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An Investigation into True Reality: Observer, 5D Space, and Cognizance

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Abstract

A process of idea filtration in two distinct streams of physics i.e., 1) The dimensionality perspective of spacetime, and 2) The quantum perspective leads us to an understanding of what might be a true reality of all that we perceive. The conclusions arrived at in this paper are a bit perplexing in the sense that our perceived reality could be a manifestation of a combination of 4D + n ($n > 0$) flat space-time, universal wave function, and cognizance. The work is based on a review and analysis of the main concepts in quantum theory, relativistic physics, and cosmology. Key ideas and conclusions are filtered and logically connected to arrive at what might be a view of the true reality. A significant part of the paper is dedicated to the concept of the "observer" and the "ability of cognizance" that should accompany the "observer". Though the "observer" is central to modern physics, it is not known what constitutes observation, and the term *observer*, often open to interpretations, does not have a standard definition and hence, is lacking in clarity. In our analysis, we have argued that the environment, in which the observer-observed system is embedded, emerges as an all-knowing, cognizant, and ideal observer that has the knowledge of the observer-observed system. At a philosophical level, we link to the fundamentals of physics, "consciousness" or "ability of cognizance" as an unavoidable and key element in not only carrying out the observation but perhaps, as believed by many, having a role in shaping the reality perceived. In the review and analysis of another stream of physics, that of General Theory of Relativity (GTR) and cosmology, we examine the question of reality from a cosmological and dimensionality perspective. Research on the 4D and 5D constructs of the universe indicates that the "reality" perceived in 4D spacetime as matter, distance, time, etc., is a manifestation of a higher dimensional 4D + n ($n > 0$) reality. Theoretical research on this front points towards a 4D-spacetime embedded in a 5D or higher dimensional flat space with matter and energy being a manifestation of the higher dimensions. The flow of logic in this paper leans towards a view of an ultimate true reality that is flat 4D + n (n > 0) space combined with cognizance, universal wave function, and the environment.

Keywords

Wave Function, Decoherence, Spacetime, Entanglement, Quantum, Reality, Observer

1. Introduction

In physics, the main motivation of research is always to gain an understanding of the reality of the observed physical world and to come up with models that adequately describe the universe. Each theory proposed, every observation made, and each experiment conducted represents a progressive stride in enhancing our comprehension and knowledge of diverse facets of the physical cosmos. These facets can encompass the domain of fundamental particles, the intricacies of the quantum field, or the profound origins of the universe itself.

Let us consider, for example, the insights brought forth by Albert Einstein. He associated the very geometry of spacetime with the force of gravity, overturning the conventional notion of gravity as a mere force, as espoused by Newtonian mechanics. Similarly, the groundbreaking work of Erwin Schrödinger, Heisenberg, and other scientists in early 20th century introduced us to the profound world of quantum systems through the conceptualization of the uncertainty principle, probabilities, and wave function.

However, while recognizing the remarkable achievements made so far, a comprehensive understanding of the physical world and its underlying reality remains tantalizingly beyond our grasp, as we shall see in the discussions later in this paper. One of the paramount conundrums confronting us lies in the transition from the probabilistic nature of quantum systems to the deterministic macroscopic world that we directly observe. In our pursuit of uncovering the true nature of the observed and perceived universe, it is imperative that we delve into profound inquiries concerning the "true nature" or the "fundamental essence" of entities such as Space, Time, and Matter.

In this paper, we address certain fundamental questions that underpin our understanding of the nature of reality:

The Deviation between the Underlying and Perceived Reality:

We have delved into the intriguing question of whether the true, underlying reality of the universe fundamentally differs from the reality as we perceive and observe it. This inquiry challenges the instinctive grasp of the world that we have acquired in our macro world existence. Here we have contemplated whether our intelligence and the sensory apparatus are adequate to provide us with a true representation of the cosmos.

The Role of Observer:

Given that our understanding of reality hinges on the observation and hence the “observer”, we have investigated the aspect of the role of the “observer” in shaping our understanding of reality?

Consciousness and Cognizance:

Rocognising that “Observation” necessitates some level of “Consiousness” or the “ability of Cognizance”, we examine latest works in quantum decoherence and einselection to arrive at conclusive understanding of the universality of the “ability of cognizance” in an open system, which is the universe.

True nature of the physical world:

We have reviewed existing works on spacetime, general relativity and cosmology to figure out if the observed reality can be distilled to a mere geometric form with in a multi-dimensional 4D + n (n > 0) spacetime.

