Zero Kelvin Big Bang, an Alternative Paradigm:

II. Bose-Einstein Condensation and the Primeval Atom

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Abstract

In the first of a series of three papers, we described how logic suggests a “cosmic fabric” as the starting point for our universe: a sparse distribution of spin-oriented hydrogen atoms at zero kelvin, perhaps infinite and (almost) eternal. This second paper describes how a portion of this cosmic fabric could have condensed into a Bose-Einstein condensate (BEC). This cold ball of highly concentrated matter may be the “primeval atom” proposed by Georges Lemaître in 1931, as the beginning of our universe.

Keywords: Bose-Einstein Condensation, Zero Kelvin Big Bang, Atomic Hydrogen, Primeval Atom, Origin of the Universe

1. Introduction

In the first paper of this series, we introduced an alternative paradigm for the history of the universe, the Zero Kelvin Big Bang (ZKBB), a rational and comprehensive alternative to the widely-accepted Standard Big Bang (SBB). The ZKBB model hypothesizes a pre-Big Bang “cosmic fabric” of spin-oriented hydrogen atoms at a temperature of zero kelvin, and a density of , at most, only a few atoms per cubic meter of space. Thus, both matter and space existed prior to the Big Bang. In this second paper we will look at the transition which must have taken place to get from such a sparse matter distribution to a state of concentrated mass, capable of supporting an explosive Big Bang event.

This paper is laid out as follows. Section 2 describes Bose-Einstein condensation in general, and section 3 the Bose-Einstein condensation of spin-oriented atomic hydrogen. Section 4 describes how part of the cosmic fabric might have condensed into a Bose-Einstein condensate (BEC), and Section 5 provides a brief review of Bose-Einstein condensation and cosmology.

2. Bose-Einstein Condensation

Any Big Bang theory requires a starting point of unusually high density: high energy density in SBB, or high matter density in ZKBB. If one tentatively accepts the premise of the ZKBB theory, a Big Bang preceded initially by a state of extremely low matter density, then the question becomes how does one get from that low density to a density high enough for a Big Bang to take place? How and why did diffuse atomic hydrogen at zero kelvin transition into the “primeval atom”, the entity proposed by Georges Lemaître as precursor to the universe? Here again we encounter the almost uncanny serendipity of Einstein’s insights, and their close relationship to modern cosmology.

It was about seventy years ago that a then-obscure Indian physicist, Satyendra Nath Bose, sent a manuscript and letter to Albert Einstein asking him to translate Bose’s paper into German, and help him to get it published in a leading German physics journal

(Bose, 1924). As mentioned previously (Paper I), the manuscript concerned Bose statistics and the behavior of bosons. The paper predicted that at a low enough energy, photons of light (which are bosons) would all enter the same energy state and act as one. Einstein did as he was requested but also added to the idea, suggesting that particles of matter might do the same thing if they were also bosons. There the matter stood for decades, a theoretical scientific oddity, since no one believed that a sufficiently low temperature could ever be achieved at which one might be able to test this hypothesis. As with many of Einstein's seemingly bizarre predictions, it was eventually tested and found to be correct. However, it was not until 1995 that two groups of physicists, led by Cornell, Wieman, and Ketterle were able to demonstrate this feat, creation of the first man-made Bose-Einstein condensates (Anderson et al. 1995; Davis et al. 1995). A brief review of Bose-Einstein condensation follows.

One can think of a BEC as the fifth state of matter. In addition to the three most common states (gas, liquid and solid), there are, at the two extremes of temperature, two additional states. At a high enough temperature, electrons are stripped completely from atomic nuclei, resulting in a mixture of atomic nuclei and free electrons called plasma. The importance of plasma and its effects in the universe were heavily promoted by Nobel laureate Hannes Alfven (1983, 1990). The cause of "The Plasma Universe" has also been championed by Anthony Peratt (1992) and Eric Lerner (1991).

At extremely low temperature, one enters the realm of the BEC. One usually thinks of only things like light and electricity as having a wave-like property, but particles of matter do also. This property of matter-waves was predicted in 1924 by Louis de Broglie, the first scientist to receive a Nobel Prize (Physics, 1929) for a Ph.D thesis.

