Zero Kelvin Big Bang, an Alternative Paradigm:

I. Logic and the Cosmic Fabric

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Abstract

This is the first of three papers describing an alternative paradigm of cosmogony, the beginning and evolution of the universe. The Zero Kelvin Big Bang (ZKBB) theory is compared to the prevailing Standard Big Bang (SBB) paradigm, and challenges the notion that our universe is "all there is." Logic suggests that the Big Bang was not a creation event, but that the universe did have a beginning: a "cosmic fabric" of pre-existing matter, in pre-existing space. Instead, the Zero Kelvin Big Bang was a transitional event between that "beginning" and what would become our universe. Extrapolating entropy back in time (as SBB does for matter and energy), and applying simple logic, suggests a "cosmic fabric" of the simplest, stable particles of matter, at the lowest energy state possible: singlet state, spin-oriented atomic hydrogen at zero kelvin, at a density of, at most, only a few atoms per cubic meter of space, infinite and (almost) eternal. Papers II and III describe the condensation of part of the cosmic fabric into a Bose-Einstein condensate (BEC) as Lemaître's primeval atom, followed by an implosion-explosion Big Bang.

Keywords: Big Bang, Entropy, Cosmic Fabric, Spin-Oriented Hydrogen, Bose-Einstein Condensate, Primeval Atom

1. Introduction

Physics appears to be on the brink of major change. Recent news stories such as "Higgs cornered in Grenoble" (Chalmers, 2011) and "Supersymmetry 'may be wrong'" (Ghosh, 2011) describe what may be the imminent demise of supersymmetry, the Higgs boson, and string theory in general, all focal points for physics research over the past decade. Similarly in cosmology, the Lambda-Cold Dark Matter (Λ-CDM) version of the Standard Big Bang (SBB) theory is under stress. While the reality of dark matter and dark energy appear secure, decades of effort have yielded a limited number of MACHO candidates (massive compact halo objects), and no confirmed detection of dark matter particles, baryonic or otherwise, no WIMPs (weakly interacting massive particles), no heavy neutrinos, neutralinos, axions or strings. Likewise, there is no satisfactory physical explanation of what Lambda (dark energy) actually is, or why it even exists.

Over the past few years, new telescopes and innovative technology have greatly expanded our observations of the universe. Surprisingly, many papers have concluded that these new observations or results are inconsistent with the prevailing Λ-CDM-SBB theory. The discrepancies fall primarily in the areas of structure formation and nucleosynthesis. A paper by Kroupa et al. (2010) offers an excellent summary of the former, and a paper by Cyburt et al. (2008) a good example of the latter. Unfortunately, there are few complete alternative cosmology paradigms against which to test these observations. This series of three papers introduces an alternative paradigm, the Zero Kelvin Big Bang (ZKBB) theory. Rather than complex mathematics, ZKBB utilizes logic to develop a conceptual theory, based on real matter, undergoing known transitions, according to the existing laws of physics.

In this paper, we will show how ZKBB theory provides a plausible description of a "past-eternal" (Aguirre & Gratton, 2003); a "cosmic fabric" of pre-existing matter in pre-existing space, at equilibrium. The second paper will describe the formation of a Bose-Einstein condensate (BEC) from this matrix, Georges Lemaître's "primeval atom." The third paper will describe the Big Bang itself, an actual implosion-explosion of the BEC, due to nuclear fusion. Future papers will describe how contemporary observations are consistent with the physical consequences of the ZKBB, and how outstanding problems in SBB theory, such as dark matter, dark energy, galaxy formation, etc. are plausibly addressed.

Stephen Hawking, in a 2003 talk "Cosmology from the Top Down", framed the central question(s) of cosmology as follows: why is the universe the way it is, and how did it get here? (Hawking, 2003). He argued that, "One shouldn't follow the history of the universe from the bottom up, because that assumes there's a single history, with a well-defined starting point and evolution", and "The trouble is, there's no natural boundary condition, like the universe being in its ground state. The universe doesn't have a ground state." It is possible that he may have been incorrect on both counts. In this and subsequent papers, we will show how the universe may have arisen from a realistic ground state, and how it could have evolved via a single history, from a logical and well-defined starting point, to our present universe.

