory, and its inherent probabilistic nature, the universe has traveled on a single trajectory; events have occurred in a unique sequence, whether someone was there to measure them or not. To believe that the early universe had no reality, just because we were not there to measure it, seems the height of human arrogance.

However, as human beings, we are special; we do have unique capabilities that enable us to reconstruct reality in our minds. One capability is that of logic. With a basic understanding of nature, we can use reasoning and logic to imagine a reality which does not now exist. Along with logic we are also able to extrapolate forward in time, predicting what will happen based upon what has already happened. But even more remarkably, we can extrapolate backwards in time, so that we can reconstruct a past reality, which has just as much validity as the here and now.

Reality is "the way it is, or was", whether we can see it, imagine it, or not. Information, on the other hand, is the signals which our senses perceive about this reality. In cosmology, information usually comes in the form of electromagnetic waves, light in all its wavelengths. These signals are corruptible however; what you see is not always what you get! Optical illusions can be just as clear and persuasive as reality. Adding to the unreliability of this information is human fallibility. Signals are subject to interpretation as to what they reveal. Sometimes we misinterpret what we see and measure because, being human, we sub-consciously try to reconcile what we see with a theory or model we have already decided must be correct. The tendency will always be to massage the data to fit the pre-conceived theory, rather than to adjust theory to match observations.

Another pitfall is that of scientific sociology; the more senior and influential scientists, through peer review and research grant prioritization, can subtly influence what the entire community chooses to believe. Everyone likes to be liked, and consensus is a seductively comfortable state. Unfortunately, consensus is not always coincident with "truth". Early in the 20th century everyone knew that the universe was static, and Einstein even introduced the cosmological constant into his equations to make sure that it stayed that way. Slipher, Lemaitre, and Hubble showed otherwise. Next, the consensus was that the universe was expanding, but the expansion must be slowing down due to gravity. But in trying to measure this deceleration, the teams of Riess and Schmidt (Riess et al,1998) and of Perlmutter (Perlmutter et al, 1999) found the universe expansion was actually accelerating. Another consensus crashed and burned, but from the ashes a new consensus emerged, that of "dark energy". We may want to believe that we are in an age of "precision cosmology", but future generations may view today's cosmology to be as quaint as the works of Copernicus, Brahe, Kepler, and Galileo seem to us.

In this paper I will pose an alternative paradigm for the origin and evolution of our universe. Through logic and extrapolation, we can imagine a plausible beginning for our universe, and based upon known and demonstrated physics, we can construct a plausible single trajectory which arrives at a universe which looks like the one we now observe.

Crisis in Cosmology

Thomas Kuhn, in his book "The Structure of Scientific Revolutions" (Kuhn, 2000), applied the term "crisis" to the point when the "puzzle solving" phase of scientific inquiry into a particular model or paradigm is reaching its end. At some point there are so many inconsistencies, unanswered questions, and unresolved problems, ("anomalies" in Kuhn's terms), that a crisis of confidence in the model results. This sets the stage for the emergence of alternative models, a "revolution", and eventually a "paradigm shift", where the old model is supplanted by a radically different and new model.

In cosmology, dark matter has not been identified, dark energy (the accelerated expansion of the universe) and inflation are unexplained, galactic haloes remain unverified, the concept of super-symmetry has been discredited, and the "flatness problem" and why omega is exactly 1 remain unresolved. In light of these and other "anomalies", some physicists have suggested that cosmology may now be close to a point of crisis. It was in response to this perceived crisis that I decided to re-imagine the universe, starting with no pre-conceived model of how it might have originated. The result is what I have termed the Zero Kelvin

Big Bang (ZKBB) theory: a past-eternal state of atomic hydrogen, at zero kelvin, evolving via a Bose-Einstein condensate and a thermonuclear Big Bang into the universe we observe today.

Reality, Information and Logic

Reality, in this case, is our universe. It has certain characteristics and properties, all circumscribed by the laws of physics. Information is what we, as human beings, perceive when we observe the universe, in almost all cases via radiation in some part of the electromagnetic spectrum. Information, the observational data, is usually not controversial. Facilitated by increasingly sophisticated technology and very creative scientists, a major concern is the sheer volume of data, and the increasing number of publications. More pieces are added to the cosmic jigsaw puzzle, but the big picture remains elusive.

