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A Quantum Space Model of Cosmic Evolution: Dark Energy and the Cyclic Universe

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Abstract

We present a Quantum Space Model (QSM) of cosmic evolution based on the theory that space consists of energy quanta from which our universe came about. We used the Friedmann equations to trace its history and predict its ultimate fate. Results provide further support to our recent proposal that the accelerating expansion of the universe is due to a scalar space field which has become known as Dark Energy. In our model, the universe started from high energy space quanta which were triggered by quantum fluctuations that caused the Big Bang. It then expanded and cooled undergoing phase transitions to radiation, fundamental particles, and matter. Matter agglomerated and grew into stars, galaxies, etc. and was eventually consolidated by gravity into Black Holes, which finally ended in a Big Crunch in a state of deep freeze inside the Black hole at 1.380 trillion years. Fluctuations, quantum tunneling, or some other mechanisms caused a new Bang to start another cycle in its life. Our results are in good agreement with the theoretical predictions of a cyclic universe by Steinhardt and his associates, and by Penrose. Space and energy are equivalent as embodied in the Planck energy equation. They give rise to the two principal long range forces in the universe: the gravitational force and the space force. The latter may be the fifth force in the universe. The two forces could provide the clockwork mechanism operating our cyclic universe. If the Law of Conservation of Energy is universal, then the cosmos is eternal.

Keywords

Quantum Space Model, Spaceons, Dark Energy, Gravitational Waves, Cosmic Evolution, Expansion of the Universe, Black Holes, Big Bang, Big Crunch, Cyclic Universe

1. Introduction

The evolution of the universe is of great interest in astronomy, astrophysics, cosmology and science in general. It also has important implications in philosophy and religion. Theories abound on how the universe started and evolved. Creationists begin with the biblical statement "Let there be light…", while nonbelievers and some others say that "The universe started from nothing… [1] [2]". Science has made great progress in answering the question of where the universe came from through the widely accepted Big Bang theory of Cosmology. However, many observations remain mysterious and unexplained; there is need for improvement in theories, better models, and more experimental work. This work attempts to do that.

In a recent paper [3], we presented a model that could help understand our universe better. We postulated that space consists of energy quanta. Using a themodyanamic approach, we showed how gravitational energy and the energy of space could give rise to dark energy which causes the accelerating expansion of the universe. We follow up on this approach to predict the future and the ultimate fate of the universe.

2. The Quantum Space Model (QSM)

Space consists of energy quanta which we call spaceons. It is a dynamical entity which actively participates in the creation and evolution of the universe rather than acting merely as a static background in which events are portrayed. The universe started as a quantum size volume of space of nearly infinite energy density. The wavelength of spaceons, λ, defines the size of space with its volume,

$$V = (4/3)\pi\left(\frac{\lambda}{2}\right)^3 \tag{1}$$

Its energy content is defined by the Planck equation, $E = hc/\lambda$, hence, E is inversely proportional to $V^{1/3}$, *i.e.*, the smaller the volume (shorter wavelength, λ), the higher the energy.

From wave-particle duality, spaceons can be regarded as an ideal gas. From its initial state of a near-singular volume with near-infinite energy content, quantum fluctuations caused the release of energy in what we call the Big Bang, at high temperature and pressure. This tiny "ball of hot spaceons" expanded and cooled undergoing phase transitions forming ultra-high energy radiation and neutrinos, as well as, matter (dark and ordinary or baryonic). The expansion rate slowed down due to the action of gravity. It then re-accelerated at about 7.5×10^9 years due to dark energy [3]. We theorized earlier [3] that the re-aceceleration in expansion was due to the decrease in gravitational potential energy as matter was consolidated by agglomeration to form stars, galaxies and clusters. This energy was transformed into the energy of space which was dubbed "dark energy". Further consolidation by Black Holes resulted in a Big Crunch which brought back the universe to its beginning of a small point volume of space, *i.e.*, essentially a quantum dot.

3. Results and Discussions

1) The Universe from the Beginning to the present

Details of the calculational procedures appear in ref. 3. Briefly, we used the Friedmann equations to provide information on the evolution of the universe by constructing a plot of its composition as a function of time [3]. We used experimental data provided by the measurements of the Wilkinson Microwave Platform (WMAP) given previously. We plotted the fractional amount of radiation (high energy radiation plus neutrinos) and matter, "*f*", as a function of the scale factor "*a*". This was calculated using the Friedman equation,

$$H^2 = \left(\mathrm{d}a/\mathrm{d}t\right)^2 a^2 = \left(H_0\right)^2 \left[\Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_s a^{-3(1+w_s)}\right] \quad (2)$$

where H is the Hubble constant, a the scale factor, omega, Ω, the fractional energy density of each component, *i.e.*, matter (with $\Omega_m a^{-3}$), radiation (with $\Omega_r a^{-4}$), and space (with $\Omega a^{-3(1+w_s)}$) where w_s is the equation of state parameter [4]. This has been explained in ref. [3] and appears in most books in Cosmology (see for example, ref. [4]).