The paper is laid out as follows: sections 2 and 3 outline the consensus SBB paradigm, and the assumptions on which it is based. Section 4 discusses the difference between an origin and a beginning for the universe. Sections 5, 6, and 7 describe extrapolation of matter, energy, and entropy, backwards in time, and how logic leads to a "cold" Big Bang. Finally, sections 8, 9, and 10 describe how a "cosmic fabric" of a specific state of atomic hydrogen, may have preceded the Big Bang.

2. Standard Big Bang (SBB) Theory: The Existing Paradigm

While called the **Standard** Big Bang theory, there are innumerable variations in use. Here, SBB will refer to the following broad outline of a generally accepted sequence of conditions, mechanisms, and events.

1. Creation of all matter, energy and space *ex nihilo* (from nothing).
2. A starting condition of infinite density and temperature (a singularity?). Or, staying within General Relativity, the Planck epoch at 10^{-43} sec, with a maximum density of 1.5×10^{96} kg/m^3 and temperature of 1.4×10^{32} K.
3. Matter and anti-matter created in almost equal amounts, with matter annihilation returning most of the energy and leaving a tiny surplus of matter as our universe.
4. A process of inflationary expansion which purportedly resolves problems with the SBB scenario (horizon problem, flatness problem).
5. Anisotropies in the cosmic microwave background (CMB) which reflect defects in this smooth, almost homogeneous matrix, serving as the "seeds" for future structure formation.
6. A process of "recombination" 300,000 years after the Big Bang, when the universe had cooled to approximately 3000 K, and complete atoms formed.

7. Continued but slower expansion and cooling of the universe, allowing matter to gravitationally collapse around the "seeds", and accrete or aggregate into the structures that we now see: stars, galaxies, galaxy clusters, etc.
8. Approximately 80% of the matter in the universe consisting mostly of unidentified and unexplained "dark matter", most of it non-baryonic (baryonic being the "normal" matter with which we are familiar, containing protons, neutrons and electrons).
9. For the past few billion years, the expansion of the universe has been accelerating due to "dark energy", which constitutes about 73% of the total mass/energy budget of the universe; also unidentified and unexplained.

3. SBB Assumptions

The SBB scenario relies on certain basic "bedrock" assumptions:

1. The universe is "all there is"; there is nothing "outside" the universe.
2. The Cosmological Principle. The universe is homogeneous and isotropic, uniform in distribution, and the same in all directions.
3. The Copernican Principle. We do not occupy a "special" position in the universe (like being at the center); the universe looks exactly the same from **any** location in the universe, and in **any** direction.

It will be suggested that all three assumptions may be suspect. ZKBB theory, using contrary assumptions, offers a more realistic scenario for a beginning, and subsequent evolution of the universe. In this paper we will primarily deal with assumption number one.

4. Universe: Beginning Versus Origin

SBB theory envisions a universe with an "origin", although its exact description is unclear and open to numerous interpretations, some even contradictory (was the Big Bang an explosion or not?). Many cosmologists propose a mathematically derived "singularity" beyond the Planck scale, infinite in density and temperature, originating from nothing, where "the Laws of Physics do not apply." If one stays within the realm of General Relativity, where the Laws of Physics do apply, the Planck limits are 1.5×10^{96} kg/m^3 and 1.4×10^{32} K. Accepting the concept of an origin obviates the question, asked by naïve amateur cosmologists, "What came before the Big Bang?" This question drew the well-known response from Stephen Hawking that it is like asking "What lies north of the North Pole?" (Filkin, 1998).

Perhaps the question is not as foolish as generally depicted. "Something" prior to the Big Bang is only ruled out because of assumption number one above, that our universe is "all there is". Rees (2001), Silk (2006), Tegmark (2007), Linde (2010), and others have already suggested the possibility of a multiverse, where our universe may be only one of many. More recently, several scientists (Aguirre et al. 2007; Feeney et. al. 2011; Kleban et al. 2011) have suggested that more detailed analysis of the cosmic microwave background (CMB) could actually reveal evidence of "bubble collisions" between other universes and our own. So, the assumption that our universe is all there is has already been questioned by respected physicists. If there are other universes, what lies between them? If one accepts that multiple universes could exist in a much more expansive matrix, then "something" prior to the Big Bang may be conceivable. Here we suggest what that something might be. We will present a model which can just as easily and realistically support multiple universes as only one, without the need for creative theoretical physics or supernatural phenomena.

