Journal of Modern Physics, 2024, 15, 1959-1979
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

# Astrobiological Constraints on Astrophysics

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**How to cite this paper:** McGruder III, C.H. and Schulze-Makuch, D. (2024) Astrobiological Constraints on Astrophysics. *Journal of Modern Physics*, **15**, 1959-1979.
https://doi.org/10.4236/jmp.2024.1511081

**Received:** September 9, 2024
**Accepted:** October 27, 2024
**Published:** October 30, 2024



## Abstract

Life exists in the universe and therefore the astrophysical properties of the universe must be such that they allow the origin of life. We connect astrobiology and astrophysics via one astrobiological quantity—the probability of the origin of life. We show how this probability, if it is very low, will allow us to answer profound astrophysical questions such as the type of universe we live in, the fate of our universe, whether neutron stars, white and brown dwarfs evaporate and whether protons decay.

## Keywords

Astrobiology, Astrophysics, Cosmology, Relativity

## 1. Introduction

Astrobiology concerns life in the universe. Astrophysics is about applying the laws of physics that we have discovered on Earth to astronomical phenomena. These two fields appear to be completely separate from each other. We will show that they are actually intimately connected. The connection between them comes about because the universe must have characteristics that allow the origin of life. This circumstance may introduce astrobiological constraints into astrophysics, particularly on the standard theory of cosmology, proton decay, stellar evolution, specifically white and brown dwarfs as well as neutron stars.

## 2. Astrophysics

In this section, we will discuss two areas of astrophysics that are impacted by astrobiology—cosmology and stellar evolution. We will show that the imposition of

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astrobiological constraints may have a major influence on each of these areas of astrophysics. Consequently, they should be taken into account in theoretical work. We also show that astrobiological constraints may lead to the conclusion that protons do not decay, whereby such a circumstance has heretofore not been considered part of astrophysics.

## 2.1. Cosmology

Cosmology is concerned with the universe as a whole—its structure in the past, present and future. We consider two cosmological theories—the standard theory of cosmology and the Taub-NUT universe. Both of these theories are based on Einstein's theory of general relativity. Therefore, we will begin with a section on the theory of relativity.

### 2.1.1. Relativity

Einstein formulated two theories of relativity. The first in 1905 [1], which is called special relativity. It is also sometimes referred to as restricted relativity because it only concerns physical systems that are moving relative to each other at constant velocities and does not include gravity. The second theory of relativity was published in 1915 [2]. It is called general relativity and includes gravity. General Relativity is also referred to as Einstein's Theory of Gravitation.

Special Relativity

In his formulation of special relativity, [1] came to the conclusion that both time and space are relative. Specifically, an observer at rest perceives that time slows down and space is contracted in a system moving at constant speed. In his publication, Einstein was referring only to physical time. However, biological systems must obey the laws of physics, meaning that moving biological systems to a non-moving observer must experience time dilation, as the slowing down of time is referred to. This circumstance has given rise to the famous twin paradox, whereby a twin, who travels in a space ship ages slower than his Earthly twin [3]-[6]. Clearly, this is counter-intuitive and it is one of the reasons, why Einstein's theory had many opponents [7].

General Relativity

Just two years after Einstein published his special theory of relativity and eight years before he published his Theory of Gravitation, Einstein realized that gravity also causes time dilation [8], which is appropriately called gravitational time dilation. It means: the closer one is to a source of gravity the slower time passes and the farther one is from a gravitating body the faster time passes.

Gravitational time dilation has been observed in a number of circumstances. In the Hafele-Keating experiment four atomic clocks were taken on commerical airlines. They were flown twice around the Earth first eastward and then westward. Upon landing, these clocks were compared with atomic clocks that remained on the ground. All atomic clocks showed time intervals that agreed with the prediction of gravitational time dilation [9].

Gravitational time dilation has been measured in experiments with time signals sent to and from the Viking 1 Mars lander [10]. In other experiments gravitational time dilation has been measured [11] [12]. The Global Positioning System's artificial satellites are so accurate that they have to take into account the gravitational effect on time from general relativity and the effect of motion on time from special relativity. Finally, we note that because gravity on the Moon is different than on Earth and the motion of the Moon also differs, the length of time intervals on the Moon is different than on Earth. Currently, discussions between NASA and the European Space Agency are taking place on how to define Moon time [13] [14].

Below, we show that the effect of gravity on time may play a crucial role in the origin of life in the universe.

#### 2.1.2. Standard Theory of Cosmology

There is a consensus in the astronomical community that the universe came into being 13.8 billion years ago [15]. Initially, everything was concentrated in some sort of singularity consisting of only energy, that is, it contained no matter and therefore no life. This lifeless universe expanded, whereby the energy was converted to mass according to Einstein's famous equation, $E = mc^2$. This beginning of the expansion of the universe is called the Big Bang. This theory is referred to as the standard theory of cosmology. It is based on Einstein's theory of general relativity and is denoted with the acronym ΛCDM, whereby Λ is a constant (the cosmological constant) in Einstein's field equations. Λ denotes the presence of dark energy, which is an unknown form of energy, which gravitates repulsively causing the expansion of the universe to accelerate in opposition to attractive gravity, which causes the expansion rate to slow down [16] [17]. CDM stands for Cold Dark Matter. Dark Matter is a form of matter, which is widely believed to only interact gravitationally and not with electromagnetic radiation, which is why it is called dark [18] [19]. To date dark matter has not been detected in terrestrial laboratories [20]-[26]. It is evident that the standard theory of cosmology rests on two concepts—dark energy and dark matter, which are not understood.

