Cosmic growth of matter – the evidence

Akinbo Ojo

Abstract

Why do living things have this pervasive urge to grow? Could this pursuit of growth be in obedience to some overarching principle of Nature? An increasing abundance of matter in the universe would provide a basis for the selection of such a goal oriented endeavor by biological systems within it. In this essay, the supportive evidence for the growth of the matter-energy content of the universe within the context of the Big Bang model is presented.

Introduction

The study of the expanding size of the universe is already a well-traveled road following Hubble's 1929 discovery of redshifts from galactic clusters and the finding of other evidence like the cosmic microwave background radiation. Within the Big Bang cosmological model, this astronomical increase in the size of the universe from an initial beginning of miniscule or zero size is widely accepted in mainstream cosmology. However, an area less discussed is the issue of whether the observed matter-energy content in the universe has been a feature right from the beginning or whether this astronomical amount of matter has been acquired gradually as the universe expanded. The matter-energy content of the universe (about 10^{52}kg or ~10^{69}J) is usually inferred from astronomical observations that the cosmological parameter Omega (symbol Ω) is today not far from unity (i.e. $\Omega \sim 1$). This essay focuses on this less plied road concerning the astronomical matter-energy content. Has the universe always had this astronomical amount of mass or has the mass also been growing along with its radius?

To be clear, the Big Bang model is not acceptable to all, and there are supporters of rival theories like the Steady-State model. This essay is based on the assumption, probably wrong, that the Big Bang model is the nearest to truth.

For those who believe in a Big Bang of some sort, there is news. Not only has the universe been expanding, it has also been growing at a rate of about 6.75 x 10^{26} kilogram per metre change in radius, from an early mass of ~10^{-8}kg (the Planck mass) till its current 10^{52}kg and 10^{26}m size. This is contrary to current dogma that its mass is unchanging. If the evidence adduced are countenanced, the fact that it has become the hallmark for living things to also grow in mass, subsequently fragment into smaller, more stable and simpler units, with the fragments again embarking on another pursuit of growth in mass, before fragmenting again in a process we call 'reproduction' would seem to be a shared behavior with the cosmos, with the difference that for the universe its matter for growth arises *de novo*.

Evidence from the singularity problem

It may be appropriate to start presenting the evidence right from the very beginning. One of the motivations for a cosmological theory was to banish infinity of time and space from physical theory, infinity being a mathematical concept without objective evidence that it corresponds to anything in physical reality. For instance, there is no clear dynamical path to transform an infinite physical quantity to either an increased or reduced value. If the 10^{52}kg mass of the universe were present right from time zero, we get a cosmological singularity, a state of infinite energy density where all physical laws, including General relativity theory break down. This unfortunately then returns an unwanted infinite quantity back into the physics textbook.

The desire to acquire material things in the shortest possible time is a human trait, like wanting to 'get rich quick' or 'becoming a millionaire overnight', whereas various examples suggest that Mother Nature is gradualist, especially in her approach to the acquisition of substantial things. All life forms evolved gradually according to Darwin's theory, rather than immediately. Likewise inanimate things like galaxies, stars and planets formed gradually. The universe is now astronomical in extent and in material and cosmologists are mostly in agreement that its now astronomical extent was acquired gradually according to the Big Bang model. Must we, as some cosmologists would have us do, impose our human weakness on Mother Nature by modeling the universe as also acquiring all its astronomical material content immediately? Why must all the mass in the universe have been present from the beginning? Why can't the universe's radius and mass not both be gradually acquired over time to reach their current astronomical values?

In his popular book, *The Emperor's New Mind*, Roger Penrose discussed the 'singularity theorems', he and Stephen Hawking are well known for. They both demonstrated that space-time singularities were inevitable within the context of the theory of General relativity and they described two types of singularities, initial and final. Taking note here of Penrose's exact words, "It might appear that there is an exact temporal symmetry between these two types of singularity: *initial* type, whereby space-time and matter are **created**, and the *final* type, whereby space-time and matter are **destroyed**". The two eminent physicists then concluded that their singularities had infinite densities! It is here that they inadvertently fell into error by not taking into consideration that when matter is destroyed or when it is yet to exist (using their own words), there can be no mass to cause the infinite density attributed to their singularities. Mass is an attribute of matter, thus when you say matter does not exist because it is yet to be created or that matter has been destroyed, from whence does the mass attribute resulting in the infinite density come from? Can a state without matter have mass? And can a state without mass have a density? The reader may note that in physics while matter and energy may qualitatively differ, they are quantitatively equivalent.