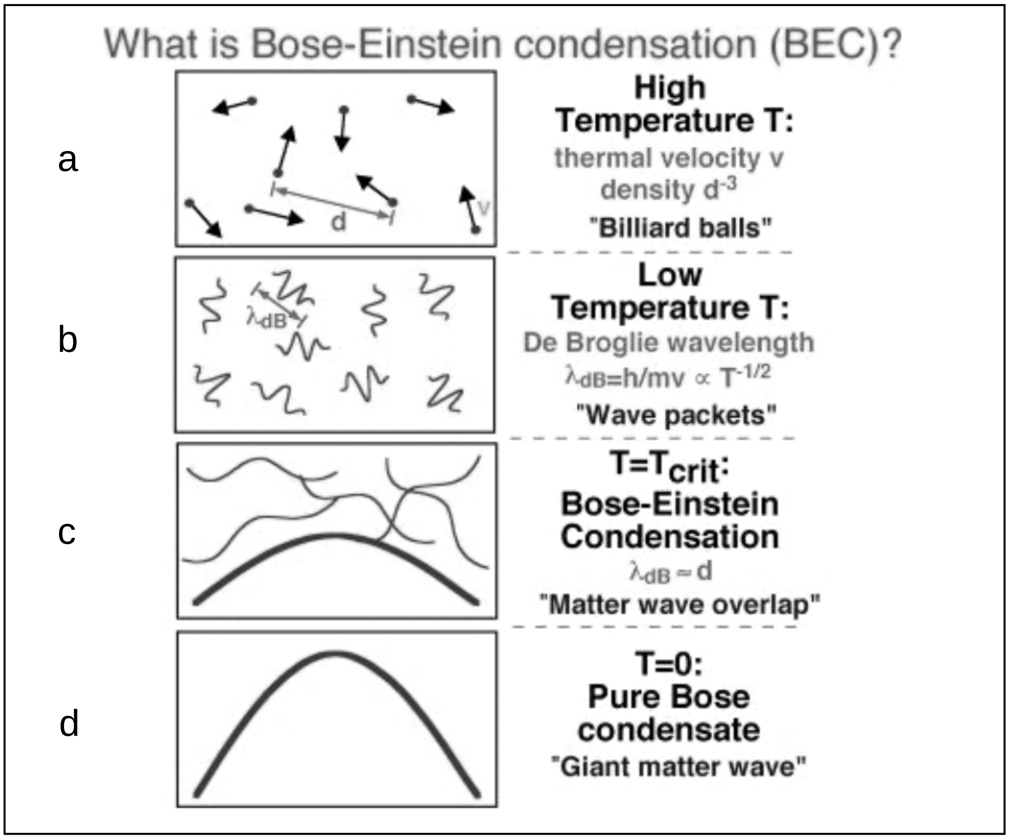

Figure 1: What is Bose-Einstein condensation (BEC)? *Reprinted by permission.*
http://cua.mit.edu/ketterle_group/intro/what%20is%20BEC_150.jpg

As shown in Fig. 1, particles of matter have a certain wavelength, but at normal temperatures that wavelength is extremely small (Figure 1a), so much so that they appear as point particles. As temperature decreases and the energy of the particles decreases, their wavelengths increase (Figure 1b). As the temperature approaches zero kelvin, the wavelengths of individual particles approach the inter-particle distance, and they begin to overlap (Figure 1c). Finally, below the critical temperature, the waves overlap completely (Figure 1d). In this state the particles lose their individual identity, all occupying the same phase space, and they act as if they were a single particle, with a single, very large matter wave; they become a Bose-Einstein condensate (BEC). One can now perhaps imagine how almost the entire mass of the universe, as spin-oriented hydrogen, could realistically be compressed into a super-dense entity, an actual, physical primeval atom.

3. Bose-Einstein Condensate of Atomic Hydrogen

In 1998, after a twenty year quest, a group headed by Thomas J. Greytak and Daniel Kleppner reported success in forming a BEC of atomic hydrogen, (Fried et al. 1998; Fried, 1999). Although, according to theory, hydrogen should have been one of the easiest atoms to condense because of its low mass, in practice it turned out to be one of the most difficult. The reason for the problem was the spin of hydrogen's electron, as described earlier in Paper I. Hydrogen atoms with opposite electron spins react very rapidly, forming molecular hydrogen and releasing energy. This energy causes other hydrogen electrons to "spin-flip", thereby accelerating the process, almost like a chain reaction. This phenomenon made it almost impossible to maintain the extremely low temperatures necessary to facilitate condensation.