ZKBB theory proposes that there are at least two entities, one embedded within and derived from the other. The first primordial structure we refer to as the “cosmic fabric” which consists of spin-oriented hydrogen atoms, at zero kelvin, with a distribution of, at most, a few atoms per cubic meter of space, perhaps infinite in extent and almost eternal. The second, relatively small structure is our universe which was derived from, and still lies embedded within, the cosmic fabric. This may represent only the latest (and perhaps final) logical expansion of man’s concept of the cosmos. This may seem a controversial proposal, until one considers that, less than a century ago, the prevailing consensus paradigm was that our galaxy, the Milky Way, was the **entire universe**.

Likewise, there was also once a consensus that the universe was static, neither expanding nor contracting. However, early in the 20th century, Slipher, Lemaître and Hubble showed a universe expanding. It was expanding, but the consensus was that the expansion should be decelerating due to the gravitational pull of all the matter within. When measured, however, the scientific teams of Perlmutter, Reiss and Schmidt showed the expansion actually accelerating, generally considered as evidence of “dark energy” (Riess et al. 1998; Perlmutter et al. 1999). Rather than a cosmological constant, quintessence, or “repulsive gravity”, in a later paper we will show how ZKBB theory provides a natural explanation for dark energy, both conceptually and quantitatively: a simple vacuum between our universe and an encompassing “matter-depletion” zone.

In the above examples, one can see that consensus is no guarantee of validity. As Tim Eastman recently stated, “Science should not be confused with democracy and the popular notion that the theory with the most ‘votes’ wins” (Eastman, 2010). There is no reason to believe that today’s consensus opinions are any better than yesterday’s. Some assert that we are in a time of “precision cosmology” (Turner, 1999; Primack, 2005); however, our present technology and theories may appear as quaint to future cosmologists as Galileo’s are to us.

In the ZKBB scenario, the Big Bang was not an **origin** event, as assumed by SBB theory. Instead it was a **transitional** event between a pre-existing state (a part of the cosmic fabric) and our present universe. Since a universe with an origin appears to violate the First Law of Thermodynamics, then the possibility of a “beginning” rather than an “origin” must be entertained. This may appear to be a semantic difference, but it is not. An origin in this case implies that there was nothing in existence prior to the Big Bang. A beginning implies that the universe arose from something which already existed. If there was already matter and space, then there may truly be an answer to what came before the Big Bang. Here we will describe exactly what this state might have been, and how this model is realistic from a scientific perspective.

5. Extrapolation

Extrapolation, projecting known information into unknown territory, is a key process in almost all fields of science. It can, however, face limitations and pitfalls if the correct assumptions are not applied. Here we will consider three extrapolations (matter, energy and entropy) as they relate to cosmology. The first two serve as the basis of SBB theory, but the third has been curiously overlooked.

5.1. Extrapolation of Matter

Perhaps one of the most significant extrapolations in cosmology was done by Georges Lemaître (1927, 1931). Based upon evidence that the universe was expanding (from Slipher's, Hubbell's and his own work), he extrapolated back in time to conclude that all of the matter in the universe had once resided in a super-dense mass which he called the "Primeval Atom" or "Cosmic Egg." From this beginning, he then hypothesized a smooth expansion of the primeval atom via radioactive disintegration of this single quantum, eventually leading to the present universe, an event depicted by Fred Hoyle as "one big bang at a particular time in the remote past" (Hoyle, 1939). Hoyle created the Big Bang name, but it is Lemaître who can legitimately be credited as "the father of the Big Bang", and George Gamow who was primarily responsible for the idea of a hot Big Bang.