If we however extrapolate into the past and follow the reasoning of the singularity theorems that space and matter can be created from an initial singularity, we find a universe that has been evolving with a Schwarzschild mass and radius, **increasing in mass and radius from an initial zero value in accord with the formula $M = rc^2/2G$. This amounts to about 6.75 X 10^{26}kg per metre change in radius (and about 2.02 X 10^{35}kg per second)**, where M in the formula is the mass of the universe, r its radius, G the gravitational constant and c the value of velocity of light in free space. This hypothesis overcomes many of the shortcomings of the Big Bang model and better copes with its identified flaws when compared with alternative propositions like inflation. As will be later pointed out in this essay, it also corresponds more closely with the thermal history of the early universe. Further discussion can be found in my e-book, *Hypotheses Fingo* or in my arXiv article, '*Does the universe obey the energy conservation law by a constant mass or an increasing mass with radius during its evolution?*', http://arxiv.org/abs/0810.1629.

To my mind, Penrose was very close to this hypothesis having admitted as quoted above that matter and space-time did not exist at the initial singularity and even making references to the

Schwarzschild radius, i.e. $r = 2GM/c^2$ in his several discussions of singularities. However, he repeatedly assumes that while radius can reduce to zero in a final singularity or increase from zero in an initial one like the Big Bang, the mass is prevented from similarly varying but must remain unchanging. It is this likely wrong assumption that gives an infinite density instead of zero density when the expanding universe is extrapolated backwards in time. On the other hand, if M reduces as r reduces, or M increases as r increases, according to the Schwarzschild relationship ($M = rc^2/2G$), there will be no infinite singularities. This not only resolves the singularity problem, but as we shall later it also mitigates the flatness and temperature problems plaguing the Big Bang theory as these are also self-inflicted consequences of erroneously making the 10^{52}kg mass a feature of the early universe.

Evidence from the flatness riddle

The flatness riddle arose from the pioneering work of Dicke and Peebles (see *300 Years of Gravitation* for the reference) and discusses the puzzling observation that the density of matter in the universe is so delicately balanced near the critical value that would either result in perpetual expansion or immediate re-collapse into a Big Crunch. Not only is this so, this balance is historical and has obtained right from very early eras. According to the narrative, if the universe had just slightly more mass, its density would be higher than its critical value and it would have collapsed not long after birth. If its mass was just a tiny bit less to give a density less than the critical value in the early era, the universe would have expanded so much that it would be virtually empty of content by now. Yet at each era from birth till date the universe balances on this knife edge between collapse and expansion. That is, despite the radius of the universe increasing astronomically over time, the density does not seem to be falling off as fast as it should but rather remains delicately balanced in a certain peculiar ratio between the radius and matter-energy content.

It is good to expatiate on what the terms 'critical density' (ρ_c) and 'critical mass' (M_c) mean. In less technical terms, we can also discuss them using the cosmological parameter, omega (Ω). Ω is the ratio of the actual density of the universe, ρ and the critical density, i.e. $\Omega = \rho/\rho_c$ and can be above unity, below unity or equal to unity, i.e. $\Omega > 1$, $\Omega < 1$ or $\Omega = 1$ which correspond to a closed, open or flat universe respectively. Multiplying the numerator and denominator by the volume of the universe at an epoch, we get Omega as equivalently, the mass of the universe and the critical mass for a universe of the given size (i.e. $\Omega = M/M_c$). It can be seen that when the actual density of the universe is equal to its critical density (i.e. $\rho = \rho_c$) or equivalently when the actual mass of the universe is equal to its critical mass (i.e. $M = M_c$), the parameter Omega is equal to one.

To throw light on salient issues that may otherwise be hidden in complex equations, the critical density, ρ_c can be related to other cosmological parameters as $\rho_c = 3H^2/8\pi G$, where H is the Hubble parameter and is the inverse of the expansion time, t (i.e. $H = 1/t$). The distance that light can cover travelling at velocity, c, during the expansion time is the radius of the observable universe, i.e. $r = ct$.