Figure 1 gives the results of our calculations, which shows the evolution of the universe from the Big Bang (BB) up to the present time (13.8 billion years). In the figure, we have classified photons (radiation) and neutrinos as waves, which travel at the velocity of light, *c*. The other class is particulate matter which consists of dark matter and ordinary (baryonic) matter. In the beginning of the hot universe (the Big Bang), there were only spaceons, radiation and neutrinos (point I, BB, in **Figure 1**). This tiny ball of fire expanded and cooled. In the process of condensation, the elements of matter started to form (point II). We will refer to the forerunner of matter as gravitons, which has long been postulated by physicists to carry the force of gravity. They gave rise to the fundamental particles of matter, *i.e.*, quarks, leptons, etc. associated with gravity. There was no matter at the Big Bang. Fundamental particles were created 0.01 sec ($a = 10^{-10}$) later [5], point II. **Figure 1** indicates that Dark and Ordinary matter did not exist before 1.4×10^{-2} year ($a = 10^{-6}$). Our observation of matter for the first time came from the Wilkinson Microwave Auxiliary Platform measurements (WMAP) at 3.8×10^5 years ($a = 0.01$) at III, when electrons recombined

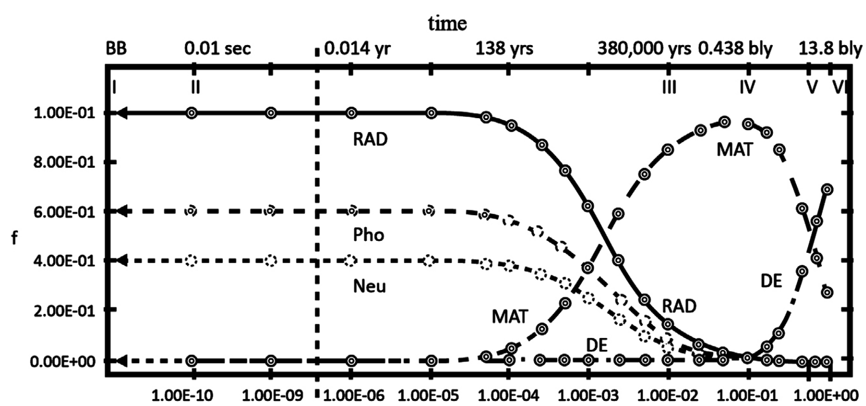

Figure 1. Fractional composition of the universe (f) vs scale factor (a) bly-billion light years; RAD-radiation; Pho-photons; Neu-neutrinos; MAT-matter; DE-dark energy, with equation of state parameter, $w_s = -0.7$.

with protons to form atomic hydrogen and released light. Thus the Big Bang was not an explosion of matter and radiation "all over the place" as commonly expressed; it was just a silent burst of spaceons and, high energy radiation. The amount of matter increased with time as the force of gravity consolidated it by agglomeration to form massive objects, stars, etc.. They continue to grow in mass, and eventually collapse to form Black Holes. The energy density of matter reached a maximum at about 4.36×10^8 yrs ($a = 0.1$) at point IV, **Figure 1**. The fractional energy density of spaceeons and radiation decreased correspondingly, reaching a minimum (nearly negligible) at point IV. This is the onset at which time the so-called Dark Energy appeared. The total energy density of matter started decreasing until the present time (point VI), at 13.8×10^9 years (a = 1). Dark Energy continued increasing, which correlated with the re-acceleration of the expansion of the universe that we observed [3], starting at about 7.5×10^9 years ($a = 0.65$), at point V, when the fractional density of total matter equaled that of dark energy. In effect, the gravitational energy decrease has been converted into the energy of the space field. This is the Dark Energy which is causing the reacceleration in expansion of the universe. It is the energy of space (the spaceons), just given the name "Dark Energy" because it was an unknown form of energy. A simple analogy to this mechanism is to imagine a quiet lake on a nice day. The ripples on the surface are small. When a motorboat passes by from a distance, the surface is disturbed and bigger waves are generated reinforcing the ripples which travel at higher velocity toward the shore. Gravitational waves are distortions in space [6]; they are generated, propagated and have been observed when two massive objects like neutron stars and Black Holes merge. The energy reinforces the energy of space which results in the acceleration of the expansion of the universe. Dark Energy is also Einstein's cosmological constant.