Problems usually arise when it comes to interpreting the information. In the "puzzle solving" phase, scientists attempt to reconcile their observations with the generally agreed upon model. With pressure to preserve model orthodoxy, conflict between fact and theory, or inconsistency between information and the consensus model, is usually just left as an observed, but unexplained, discrepancy. Rarely do researchers question the basic validity of their model, since then they would be obligated to propose a replacement.

The ZKBB model came about through an attempt to visualize a realistic origin for the universe using only basic logic. Relying only on known and demonstrated physics, I constructed a logical evolutionary process which results in the universe we now observe. This model had to not only be consistent with all of the observations, but also had to provide plausible explanations for the anomalies, the unobserved or unexplained features of the standard Lambda Cold Dark Matter (ΛCDM) model.

Logic of an Origin

In ΛCDM, the concept of an entire universe arising from "nothing" seemed implausible, and the idea of a matter universe accompanied by an anti-matter universe, followed by annihilation, struck me as utterly impossible. So, if one were to start with "something", and wanted to construct a universe using logic, where would one begin?

First of all, one would start with the simplest, stable matter particle, atomic hydrogen, just a single proton and a single electron. However atomic hydrogen in its ground state has four spin configurations; (proton-electron) up-up, up-down, down-up, and down-down (Figure 1). One can think of the proton and electron as bits of information, each with a spin either "up" or "down", making this a two-bit atom. One of these states, up-down (the singlet state), has negative energy relative to the other three states (the triplet states); and importantly in this case, negative energy is synonymous with mutual repulsion, a key component of the ZKBB theory.

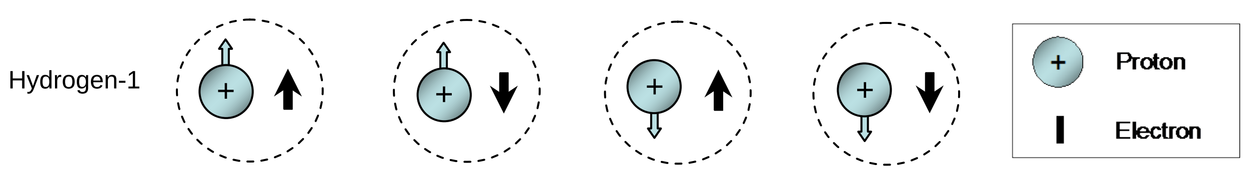

Figure 1. The four spin configurations of atomic hydrogen-1.

The next clue for an origin came from entropy. The Second Law has entropy constantly increasing, the so called "Arrow of Time". Analogous to Lemaitre's reversing of the universe expansion, and extrapolating back in time to the Big Bang, extrapolating entropy back in time gets to a point where entropy is zero. According to the Third Law, zero entropy occurs at a temperature of zero kelvin, so it is logical to believe that the origin of the universe was at zero K.

So, before the “beginning”, one can visualize what I term the “cosmic fabric”: an infinite array of spin-oriented atomic hydrogen, in its lowest possible energy state, at an extremely low density, in pre-existing space. In keeping with the lowest energy requirement, the cosmic fabric exists at zero kelvin, so there is absolutely zero energy. Since the atoms are mutually repulsive (the singlet state), such a cosmic fabric would be stable and in equilibrium, and must have existed in this condition for past eternity (Figure 2A).

Bose-Einstein Condensation

In the “it from bit” view, all 10^{80} or so protons and electrons which would constitute the universe were in an identical configuration. If the universe were a computer, it would be like 10^{80} transistors all in the “0” state. So, how does one start forming a universe from this ground state? The answer is as a Bose-Einstein condensate (BEC). A BEC can be thought of as a fifth state of matter, after plasma, gas, liquid, and solid. At a temperature close to zero K, spin-oriented atoms (ones whose electron spins are identical) can condense into an extremely dense object, a BEC, with all of the atoms occupying the same phase space and acting as if they were a single atom.

The possibility of a BEC was first suggested by Einstein in 1925 (Einstein, 1925). Satyendra Nath Bose, an Indian physicist, had written to Einstein requesting his help in getting Bose’s paper published in a prestigious German journal. The paper described what is now known as the Bose statistics of photons. Photons are bosons (named after Bose), particles with whole integer spin, as opposed to fermions which have fractional spins. Bose theorized that, when a collection of bosons are all in the same ground-state, their waves would become coincident, and they would all act together as a single coherent wave. Einstein extended this concept, supposing that matter bosons would act likewise, if they could be cooled to a temperature low enough for the matter-waves to overlap.

