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Article

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 the evolution of the universe based on the theory that space consists of energy quanta from which it began. We used the Friedmann equations to trace its history and show that Dark Energy is the energy of space which caused its accelerating expansion.The universe started from a quanta of space which was triggered by quantum fluctuations that caused the Big Bang. It then expanded and cooled undergoing phase transitions to radiation, fundamental particles, and matter. Matter grew into galaxies, and was consolidated by gravity into Black Holes, ending in a Big Crunch and Deep Freeze inside a Black hole at 1.380 trillion years. Fluctuations caused a new Bang to start another cycle in its life. If the Law of Conservation of Energy is universal, then the cosmos is eternal. Our results support the theoretical predictions of a cyclic universe by Steinhardt and associates, as well as Penrose. Space and energy are equivalent as embodied in the Planck energy equation. They are the two most fundamental quantities that govern cosmic evolution. The two principal long range forces are the gravitational force and the space force,which maybe the fifth force in the universe. They provide the clockwork mechanism operating our cyclic universe.

Keywords: early universe; dark energy; theory; observations

1. Introduction

The evolution of the universe is of great interest in astronomy, astrophysics, cosmology and science in general. It has important implications in philosophy and religion, i.e., the creation and ultimate destiny of the universe. Theories abound on how the universe started and evolved. Creationists began with the biblical statement "…let there be light…"; non-believers and some others say that…."the universe started from nothing…" as suggested (Krauss & Starkman 2000;Krauss 2012).Science has made great progress in answering the question of where the universe came from, through its discovery of the Big Bang. However, many observations remain mysterious and unexplained; they need theories, models, and more experimental work in order to clarify. This work attempts to do that.

In a recent paper we presented a model (Melendres 2021) that could help understand cosmic evolution. 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 caused its accelerated expansion. We follow up here on this approach to predict also the future and the ultimate fate of the universe.

2. The Quantum Space Model

Space consists of energy quanta which we called 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,

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

Its energy content is defined by the Planck equation, $E=hc/\lambda$, hence, E is inversely proportional to $V^{1/3}$.

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 at very high temperature and pressure in what was called the "Big Bang". 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 (Melendres 2021). We theorized earlier that dark energy and the re-aceceleration in expansion are due to the decrease in gravitational potential energy as matter consolidated by agglomeration to form stars, galaxies and clusters. This energy was transformed into the energy of space which became known as"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

A. The Universe from the Beginning to The Present

We used the Friedmann equations to obtain information on the evolution of the universe by constructing a plot of its composition as a function of time. We used experimental data provided by the measurements of the Wilkinson Microwave Platform (WMAP) given previously (Melendres 2021). 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,

$$H^2=(da/dt)^2a^2=(H_0)^2[\Omega_m a^{-3}+\Omega_r a^{-4}+\Omega_s a^{-3(1+w_s)}] \quad (2)$$

where H is the Hubble constant, a the scale factor, omega the fractional energy density of each component, matter, radiation and space, and w_s the equation of state parameter.