2) The Future and Ultimate Fate of the Universe

We use the Friedmann equation further to obtain information on the future of the universe beyond 13.8×10^9 years ($a = 1$). **Figure 2**, shows a plot of a vs the fractional energy density of particulate matter and Dark Energy (Spaceons) as a

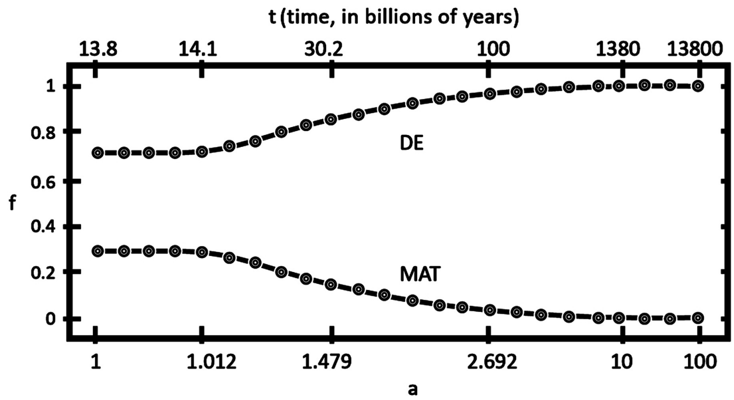

Figure 2. Fractional composition of the Universe in the future; a-scale factor; f-fractional energy density; MAT (Total Matter); DE (Dark Energy; with $w_s = -0.7$).

function of time (scale parameter, a) for the future; it is an extension of the curves of **Figure 1**, for $a > 1$. The DE curve rises very slowly but continuously then levels upon reaching a maximum. Likewise the energy density of matter decreases towards a minimum. The leveling occurs at about $a = 10$, equivalent to 1.380×10^{12} years. At this point, all the matter in the universe has been consolidated and converted to Dark Energy by Black Holes. This is the energy of space (spaceons). Recall that this was actually the initial state of the universe before the Big Bang. But now all the energy of matter and space are inside a Black Hole! During the process of consolidation, Black Holes gobbled up everything in the universe, including space (in a waterfall effect), and converted them into Dark Energy (spaceons). It is interesting to think of or speculate on the state of spaceons inside inside a Black Hole. Some information can be gained from the theoretical works of Hawking (7) and Chapline (8, 9). The theory of Hawking Radiation [7] allows one to calculate the temperature inside a Black Hole to be nearly absolute 0 K (about 1×10^{-14} K), for a supermassive black hole with a mass of about a million times that of the sun. Chapline's theory showed that the contents of Black Holes are Bose-Einstein condensates [8] [9]. This state of the universe inside the Black Hole can be called the "Big Crunch". But being at extremely low temperature it may also be called a "Big Freeze". We prefer to use the term "Big Crunch". The universe will remain in this state; but it is probable that this state of Big Crunch will not last forever. Fluctuations, quantum tunneling, or some other mechanism will likely occur, since they are random statistical processes. A new Big Bang is then quite likely which would lead to a new cycle in the life of the universe. As Krauss [1] said "… the state of nothing is unstable" and if there is nothing then there will be something though not visible to us, observers.

Our model thus shows that our universe can undergo at least one cycle in its evolution. Moreover, if the universe is closed where the law of conservation of energy is obeyed, then our universe can be eternal. It is important to point out that the theoretical work of Steinhardt and his co-workers first predicted the possibility of a cyclic and eternal universe without using a particular physical model and without invoking the need of a theory of Inflation [10] [11] [12]. Their calculated life of over 1 trillion years for one cycle is in agreement with our result of 1.4 trillion years. Penrose has also proposed a cyclic universe, which was met with much skeptism [13]. Our QSM is a good physical model for their theories. This agreement between theory and the results presented here is quite satisfying.

Another possibility for the fate of the university is that predicted by Rovelli's theory of Planck Stars [14] [15], *i.e.*, that a "bounce" is more likely rather than a crunch. Using a quantum gravity approach, he showed that there is no singularity in a Black Hole because the universe undergoes a bounce due to quantum pressure counteracting the force of gravity and the volume does not shrink beyond a certain size. The universe could therefore undergo a bounce, explode and eventually turn into a White Hole. However the time of conversion will take about a thousand trillion times the current age of the universe [16]. White Holes have not been confirmed to exist. Rovelli and associates continue to improve their theory but at this time it does not appear viable [17].