As with other revolutionary Einstein ideas, this one was initially disregarded, since no one believed that the extremely low temperatures required for such a transition were remotely possible. Theoretically, because of its small mass and the fact that it remains a gas all the way down to zero K, atomic hydrogen should have been the easiest atom with which to achieve a BEC. However, due to spin-flip of the electrons and auto-heating, it proved to be extremely difficult. In 1995, the group of Cornell and Wieman (Anderson et al, 1995) reported the creation of the world’s first BEC of rubidium-87 atoms at a temperature of only 170 nK. Ketterle’s group followed with a BEC of sodium-23 (Davis et al, 1995). For this they received a Nobel Prize. It was not until 1998, after 20 years of effort, that the group of Kleppner and Greytak were able to report a BEC of atomic hydrogen; and then it was only possible with the up-up spin configuration (Fried et al, 1998). For this they received a standing ovation.

The Primeval Atom

Starting with a cosmic fabric, with a matter density of only perhaps a single hydrogen atom per cubic meter of space (Figure 2A), and only zero-point motion, the probability of two atoms contacting each other, overcoming their mutual repulsion, and starting a BEC is very close to zero. However, eternity is a long time, and in quantum theory there is never a “never”. It must have happened at least once, since we are here to witness its ultimate result. BEC formation has a probability function whereby, as more atoms enter the BEC, the probability of other additions increases. So, once started, BEC propagation becomes a self-reinforcing process. Eventually, all of the baryons which would eventually make up our universe were concentrated in and around an extremely compact object, a BEC of atomic hydrogen (Figure 2B).

Concurrent with formation of the BEC, the surrounding spherical space would become depleted of the small amount of matter which it had contained, becoming a “matter-depletion zone”, and effectively becoming a “vacuum” relative to the universe (Figure 2B). It is this vacuum effect, billions of years later, with the universe being “sucked out” by the matter-depletion zone, which one can identify with “dark energy”, both conceptually and quantitatively. Beyond the matter-depletion zone, the primordial cosmic fabric would still exist in its original state, perhaps extending to infinity.