Since $H = 1/t = c/r$, the critical density, $\rho_c = 3H^2/8\pi G$ can be written, $\rho_c = 3c^2/8\pi Gr^2$. Multiplying both sides of $\rho_c = 3c^2/8\pi Gr^2$ by volume, $(4\pi r^3/3)$ gives the formula for the critical mass, M_c making up the critical density as $rc^2/2G$, which as can be seen is the 'Schwarzschild mass'.

Therefore, when the actual mass of the universe at any epoch is equal to its Schwarzschild mass (i.e. $M = M_c$), the parameter Omega equals unity, i.e. $\Omega = 1$.

Astronomical observations of cosmic microwave anisotropy and the frequency of Type-Ia supernovae at different distances from Earth show that the universe is currently not far from flat with Ω being within one or two orders of magnitude of being one. From $M_c = rc^2/2G$, this is an estimated current mass of about ~10^{52}kg. See Wendy L. Freedman, Determination of cosmological parameters, (https://ned.ipac.caltech.edu/level5/Freedman2/frames.html) and Wikipedia (https://en.wikipedia.org/wiki/Planck_units#Cosmology).

The significance of the work of Dicke and Peebles, stated as the 'flatness riddle' is that for the actual density, ρ (or equivalently, for the mass, M) of the universe to be approximate to its critical density, ρ_c (or equivalently its Schwarzschild mass, M_c) in the year 2017, then the two must have shared this approximation to each other in earlier eras. That is, in order to make the history of the cosmological parameter omega, Ω to be within the vicinity of one today after ~10^{60} Planck times of expansion, the actual mass of the universe could not have differed from what its Schwarzschild mass was at the earliest eras, i.e. $M \sim M_c$ ($rc^2/2G$) from the beginning. To paraphrase the British cosmologist and astronomer, Martin Rees and author of the readable book, *Just Six Numbers*, "…at one second after the Big Bang, Ω (M/M_c) could not have differed from unity by more than one part in a million billion (one in 10^{15}) in order that the universe should now, after over 10 billion years be still expanding with a value of Ω that has not departed significantly from one".

If mass is constant in an expanding system, the density reduces as r^3 increases. A look at the above equation, $\rho_c = 3c^2/8\pi Gr^2$ however shows that as r increases with time, ρ_c reduces as r^2 which is a much lower rate of reduction than expected. Inherent in this cosmological formula is the hint that the matter-energy content of the universe may not be constant and that the mass of the universe may be increasing linearly with its increasing radius. If therefore the flatness riddle stipulates that Ω (M/M_c) ~ 1, then at the Planck epoch, r ~10^{-35}m, the actual mass of the universe would be ~10^{-8}kg, since this is the Schwarzschild mass for a universe of that size and not 10^{52}kg.

However, if our universe is theoretically forced to contain 10^{52}kg at the early epoch instead of ~10^{-8}kg, it would be extremely curved with Ω (M/M_c) being about 10^{60} at the Planck epoch and not the Big Bang model flat universe with Ω = 1. To solve this difficulty of the mass of the universe being constant at 10^{52}~kg from the beginning, the volume of the universe is the only other parameter that can be varied to make the high density (~10^{157}kgm^{-3}) reduce to the critical density (~10^{96}kgm^{-3}, the Planck density), hence the invention of *"inflation"* as a solution. This requires the universe to expand by a factor of at least 10^{60} in less than 10^{-32} seconds in order to make Ω = 1. Does this scheme succeed?

If the universe was already flat with Ω = 1 from the Planck epoch and had a mass 10^{-8}kg, instead of ~10^{52}kg (i.e. a density ~10^{96}kgm^{-3}, instead of ~10^{157}kgm^{-3}), the motivation for an inflationary scenario to resolve the flatness riddle becomes unnecessary. In the more detailed analysis, it is shown that even if applied to the problem, inflation still fails to resolve the flatness riddle. All you need ask anyone who claims it does is to tell you the radius or size of our universe after inflation ended in their model; next ask its matter-energy content; then ask that the value of Ω after inflation be calculated.

