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A QUANTUM SPACE MODEL OF COSMIC EVOLUTION:

DARK ENERGY AND THE FATE OF THE 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 which participates in the evolution of the universe. It shows that Dark Energy is the energy of space which causes its accelerating expansion. We used the Friedmann equations to trace the history of the cosmos from a time before the Big Bang to its ultimate end. The universe started from a quantum size volume of space with high energy density.Quantum fluctuations triggered the release of energy in a Big Bang at very high temperature and pressure. It then expanded and cooled undergoing phase transitions to radiation, fundamental particles, and matter. Matter grew into galaxies, and was further consolidated by gravity into Dark Energy Stars/Black Holes, ending in a Big Crunch at about 1.380 trillion years, thus bringing the universe back to its initial state. It can stay in a Deep Feeeze inside a Black Hole and through fluctuations or other mechanism may start a new cycle in its life with a new Bang. If the Law of Conservation of Energy is universal, then the cosmos is eternal. Space and energy are equivalent just as matter and energy are. This is well founded in Planck's energy equation. They are the two most fundamental quantities in the universe that govern cosmic evolution. The two principal long range forces are the gravitational force and the space force.The latter could be the fifth force in the universe. They may provide the clockwork mechanism that operates our eternal cyclic universe.

Keywords: Quantum Space, spaceons, cosmic evolution, Friedmann equation, cyclic eternal universe, gravitational force, space force.

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1.Introduction

The evolution of the universe is of great interest in astronomy, astrophysics, cosmology and science in general. It has implications in philosophy and religion. 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…[1,2]”.Science has made great progress in answering the question of where the universe came, 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 is an attempt 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 [3].Using a themodyanamic approach we showed how gravitational energy and the energy of space gave rise to dark energy which caused its accelerated expansion. We follow up on this approach to predict the future and the ultimate fate of the cosmos.

2 . The Quantum Space Model

Space consists of energy quanta which we called spaceons. It is a dynamical entity which actively partcipates 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,

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

Its energy content is defined by the Planck equation, E=hc/λ, 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 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 radiation, neutrinos and matter (dark and ordinary or baryonic matter). The radiation and neutrinos were of ultra high energy.The expansion rate slowed down due to the action of gravity. It then re-accelerated at about 7.5 x 10^9 years due to dark energy [3]. We theorized earlier [3] 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, a quantum dot.

3. Results and Discussions

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A. The Universe from the Beginning to The Present

We used the Friedmann equations [3] to provide information on the evolution of the universe by constructing a plot of its composition as a function of time. We make use of experimental data provided by the measurements of the Wilkinson Microwave Platform (WMAP) shown previously in ref.3 We have plotted the fractional amount of radiation (high energy radiation plus neutrinos) and matter “f” as a function of the scale factor “a” (a measure of time).This was calculated using the Friedman equation as explained earlier, i.e.,

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

where H is the Hubble constant, a the scale factor, omega the fraction energy density of each component, matter, radiation and space, and w_s the equation of state parameter [3].

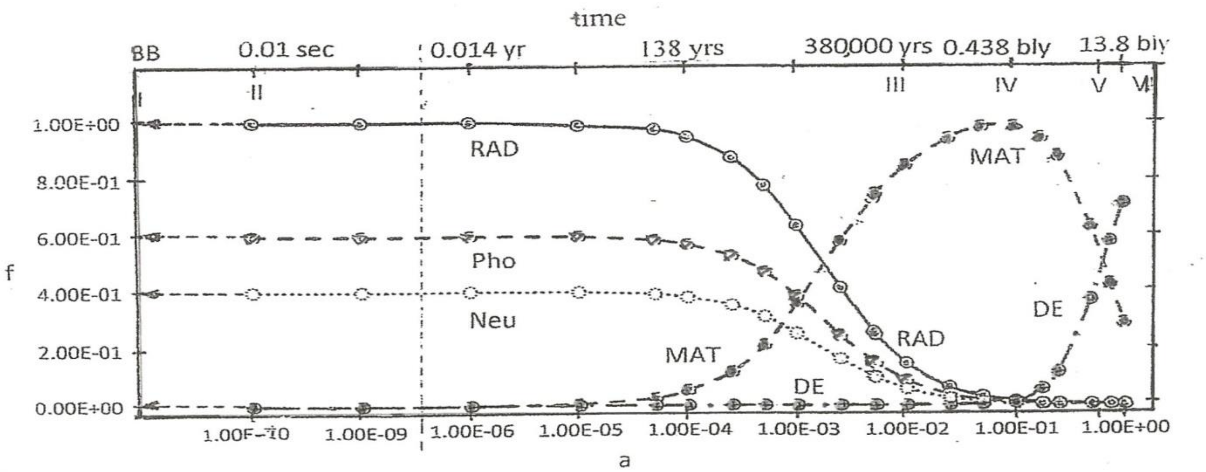

Fig 1- Fractional Composition of the Universe vs Scale Factor (time)