5.2. Extrapolation of Temperature/Energy

In the second case, cosmologists extrapolated temperature back in time, just as they did with density. Thus, if one extrapolated back in time from the present state to a universe compressed to almost infinite density, one would expect, concurrently, an almost infinite temperature. This presumption is questionable, however, because it is based on the unwarranted assumption that matter **always** had kinetic and thermal energy. Prior to a Big Bang energy release, it is perfectly plausible that one could have an entity of condensed matter with no energy at all; matter at zero kelvin or absolute zero. At 0 K, even the existence of zero point energy (ZPE) appears to be in question (Jaffe, 2005). Thus, matter without energy is a quite plausible starting condition, whereas energy without matter is questionable.

Extrapolation of energy backwards in time, to a state of infinite temperature, was primarily the idea of George Gamow, who envisioned **all** of the elements being created in the Big Bang (Alpher et al. 1948). It later became clear that, in addition to hydrogen, only helium and lithium would result. The Burbidges, Fowler and Hoyle (B2FH) (1957) and others showed how elements between helium and iron would be formed in stars, and how the elements heavier than iron would originate in supernovae explosions. Even though most physicists accepted the fact that an infinitely hot Big Bang was no longer essential for total nucleosynthesis, the assumption of a **HOT** Big Bang was still retained. In ZKBB theory, we will show how an initial high matter density may be unavoidable, but an infinite temperature is not.

5.3. Extrapolation of Entropy

The third extrapolation, and one which has been curiously overlooked or avoided, is that of entropy. Even though all cosmologists concede that the universe must have begun with extremely low entropy, **zero** entropy seems to have been rarely considered or quickly dismissed. It is here, with entropy, that we see the initial rationale for an alternative paradigm, radically different from that of the SBB theory and others. The logic of this process is as follows.

6. Entropy and Logic

Even those with little formal physics education are cognizant of entropy, and the Second and Third Laws of Thermodynamics. The Second Law states that the entropy of a closed system can only increase and the Third Law states that zero entropy occurs only in a perfect crystal at zero kelvin. If the entropy of the universe (a closed system in SBB theory) can only increase with time, then extrapolating backwards in time, as Lemaître did with matter density, irrevocably leads to a condition of zero entropy at the beginning of the universe. Here there is no kinetic/thermal energy whatsoever, only matter; perhaps that is a state where the universe could have begun.

This is obviously in stark contrast to the “infinite” temperature, and presumably infinite entropy inherent in the SBB model. If entropy appears close to a maximum in the SBB event (a “seething sea of sub-atomic particles”) and at almost infinite temperature, it is difficult to see how entropy could possibly increase, as circumscribed by the Second Law. In ZKBB theory, the universe starts at zero kelvin and zero entropy, so it is hardly surprising that entropy increases with time. Here, perhaps, is the key to connecting entropy and the arrow of time; **both began at zero** prior to the Big Bang. Entropy increases as energy is released in the Big Bang, and by subsequent nucleosynthesis in stars. There is undoubtedly moderation of the entropy increase by cooling of the universe, but this is counterbalanced by universe expansion and the diffusion of the matter within.

The Third Law of Thermodynamics requires that matter with zero entropy be the equivalent of a perfect crystal, a quantum entity with only a single degree of freedom. It is surprising that Georges Lemaître actually proposed a single quantum state for his primeval atom (Lemaître, 1950). Even more surprising is that modern physics can actually describe, **and demonstrate**, an entity like this: a Bose-Einstein condensate (BEC). In a BEC, each individual atom is indistinguishable, and the whole entity behaves as if it were a single atom, in effect a perfect crystal. In ZKBB theory, this BEC, this single quantum, is composed of “spin-oriented” atomic hydrogen and will be described in this and the following paper.

7. A Cold Big Bang

The idea of a "cold" Big Bang, as opposed to the prevailing hot Big Bang, is neither original nor unique. Zeldovich (1972), Layzer (1991), and Aguirre (1999) have all suggested the possibility of a cold beginning for the universe. Unfortunately, in most cases, either the identity of the cold "something" was not identified, or the evolutionary processes leading to our universe were inconsistent with observations such as the isotropic Cosmic Microwave Background (CMB). However, in the case of the ZKBB, we now have an exactly specified starting condition (cosmic fabric), and already-demonstrated processes which logically and naturally result in the phenomena which we observe, both qualitatively and quantitatively.

