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# Non-Physicality of Time and Introduction to Time-Invariant Cosmology

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**Abstract**

Today's understanding of the information relates information to elementary particles. Recent research suggests that there is around $6 \times 10^{80}$ bits of information stored in all the particles of the observable universe. The open question is how this information stored in particles is related to space and time. We have experimental evidence that particles exist in space, and we do not have experimental proof that particles exist in some physical time that is the 4th dimension of space. Several studies deny the existence of physical time. Non-physicality of time opens a new perspective where time is only information that exists in the space, which itself is timeless, we can say time-invariant. Elementary particles move, and irreversible material change runs in the time-invariant space. On the micro and macro scale, there is no physical past, and there is no physical future. Time is only information of motion and the numerical order of changes. The model of time as an information unit quantum world with cosmology. Particles and stellar objects all move in the same time-invariant space, and time is the numerical order of their motion. The universe does not exist in some physical time; it exists in a time-invariant space. Linear time past-present-future exists only in the human mind.

**Keywords**: information, time, space, universe

## 1. Introduction

Since the famous quote of St. Augustine, "What, then, is time? If no one asks me, I know what it is. If I wish to explain what it is to him who asks me, I do not know", the concept of time has received attention from philosophers and scientists. If all the history of physics can be seen as an evolution of the models regarding the background of processes, today the debate about the role of time is far from being concluded. The most important problem probably regards whether or not time is a fundamental quantity of nature (namely a primary physical dimension which flows on its own in the universe, i.e., an external parameter with respect to which the dynamics of events takes place). This issue acquires a relevant significance when one attempts to provide a treatment of the quantum gravity regime, since general relativity does not seem to possess a natural time variable, in the sense that implies that the material change is described in terms of a relation among equal footing variables associated to specific physical clocks, while quantum theory relies quite heavily on a preferred time, an absolute idealized time as a medium where events take place.

To throw new light on the time conundrum, we start with the consideration that, in the Special Theory of Relativity, developed by Einstein in 1905, time was introduced as a 4th dimension of space, according to the following equation

$$X_4 = ict \quad (1),$$

where $X_4$ is time as a $4^{th}$ dimension of space, the so-called coordinate time, $i$ is an imaginary number, $i^2 = -1$, $c$ is the velocity of light, and $t$ is time as the duration of light motion on distance $X_4$. In the original version of Special Relativity, $X_4$ is an imaginary coordinate. This peculiar feature of time in Einstein's theory implicitly encodes the understanding that past and future do not exist as physical realities but are only man-made inventions in order to organize events. Einstein was aware that there is no physical past and no physical future; a photon moves only in space. Therefore, he developed a model where the 4th coordinate of space-time is imaginary. In his book *The Special and General Relativity*, he wrote: "If we replace $x, y, z, \sqrt{-1}ct$ by $x1, x2, x3, x4$, we also obtain the result that $ds^2 = d_{x1}^2 + d_{x2}^2 + d_{x3}^2 + d_{x4}^2$ is independent of the choice of the body of reference. We call the magnitude $ds$ the "distance" apart of two events or four-dimensional points. Thus, if we choose as time variable the imaginary variable $\sqrt{-1}ct$ instead of the real quantity $t$, we can regard the continuum space-time, in accordance with the special theory of relativity, as an "Euclidean" four-dimensional continuum" [1]. In the original version of Special Relativity, the space-time continuum is imaginary, a model only, which means it does not have a physical existence.

Einstein's introduction of coordinate time $X_4$ in physics led to the view that time is the fourth dimension of space, which is an oversimplification. In Special Relativity, we have to distinguish between coordinate time $X_4$ and proper time $t$, which is the duration of photon motion in space. After Einstein published special relativity, the view prevailed that time is the 4th dimension of space, although nobody has observed time as a dimension of space. In Newton's physics, time was an abstract physical quantity that runs in the universe, that plays the role of the independent variable of physical evolution; with Einstein, time became a part of space, a medium in which material change runs. This misunderstanding regarding the interpretation of time happened because, in the 20th century, physicists missed the fact that coordinate time is Einstein's theoretical invention, and proper time is the duration of material change that runs in space, and we measure them by clocks. Now, in the 21st century, several eminent physicists are denying the existence of time as a 4th dimension of space, namely that time is the medium in which material changes run, by suggesting that, at a fundamental level, the background of events is timeless and time exists as an emergent quantity. In this article, we explore the 21st-century view that coordinate time $X_4$ and proper time $t$ both have no physical existence; they exist only as information. This view supports Einstein's original vision of time. He denied the existence of the past and the future. That is why he introduced a model of space-time continuum, which was misunderstood by most of the physicists of the 20th century.