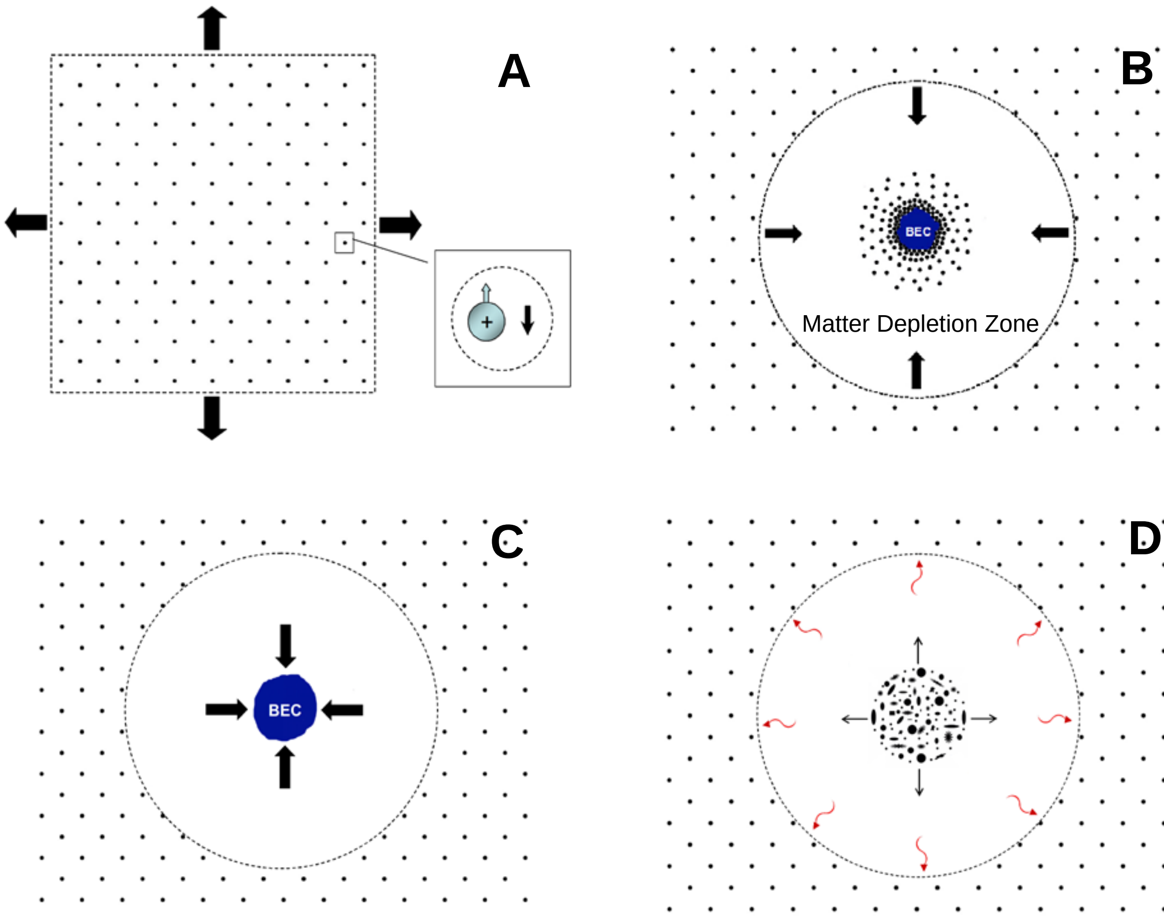

Figure 2. The Zero Kelvin Big Bang (ZKBB). A. The Cosmic Fabric. The cosmic fabric was a pre-existing matrix of spin-oriented atomic hydrogen (black dots) in the up-down configuration (singlet state) that were mutually repulsive, and therefore formed an “eternally” stable matrix. B. Formation of a Bose-Einstein Condensate (BEC). At one point in the cosmic fabric, two hydrogen atoms overcame their mutual repulsion and initiated the formation of a BEC (blue central body), Lemaitre’s “primeval atom”. As more hydrogen atoms are drawn into the BEC, a matter depletion zone forms between the cosmic fabric and the BEC. C. Implosion of the Primeval Atom. A spin-flip initiates formation of molecular hydrogen, setting off a chain reaction of molecule formation surrounding the BEC. This sudden burst of energy causes a massive implosion of the BEC, followed by an explosion (a “bosenova”). D. The Big Bang. Following the implosion, the BEC explodes releasing massive energy into the matter depletion zone (red wavy lines) and fragmenting the BEC into “cosmic shrapnel” which will become the structure of our universe.

Georges Lemaitre, “father of the Big Bang”, along with Vesto Slipher and Edwin Hubble, had shown that the universe was expanding. Lemaitre was also the first to propose what would later be called the Hubble Law or Constant, even though it is not a law, it is not constant, and Hubble was not the first to propose it. As a consequence of the expansion, Lemaitre proposed that one should be able to extrapolate back in time, to a point where all of the matter in the universe was concentrated at a single point in space (Lemaitre, 1946). To this he gave the name "l'atome primatif", translated as the Primeval Atom.

At the time, immersed in the popular physics of the day, Lemaitre imagined the evolution of the universe as being analogous to nuclear fission, with the present structure resulting from a series of multiple fragmentations and subdivisions over time from that initial atom. Again, extrapolating back in time, he envisioned the Primeval Atom consisting of a single quantum, and thus synonymous with an entropy of zero. Surprisingly, the ZKBB model comes to the same conclusion! With all of the atoms indistinguishable and occupying the same phase space, the BEC would be equivalent to a perfect crystal at zero K, and that is exactly how zero entropy is defined. Here, perhaps, is that ephemeral connection between quantum theory and the universe, for which physicists have been seeking for so long.

The Big Bang

ZKBB theory also envisions a Big Bang, but in this case it is an actual thermonuclear explosion, involving close to a third of the matter in the Primeval Atom. The Primeval Atom would have been extremely stable; however at some point this equilibrium must have been broken. How might this have occurred?