8. Hydrogen

If logic suggests a beginning at zero kelvin, then what exactly existed at zero kelvin? And by what mechanisms and processes has it managed to morph into our present universe? Harlow Shapley, who first determined our position in the Milky Way, was perhaps prescient when he was quoted as saying, "Some piously record 'In the beginning God', but I say 'In the beginning hydrogen'." If one accepts the initial premise from the extrapolation of entropy, that the universe may have begun with zero energy at zero kelvin, simple logic would suggest the most basic possible building block: atomic hydrogen, at its absolutely lowest energy level.

In our universe, hydrogen in its various forms is predominant at about 74%, with 24% helium, and only minor amounts of the other elements. All complex nuclei containing neutrons, can be derived from atomic hydrogen, by some process or series of processes. Even the unidentified and unexplained dark matter, "missing" matter invoked to solve problems with SBB theory, has been hypothesized as various forms of hydrogen (White, 1996; Valentijn & van der Werf, 1999; Heithausen, 2004; Revaz et al. 2009; Lin et al. 2011). In a later paper we will argue that these ideas may, in fact, be correct.

Atomic hydrogen, a single proton and electron, is extremely reactive under terrestrial conditions, and spontaneously converts to molecular hydrogen, H_2. However at a temperature close to zero kelvin, if the electrons all have the same spin, spin-oriented atomic hydrogen is extremely stable and unreactive. Due to the Pauli exclusion principle, only atoms of hydrogen with opposite electron spins can combine to form a molecule of hydrogen. The hydrogen atom is also extremely stable. Decades ago, most physicists subscribed to the Grand Unified Theory (GUT), then and even now an integral component of SBB theory. One prediction of GUT was that the hydrogen atom would eventually disintegrate. Experiments searched for the predicted light flashes from this event, but tellingly none were ever seen. It was concluded that hydrogen was stable for at least 10^{33} years (Nishino et al. 2009) and perhaps forever, and that at least this aspect of GUT was wrong.

One can use logic to hypothesize that the primeval matter (prior to a Big Bang) was, in fact, atomic hydrogen. The simplest, stable unit of matter, at its lowest possible energy state, thus becomes a seemingly rational state from which to initiate a universe, and is the starting point for the ZKBB theory. If this premise is at all valid, what can contemporary physics tell us about this initial state?

9. The Cosmic Fabric

Prior even to the beginning of the Big Bang, ZKBB theory envisions a “cosmic fabric” of pre-existing matter in pre-existing space. This appears less of an arbitrary, ad-hoc assumption when one sees that the eventual consequences are consistent with predictions of standard physics, and a physical reality that can be supported by observational cosmology. An obvious question would be, where did the hydrogen come from, and would this be a case of just moving an origin further back in time? One answer would be that the hydrogen did not come from anywhere. Instead, it may have always existed and, far outside the sphere of our universe, will continue to exist. Another question would be how the cosmic fabric could have been at equilibrium, and essentially “past-eternal”, until the Big Bang. Would it not spontaneously collapse by gravity as envisioned by Isaac Newton 400 years ago? The cosmic fabric would initially appear eternal and at equilibrium because there was no energy; the hydrogen atoms were non-reactive, with positive s-wave scattering length and therefore mutually repulsive (Sen et al. 2006), thus precluding gravitational collapse.

Another, even more speculative idea, is similar to the proposal for Modified Newtonian Dynamics (MOND), developed by Milgrom (1983a, 1983b) and others, to explain anomalous observations such as flat galactic rotation curves, where MOND proposes a deviation from strict Newtonian dynamics at very low accelerations. General Relativity envisions mass as always resulting in a curvature of space. However, when individual hydrogen atoms are separated by about a meter of space, it may be that the curvature of space is effectively zero. This might then represent a deviation from strict Newtonian dynamics at the low density extreme, analogous to the relativistic deviation at the high density extreme. Here, supplementing the philosophical belief, may be a physical basis of why omega, the ratio of the universe density to the critical density, is exactly and precisely 1.00000. The density of the original cosmic fabric may actually be the critical density, and the observed expansion of the universe is simply a return back to that average critical density.