In the standard theory, the future of the universe is determined by the interplay between the momentum of expansion and gravity. There are four widely discussed possibilities. They are referred to as the Big Freeze, the Big Rip, the Big Crunch and the Big Bounce.

Big Freeze

The Big Freeze is also referred to as the Big Chill or Heat Death. It will occur, if gravity is less than the momentum of expansion meaning that the universe will expand forever. Stars form in interstellar clouds of gas and dust, whereby gas is the major component. When this interstellar matter is consumed by stars, star formation will cease. This is expected to occur in $10^{12}$ to $10^{14}$ years in the future. When all stars run out of the elements in their cores that fuel nuclear fusion, they will eventually cease to shine eventually leading to a dark universe, which is everywhere in thermodynamic equilibrium. Thus, energy transfer can not take place and the universe will become lifeless again. This state of the universe is expected to occur $10^{109}$ years in the future [27]. This time span is so large because about 0.1% of all matter ends up in black holes, which evaporate extremely slowly via Hawking radiation [28].

Big Rip

Observations of distant supernova interpreted in the context of the standard theory of cosmology lead to the conclusion that the expansion rate of the universe is increasing. This increase in the expansion rate is caused by so-called dark energy, whose nature is unclear, which is why it is called dark. Dark energy manifests as a repulsive force. If the increase in the expansion of space increases indefinitely then this repulsive force will become greater than the gravitational forces, which hold celestial objects together and they will be ripped apart. As the rate of expansion increases the repulsive force will become so great that even molecules and atoms will be ripped apart, meaning the universe will become lifeless again. This scenario for the future of the universe is call the "Big Rip". If it happens, it will occur about 152 billion years in the future [29].

Big Crunch

If gravity is greater than the momentum of expansion then the universe will contract and the universe will revert back to its initial condition of some sort of singularity consisting of only energy. This means all matter will be destroyed and the universe will again become lifeless. This scenario is referred to as the Big Crunch. If it happens, it is estimated that the collapse time is >24 billion years [30].

The Big Crunch creates the initial conditions of the Big Bang meaning that the universe may expand again. This scenario is called the Big Bounce. Clearly, this sequence can go on forever and if it does it is called the cyclic or oscillating universe.

The Future of the Universe

We do not understand the nature of dark energy. Therefore, we can not predict how it will behave in the future. Consequently, we can not predict, which of these four scenarios will actually happen. However, if the effect of dark energy is not time dependent, it would mean that the future of the universe is the Big Freeze. If however the repulsive effect of dark energy increases the universe may very well may experience the Big Rip. But, if the effect of dark energy decreases with time, the Big Crunch or Big Bounce are possible.

#### 2.1.3. Taub-NUT Universe

The standard theory of cosmology is known to have a number of fundamental flaws, which are described and addressed in a recently proposed theory of cosmology [19]. The model of the Taub-NUT universe was derived by following the approach Einstein took in deriving special relativity. [1] derived time dilation and space contraction by deriving the consequences of two observational facts—the principle of relativity and the principle of the constancy of the speed of light. He made no additional assumptions. Similarly, the Taub-NUT universe was derived by employing only two basic astronomical observations: 1) The redshift distance relationship—the more distant a cosmological source is, the greater its spectral lines are shifted to the red. 2) Cosmic time dilation—the more distant a cosmological object is the slower time passes. No additional assumptions are made.

In contrast to the Taub-NUT universe, the standard model is based on the assumption of the validity of the cosmological principle, which maintains that the matter in the universe is homogeneously distributed. However observations indicate that this assumption may not be valid [31]-[40]. Additionally, it has been proven that this assumption can not be confirmed through astronomical observations [41].

Unlike the standard model, the Taub-NUT model universe does not have a beginning, that is there was no Big Bang, nor an end. Its size is finite [42] and it is not expanding. It also maintains that dark energy does not exist.

Observations show that the light of distant galaxies is redshifted compared to nearby galaxies. This phenomenon is referred to as cosmological redshift. In the Taub-NUT universe the observed cosmological redshift is not due to the expansion of space as the standard theory maintains rather it is due to the gravitational redshift, which is associated with gravitational time dilation. Thus, it explains both the observed cosmological redshift and the observed cosmological time dilation.

## 2.2. Stellar Evolution

One of the most profound conclusions of astrophysics is that we are living in an evolving universe. The evolution of the universe is divided into five eras [43]. We are in the Stelliferous Era in which the matter in the universe is highly structured in the form of stars, galaxies, clusters of galaxies as well as superclusters and most of the energy produced comes from stars.

Stars form in interstellar clouds, which are areas in interstellar space with a particular high concentration of interstellar matter. If the mass of the protostar is not high enough it will end up as a brown dwarf or failed star, which does not produce energy via nuclear fusion.

When stars consume the fuel that they fuse, their cores contract to one of three final phases of stellar evolution—white dwarf, neutron star or black hole. Their envelopes (anything outside the core, where nuclear fusion took place) are ejected into interstellar space much of which ends up in new stars that form.