Figure 1 shows the evolution immediately after the Big Bang up to the present. In the figure, we have classified photons (radiation) and neutrinos into the class of radiation (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, 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 gave rise to the fundamental particles, quarks, leptons, etc. There was no matter at the Big Bang. Fundamental particles were created 0.01 sec ($a=10^{-10}$) later [5], 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 measurement (WMAP) at 3.8 x 10^5 years (a=0.01), when electrons recombined with protons to form atomic hydrogen and released light (point III). Thus the Big Bang was not an explosion of matter and radiation “all over the place”; 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

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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 amount of spaceeons and radiation decreased correspondingly, reaching a minimum (nearly negligible, but not zero) at point IV. This is the onset at which time Dark Energy appeared. The total energy density of matter decreased until the present time (point VI), at 13.8 x 10^9 years (a=1).Dark Energy correspondingly increased which correlated with the re-acceleration of the expansion of the universe that we observed [3] starting at about 7.5 x 10^9 years (a=0. 65), at point V, when the fraction of total matter equaled that of dark energy. In effect, the decrease in gravitational energy was converted into Dark Energy which is the energy of space that caused the reacceleration in the expansion of the universe. Dark energy is the energy of space (spaceons), just given another name. 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 [6] 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. It might be the fifth force in the universe, with spaceons as the force carrier.

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 amount of matter. The latter shows that the state of the universe is back to its point of origin at about 1400 x10^9 years (a=10). The curve levels of at this point. It is when all the energy of the universe is consolidated and converted back to the energy of space, as Dark Energy. It can remain forever in this cold, dreary state inside a Black Hole, in what we may call the "Big Freeze". We may also call it the "Big Crunch", where all the energy of matter has been transformed back to space in a very small volume, i.e, a quantum dot. This was the state of the universe we started with before the Big Bang , an energy quantum of space. The universe will remain in this state until triggered once again by fluctuations or quantum tunneling,resulting in a new Big Bang and a new cycle in its life. The theory of Hawking Radiation [7] 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 [8,9]. It is more probable that this state of deep freeze will not last too long. Fluctuations will likely occur since they are random statistical processes; a new Big Bang is then quite probable. As Krauss [1] said "…the state of nothing is unstable" and if there is nothing then there will be something (even if they are not visible to us, observers).

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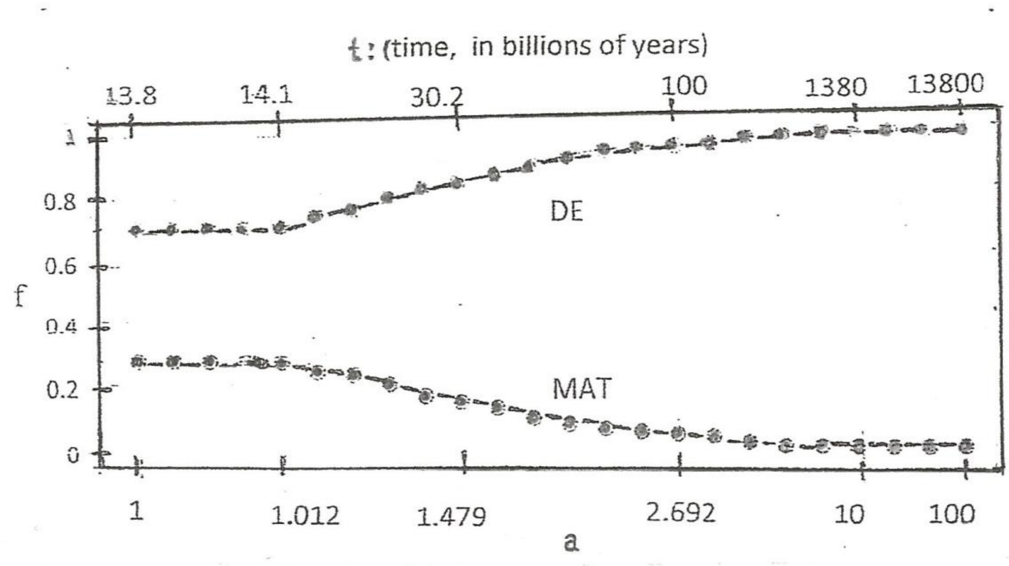

Fig.2- Fractional Composition of the Universe in the Future;
a-scale factor; f-fractional energy density; DE-dark energy; MAT
(total matter)

Another possibility is predicted by Rovelli's theory of Planck Stars [10, 11], 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 may therefor undergo a bounce. This would lead to the "Heat Death" and "Big Feeze"often discussed in the literature. 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. This seems rather unrealistic.