Due to technical difficulties, these physicists were only able to form a BEC with the doubly polarized "d" (up-up) form of atomic hydrogen (see Figure 3, Paper I), but it was a BEC of atomic hydrogen nonetheless. If the ZKBB theory is correct, a cosmic fabric consisting exclusively of atomic hydrogen "a" at its lowest energy state (proton and electron spins anti-parallel) and mutually repulsive, could only have existed prior to the Big Bang, at zero kelvin when there was zero kinetic and thermal energy. The electron spin-flip of atomic hydrogen requires only 5.9×10^{-6} eV of energy (the equivalent of 0.07 degrees K), but at zero kelvin even this miniscule amount of energy is lacking. Based on Greytack and Kleppner's work it may be technically impossible to replicate conditions prior to the Big Bang in our energetic universe, because zero kelvin is theoretically unattainable, and one would always have to start with atomic hydrogen with a mixture of spin states.

4. Cosmic Fabric to BEC

If a BEC forming somewhere within the cosmic fabric is theoretically possible, how might it have happened? One possibility is a quantum event or fluctuation, as claimed for the appearance of the entire universe in SBB theory. With this low of a density and with zero energy (even zero point energy may be questionable [Jaffe 2006]), the chance of two atoms even encountering each other is essentially zero; it could never happen. However, one must remember that in quantum theory there is never a “never”, especially during eternity. The fact that there is, as far as we know, only a single universe, might attest to the incredibly low probability of whatever events happened prior to the Big Bang.

Figure 2 shows a representation of the original cosmic fabric, with hydrogen atoms at equilibrium and distributed uniformly throughout space. If the wavelengths of two hydrogen atoms did manage to overlap, this could have created an infinitesimally small gravitational dimple in space, towards which other hydrogen atoms might move.