10. Which Hydrogen?

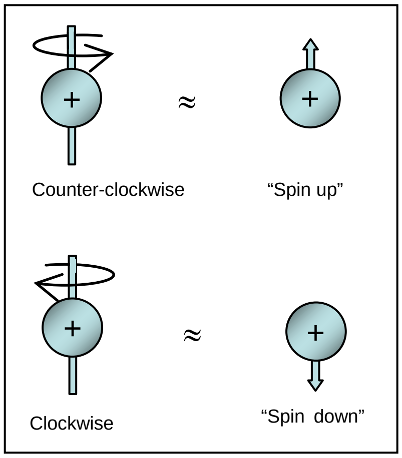


Figure 1. The spin-oriented proton. Protons and electrons have the property of "spin", either clockwise or counter-clockwise. These are commonly described and diagrammed as being "spin up" or "spin down" for ease of discussion.

The elementary particles of atomic hydrogen, proton and electron, have the property of "spin". This can be visualized (but not described) as being like a spinning top, spinning clockwise/counter-clockwise, or with spin up/spin down (Fig. 1); the latter being easier to diagram, spin up/spin down will be used for this discussion. Because of the spin of the two elementary particles, proton and electron, atomic hydrogen can have four different spin configurations, as shown in Fig 2.

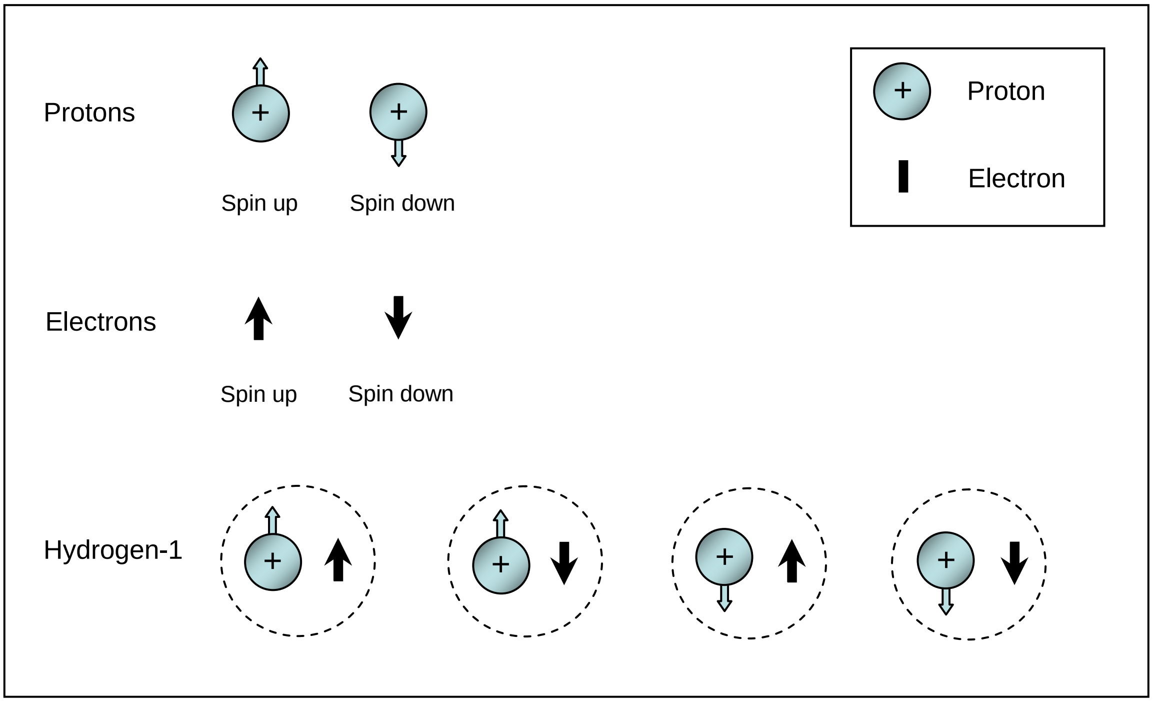


Figure 2. The spin configurations of atomic hydrogen. Because of the spin of the two elementary particles, protons and electrons, hydrogen-1 can have four possible spin configurations.