The inflation hypothesis proposes that soon after the Planck epoch the universe expanded rapidly to a size about 0.1m, all within a time span of less than 10^{-32}seconds. If this 0.1m radius after inflation contained all the current estimated matter-energy ~10^{52}kg (~10^{69}J), Ω would not be one. The Schwarzschild mass for a universe of that size, from $M_c = rc^2/2G$, is 6.75 X10^{25}kg, thus given $\Omega = M/M_c$, if a universe contains 10^{52}kg and is of 0.1m radius, Ω will be about ~10^{27} (10^{52}kg/10^{25}kg) after inflation! On the other hand, if our universe was just a tiny fraction of the 0.1m as some other inflationary models propose, for example ~10^{-24}m, the case is even worse as an observable universe of that size having a matter-energy content of 10^{52}kg will have an Ω value ~10^{49}.

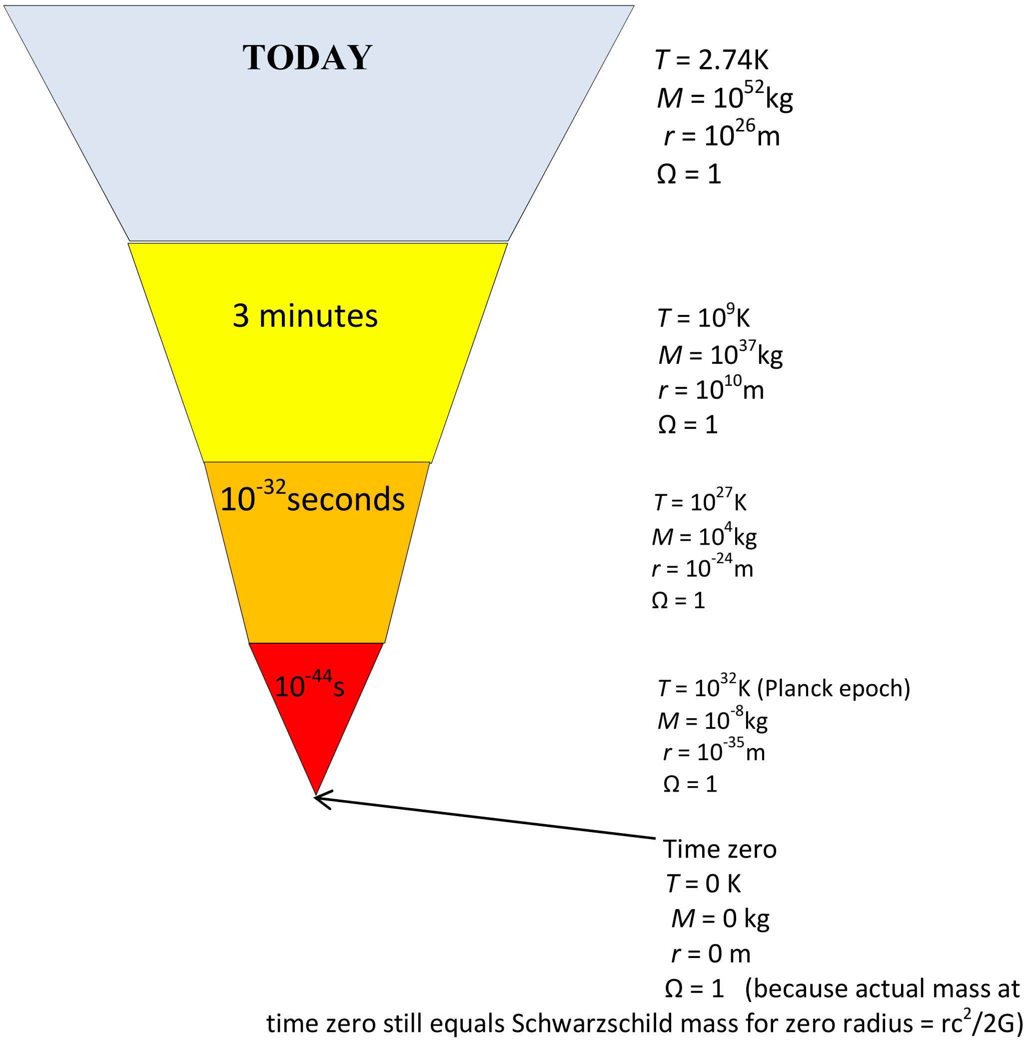

Diagram illustrating historical changes in the cosmological parameters (time, temperature, mass, radius and Ω) of our universe.