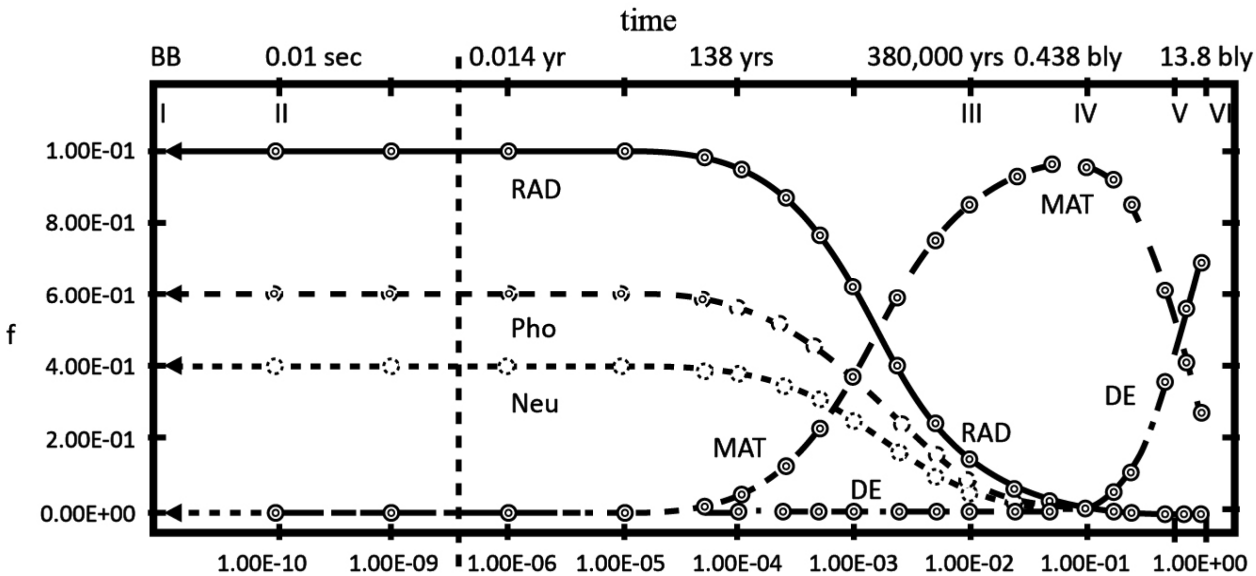

Figure 1. Fractional Composition of the Universe (f) vs Scale Factor (a). Bly-billion light years

Figure 1 shows the evolution of the universe from the Big Bang (BB) up to the present time. 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 (at the Big Bang), there were only spaceons, radiation and neutrinos (point I, BB, in Fig.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 as the force carrier for gravity. Our model purports that they gave rise to the fundamental particles of matter, i.e., quarks, leptons, etc. associated with the gravitational force.There was no matter at the Big Bang. Fundamental particles were created 0.01 sec ($a=10^{-10}$) later (Weinberg 1977), point II. Fig 1. indicates that Dark and Ordinary matter did not exist before 1.4 x 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 x 10^5 years (a=0.01) at III, when electrons recombined 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 may just have been 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 and through Black Holes. It reached a maximum at about 4.36 x 10^8 yrs (a=0.1) at point IV, Fig 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 x 10^9 years (a=1).Dark Energy continued increasing, which correlated with the re-acceleration of the expansion of the universe that we have observed, starting at about 7.5 x 10^9 years (a=0. 65), at point V, when the fractional density of total matter equaled that of dark energy. In effect, the decrease in gravitational energy has been converted into Dark Energy, which is the energy of space that caused the reacceleration in expansion of the universe. Dark energy may then be called the energy of space (spaceons), but 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 which travel at higher velocity toward the shore. Gravitational waves are distortions in space (Piccioni 2017), which are generated and propagated 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 in effect Einstein's cosmological constant.

B.The Future and Ultimate Fate of the Cosmos

We use the Friedmann equation further to obtain information on the future of the universe, beyond 13.8 x 10^9years (a=1). The result is shown in Fig.2, as a plot of a vs the fractional energy density of matter and radiation (spaceon). There is an initial flat portion of the curve before rising up continuously then leveling upon reaching the maximum energy density of space and minimum for matter. The latter shows that the state of the universe is back to its point of origin at about 1380 x10^9 years (a=10). The curve levels of at this point. This is when all the matter in the universe has been consolidated and converted back to the energy of space (spaceons, or Dark Energy) inside a Black Hole. Black Holes gobble up everything in the universe, including space, and convert them into Spaceons or Dark Energy at very low temperatures.The theory of Hawking Radiation (Page 1976), allows one to calculate the temperature inside a Black Hole to be nearly absolute 0K (about 1 x 10^{-14} K), for a supermassive black hole with a mass a million times that of the sun. Chapline has shown that the contents of a black hole are Bose-Einstein Condensates (Chapline et al 2003; Chapline 2005). It can remain forever in this state inside the Black Hole, at extremely low temperature in what we may call a "Big Freeze". We may also call this state the "Big Crunch", where all the energy of matter has been transformed back to space in a very small volume. This was the state of the universe we started with before the Big Bang. The universe will remain in this state until triggered once again by fluctuations or some other mechanism, resulting in a new Big Bang and a new cycle in its life. It is probable that this state of deep freeze will not last forever. Fluctuations will likely occur since they are random statistical processes; a new Big Bang is then quite probable. As Krauss said "…the state of nothing is unstable"(Krauss 2000), so we can expect that there will be something, though not visible to us observers.