Eventually, all interstellar matter will end up in stars, which eventually will exhaust their matter that fuses to produce energy. Thus, the Stelliferous Era will end. The universe will enter the Degenerate Era, in which it will consist of white dwarfs, neutron stars, brown dwarfs and black holes.

### 2.2.1. White Dwarfs

These stellar remnants have the masses of stars and the size of the Earth. Thus, their densities are of the order of $10^6$ g/cm$^3$. Their masses are $<1.44 M_\odot$, the Chandrasekhar limit [44]. Calculations show that stars with initial masses between 0.07 and $10 M_\odot$ will become white dwarfs. That is 97% of all stars will end up as white dwarfs. These objects do not generate energy via nuclear fusion rather they shine because they are cooling.

Most important is that it is generally thought that white dwarfs and brown dwarfs do not evaporate. Thus, the universe ends up being occupied with stellar corpses. Consequently, further evolution does not take place.

#### 2.2.2. Neutron Stars

What happens to the 3% of stars, whose initial masses are greater than $10M_\odot$, when nuclear fusion is no longer possible because they have consumed the elements that fuse? If their initial masses are in the range of $10 - 25M_\odot$ they will form an object with a radius of about 10 km with a density of $10^{14}$ g/cm$^3$, which consists chiefly of neutrons.

During the formation of a neutron star the envelope is blown off violently in a supernova explosion. The mass of the remaining neutron star is considerably less than its initial mass. Like white dwarfs neutron stars have a maximum theoretical mass, which is called the Tolman-Oppenheimer-Volkoff limit [45]. It is between 2.2 and 2.9 solar masses. The most massive neutron star detected to date has a mass of $2.35M_\odot$ [46]. Most important is that it is generally thought that neutron stars do not evaporate.

#### 2.2.3. Black Holes

In normal stars, the effect of inward gravity is balanced by outward pressure due to heat. In both white dwarfs and neutron stars, the heat pressure is not large enough to counterbalance gravity. In white dwarfs the electron pressure and in neutron stars the neutron pressure caused by the Pauli exclusion principle [47] of quantum mechanics, negates the inward force of gravity.

Both white dwarfs and neutron stars have a maximum mass. What happens to the <0.1% of stars, whose initial masses are greater then $25M_\odot$? Neither heat pressure nor the pressure caused by the Pauli exclusion principle are large enough to lead to a stable stellar configuration so the star collapses to a singularity, which is called a stellar black hole.

Black holes are govern by general relativity. The escape velocity of a black hole is greater than the speed of light, so not even light can escape, which is why they are called black.

Black holes evaporate [28]. However, the time it takes is extremely large. It is about $10^{67}$ years for a solar mass black hole. For supermassive black hole, which are in the cores of most galaxies, the evaporation time is: $>10^{100}$ years [48].

#### 2.2.4. Proton Decay

Particles and antiparticles have exactly the same properties except for charge. If a particle and its antiparticle collide they turn completely into energy. In the standard theory of cosmology the universe in the very beginning was some sort of singularity consisting of only energy. As the universe expanded this energy was converted to mass. But in every laboratory experiment, when energy is converted to mass, we always obtain an equal number of particles and antiparticles. Astronomical observations show however, that this equality is not true for the universe. This circumstance is referred to as the matter-antimatter asymmetry problem or the baryon asymmetry problem [49]. In fact, if there were an equal number of particles and antiparticles in the universe over time through collisions the universe would consist of only energy.

According to the standard model of elementary particles, the proton can not decay because it is the least massive baryon and its decay would violate the law of conservation of baryons. However, in 1967, [50] suggested this asymmetry could be explained if the proton decays. So, called Grand Unified Theories (GUTs) as well as theories of quantum gravity predict that proton decay must occur along with the existence of magnetic monopolies. However, neither prediction have been experimentally observed. Experiments show that the half-life of proton decay is $>2.4 \times 10^{34}$ years [51]. However, supersymmetry (SUSY) predicts that the proton decay lifetime can be as large as $10^{36}$ years.

The existence or non-existence of proton decay is very important for stellar evolution. If it exists, it means that white dwarfs will evaporate through proton decay which would mean that matter would no longer be available for longer periods than the proton decay rate.

Finally, we note that the observed asymmetry between particles and antiparticles is one of the fundamental flaws of the standard theory that the Taub-NUT universe resolves. Its resolution comes about because in the Taub-NUT universe, there was no Big Bang.

## 3. Astrobiology

Astrobiology deals with the question about life on Earth and in the universe, including the question of the beginning and future of life. Life interacts with the matter and energy of the universe and has to adhere to the physical laws. Given that life is present in the universe (at least the one on Earth), it is required that the physical laws and universal constants are compatible with life. Thus, if we compare different types of universes or proposed types of universes, for example the standard model with the Taub-NUT universe, we might be able to deduce that one or the other is more compatible with life. Or, at least determine in which one life is more likely to originate.

### Astrobiological Constraints—How Did Life Begin?

Current astrophysical theory says absolutely nothing about life in the universe. All constraints on its theories are physical and not biological. In this section, we will present astrobiological constraints that some astrophysical theories may have to adhere to.