Despite its invention and the valiant attempt to make Ω ~ 1 post-inflation, the parameter omega remains very much higher than one, no matter the inflation model. Inflation therefore fails in the purpose for which it was invented which was to solve the flatness problem, a problem which may not have existed in the first place if the matter-energy content at the Planck epoch was 10^{-8}kg.

To follow the flatness history of the universe, at radius ~10^{-24}m and 0.1m, the actual mass of the universe will be 675kg and 6.75 X10^{25}kg respectively. Today, more than 10 billion years after time zero, the mass of the observable universe is about 10^{52}kg with a radius about ~10^{26}m. To remain flat, it is clear that the mass of the universe must track its radius according to the formula $M = rc^2/2G$. Any universe obeying this relationship between its mass and radius will be flat like ours. While those evolving with a constant mass but increasing radius, will remain plagued with flatness problems and require ad hoc mechanisms like inflation. From the history of the cosmological parameters as shown in the diagram above, as already speculated by some cosmologists, notably Edward Tryon and Alexander Vilenkin, it would appear that our universe was created from nothing. An arrow of time can also be discerned as pointing in the direction of cosmic increase of mass and radius.

The genuine reservation over what this mass increase with radius may imply for the energy conservation principle is understandable, if and only if mass and energy are fundamental and absolute quantities that cannot perish. But if as hypothesized, the universe can start from zero, then they are properties that are not ultimately conserved, and that reservation will not be tenable. If matter-energy content and radius are two sides of the energy ledger, e.g. credit and debit, then if as one side of the ledger increases, so does the other, the total energy would always sum up to zero, which will be same as the initial zero energy state at time t = 0. In this sense, there is no contravention of energy conservation laws when a universe is created from nothing since at all times, total energy still sums to zero energy-wise.

Evidence from cosmic thermal history

The thermal history that can be inferred from the hierarchical stability of structures and subsequent nucleo-synthesis has been worked out to a reasonable extent in the Big Bang model. If the universe is "all there is", the universe's radiation could not have originated from another radiating body and transmitted through it or reflected from it. The radiation would therefore be intrinsic to it, possessing the characteristics of a black body and obeying the laws associated with such radiation. Among such laws is the Stefan Boltzmann law

$$P/A = \sigma T^4$$

where P is the power or the energy radiated per second, A is the surface area, σ is Stefan's constant (5.7 X 10^{-8} $Wm^{-2}K^{-4}$) and T is temperature in Kelvin. The energy density, E_D for radiation of all wavelengths in a given volume, can be related to the Stefan-Boltzmann law by

$$\sigma T^4 = (c/4) \times E_D$$

where c is light velocity. Rearranging, we can write

$$E_D = (4\sigma/c) \times T^4$$

Since the expression 4σ/c gives a constant, we have

$$E_D = aT^4$$

where a has the value 7.56 X 10^{-16} $Jm^{-3}K^{-4}$ and is known as the 'radiation constant'. For supporting reference, see "Radiation Energy Density", http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/raddens.html#c1. Thus the amount of energy in a known volume of space can be related to temperature when it is in the form of radiation. By knowing the temperature and volume at an epoch, the matter-energy content can be calculated from the energy density.

The important message here is that when the thermal history of the Big Bang model is viewed alongside the laws of black body radiation at each epoch, it is possible to deduce the matter-energy content of our universe knowing the radius at each epoch. When this calculation is done, it will be found that indeed the matter-energy content of the universe has been increasing with its radius as depicted in the diagram above. A reference table of the timeline of the standard Big Bang model is shown below with the corresponding temperatures. Also see, Chronology of the universe, https://en.wikipedia.org/wiki/Chronology_of_the_universe.