Since the pioneering study of Szilard in 1929, suggesting that information fixes the modalities of evolution of a system, the issue of information content of physical processes has attracted several scientists [2]. In particular, in 1961, Rolf Landauer stated that information is physical, i.e., can be considered as a physical aspect of the world, in that the physical state of a system incorporates the "information" which has the potential to be processed and transferred thus creating time intended as information flow through evolving systems [3]. Later, J.A. Wheeler considered that each entity of the universe acquires its features from information, i.e. that space, time and matter as vehicled expressions of an informational matrix "at the bottom of the world" and therefore, that information is the primary constituent of the world, by suggesting the view of "it from bit" [4]. The idea of a physical information has then led to several puzzling developments such as the black hole information paradox and the holographic principle [5].

However, if time emerges from the information flow through evolving systems, how is this information flow processed and transferred? What is the intermediary of this information, and what are the real fundamental features of this information flow?

Today's physics view is that information is stored in elementary particles. By utilizing Shannon's information theory, recent research has computed that each particle in the observable universe contains 1.509 bits of information and that all the baryonic matter in the observable universe stores around $6 \cdot 10^{80}$ bits of information [6]. This result raises a question about how many bits of information are in the entire universe, which also includes the unobservable part of the universe. In this regard, NASA measured that the universe has an Euclidean shape [7], and so the number of bits of information in the infinite universe should be infinite. The important question of our research lies in providing a new understanding of the features of information, i.e. in asking ourselves whether information exists also in time or only in space.

Special relativity teaches us that the photon can be seen as a classical carrier of information. In a similar way, quantum physics implies that elementary particles are carriers of information whose bits (represented by their specific properties, such as spin, charge, etc...) interact with each other according to quantum laws, and this information about particles and their interactions is transmitted by fields permeating the universe. The transfer of information generated by photons or massive elementary particles occurs in space and time is only a mathematical measure of this transfer, which enters existence when it is measured by the observer.

Let us consider, for example, a photon coming from the Sun. It is well known, this photon takes 8 minutes and 27 seconds to reach from the Sun to the Earth. The fact is that we do not have any perception or any experimental confirmation that this photon moves in time. Time is a duration of photon motion in space when measured by the observer [8]. This simple experimental fact confirms that a photon carries information only in space, and the duration of photon motion is information that describes motion.

In [9] Liu and Zhu developed a unifying treatment of the information in cognition and Shannon information, by suggesting a General Information Theory where information can be seen as probability and time is interpreted as a special measure of space probability and therefore as a measure of information. Liu's and Zhu's General Information Theory seems to contradict the fact that information exists only in space and time is information that describes the motion of the system under consideration. In fact, it proposes that information exists in time and that the entropy of information increases in time. The weak point of this model is that there is no experimental evidence to support the existence of information in time and the increase in information entropy in time. In general, we do not have experimental data in physics proving that time is a medium in which the entropy of a given system increases. We observe an increase in the entropy of a given system only in space. According to the authors of the present paper, the idea that time is just information is plausible and needs in-depth research. This paper aims to introduce some considerations about this topic that have the potential to further fuel the debate regarding the nature of time.

The structure of the paper is the following. In chapter 2, we analyse the concepts of time and information in a time-invariant space. In chapter 3, we make some considerations regarding the parallelisms of our view of time with other famous views of time that are present in the literature. Finally, in chapter 4, we summarize the main results of the paper.

## 2. Time as information of the numerical order of events that run in time-invariant space

Clocks and time are human inventions to measure the velocity of motion of physical objects in time-invariant space. The increase of entropy of a given system occurs only in time-invariant space, and we measure the increase of entropy with clocks that are invented by humans [8]. Imagine we have a source of information and the receiver of information. On the way from the source to the receiver, a part of the information is lost due to the technical properties of the information line. In this case, the entropy of information increases, but not in time; it increases only in time-invariant space.