Life on Earth as we know it is mainly composed of the elements of carbon, oxygen, nitrogen, hydrogen, phosphorus and sulphur, which are common elements in the universe. Biological compounds are made of these elements together with other important trace elements (such as iron and magnesium) to form large macromolecules, without which life could not function. It is well known that the earliest life on Earth was microbial life, but it is not understood how the non-living macromolecules turned into the most simple forms of life.

The transformation of non-living elements to living microbes is called abiogenesis, which is a sub field of astrobiology. To date such a transformation has not been observed in nature and it has not been observed in any experiment. Yet, it is generally assumed that the process occurred on Earth many billions of years ago [52].

There are conceptional difficulties which any hypothesis of abiogenesis has to address: 1) the origin of a semipermeable membrane to maintain a thermodynamic disequilibrium with the surrounding environment and regulate the exchange of nutrients and waste products; 2) the origin of metabolism and a cellular machinery that harvests the energy generated; and 3) the invention of a genetic code capable of transferring information from one generation to the next [53]. Further, all three events must occur at about the same time, since the lack of any one event without the other would not result in anything resembling an organism. Assembly and concentration of interacting biomolecules without a bounding membrane would not be possible. Without harvesting and regulating the flow of energy, thermodynamic disequilibrium could not be maintained. And the lack of a replication mechanism would render reproduction impossible [54]. Another hurdle for life is the 2nd law of thermodynamics which generally disfavors the assembly of macromolecules. In fact, life represents islands of order in a universe in which entropy is constantly increasing. Only the dynamic activity of life can maintain the stability of these islands for a limited amount of time.

Nevertheless, life is present on our planet and arose as early as it possibly could when Earth cooled down to allow oceans of liquid water on its surface [55]. Life was already present at least 3.5 billion years ago, based on stromatolites which were dated that old [56]. Very strong proof for the presence of fossils goes back 3.7 billion years ago [57] and the isotopic fractionation typical for life (preference of lighter isotopes as they require less energy to process) can still be observed in 4.1 billion old minerals [58]. It is unclear whether life originated on our planet, but given that life's composition resembles roughly the composition of the early oceans on Earth seems to point in this direction. Panspermia is another possiblity, but mostly only within the interior solar system, specifically Mars [59]. A transferral of life from some other solar system to Earth seems statistically exceedingly unlikely [60], but is not impossible [61].

In summary, current evidence does not let us conclude what the probability of the origin of life is. We also do not know how life originated on our planet, not when, not even in which type of environment. Currently, hydrothermal vents are favored [62], but it could also be Darwin's little pond [63] or some other type of environment [64]. Thus, we could be the only life in the universe or on the other extreme side, life may be fairly common in the universe. Given that scenario, several authors tried to address the frequency of the origin of life using a statistical approach.

## 4. Presence of Life and Its Impact on Astrophysics

In this section, we show how the existence of life may impose constraints on astrophysics. To date such constraints have not been employed in astrophysical theory, although the well-known astrophysicist, Fred Hoyle, concluded after a detailed quantitative study that the probability of the origin of life is a cosmological problem [65] [66].

### 4.1. Probability of the Origin of Life

There are no known laws of nature, which govern or drive the transformation of non-living matter to living matter. Consequently, our first assumption has to be that abiogenesis is based on probability. The purpose of this section is to explore the probability of the origin of life from non-living matter with emphasis on the impact on astrophysics.

Let $P$ be the probability that life can emerge. As always $0 \le P \le 1$. Since life exists, it is clear that $P > 0$. We do not know the value of $P$, but it may be a very small number, so it is convenient to express it in scientific notation: $P = 10^{-x}$. We employ the letter, $x$, to indicate that it is an unknown quantity.

[65] [66] calculated $x = 40000$, which is the largest value of $x$ ever calculated. Life is obviously present. There are however doubts, that the above approach by Hoyle and his colleagues is appropriate to calculate the probability of the origin of life. [67] estimated $x = 1018$, [68] $x = 139$ and [69] $x = 100$.

Even if the lowest of these values is correct, it means that the origin of life is essentially impossible according to our current understanding of astrophysics. Therefore, chance alone can not explain the origin of life as suggested by [70]. There may be an intrinsic property of matter and energy to coalesce to greater complexity and eventually life [71]. However, as this notion is usually considered quite speculative, we stick—at least for now—to the assumption that the origin of life is a chance event.

Following our discussion in Section 3, life could have arisen relatively fast, essentially as soon as Earth became habitable. The origin may have taken as little as thousands of years for a first organism that could be considered life to a value of 10 million years as suggested by [72]. [73] suggested that it took 10 million years for the first cyanobacteria to evolve. However, cyanobacteria are already relatively complex microorganisms, and any first life form must have formed significantly faster. Thus, for our calculations we use a range of $10^3 \le t \le 10^7$ years. Below, we calculate the range of $x$-values this time interval corresponds to.

The time for life to emerge is crucial to understanding the origin of life in the universe. The probability per unit time is: $\frac{10^{-x}}{\Delta t}$. Clearly the number of times life emergences, $N$, is proportional to the total time, $t$. Thus:

$$\boldsymbol{N} = \frac{\boldsymbol{t}}{\Delta \mathrm{t}} 10^{-x} \tag{1}$$

Solving for $x$ leads to:

$$x = \mathrm{Log}\left[\frac{t}{N\Delta t}\right] \quad (2)$$

where Log is the logarithm to the base 10.