Thus, our model shows that our universe can undergo 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 (Steinhardt,P.J.,Turok,N.2002;Lehners, J.L.,Steinhardt, P.j.,2009; Ijjas,A.,Steinhardt,P.J.,2022).

Even their calculated life of over 1 trillion years for one cycle is in agreement with our result of 1.38 trillion years. Penrose has also proposed a cyclic universe, which was met with much skeptism (Penrose 2010). Our QSM is a good physical model to complement their theoretical works.

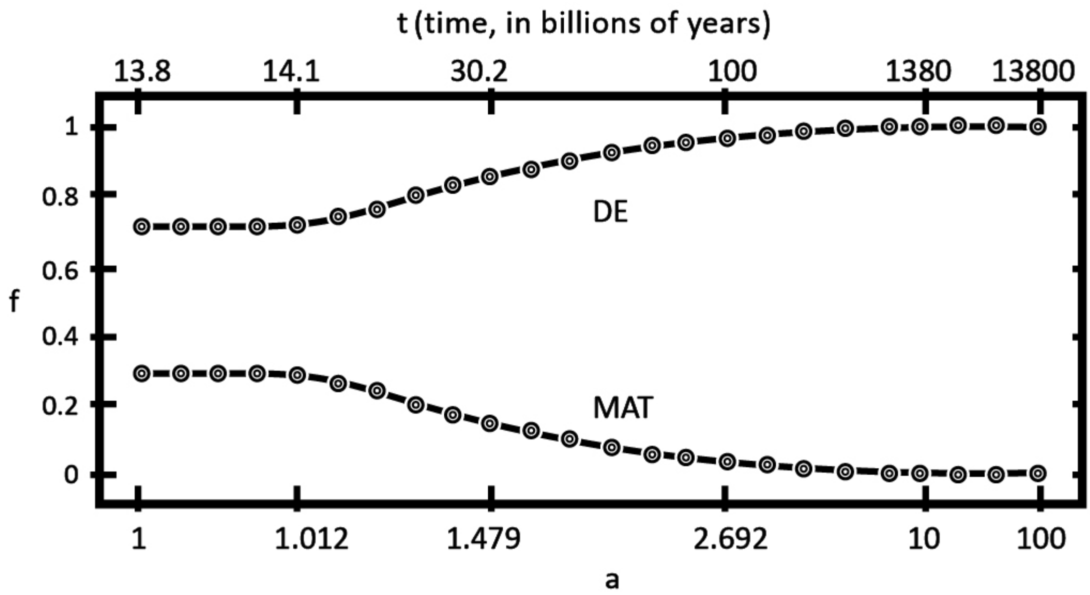

Figure 2. Fractional Composition of the Universe in the Future; a-scale factor; f-fractional energy density; DE-dark energy; MAT (total matter).

Another possibility for the fate of the university is that predicted by Rovelli's theory of Planck Stars (Rovelli 2007; Barrau, Rovelli, Vidotto 2014), i.e., that a "bounce"is more likely rather than a crunch.Using a quantum gravity approach, they 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 may therefore undergo a bounce. This would eventually lead to a state of the universe without thermodynamic free energy and would therefore be unable to sustain processes that increase entropy. This is the "Heat Death" which is widely predicted to be the ultimate fate of the universe. However, this will leave a lot of Black Holes floating around in the universe since their lifetime is longer than the age of the universe. Whether the universe can be eternally in this state is highly questionable and unlikely.

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Our model has no singularity because the size of space is finite, i.e., the wavelength of spaceons (hence the volume) cannot be zero. We postulate that Black Holes continue to grow by merger and gobbling up everything including space through a "waterfall"effect along with matter. It will do so until the pressure it exerts is equal to the counter pressure of space (the space pressure). This is a very unstable situation so that a small perturbation can result in an "explosion", i.e., a Big Bang. Without such a mechanism, Black Holes will last forever with no way to die faster than by emission of Hawking radiation. For a supermassive black, with a mass of 10^{11}times the mass of the sun, it's lifetime would by about 2x 10^{100}years. It is necessary to find other alternative models which will give more reasonable numbers. This is an interesting subject for further theoretical work.