Time as information gives a new perspective on entanglement. Seeing entanglement occurring in some physical time generates unsolvable problems, and seeing information occurring in time also leads to misunderstandings. Time-invariant space is the direct medium of entanglement [10].

Today's understanding of information is bound to elementary particles [6], and these particles exist only in time-invariant space. Fundamental unit of information 1 bit is time-invariant; it exists only in a time-invariant space [11]. Information, elementary particles, and the entire universe exist in time-invariant space [8].

Vlatko Vedral published an article where he explored what came first, physics or information: "In this paper, I discuss the question: what comes first, physics or information?" [12]. This question is of great importance because it shows the main misunderstanding of today's physics, namely, that things happen before and after in time. His question shows that he sees physics development in some physical time in which things appear. We have another view where physics and information exist in the time-invariant space. All things happen in time-invariant space, yes, some happen before, others later, but only in the sense of the numerical order. The fundamental unit of numerical order of events that run in time-invariant space is Planck time [13]. In this perspective, time is the information about the numerical order of events that run in time-invariant space. There is no physical time; time is a man-made information that serves as an indispensable tool of physics to describe the flow of events that occur in time-invariant space.

We can therefore write the following fundamental equation:

$$time = information \qquad (3).$$

Equation (3) is valid from the microscale of elementary particles to the macroscale of supermassive black holes. There is no proper time, there is no coordinate time, there is no arrow of time, there is no cosmological time, and there is no thermodynamical time [9]. The only time that exists in physical reality is the numerical order of events that run in time-invariant space.

In [14-16], Elze proposed that time can be considered as an emergent discrete quantity related to the increasing number of incidents, i.e., observable unit changes, corresponding to the coincidences of points of the trajectory of the system with appropriate detectors. In Elze's model, only the observable unit changes which correspond to the results provided by opportune detectors have physical reality and the duration associated with these changes is only a man-made construct that enters existence when it is measured by an observer: time measured by clocks provide only the information regarding the numerical order of these observable unit changes that run in a time-invariant space.

In a similar way, in [17] Caticha suggested that time emerges as a device to keep track of the accumulation of small changes, and it is only the correlations among the particles of interest and the clock that are observable and not their "absolute" order. The treatment of Caticha seems to anticipate the view of time as information about the numerical order of events in a time-invariant space: time is a mechanism that aims to keep track of the accumulation of small changes in the sense that it is a mathematical quantity that measures the information that can be obtained from the small elementary changes of the evolving system into consideration.

Finally, in [18] Prati showed that, by considering in a timeless Hamiltonian framework a complex physical system S that can be separated in a subsystem S2 whose dynamics is described, and another cyclic subsystem S1 which behaves as a clock, by changing the separation inside S we obtain different measuring systems of the dynamics taking place in S. The fact that the ticking of each subsystem which acts as a clock provides a different reference system to describe the dynamics means that time does not exist as a physical reality but provides only a mathematical measure of the information associated with the dynamics of the evolving system, which is entangled with the system acting as a clock.

The relation between time and information was examined in detail by Scott M. Hitchcock in [19], where he suggested that time can be seen as the result of the conversion of the flow of energy between evolving systems into information. According to Hitchcock's model, time is a label or number associated with processed signal information that is stored in a detector or a memory. Hitchcock concluded his analysis affirming that "this flow of information can be computed inside a 'time independent' quantum computer in which fundamental irreversible quantum processes coupled to reversible information flow in the classical environment can be used to build complex hierarchical systems through the phenomena of collective excitations" [19]. The view of time as information about the numerical order of events that run in a time-invariant space, introduced in this paper, can go a step ahead with respect to Hitchcock's model. It explains that the flow of information associated with time can be computed in the picture of a time-independent computer because this information, which implies an elementary coupling between fundamental irreversible quantum processes and reversible classical processes, thus giving rise to complex hierarchical systems, runs in a time-invariant space where time does not exist as a primary physical reality. Our model explains in a clear way in what sense time emerges from the conversion of energy into information. This occurs because time is not a physical reality but exists only as a sequential numerical order that allows us to keep track of changes in a time-invariant space.