Based on the previously cited references we provisionally assume life originated 4.0 billion years ago on Earth, thus about 0.5 billion years after Earth's formation 4.54 billion years ago. If the origin of life occurs once, $N = 1$. $\Delta t = 1$ year and $t = 0.5 \times 10^9$ years. Equation (2) yields: $x = 8.7$.

The above simple calculation was performed assuming that the Earth is the only habitable planet in the universe, which it is not. So, we must multiple Equation (1) by the number of habitable planets in the universe, $n$. So, we have:

$$N = \frac{nt}{\Delta t} 10^{-x} \quad (3)$$

Solving for $x$ leads to:

$$x = \mathrm{Log}\left[\frac{nt}{N\Delta t}\right] \quad (4)$$

The value of $n$ is not known, but a recent estimate is: $n = 5 \times 10^{22}$ (Quirrenbach, 2024, private communication), which leads to: $x = 31.4$ assuming Earth is the only planet on which life originated despite $10^{22}$ estimated habitable planets. While this goes against mainstream expectation of astrobiologists, we do not currently have any evidence for other life in the universe, so will go with that assumption for now. We emphasize again that we do not know the value of $x$. But, if indeed $x > 31.4$ then we would conclude that our current astrophysical understanding of the universe leads to the conclusion that life did not emerge on Earth or any other planet in the universe in the time frame of 0.5 billion years.

Next, we consider panspermia for the origin of life, the hypothesis that terrestrial life arrived on Earth from elsewhere in the universe. So, instead of assuming 0.5 billion years for life to emerge, we can assume a longer period. The first stars formed about 200,000,000 years after the Big Bang, Romeel (2024, private communication), and evolved rapidly, in about 5,000,000 years. Consequently, we assume $t = 13.575$ billion years assuming the Big Bang occurred 13.78 billion years ago. Equation (4) yields: $x = 32.8$. We do not know the value of $x$. But, if $x > 32.8$ then we would conclude that our current astrophysical understanding of the universe leads to the conclusion that life did not emerge on Earth or any other planet in the universe in the time frame of 13.575 billion years. So, considering panspermia does not help lowering the x-value.

The relationship between $x$ and the time that life has available to evolve according to the standard model of cosmology, which maintains that the universe is 13.78 billion years old, is depicted in **Figure 1**. This figure makes graphically clear that the time intervals available according to the standard theory makes little difference in the value of $x$ required for life to emerge. We do not know the value of $x$, but if $x > 32.8$ then more time is required to accommodate the of life in the universe. The same can be said for $x > 31.4$.

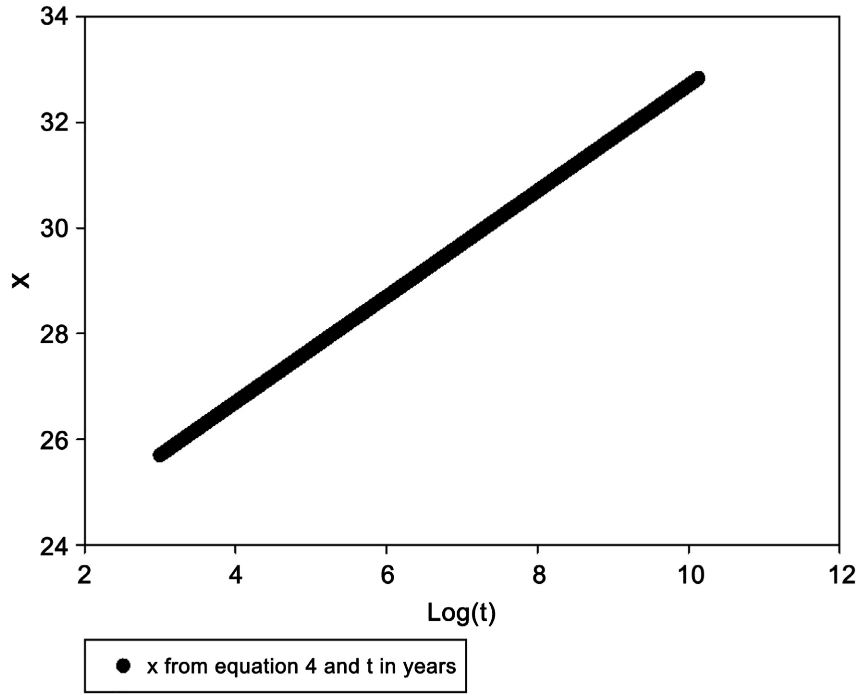


**Figure 1.** $x$ vs. Log($t$).

[65]-[69] previously estimated that $x \geq 100$ whereby such large values of $x$ would lead to the conclusion that life did not arise on Earth or any other planet in the universe in the time interval dictated by the Big Bang theory, 13.8 billion years. However, more recent work indicates that the time frame required for life to emerge is: $10^3 \leq t \leq 10^7$ years. Employing Equation (4), this time frame leads to the range of $x$: $25.7 \leq x \leq 29.8$. This range of $x$ would lead to the conclusion that life most likely did arise on Earth or elsewhere in the universe. However, we note that the upper value of $x = 29.8$ is not far from $x = 31.4$.