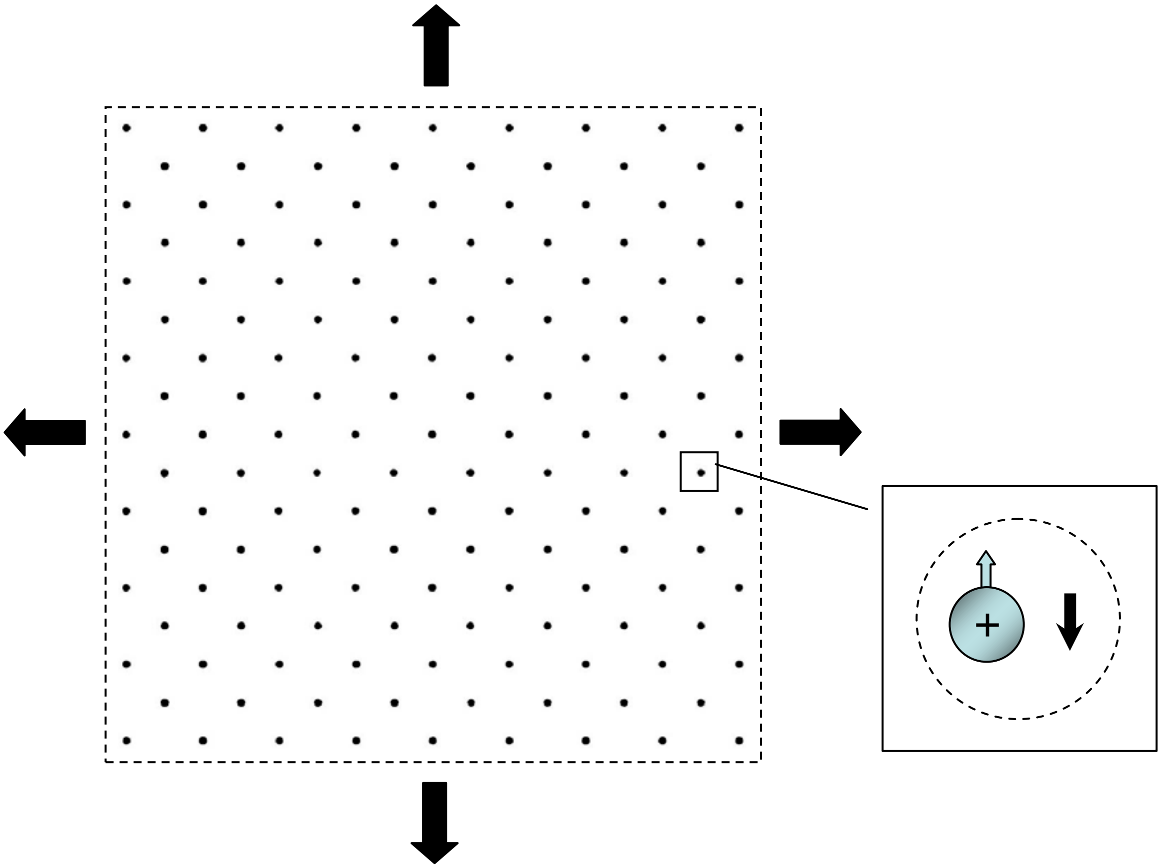

Figure 2: The Cosmic Fabric. An infinite (indicated by arrows) and (almost) eternally stable matrix of singlet state hydrogen atoms at the lowest possible energy state (proton and electron anti-parallel, shown in box to the right), mutually repulsive, and at equilibrium at zero kelvin. Black dots represent “a” state atomic hydrogen (see box to the right of diagram, details in Paper I of this series). Hydrogen atoms are at a density of, at most, a few atoms per cubic meter of space. This cosmic fabric is proposed as the pre-existing state of the cosmos before the Big Bang.

So it is like a snowball effect, with the BEC growing larger and faster, if time did in fact exist. In this scenario, the growing BEC would suck in hydrogen atoms from farther and farther out in an expanding spherical volume of the original cosmic fabric. Concomitantly, this larger volume of cosmic fabric would become depleted of hydrogen atoms creating, in effect, a “matter-depletion” zone around the growing BEC. This process is represented in Fig. 3.