Here we again have to consider quantum theory and probability. Hydrogen atoms with the same electron spin cannot react with each other. In order to initiate a change, one of the hydrogen atoms would have had to undergo a spin-flip of its electron. The hydrogen atoms in the BEC itself were, by definition, all coherent, and thus immune to change. So, a spin flip must have occurred in one of the hydrogen atoms in the cloud surrounding the BEC. A spin flip from this lowest possible energy state requires a small amount of energy, 5.9 x 10^-6 eV. Unfortunately, at zero K there is zero energy, but here again we must invoke quantum theory, ("if it can happen, it will happen"), and imagine that at least once in eternity, one atom in 10^{80} atoms underwent a spontaneous electron spin flip. This makes it the ultimate "bit to it", where a single atomic transition precipitated a universe.

However, this step is not as simple and straightforward as one might imagine. It turns out that two hydrogen atoms with opposing electron spins, reacting to form molecular hydrogen, has to be a three-body reaction, with the third atom carrying away excess angular momentum. So the spin flipped atom has to encounter two other atoms simultaneously, before its electron spin flips back to the ground state (Figure 3). One can see from this scenario that the odds of this occurring are like once in never to the third power. The fact that we are here is a testament to the fact that it did happen at least once. But the fact that, as far as we can tell, there are not a multitude of universes running around out there is a testament to the low probability of its happening at all.

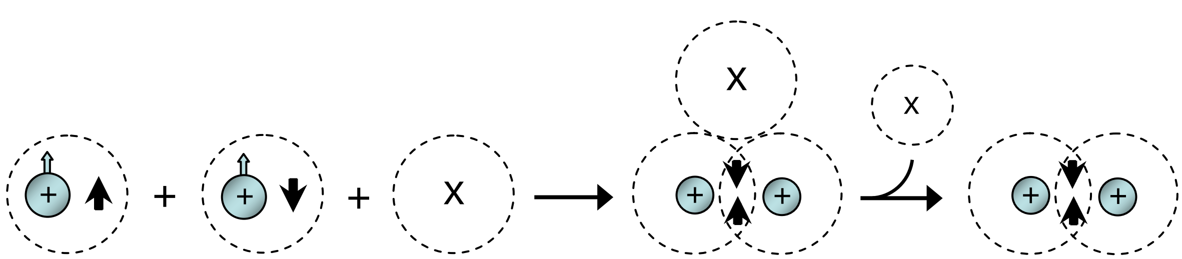

Figure 3. Formation of Molecular Hydrogen by a Three-Body Reaction.

The initial reaction of the three atoms would release energy, due to the formation of a hydrogen molecule. This would initiate an extremely rapid chain reaction, with additional spin flips, additional reactions, more energy, and more spin flips. This chain reaction rippling through the outside shell of the BEC would initiate a hot and violent implosion (Figure 2C), triggering nuclear fusion of hydrogen to deuterium and helium, and blowing the remaining BEC into millions or billions of pieces (Figure 2D). These fragments of hydrogen BEC, "cosmic shrapnel", would become the "seeds" of the structures we now observe in the early universe. These extremely dense fragments at zero K would absorb all light, emit none, and exert a strong gravitational effect on passing matter. This sounds like a primordial black hole, although here the object is not a hole, it is just black.

A "bosenova"

In support of this implosion-explosion mechanism, one can point to an observation reported by Donley et al in 2001. In this experiment, the magnetic field surrounding a BEC of rubidium-85 was adjusted so that the inter-atomic effect slowly changed from repulsive to attractive. The BEC contracted, as expected, but then suddenly collapsed and exploded! Surprisingly, a large portion of the matter seemed to have disappeared, and it is still unclear where it went. In keeping with the music genre of the time, this implosion-explosion event was dubbed a "bosenova". It appeared to have been due to molecule formation, just as surmised for the ZKBB Big Bang (Figure 2C,D).

Cosmic Microwave Background (CMB)

Because study of the CMB is so integral to modern cosmology, it is imperative that any alternative cosmology paradigm satisfactorily describe the CMB, conceptually and quantitatively. As pictured above, matter and energy from the Big Bang radiate out in a spherical distribution from the emerging universe, and out across the surrounding matter-depletion zone (Figure 2D). After billions of years this radiation encounters the zero K, atomic hydrogen of the primordial cosmic fabric. At zero K this cosmic fabric "shell" would act as a perfect black body, absorbing 100% of all radiation impinging upon it. This energy is then re-emitted as perfect blackbody radiation, indicative of the temperature of the warmed cosmic fabric. Through repeated absorption and re-radiation, 50% of the energy would disappear into the infinite heat sink of the cosmic fabric, while 50% would be re-radiated back across the matter-depletion zone and towards the expanding universe (Figure 4). It is this re-emitted "echo" of the Big Bang which we perceive as the cosmic microwave background.