These spin configurations are shown as (electron-proton) up-up, down-up, up-down, and down-down. One might think that the down-up and up-down configurations (both with total spin zero) are equivalent, but they are not. This was first shown by Satyendra Nath Bose (Bose, 1924) with his discovery of what became known as Bose statistics. These statistics govern the behavior of bosons (also named after Bose), particles which have zero or integer spins (-2, -1, 0, +1, +2). This is in contrast to Fermi statistics (named after Enrico Fermi) which govern the behavior of fermions, particles with fractional spins (-3/2, -1/2, +1/2, +3/2). The proton and electron are both fermions with ½ integer spins (+1/2 or -1/2), but when they are together in the hydrogen atom, the <u>total</u> spin is an integer (-1, 0, 0, +1) as shown in Fig. 3. Hydrogen atoms are therefore bosons, and it is this which will lead to a universe.

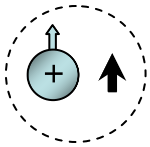
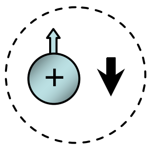
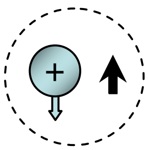
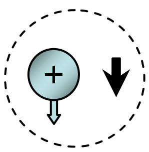
Hydrogen-1	Configuration (electron, proton)	Spins (electron, proton)	Total Spin
	up, up	+½, +½	+1
	down, up	-½, +½	0
	up, down	+½, -½	0
	down, down	-½, -½	-1

Figure 3. Spin states of atomic hydrogen. Protons and electrons are fermions and have half-integer spins. When a proton and electron are combined in a hydrogen atom, the total spin is an integer (1, 0, or -1), making hydrogen atoms bosons. Atoms containing protons and electrons with opposite spins have a lower energy state.

When first hypothesizing atomic hydrogen as the primeval matter, logic immediately suggests either the up-down or the down-up atom. In these cases, the electron spin and proton spin effectively cancel, resulting in a total spin of zero, and a lower energy state. But which of these two configurations was the correct one, and what prevented the aggregation or premature collapse of this structure? The answer to both questions came in a diagram, in papers by Isaac F. Silvera (1995) and the Ph.D. thesis of Dale Fried (1999). An adaptation is shown in Fig. 4.