The values of $x$ we have just derived above are relatively small. Consequently, we have shown that for life to emerge on Earth or on any other planet in the universe, $x$ must be a small number. The value of $x$ is not known, but if it is a large number then it means that current astrophysical understanding of the universe leads to the conclusion that life did not arise on Earth or any other planet in the universe in the time frame of 13.5 billion years. If that is the case, this circumstance would impose serious constraints on astrophysical theory as we show in the next sections.

## 4.2. Cosmology

### 4.2.1. Standard Theory

A 13.8-billion-year-old universe is not sufficient for life to emerge, if $x > 31.4$ or $x > 32.8$. Assuming the validity of the standard model, this can only be achieved if the universe has gone through more than one iteration, that is the oscillating universe must correspond to our universe. This means that astrobiological constraints would lead to the conclusion that the repulsive effect of dark energy must wain. If future observations show that this is not the case then it would mean that the standard theory would be false.

Assuming we are living in a cyclic universe, then we need to add a new variable to Equation (3), $\alpha$, which is the number of universes preceding ours. However, with each universe we have $n$ more planets, so Equation (3) becomes:

$$N = \alpha^2 \frac{nt}{\Delta t} 10^{-x} \quad (5)$$

Solving for $\alpha$ leads to:

$$\alpha = \sqrt{\frac{N \Delta t}{nt} 10^{x}} \quad (6)$$

If we assume as above $N = 1$, $\Delta t = 1$ year, $t = 0.5 \times 10^9$ years and $n = 5 \times 10^{22}$ we obtain **Figure 2** from the above equation for the number of cycles required for the origin of life to be a certainty, that is $N = 1$, as a function of the quantity, $x$. Thus, assuming we are living in an oscillating universe, we have shown that life will emerge even if $x$ is a very large number.

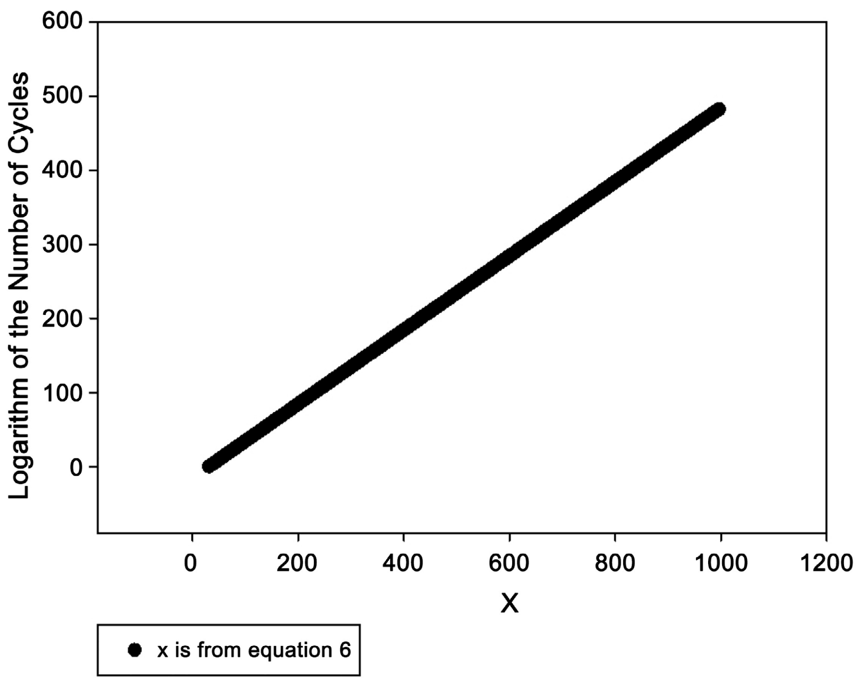


**Figure 2.** Number of cycles vs. $x$.

### 4.2.2. Taub-NUT Universe

In the Taub-NUT universe, there are two scenarios for the origin of life, whereas in the standard model of the universe there is only one scenario, namely the cyclic universe.

First Scenario—No Time Limit

In the Taub-NUT universe, there are no time constraints that is the universe does not have a definite age because there was no Big Bang. We solve Equation (3) for the age of the universe.

$$t = \frac{N\Delta t}{n}10^{x} \quad (7)$$

We employ this equation to calculate the minimum age the universe must be in order for the of life to be a certainty, that is $N = 1$. As above $\Delta t = 1$ year. The value of $n$ is larger than the above value because the Taub-NUT universe is much larger than the largest observed distance according to the standard theory of cosmology. Because supernova observations do not extend to large enough distances we do not know the finite size of the Taub-NUT universe. As shown in [42], based on extrapolating from current supernova observations, its size is: 167,534 Gpc, whereas the largest observable distance according to the standard theory of cosmology is: 44.945 Gpc. So, assuming the validity of euclidean geometry, we obtain: $n = \left(5\times10^{22}\right)\left(\frac{167534}{44.945}\right)^{3} = 2.6\times10^{33}$.

Figure 3 shows the relationship between $x$ and the minimum age the universe must be in order for life to be a certainty, that is $N = 1$. We show this relationship in the range: $1 \le x \le 1000$. Although there is no time limit in the Taub-NUT universe most of these values are in serious conflict with our present understanding of astrophysics as we elaborate below.