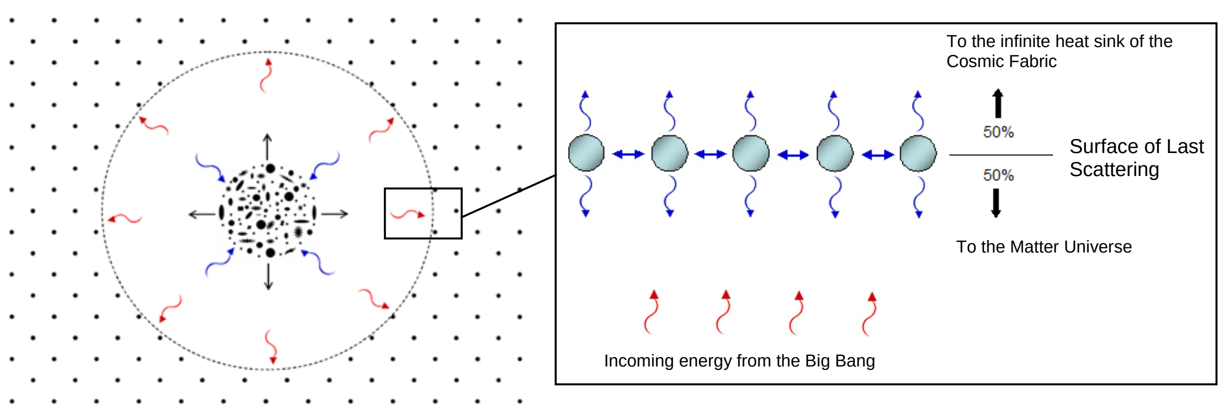

Figure 4. Radiation of the Big Bang. The radiation of the Big Bang traveled across the matter-depletion zone until contacting the primordial cosmic fabric. Repeated absorption and re-emission of this energy by the zero K atomic hydrogen would result in equipartition of radiation; out to the infinite heat sink of the cosmic fabric, or back to the expanding universe.

This scenario is consistent with observations of the CMB. The radiation is isotropic (almost uniform from any direction), consistent with the spherical distribution of the outgoing radiation, and the essentially equidistant geometry of the cosmic fabric surrounding the matter-depletion zone. The CMB shows an almost perfect blackbody spectrum, consistent with radiation from a perfect blackbody, and remaining undistorted during billions of light years travel through the quasi-vacuum of the matter-depletion zone.

Energy Stoichiometry

The concept of stoichiometry is usually used in chemistry, to balance what goes into a chemical reaction with what comes out. In its context here, we use stoichiometry to account for energy measured in the CMB, relative to the energy released by a hypothetical, thermonuclear ZKBB Big Bang. If the ZKBB model is plausible, based upon the scenario depicted in Fig. 4, one would expect to see approximately 50% of the Big Bang energy showing up in the CMB. When one does this calculation, based on the latest most probable value for helium, $Y_p = 0.326$, (Komatsu et al, 2010) one gets a result very close to 50% and very close to the predicted value. The calculations are presented in the accompanying technical endnotes. Here we have quantitative evidence that the ZKBB model may have some validity.

Dark Energy

Dark energy has been described as the most serious unsolved problem in cosmology, especially since it represents approximately 73% of the mass/energy budget of the universe. The equation of state for dark energy has been determined as very close to minus 1.0, indicative of a simple vacuum. However, the discrepancy between the quantum “energy of the vacuum”, as proposed by J. A. Wheeler, and the actually measured dark energy, is about 10^{120}; humorously dismissed as the worst scientific prediction of all time. In a case like this, one should favor concrete data over quantum speculation.
In the ZKBB model, dark energy can accurately be described as a simple vacuum, the matter universe being effectively “sucked out” by the surrounding vacuum of the matter-depletion zone, resulting in the observed accelerated expansion of the universe. Such a simple vacuum option is not available in the ΛCDM model, since here the universe is “all there is”; there can be nothing outside the universe, and so a pressure differential (a vacuum) is inconceivable.