Time (seconds)	Radius (metres)	Temperature (Kelvin)	Ambient matter-energy (GeV)	Event
0	0	0	0	0
10^{-44}	10^{-35}	10^{32}	10^{19}	Appearance of space, time and matter-energy
10^{-35}	10^{-27}	10^{28}	10^{15}	Strong and electroweak forces separate
10^{-10}	0.1	10^{15}	10^{2}	Electromagnetic and weak forces separate
10^{-6}	10^{2}	10^{13}	10	Quarks stabilize
10^{-3}	10^{5}	10^{12}	10^{-1}	Protons, Neutrons and Hydrogen nuclei stabilize (binding energy = 1.7MeV)
100	10^{10}	10^{9}	10^{-4}	Electrons, Helium nuclei stabilize

Table showing the thermal history of the universe according to the standard model of the Big Bang (1 GeV ~ 10^{13} K ~ 10^{9}J).

A temperature problem will have to be added to the list of Big Bang problems if the matter-energy content of the universe was anywhere near ~10^{52}kg (~10^{69}J) at any time during the radiation-dominated era. Using the radiation density formula, $E_D = aT^4$ we can readily calculate the matter-energy density, E_D at these times knowing the modeled temperatures. From this, if the matter-energy content of the universe was anywhere near ~10^{52}kg (~10^{69}J), the temperature at the Planck era would be 10^{47}K, by far hotter than the standard model's envisaged 10^{32}K. It may be worth noting that the mass of the universe at the Planck epoch which gives exactly the Big Bang model 10^{32}K temperature at that epoch is ~ 10^{-8} kg (~10^{9}J).

The inflation hypothesis, models a temperature ~10^{27}K after the process has ended. If the matter-energy content now ~10^{52}kg (~10^{69}J) was the same as that contained in an observable universe radius (~10^{-24}m) after inflation ended, the energy density E_D would have been

~10^{141}Jm^{-3}. This translates to a temperature about 10^{39}K, far higher than what inflation models. Thus the inflation hypothesis is inconsistent with its own predicted model temperatures and thermal history.

The matter-energy content that will be compatible with the model temperature 10^{27}K at a radius ~10^{-24}m after inflation will be ~10^{21}J (~10^{4}kg), very much less matter-energy content than what obtains today. The thermal history of the Big Bang therefore provides further supportive evidence for the cosmic growth of mass with radius as it agrees with the modeled temperatures of the Big Bang at the Planck epoch and at other times during the radiation-dominated era.

Evidence from primordial nucleo-synthesis

A quote from Steven Weinberg's popular book, *The First Three Minutes*, will serve as an exhibit for the evidence presented here: "As the explosion continued …the temperature continued to drop, finally reaching one thousand million degrees (10^{9}K) at the end of the first three minutes. It was then cool enough for the protons and neutrons to begin to form nuclei, starting with the nucleus of heavy hydrogen (or deuterium), which consists of one proton and one neutron". Cosmologists generally admit uncertainty of what the scenario is at time zero, less uncertainty at the Planck epoch because of inflationary complications but they declare reasonable confidence of the situation at three minutes because knowing what the binding energies of nuclei are, the ambient energies that must be present at three minutes to enable their formation (nucleo-synthesis) can be deduced. For example, the binding energy of the nucleus of heavy hydrogen (deuterium) and that of helium are 2.2MeV (~0.0022GeV) and 28.3MeV (~0.0283GeV) respectively, with the corresponding temperatures permitting stability being ~10^{10}K and 10^{11}K (see Table above). These quantitative values are not controversial.

We can therefore say with confidence that if the ambient energies and temperatures at the end of the first three minutes are above their binding energy values, hydrogen and helium nuclei cannot form. For example, at 10^{12}K energies will be too high and only a quark-gluon plasma can be stable. See Wikipedia: Chronology of the universe referenced in the last section. Also see http://hyperphysics.phy-astr.gsu.edu/hbase/astro/bbcloc.html#c1 for reference to the timeline and the temperature at three minutes.

From formulae that relate the energy density within a given volume to the temperature using blackbody radiation laws ($E_D = aT^4$), if cosmologists decide to greedily acquire all our current material wealth *within three minutes*, i.e. ~10^{52}kg (~10^{69}J), given the standard model expansion rate, our universe will at this time be about 5.4 x 10^{10}m radius (with volume ~6.6 x 10^{32}m^{3}), giving us an energy density of ~10^{36}Jm^{-3}. This energy density translates to temperatures about ~10^{12}K and ambient energies of ~669MeV, which is so much higher than can permit the formation of nuclei for deuterium (binding energy <2.2MeV, ~10^{10}K) and helium (binding energy < 28.3MeV, ~10^{11}K) and the Big Bang nucleo-synthesis model will collapse.