In the view explored in this paper, the numerical order of events that take place in a time-invariant space can be defined as the fundamental time, whose most elementary unit is Planck time. Time, as the duration of events, is an emergent time that enters existence in the process of measurement. Emergent time can therefore be seen as the amount of information regarding the dynamics of the evolving system into consideration, which is given by a sum of elementary Planck times on the based on the following equation [13]:

$$t = t_{P1} + t_{P2} + t_{P3} + \cdots + t_{PN} = \sum_{i=1}^{N} t_{Pi} \quad (4).$$

In this picture, Planck time $t_P$ is the one bit of information. Planck time is a discrete unit of numerical order of change. Every elapsed time is the sum of Planck times. Similarly, light is composed of discrete quanta of energy called photons.

Imagine you are the observer who moves in space from point A to point B. The distance between A and B is composed of n Planck lengths. Each Planck length corresponds to one Planck time. You move from one Planck length to another Planck length. In the time-invariant space you experience as Now, you can only be on the one Planck length. When you are on the Planck length n, you cannot be on n-1 or n+1. No matter which Planck length you are in, you are in the time-invariant space. Each Planck length corresponds exactly to one Planck time. Duration of your motion from A to B is the sum of Planck times according to equation (4). Every motion and every material change in the universe has the fundamental unit of change, which is Planck time. The paradigm shift is the insight that change and motion run in time-invariant space and that time is merely the numerical order of change, i.e., motion. Einstein's famous quote has to be fully considered as a scientific fact: “The distinction between the past, present, and future is only a stubbornly persistent illusion”. Material changes in the universe run in time-invariant space. There is no flow of some physical time in which changes run; the only flow of changes run in time-invariant space.

German philosopher Rudolf Carnap exchanged several letters with Einstein, and he wrote in his biography that Einstein was worried about the Now: “Einstein said the problem of the Now worried him seriously. He explained that the experience of the Now means something special for man, something essentially different from the past and the future, but that this important difference does not and cannot occur within physics. That this experience cannot be grasped by science seemed to him a matter of painful but inevitable resignation. So he concluded 'that there is something essential about the Now which is just outside the realm of science” [20]. With the model of time-invariant space where time is information, Einstein’s vision on time is integrated in physics.

## 3. Time as Information and Time in Daoist philosophy

Change and motion have real physical existence, and time is their numerical order and exists only as a mathematical parameter quantifying the amount of information associated with the material changes of evolving systems. Numerical order is information, and in this respect, time is just information. The realization that time has no physicality is a leap in the paradigm of physics that we urgently need if we want to step out of the perspective of space-time, which is the paradigm of the 20th century. The paradigm of the 21st century is a time-sensitive space where time is just information about material changes that run in time-invariant space.

Events run in time-invariant space. When an event X is in existence, the event X-1 is not in existence anymore, and the event X+1 is not in existence yet. When an event X+1 enters existence, the event X is not in existence anymore, and the event X+2 is not in existence yet. Past and future do not exist because they are non-existent. The flow of change runs in a time-invariant space and is irreversible.

Carlo Rovelli denies the existence of physical time [21], but he provides no clear explanation of what we measure with clocks. We can deny the existence of physical time, but we cannot deny that the existence of time in physics is the result of the measurement outcome. Carlo Rovelli has no clear interpretation of time as duration, which, in physics, is indispensable. In a similar way, Barbour published an article about the nonexistence of physical time in 2009 [22], and he also did not give a clear interpretation of the duration that we obtain by clocks.

Our model presents time as information that has only a mathematical character, because duration has the attribute of energy as elementary particles do. Time as duration is an emergent physical quantity that enters existence in the process of measurement. No measurement means no time. The idea that with clocks we measure a time that runs in the universe on its own belongs to the history of physics. Information can be carried by elementary particles [6] or it can have a mathematical character exclusively, as is the case with time as the numerical order of events that run in space; time as information exists only on the mathematical level of the universe:

- Information based on energy substratum stored in elementary particles [6]
- Nonmaterial information that exists only in the mathematical universe (Planck time $t_P$ as a fundamental unit of numerical order of events, number $\alpha$, fine structure constant $^1/_{137}$, and entire mathematics is a kind of information that has no energy substratum).