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 can postulate that Black Holes continue to grow until the pressure it exerts overcomes the counter pressure of space (the space pressure); this then results in an "explosion", i.e., a Big Bang. Otherwise, Black Holes will last forever without a mechanism 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. So, it is necessary to find other alternatives which will give more reasonable numbers. This is an interesting subject for further theoretical work. Our speculation may not be too unreasonable.

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 or galaxies which agglomerated to form clusters, then superclusters emerged. These massive bodies started to form Black Holes or Dark Energy stars which swallowed and devoured matter into a near-singular volume of space through the power of gravity. Here the

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process of transformation occurred. Chapline Laughlin, et al. [8] showed how matter is transformed into a Bose-Einstein condensate (BEC) at very low temperature. It is useful to note that there is no singularity in this model. It cannot be present because space is almost infinitely compressible with increasing energy content. There will always be space if there is energy. The singularity in Black Holes is an artifact due to the inability of mathematics to properly describe the structure of a Black Hole. 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 [11]. The forces in Back Holes are stronger such that the process of break up can go further all the way to spaceons.

D. Epochs in the Evolution of the Universe

Our universe evolved in the following sequence. Birth (Spaceons, Big Bang) , Growth (matter formation,stars),Ageing and Consolidation (galaxies, clusters,Planck Stars, Black Holes), The End (Big Crunch, Spaceons (quantum dot). We designate the various epochs in its life, using simpler terms than those of Laughlin and Adams [12]. The chronology is shown in Table I and illustrated in Fig 3

Table I. Chronology of Cosmic Evolution

Epoch	Time	Contents
1.Birth	$< 10^{-12}$sec $<10^{-4}$	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

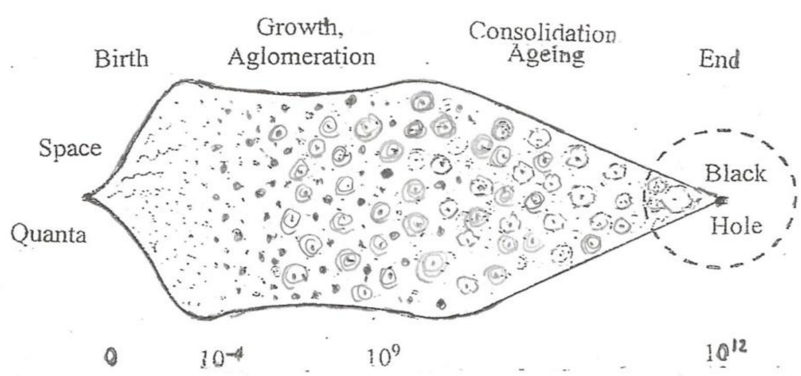

Fig. 3- Epochs in the Evolution of the Quantum Universe

In Fig3, we illustrate the evolution of the cosmos in accordance with our model

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4. Summary and Conclusions

We have elaborated on the mechanism by which dark energy emanates from the energy of space and provides the repulsive force to accelerate the expansion; it is in effect Einstein's cosmological constant.We have extended the QSM model to cover the period of the universe before the Big Bang until its ultimate end. The model is based on a dynamical theory that space consists of energy quanta, and uses the Friedmann equations to trace the history of the universe. The latter started from a near-singular volume of space with high energy density given by the Planck energy equation. Quantum fluctuations triggered the release of energy in the Big Bang at very high temperature and pressure. 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, that brought the universe back to its initial state. It can exist in this condition forever or start 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 space force (expansion). he latter maybe the fifth force in the universe. The latter is carried by bosonic spaecons while the gravitational force maybe carried by an as yet undiscovered bosonic graviton. The two maybe be the clockwork mechanism that operates our eternal cyclic Quantum Universe. We can summarize the evolution of our universe in a few words "…from nothing… there was light…then darkness…. once more… forever".

5. Acknowledgement

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