The ZKBB model accounts for dark energy, not only conceptually as a simple vacuum, but quantitatively as approximately 3 times the present matter density of the universe. In General Relativity, the second derivative (equal to the acceleration/deceleration of the universe expansion) is proportional to $\rho + 3p$, where rho (ρ) is matter density and p is pressure. In ZKBB, the pressure differential between the matter/energy density of the universe and the surrounding matter-depletion zone (the vacuum), is quantitatively close to the matter density of the universe itself. So, dark energy should be quantitatively close to 3 times the matter density. The fact that it is slightly less than 3 times is probably an indication that the matter-depletion zone is not a “perfect” vacuum, and thus the pressure differential is slightly less than the absolute matter density of the universe.

Horizon Problem

The horizon problem is usually presented as how the CMB radiation can be so close to perfectly uniform, when the matter from which it was emitted has had no causal contact for tens of billions of years. How did one side of the universe know how warm the other side should be, with no possibility of information passing between the two?

The ZKBB scenario obviates the horizon problem without the need to invoke inflation; although a thermonuclear explosion involving close to a third of the universe's mass might be expected to be somewhat inflationary. If the radiated energy, outbound from the Big Bang, was close to isotropic, and the cosmic fabric equidistant from the universe, then one might expect an isotropic CMB, and that is exactly what we see.

Flatness Problem

Another unresolved issue in cosmology is the "flatness problem", and why omega, the critical density, is exactly 1.0000….. The critical density is the density at which the universe will neither expand exponentially in a "Big Rip" (omega less than 1), nor reverse direction and collapse in a "Big Crunch" (omega greater than 1). Cosmologists have consistently made the philosophical assumption that omega is exactly 1.000..(to an estimated 60 decimal places), even though the requisite matter and energy have not been demonstrated.

In the ZKBB model, the critical density was, is, and always will be exactly 1.000.. Even as the BEC forms, the average matter density of the Primeval Atom plus the matter-depletion zone remains exactly the same as the original cosmic fabric space from which they originated. Redistributing matter in space does not change its average density. With the expansion of the universe, what we are observing is just a return to the original average matter/energy density of the original cosmic fabric. Extrapolating into the distant future, the expansion will eventually decelerate, asymptotically slowing down, and reaching equilibrium, where the spatial volume of the fully expanded universe has returned to its original volume, and the matter/energy density is exactly the same as the surrounding cosmic fabric.

John Wheeler's Dream

The essay guidance asked, "Can we realize John Wheeler's Dream, or is it unattainable?" Wheeler is reported to have expressed his faith as follows; "Surely someday, we can believe, we will grasp the central idea of it all as so simple, so beautiful, so compelling that we will all say to each other, 'Oh, how could it have been otherwise! How could we all have been so blind for so long!'. I don't know whether it will be one year or a decade, but I think we can and will understand. That's the central thing I would like to stand for. We can and will understand". (Horgan, 1996)

I would be naïve to think that the ZKBB model will turn out to be the "Theory of Everything", a modern equivalent of the holy grail and the philosopher's stone, but if it helps in getting us closer to Wheeler's dream, then the effort will have been rewarded.