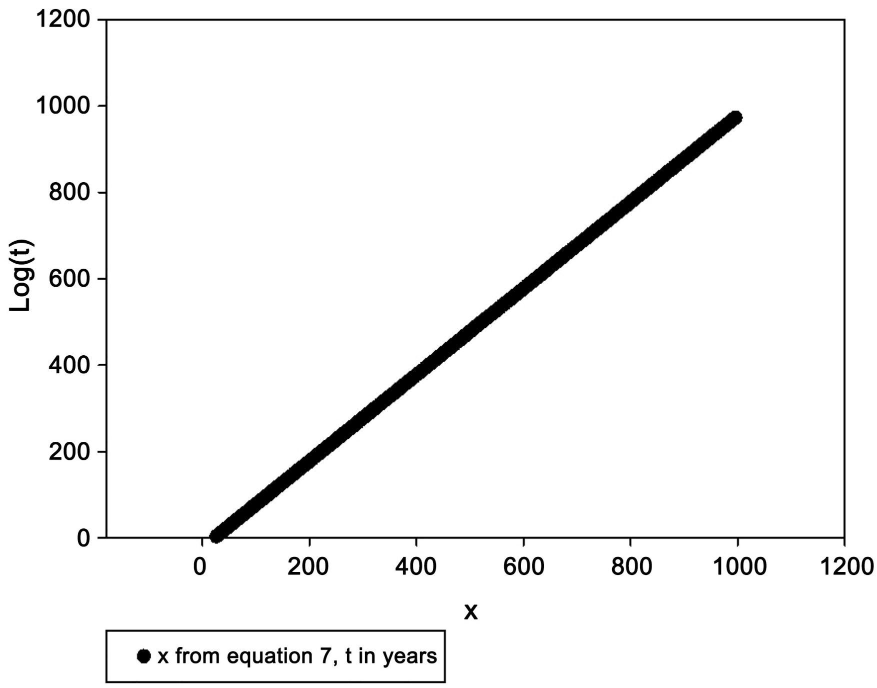


Figure 3. Time vs. *x*.

But, as described above it may be that the true value of $x$ is in a much narrower range around the crucial value of $x > 31.4$ or $x > 32.8$, so we present in Figure 4, the relationship between $x$ and the minimum age the universe must be for life to be a certainty in the range: $25 \le x \le 35$.

Second Scenario—Time Contraction

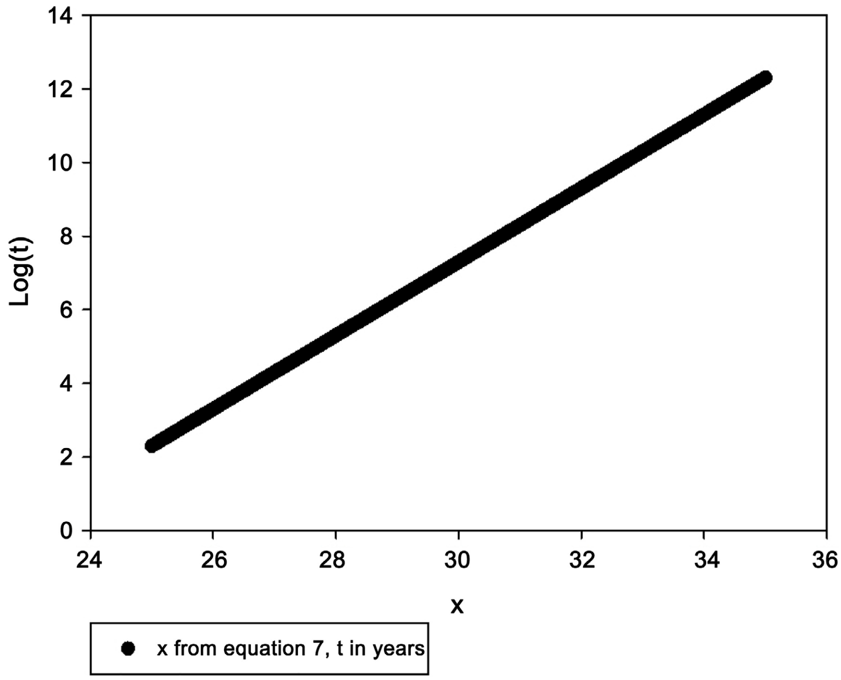


**Figure 4.** Log($t$) vs. $x$.

Einstein's theories of relativity predict time dilation, the slowing down of time. The standard theory of cosmology predicts that time dilation is also a cosmological phenomena, specifically the greater the distance of a cosmic object is, the more time slows down. Time dilation has been observed in distant supernova [74]-[77].

In the Taub-NUT universe. time dilation initially increases with distance of cosmic objects in agreement with observations, but at a certain distance it reaches a peak and thereafter decreases. The distance at which this occurs is beyond current supernova observations. Eventually it reaches a value of 1, the value it has on Earth and Earth's near environment. But, then it assumes a value less than one until the end of the universe. This means time contraction or the speeding up of time. This is a new phenomena, which is not part of special relativity or the standard theory of cosmology.