3) The Consolidation of Matter and Space in Black Holes

We say a bit more on the conversion of matter back into space/dark energy. The universe evolved from fundamental particles to form atomic hydrogen which then formed stars by fusion. The stars formed galaxies, which then agglomerated to form clusters, then superclusters emerged. These massive bodies continue to grow in seize and mass. Eventually they (stars for example) collapse to form Black Holes. The force of gravity inside a Black Hole transform matter into space (spaceons) which is in effect Dark Energy, as they have become "baptized". In our model, Black Holes swallowed and devoured matter along with space (like a waterfall), until a near-singular volume of space is reached. Transformations occurred inside the Black Holes. The problem of singularity is avoided in our model. It cannot be present because space is almost infinitely compressible with increasing energy content. There will always be space if there is energy. Mathematics cannot theoretically describe the singularity in the structure of a Black Hole. But physically, one can imagine that matter in a Black Hole is compressed until they are broken down into fundamental particles and eventually transformed back into space/dark energy. Such transformation is already observed the formation of neutron stars which stop at neutrons as the final state (they also go through a superfluid state [15]). The forces in Back Holes are stronger such that the process of breakdown of particulate matter can go further all the way to spaceons/dark energy. This interconvertibility is embodied in Eistein's energy equation, $E = mc^2$ and Planck's equation, $E = (hc/\lambda) = hc/2)(4\pi/3V)^3$ from which follows,

$$m = (h/2c)(4\pi/3V)^3 \tag{3}$$

It shows the equivalence of matter and space. This equation provides the basis of our Quantum Space Model.

4) Epochs in the Evolution of the Universe

There are many versions of the history and chronology of the universe starting with the Big Bang. Ours started before the Big Bang. We will not go in as much detail as Silk [18], but briefly as befits our simple model. We divide its stage of evolution roughly into the following stages. Birth (Spaceons, Big Bang), Growth (matter formation, stars). Ageing and Consolidation (galaxies, clusters, Planck Stars, Black Holes), and the End (Big Crunch, Spaceons/Dark Energy, quantum dot). The chronology is shown in **Table 1** and illustrated in **Figure 3**. The universe started with quanta of space and ended in dark energy inside a Black Hole. From then on the universe undergoes cycles of "death" and "resurrection"/rebirth to exist possibly for eternity.

The evolution of the cosmos in accordance with our Quantum Space model is shown in **Figure 3** below.

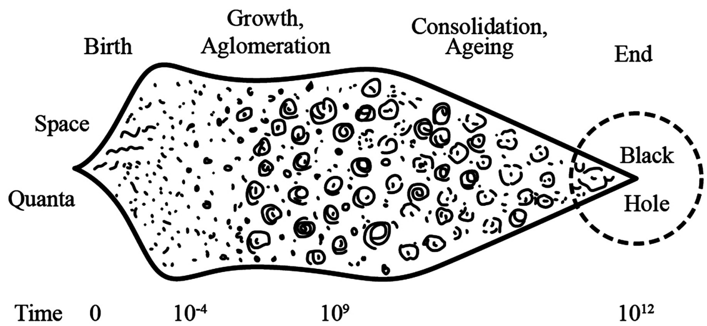

Figure 3. Epochs in the evolution of the quantum universe.

Table 1. Chronology of cosmic evolution.

Epoch	Time (t)	Contents
Birth	$<10^{-12}$ sec $<10^{-4}$ yr	Space quanta, radiation, fundamental particles, matter
Growth and aggregation	$<10^{-4}$ to 138 yrs	matter formed nebulae, stars, planets,
Ageing and Consolidation	$>10^{7}$ to 10^{9} yrs	agglomeration to galaxies, clusters, Black Hole formation
The End	10^{9} to $>10^{12}$ yrs	Stars died, Black Holes, Big Crunch

4. Summary and Conclusion

We have presented a model which explains how dark energy emanates from the energy of space and provides the repulsive force to accelerate the expansion of the universe; it is in effect Einstein's cosmological constant. The model is based on a dynamical theory that space consists of energy quanta, and uses the Friedmann equations to describe the evolution of the universe from its beginning before the Big Bang until its ultimate end in a Big Crunch and Deep Freeze. The universe started from a near-singular volume of space with high energy density given by the Planck energy equation. It then expanded and cooled undergoing phase transitions to radiation, fundamental particles, and matter. The amount of matter grew, and was consolidated by gravity into stars, galaxies, clusters, and superclusters. Further consolidation by Black Holes continued ending in a Big Crunch at about 1.4 trillion years which brought the universe back to its initial state and started a new cycle in its life. If the Law of Conservation of Energy is universal, then the universe is eternal. In our model, energy and space are equivalent as, expressed by Planck's equation, similar to the equivalence of matter and energy as expressed in Einstein's energy equation. The two most fundamental quantities in the universe appear to be space and energy. The two principal long range forces are the gravitational force (compression) and the space force (expansion); the latter may be the fifth force in the universe. It is carried by bosonic spaceons while the gravitational force may be carried by an as yet undiscovered graviton. The two could constitute the clockwork mechanism that operates our cyclic and eternal Quantum Universe. The Quantum Space Model (QSM) provides a good physical model which is well supported by the theoretical work of Steinhardt and Penrose that predict an eternal phoenix universe. It provides an explanation of the creation, evolution, and ultimate fate of the universe, which is rational without arbitrary assumptions and consistent with prevailing theories. It may have further applications in the development of a theory of Quantum Gravity.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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