The idea that time flows and has a direction is still alive in today's physics. An article was published discussing that, at the quantum level, time can have two arrows, one pointing from past to future, and the other pointing from future to past [23]. Elementary perception confirms that quanta and supermassive black holes move only in space and that time is the duration of their motion. Time-symmetry model is a scientific misunderstanding that is the result of the false idea that motion occurs in some physical time [24]. Motion occurs in time-invariant space only, and time travel on the micro and macro level is categorically excluded [25]. Closed time-like curves of Kurt Gödel are a theoretical model that is non-existent in physical reality [26]. The idea that someone could move in the past and kill his father is out of question. Hawking's chronology protection conjecture [27] is a theoretical model that attempts to prevent something (time travel) that is impossible on the micro and macro levels.

The idea that the space-time model described some existent physical reality was rooted so deeply in the minds of the physicists that even Feynman believed that space-time exists. He describes a positron as an electron that moves backwards in time [28]. Feynman was one of the brightest minds of 20th-century physics, and he fell into the mental trap of space-time, which is a stubborn scientific illusion that needs to be overcome to progress physics. Positron was discovered by Anderson in 1932 in a magnet cloud chamber [29] in which there is no evidence of some space-time where time would run in the direction from the future to the past. Electrons and positrons both exist in the time-invariant space.

In the space-time continuum of the Special Theory of Relativity, past, present, and future are coexisting [30]. The space-time continuum is the theoretical basis for the Block Universe, in which past, present, and future coexist. The common view in physics is that Einstein's Relativity supports eternalism [31]. Einstein's view, however, suggests that Einstein advocated a presentism philosophical view, where only the present moment is real. A rigorous empirical approach proves that the flow of physical change in the universe is irreversible and flows in the time-invariant space. Insisting on the idea that past material changes exist in some hidden past and that future material changes are hidden in some invisible future does not have scientific empiricism in it. Presentism is closer to today's scientific thought than eternalism, because it is affirmed by empiricism. Ervin Schrödinger's famous quote shows he deeply understood the time-invariant nature of space and time as information: "For eternity and always there is only now, one and the same now; the present is the only thing that has no end" [32].

On the micro and macro scale, time is a *subjective ordering device*, a term used by Wesson [33], of changes that run in time-invariant space. In physics, we experience the flow of change within the framework of psychological time. We project psychological time onto physical reality, and we observe the flow of change occurring within time. The fact is that this flow of change exists in space that is invariant to time and has a numerical order, which is time as a form of information. This means that time exists, but it has no physical existence. Einstein, Schrödinger, and some other physicists were aware of this, but the exact understanding was missing. In this article it is shown, that the flow of change has its own internal time, which is a numerical order. Paradigm change lies in the understanding that the flow of change runs in time-invariant space and does not require time as a duration, which is the result of measurement and does not have an essence of its own.

The paradigm shift in cosmology is understanding that the universe does not exist in some physical time; it exists only in the time-invariant space. The only universe that exists is the one we can observe. Everything else is just human imagination. True, some events happened earlier and some later, but they all happened in the same time-invariant space. Everything that has happened in the past million years and will happen in the next million years will happen in the same time-invariant space in which you read this article. There is nothing mystical about it; our measurement of time always happens in the same time-invariant space we experience as Now. We measure time always only in Now, because only Now (time-invariant space) exists. The idea that the universe has developed and exists in some physical linear time is a scientific illusion, a belief for which there is no experimental evidence; we must transcend it if we want to develop physics and cosmology, the paradigm shift is in replacing space-time model with the time-invariant model where time is an emergent physical quantity that enters existence in the process of measurement [8], see Figure 1.