We now show how time contraction can explain the origin of life in the universe. Equation (7) must be modified to take into account the relativistic time. In both the Taub-NUT universe and the standard theory of cosmology, it is proportional to $(z + 1)$, where $z$ is the shift of spectral lines. This is accomplished by setting: $\Delta t = (z+1)$. Equation (7) becomes:

$$t = \frac{N}{n}(z+1)10^{x} \tag{8}$$

From [42], it is clear that: $(z+1) \geq 0$. It follows that $t$, the time for life to emerge with certainty ($N = 1$) can assume any value regardless of how large $x$ is. So, the problem of life having sufficient time to emerge has been solved, but another has arisen: the transport of microbes from the far reaches of the universe to Earth. Once again, we state there is no time limitation in the Taub-NUT universe, so microbes travelling at any speed will eventually reach Earth. The problem is survivability.

If microbes can survive to the next habitable planet [78] from which new microbes could emerge most likely through hypervelocity ejection during impact events [79]-[81], then planet hopping may be the most likely way that microbes could have reached our planet. This scenario means that panspermia might be responsible for life on Earth [82] [83]. Planet hopping over intergalactic distances also means that life might be widespread in the universe. However, many astrobiologists would consider this scenario highly unlikely due to long travel times in interstellar space, high amounts of radiation exposure, and some arguments favoring an origin of life on our home planet [53].

We have completed our discussion of astrobiological constraints on cosmology. We now turn to a discussion of astrobiological constraints on other areas of astrophysics.

### 4.3. Neutron Stars, White and Brown Dwarfs

As mentioned above it is widely assumed that neutron stars as well as white and brown dwarfs do not evaporate. Thus, the universe would end up consisting of dead cosmic bodies. But, this may be contrary to life in the Taub-NUT universe, which depending on the value of $x$, may require longer times then it takes for stellar objects to become stellar corpses. Consequently, astrobiological constraints may require that neutron stars, white and brown dwarfs evaporate. Recently, it has been shown that neutron stars and white dwarfs do evaporate [84]. Then new stars will form and this process of birth and death of stars will go on and on. Thus, depending on the value of x, life in the Taub-NUT universe coupled with our understanding of stellar evolution may require a universe, which repeatedly goes through stages of birth, death and rebirth.

#### Proton Decay

After the evaporation of neutron stars, white dwarfs and brown dwarfs, new stars and planets can not form, if protons decay. Consequently, depending on the value of $x$, astrobiological constraints may lead to the prediction that protons do not decay in agreement with the standard model of elementary particle physics and in disagreement with other theories. This astrobiological constraint on protons may be necessary due to the large times that may be required for life to emerge in the universe and travel to Earth, if the second Taub-NUT scenario is the correct explanation for the origin of life.

## 5. Conclusions

The value of $x$ in the above equations, which is a measure of the probability of origins of life, is not known. If the standard theory of cosmology is correct and if $x > 31.4$ or $x > 32.8$ then given the constraints of the standard theory of cosmology, which maintains that the universe is only 13.78 billion years old, astrobiological considerations lead to the conclusion that we must reside in a specific type of universe, namely the oscillating universe. Otherwise, there is not sufficient time for life to emerge. Consequently, these considerations would predict the Big Crunch is the fate of our universe, meaning the effect of dark energy must wain. If future observations indicate that this will not happen, then it means that the standard theory of cosmology is not correct. These conclusions are based on the case $N=1$ for the number of origins of life in the universe. We do not know what the number of origins of life is in the universe, but the most conservative assumption is $N = 1$, because at present, we do not have evidence of any other origin of life in the universe.

We presented two scenarios on how life could have emerged in a Taub-NUT universe. The Taub-NUT universe has no time limitation because it maintains there was no Big Bang. This lack of time limit means there is sufficient time for life to emerge through abiogenesis. Secondly, we suggest the possibility that life first appeared in the very distant Taub-NUT universe where time contraction occurs. These scenarios are not mutually exclusive, meaning that they both may play a role in the origin of life in the universe. If $x$ is a large number, then both of these scenarios impose constraints on astrophysical objects. Specifically, neutron stars, as well as both white and brown dwarfs, must evaporate. Also, it demands that protons do not decay.

The value of $x$ is not known. Yet, hardly anyone in the field of astrobiology thinks that the origin of life is extremely unlikely, that is, astrobiologists generally assume that $x$ is small, meaning life on Earth is not an exceptional case, consequently origins of life are common in the universe. However, taking a conservative approach, we also have to admit that we do not have evidence for other life in the universe aside from Earth, and given that we still don't know how life occurred on Earth, life may be exceedingly rare or even unique to Earth, in which case, it would have the above repercussions on astrophysics.

The existence of life demands that the universe must have properties that allow the origin of life. It is usually assumed that abiogenesis is a probabilistic event. The probability of the origin of life by chance can be expressed as: $P=10^{-x}$. We have shown that the astrobiological quantity, $x$, is an important quantity not just for astrobiology, but also for astrophysics, especially if $x>31.4$ or $x>32.8$. Earlier work leads to values of $x$, which are so large that some authors came to the conclusion that the origin of life by chance is impossible. On the contrary, we have shown no matter how large $x$ is, astrophysics can accommodate the origin of life.

## Acknowledgements

Many thanks to Dr. and Mrs. William McCormick, whose generous support has provided the prerequisite financial basis and most importantly, the necessary time to complete this project.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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