If however, we allow Mother Nature to gradually build the universe according to the formula $M = rc^2/2G$ which amounts to about 6.75 x 10^{26}kg per metre change in radius (and about 2.02 x 10^{35}kg per second), then the mass of the universe will be about 3.6 x10^{37}kg (~3.24 x10^{54}J) at the end of the first three minutes, and not 10^{52}kg. This being so, given the volume at this time, the energy density will be 4.9 x10^{21}Jm^{-3} and the corresponding temperature and ambient energy will be ~10^9K and 0.1MeV (~10^{-4}GeV) respectively, just the right temperature for Mother Nature to cook us a perfect dinner of hydrogen-helium nuclei soup where both nuclei are stable.

Terrestrial evidence

There are reasonable suggestions that the Earth itself is growing in radius and mass. The major supporting geological evidence is that the ancient continents could be refitted together like a kind of jigsaw puzzle into a kind of terrestrial 'eggshell'. In so doing they are found to produce a tight, coherent fit of continents *only if the globe was between 55 to 60% of the present Earth radius*. This increase in radius provides an alternative and probably better explanation for many other geological features. View 'Global Expansion Tectonics' website, http://www.bibliotecapleyades.net/ciencia/earthexpanding/00_GlobalExpansionTectonics.htm#menu.

From a structural design engineer's perspective, Stephen Hurrell in his book, *Dinosaurs and the Expanding Earth*, discusses how a study of the fossils of the large dinosaurs shows that their bones could not have supported their body weight and therefore dinosaurs could only have thrived and evolved at a time when the force of gravity at the Earth's surface was much less than at present. Such reduced surface gravity in the past could come either from a larger radius or a lower mass of Earth in the past. The geological evidence does not support a larger radius in the past so an Earth increasing in mass with time is more appealing. See the website http://www.dinox.org/ and the video https://www.youtube.com/watch?v=l3ooOwJ4hww for more discussion of the interesting, separately arrived at geological and biological evidence.

The 'faint young sun paradox' first pointed out by Carl Sagan and George Mullen may be yet another evidence (https://en.wikipedia.org/wiki/Faint_young_Sun_paradox). According to models of stellar evolution, the Sun's output would have been only 70% of what it is today during the Earth's early history with the consequence that the oceans would have been frozen and the liquid water required for life would not exist. If the Earth was however of a much smaller mass in its early history as other evidence suggests then the output from such a faint yellow sun may have been sufficient to keep terrestrial water in liquid form.

Assuming the validity of the evidence for an 'increasing mass expanding Earth', where is the additional mass coming from? It is here that the ideas expressed in this essay find resonance with others that have proposed a possible cosmic origin for the additional mass. Quoting from the 'Global Expansion Tectonics' website linked above, "The ultimate cause of Earth expansion must however be considered intimately related to a cosmological expansion of the universe, i.e. where does the mass of the universe come from?"

Concluding remarks

There are other remaining puzzles in cosmology but those discussed here suffice to make a case for a universe that has been increasing in mass as well as in radius. If according to the Big Bang model the factory size is increasing (expanding universe), an astronomical production time is allowed, the raw material for structure is increasing in abundance and the environment favors the stability of certain configurations while others are not so favored, it is only a matter of time for all the wandering to achieve a goal, one of which may be the chance appearance of rudimentary life which in turn take the pursuit of growth in mass and size as a goal.

Further reading

1. Penrose, Roger, *The Emperor's New Mind*, Oxford University Press (1990).
2. Ojo, Akinbo, *Hypotheses Fingo,* ebook in kindle and pdf versions, Booktango (2016).
3. Hawking, S.W. and Israel, W. (eds), *300 Years of Gravitation*, Cambridge University Press, Cambridge (1987).
4. Weinberg, Steven, *The First Three Minutes,* Basic Books (1993*).*
5. Rees, Martin, *Just Six Numbers*, Basic Books (2001).
6. Hurrell, Stephen, *Dinosaurs and the Expanding Earth*, ebook, One Off Publishing (2003).