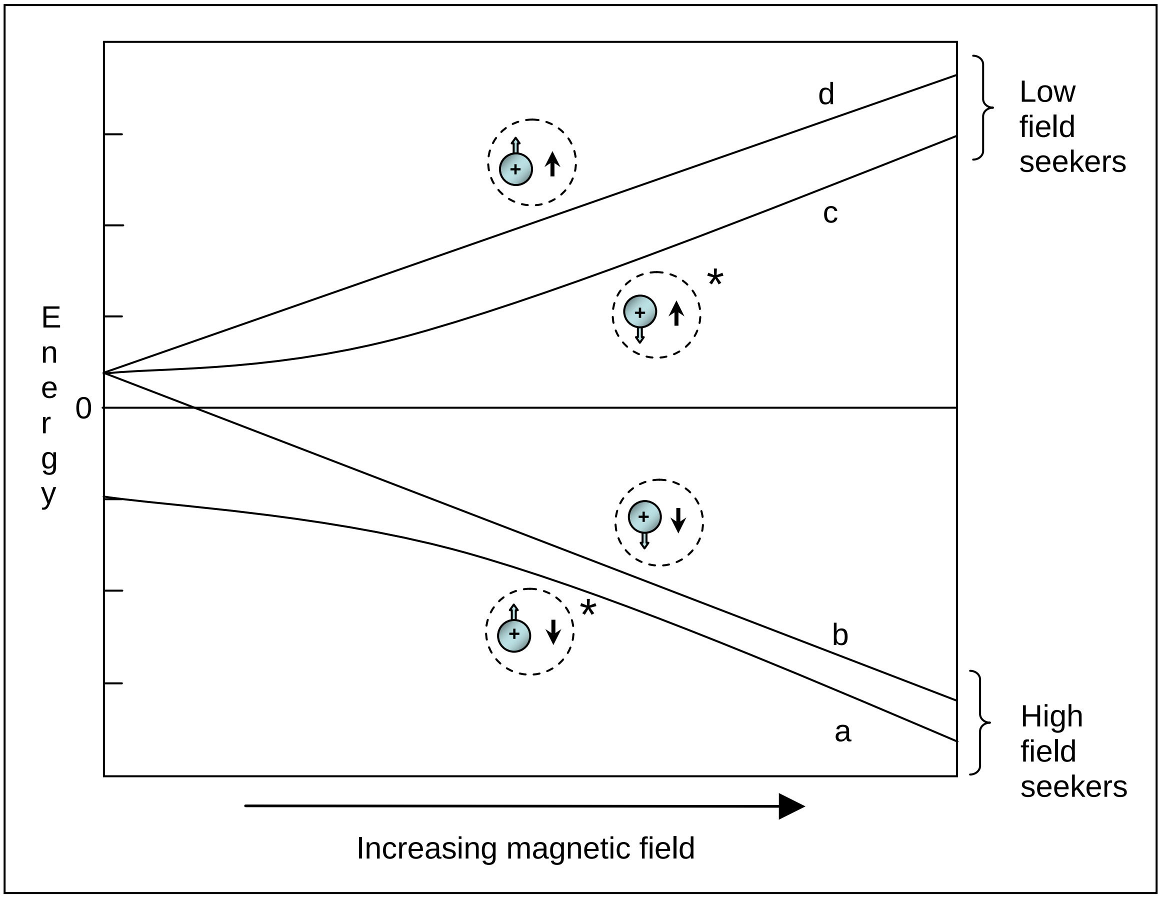


Figure 4. Energies of the hydrogen hyperfine states as a function of magnetic field. *Adapted from Silvera (1995) and Fried (1999).* When subjected to a strong magnetic field, atoms with "spin down" electrons are high-field seekers and congregate where the magnetic field is highest (configurations a and b) while atoms with "spin up" electrons are low-field seekers and are repelled (configurations c and d). Although both "a" and "c" hydrogens (indicated by asterisks) have the same total spin of zero, "a" hydrogen atoms (singlet state) have lower energy as shown by the y-axis intercept, and would therefore be the best candidate for the cosmic fabric.

This shows the energy of hydrogen atoms subjected to a strong magnetic field, which interacts with the spin or magnetic moment of the protons and electrons. Atoms with "down" electrons (a and b) are high-field seekers and congregate where the magnetic field is the highest. Atoms with "up" electrons (c and d) are low-field seekers and are repelled by the field. One can see a difference in the vertical axis intercept between the "a" atoms (down-up) and the "c" atoms (up-down) (indicated by asterisks), even though they have the same total zero spin. The "a" atoms, the **singlet** state, show a negative intercept or negative energy relative to the **degenerate** “b”, “c” and “d” atoms, at zero magnetic field. It has been found that the “a” atoms have a positive s-wave scattering length (Sen, 2006), indicating that they are mutually **repulsive**. This might then explain why the cosmic fabric would not spontaneously collapse. Whatever gravitational influence there might be between proximal atoms could be more than compensated by their mutual repulsion. If correct, a cosmic fabric of exclusively singlet state “a”, down-up atoms, would be (almost) eternally stable. This suggests a rational and realistic ground state from which a universe could evolve; a cosmic fabric of atomic hydrogen “a”, at zero kelvin.

A recent paper entitled “Ruling out bosonic repulsive dark matter” (Slepian & Goodman, 2011) would appear to cast doubt on the ZKBB hypothesis, at least as far as dark matter is concerned, since “a” hydrogen atoms are both bosons and repulsive. However, these authors’ conclusion is based upon the assumption that the bosons are at a finite temperature and at thermal equilibrium, neither of which is the case in the ZKBB scenario.

In the second paper of this series, we will consider the breaking of this equilibrium state, and the condensation of the atomic hydrogen into a Bose-Einstein condensate (BEC), Lemaître’s primeval atom. We will see that mutual repulsion is also a prerequisite for the formation of this entity.

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