C. The Consolidation of Matter and Space

We say a bit more on the conversion of matter back into space. 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 started to form Black Holes or Dark Energy stars which swallowed and devoured matter and space into a near-singular volume of space through the power of gravity. Here the process of transformation occurred. As mentioned above, there is no singularity 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, matter in a Black Hole is compressed until they are broken down into fundamental particles and space in a similar manner as in neutron stars which stop at neutrons as the final state; they also go through a superfluid state (Barrau, Rovelli, Vidotto 2014). 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 interconvertility is well described by Eistein's energy eequation, $E=mc^2$and Planck's equation, $E=(hc/\lambda)=hc/2)(4\pi/3V)^3$so that,

$$m = (h/2c)(4\pi/3V)^3 \qquad (3)$$

shows the equivalence of matter and space. This equation puts the Quantum Space Model model on a strong theoretical foundation.

D. Epochs in the Evolution of the Universe

There are many versions of the history and chronology of the universe starting with the Big Bang. We will not go in as much detail as Silk (1989) but briefly as befits our simple model. We divide its stage of evolution in the following sequence. Birth (Spaceons, Big Bang), Growth (matter formation,stars). Ageing and Consolidation (galaxies, clusters,Planck Stars, Black Holes), and the End (Big Crunch, Spaceons , quantum dot). The chronology is shown in Table I and the various epochs in a cycle in its life illustrated in Fig 3. The universe started from quanta of space, before the Big Bang, and ended in dark energy inside a Black Hole. From then on the universe can undergo cycles of "resurrection"and rebirth to exist possibly for eternity.

Table 1. Results.

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

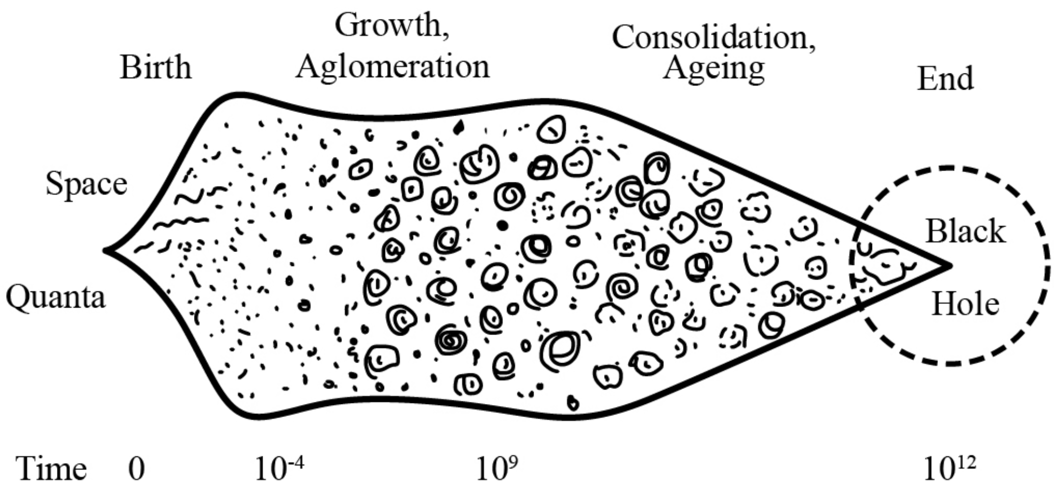

Figure 3. Epochs in the Evolution of the Quantum Universe.

4. Summary and Conclusion

We presented a Quantum Space 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 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 were consolidated by gravity into stars, galaxies, clusters, and superclusters. Further consolidation by Black Holes or Dark Energy Stars 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 maybe the fifth force in the universe. It is carried by bosonic spaceons while the gravitational force maybe carried by an as yet undiscovered graviton. The two could be the clockwork mechanism that

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operates our cyclic eternal Quantum Universe. QSM provides a good physical model which is well supported by the theoretical work of Steinhardt and Penrose that predict an eternal phoenix universe. The model has interesting implications to both Philosophy and Religion. It may have further applications in the development of a theory of Quantum Gravity.

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