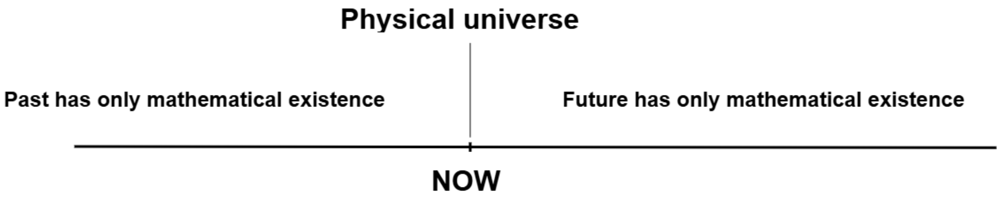


**Figure 1**: Physical universe in time-invariant space

The result of our research is that the past and future have only mathematical existence. Universal changes run in time-invariant space that we experience as Now. In the Time-Invariant cosmology, the physical past and the physical future have only mathematical existence. In a famous quote, Hermann Bondi said: "Time must never be thought of as pre-existing in any sense; it is a manufactured quantity" [33]. The view of time as numerical order can be considered a direct development of Hermann Bondi's quote. Physicists who denied the existence of physical time had the idea that the past and the future coexist in the present: "Hoyle: "All moments of time exist together" [33]. In general, this is the eternalist view. The presentist view is that only the present moment exists. Our results support the presentist view. Also, the Daoist philosophy suggests that linear time "past-present-future" is only a mental concept [34]. Ancient Chinese wisdom and modern science share the common experience that the universe exists beyond psychological time, see Figure 2.

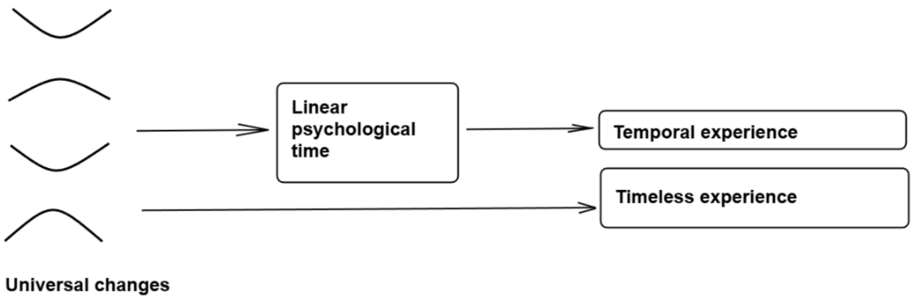


**Figure 2**: Temporal and timeless experience

The scientific experience of mainstream physics is still within the framework of psychological time. This paradigm shift is in the development of a timeless experience that has already been developed in ancient Daoist Chinese wisdom.

Time only as psychological reality has support also in Aristotle view on time: “A line is not made out of points. In the same way, time is not made-up parts considered as indivisible 'nows' “[35]. In his view, nows are not following each other and building time. Aristotle was clear that physical past and physical future do not exist: “Aristotle’s well-known paradox of the absence of time because the past no longer exists, the future does not exist yet, and the present is only a moment without duration” [36].

Time as information, Aristotle's view of time, and the Daoist view of time are compatible. They affirm that ancient philosophy and modern physics have come to the same conclusions about the non-physicality of time.

In our recent article, we developed a model of AGNs in the centre of galaxies where old matter is transformed into fresh energy that AGNs throw in intergalactic space in the form of jets or winds [37]. In our vision, which is based on the non-physicality of time and astronomical observations, AGNs are rejuvenating systems of the time-invariant universe with no beginning and no end. We will proceed with our Time-Invariant Cosmology research, where the universe does not exist in some physical time; it exists in time-invariant space we experience as Now.

## 4. Conclusions

The space-time model, where time is the 4th dimension of space, has never been experimentally proven. Time as a physical dimension of space belongs to the history of physics. Albert Einstein’s, Ervin Schrödinger's, Rovelli’s, and Barbour’s insight about the nonexistence of physical time is fully integrated in the model of the time-invariant space, where time is information about the numerical order of universal events that run in the time-invariant space; all the rest is human memory and imagination. Also, ancient Chinese wisdom suggests that the universe is a system that exists beyond psychological time. The current view in cosmology is that the universe develops in physical time. In this article, this temporal model is replaced by the model where the universe develops in the ever-present moment of the time-invariant space, where there is no past, and there is no future.

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