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Technical Endnote

Calculation of Energy Stoichiometry in ZKBB Cosmology

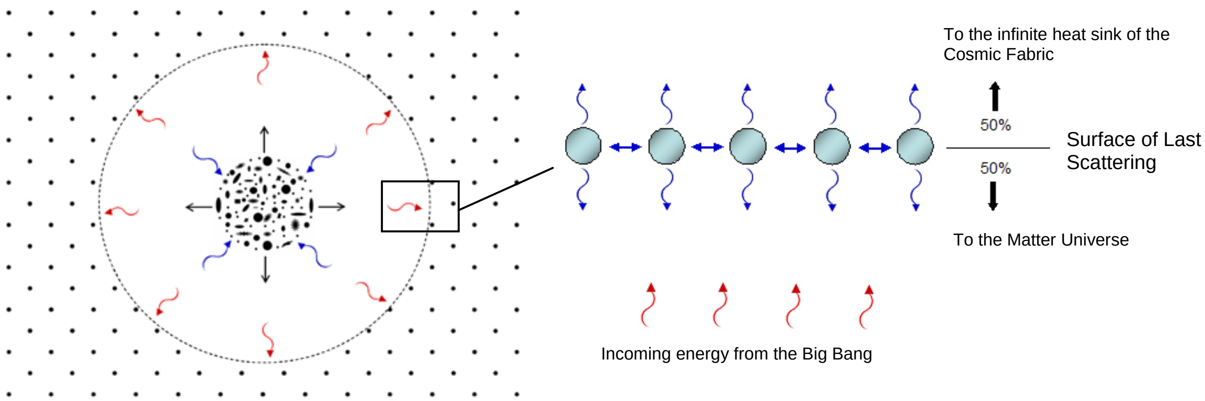

Figure 4 repeated here, depicts the Big Bang radiation and the cosmic microwave background (CMB) "echo". Here we show the energy stoichiometry, between energy released in a thermonuclear Big Bang, and energy detected in the CMB radiation. In order to make this comparison, units of electron volt (eV) per baryon are used, since this is easily calculated for both sides of the process.

Energy from Big Bang Nuclear Fusion

Starting with a given mass of hydrogen, nuclear fusion of a defined mass fraction releases energy via $E = mc^2$. The most recent WMAP 7-year results from the combined WMAP + ACBAR + QUaD data (Komatsu et al. 2011) give a most probable value for primordial helium abundance, Y_p = **0.326 +/- 0.075.** Based upon this, one can calculate the energy per baryon as follows:

One mole of atomic hydrogen = 1.007825 g = 6.022×10^{23} baryons (Avogadro's number)

32.6% hydrogen converted to helium = 0.32855 g

Assuming a 0.7119% conversion of mass to energy (4H > He):

$$(0.32855\text{ g}) \times (0.007119) = 0.002339\text{ g}$$

Energy release (NIST, 1998): ($E=mc^2$)

$$(0.002339\text{g}) \times (5.60958885 \times 10^{32}\text{ eV/g}) = 1.312 \times 10^{30}\text{ eV}$$

Energy per baryon:

$$(1.312 \times 10^{30}\text{ eV}) / (6.022 \times 10^{23}\text{ baryons}) = 2.179 \times 10^{6}\text{ eV/baryon}$$

Here we will apply a somewhat arbitrary, but still reasonable, assumption that 95% of the energy release is thermal and 5% kinetic. Thermal energy could result in rapid spatial expansion (inflation?). Kinetic energy could add additional velocity to the BEC fragments, while imparting varying degrees of triaxial angular rotation; rotation still observable in the structural elements of the universe.

The thermal energy release would then be:

$(2.179 \times 10^6$ eV/baryon$) \times 0.95 =$ **2,069,900 eV per baryon**.

As described for the ZKBB model and depicted in the figure above, only 50% of the energy absorbed by the cosmic fabric would re-radiate back to the expanding universe, while the other 50% would radiate out to the infinite heat sink of the cosmic fabric. Assuming that the ZKBB model is correct, perfect energy stoichiometry would predict the energy observable in the CMB radiation:

(2,069,900 eV/baryon) x 0.50 = **1,034,952 eV/baryon**

Energy in Cosmic Microwave Background (CMB) Radiation

Seven years worth of data from the Wilkinson Microwave Anisotropy Probe (WMAP) satellite have now resulted in extremely accurate values for the number of photons in the CMB relative to the number of baryons (protons and neutrons), and the average energy of those photons.

Photons per baryon = 1.639×10^9 (Bennett et al., 2003)

Average energy per photon ($E = 2.7kT$; where k=Bolzmann constant and T=2.726K):

Average energy per photon = 6.34×10^{-4} eV/photon

Energy per baryon:

$(1.639 \times 10^9$ photons/baryon$) \times (6.34 \times 10^{-4}$ energy/photon$)=$ **1,039,126 eV/baryon**

One can immediately see that, relative to the predicted ZKBB energy release, the energy detected in the CMB is extremely close to that which one would expect in the ZKBB model. Even taking into account the uncertainty in the 0.326 number and the assumption of 95% thermal energy release, this is a remarkable correspondence of theoretical calculations and experimental data.