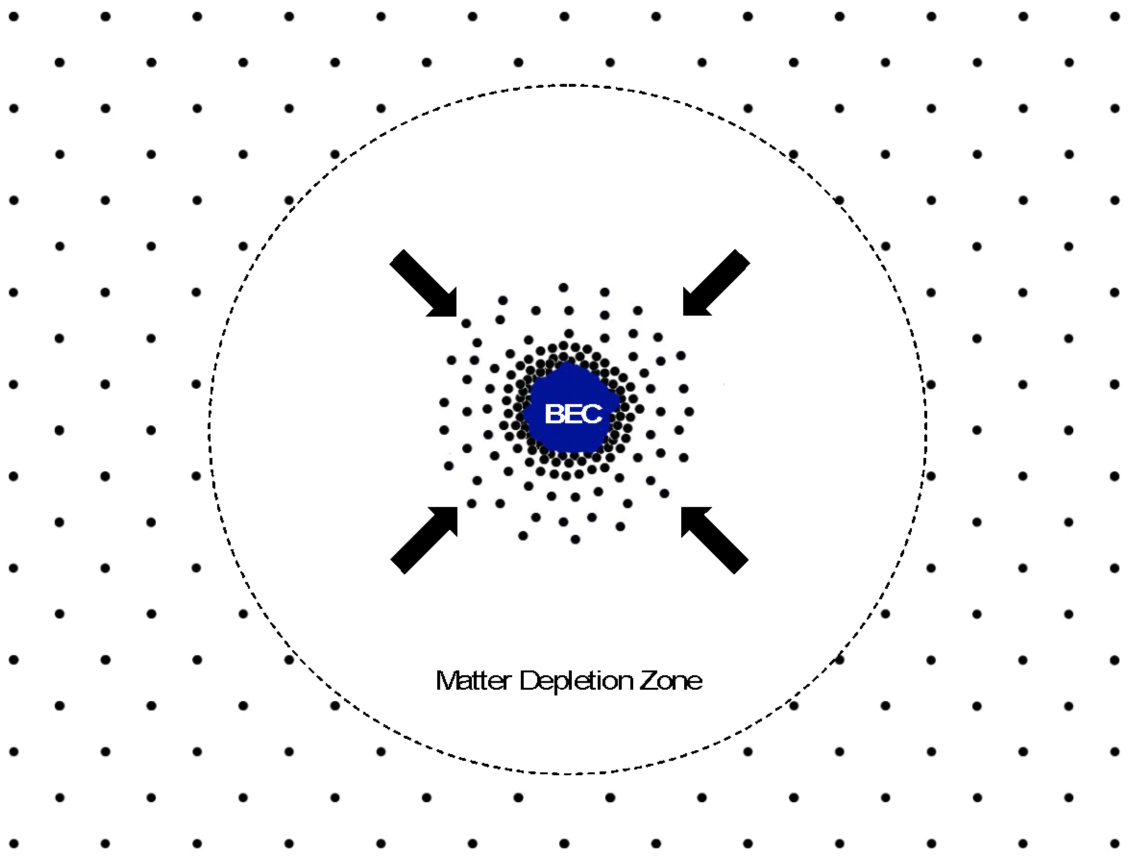

Figure 3. Bose-Einstein Condensation of Singlet State Atomic Hydrogen into a Primeval Atom. If the wavelengths of two atoms managed to overlap, a gravitational dimple could form at a single point in the cosmic fabric, and initiate formation of a Bose-Einstein condensate (BEC – shown in blue). As BEC formation is a self-reinforcing process, hydrogen atoms from the surrounding cosmic fabric would be drawn towards and into the BEC (indicated by arrows), creating a spherical matter-depletion zone between the primeval atom and the surrounding cosmic fabric.

Three questions might arise here:

Q. If the hydrogen atoms were mutually repulsive, how or why would they aggregate?

> **A.** Laboratory studies of BECs have shown that even atoms which are mutually repulsive can, and will, form BECs. In fact, it is only mutually repulsive atoms which are able to form large, stable BECs.

Q. An even more serious question is: if the system was already at zero entropy, as claimed, would not the formation of a BEC (a phase change) imply a decrease in entropy, and perhaps negative entropy?

A. The key here is that, theoretically, any reaction at zero kelvin involves no change in entropy, because any reaction at zero K is completely reversible. So, even though it seems like entropy should decrease, it does not.

Q. A third question might be: why didn't the pressure of the concentrated atomic hydrogen gas cause it to re-expand?

A. At zero kelvin a gas has zero pressure, so concentrating a gas with zero pressure results in concentrated gas, still with zero pressure; there would be no impetus for the growing primeval atom to re-expand, that is until energy was released in the Big Bang event.

5. Bose-Einstein Condensation in Cosmology

Starting even before BECs were physically demonstrated by the groups of Cornell and Weiman (Anderson et al. 1995) and Ketterle (Davis et al. 1995), numerous cosmologists have proposed links between BECs and cosmology. BECs are attractive in this regard because of their quantum nature and unusual properties such as high density, super-fluidity, super-conductivity, and the formation of vortices when subjected to rotation. The following is a far from complete list of papers exploring this connection, but are included to demonstrate that the idea of BECs and cosmology is far from uncommon: Sin (1994), Ji and Sin (1994), Goodman (2000), Hu et al. (2000), Ferrer and Griffols (2005), Guzman and Urena-Lopez (2006), Fukuyama et al. (2007), Fukuyama and Morikawa (2009), Lundgren et al. (2010), Izquierdo and Besprosvany (2010), Chavanis (2010), Rindler-Daller and Shapiro (2011), Chavanis (2011), Harko (2011) and Chavanis and Harko (2011). I apologize for omission of many other excellent papers on this topic.

Essentially, all of these papers involved primarily mathematical analyses of two specific areas of cosmology, dark matter and structure formation. As such, they involved hypothetical solutions to various aspects of these two anomalies that are presented by the Λ-CDM paradigm. Perhaps due to the assumptions inherent in this paradigm, the hypothetical BEC particles are of such low mass that they are unrealistic from a physical standpoint, impossible to detect observationally, or both. Utilizing the assumptions of the ZKBB paradigm, it is hoped that a similarly rigorous mathematical treatment will lead to validation of this theory.

In the ZKBB model, we consider BECs to be an integral component of cosmology, from a pre-Big Bang beginning, through structure formation, to the present state of our universe. The ZKBB model involves matter that is known to exist, atomic hydrogen, undergoing Bose-Einstein condensation, which has been shown to occur. Further, it envisions an already-observed "bosenova" event, leading to nuclear fusion and an inflationary, explosive Big Bang. After the Big Bang, the BEC fragments, with their somewhat unique properties, provide attractive starting points for structure formation in an expanding universe.

In the third paper of this series, we will consider an implosion-explosion process by which the BEC primeval atom could explode and disintegrate in a truly Big Bang.

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