A true picture of the underlying reality will help us in addressing problem areas where we find differences between theory and observation or between two alternative approaches. For example, in recent times, new high redshift deep space observations of James Web Space Telescope (JWST), reveal a strong tension (Gupta, 2023) between the JWST findings and the standard model of cosmology (Robson, 2019; PJE Peebles, 1993). This raises a question mark not only about the standard model but also about the Big Bang theory. In earlier works, some physicists including this author have proposed a 4D + n (n > 0) universe (Wesson, 2012; Wesson, 2015; Wesson, 2008; Wesson & Overduin, 2013; Wesson & de Leon, 1995), Kaluza (2018), Others (Randall & Sundrum, 1999; Arkani-Hamed et al., 1998; Lidsey et al., 1997; Hossain, 2022). In 4D + n (n > 0), Big Bang, dark matter, dark energy, and even gravity have to be examined differently. Many other aspects related to the dimensionality of the universe, quantum theory, decoherence etc. have been discussed in detail in this paper. Each problem area discussed relates to some or the other aspect of the reality and only by piecing together these different underlying elements of the true reality, do we arrive at a certain holistic view.

From the beginning of the twentieth century, periodically, over every decade or so, there have been path-breaking and disruptive theories or discoveries in physics. To name a few, we have Einstien’s general theory of relativity (Saha & Bose, 1920; Einstein, 1905a; Einstein, 1920; Einstein, 1905c), wave-particle duality (Weinberger, 2006), quantum theory (Tong, 2006; Peres, 2002; Bohr, 1923; Pahlavani, 2012), Copenhagen Interpretation (Faye, 2022), Heisenberg’s principle (Busch et al., 2007; Martens, 1991; Heisenberg, 1925), collapse postulate[1], Schrodinger’s wave function (Trimmer, 1980), Feynman’s Experiments and interpretations (Feynman Lectures, 2022), Everett’s many world interpretation (Dewitt & Graham, 1973; Barrett, 2018), standard models in cosmology (Robson, 2019; PJE Peebles, 1993) and particle physics (Mann, 2010), entanglement (Einstein, 1935; Aubrun et al., 2011) (EPR), decoherence (Einstein et al., 1935), einselection (Zurek, 2003, 1998), etc. As these theories have advanced, they have branched off into highly specialized areas such as the string theory, black hole

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[1] Philosphical Issues in Quantum Theory (https://plato.stanford.edu/entries/qt-issues/).

physics, Conformal Cyclic Cosmology (Penrose, 2012), The Higgs Boson (2022), physics of the origins of the universe etc. Moreover, every advanced topic in physics is heavily cloaked in complex mathematics, and full understanding of all the diverse topics in different streams becomes a challenging task. As a result, it is quite possible that we overlook a larger picture of the true reality that might already exist and emerge if one undertook holistic studies that are cross-cutting over diverse topics. In this paper we attempt to overcome the challenge of individual complexities of each different theory, through a process of idea filtration of two distinct streams in physics i.e., 1) cosmology and dimensionality of the universe, and 2) quantum theory to arrive at a conclusive understanding, at least at a theoretical level, of the true nature of reality. The process of idea filtration hinges on the conclusive, and to the extent possible, reasonably well-validated aspects of each theory, postulate, or interpretation leading up to final conclusive arguments. This enables us to stick to the core concepts while bypassing the mathematical intricacies of each topic or theory. Topics pursued have been detailed in **Table 1** and the approach is visualized in **Figure 1**.

The underlying common aspect of different fields in physics is the "*observer*". The central positioning of the *observer* can be seen in the theory of relativity, topics in the realm of quantum theory, Schrodinger's equation (Trimmer, 1980; Einstein et al., 1935) (EPR), Everett's many world interpretation (MWI) (Dewitt & Graham, 1973; Barrett, 2018), entanglement, decoherence (Zurek, 2003, 1998), interpretations of Carrol (2022) and Greene (2011), and work on Einstein's theory by Kaluza (2018), Klien (1926), Wesson (2012), Wesson (2015), Wesson (2008), Wesson & Overduin (2013), Wesson & de Leon (1995) and many others (Randall & Sundrum, 1999; Arkani-Hamed et al., 1998; Lidsey et al., 1997; Hossain, 2022).

Table 1. Diverse topics probed in the context of true reality.

Cosmological & Dimensionality Perspective	Quantum Perspective
4D Spacetime	Heisenberg's Uncertainty Principle
General Theory of Relativity (GTR)	Schrodinger's Wave Function
Gravity	Collapse Postulate
Spacetime Curvature	Copenhagen Interpretation
Standard Model of Cosmology	EPR
4D brane in 5D Universe	Entanglement
Campbell's embedding theorem	Feynman's Experiments
Matter & Energy induced from 5D flat Space into 4D Spacetime	Everett's Many World Interpretation
	Universal Wave Function
	Decoherence, Environment & Observer
	Cognizant Environment

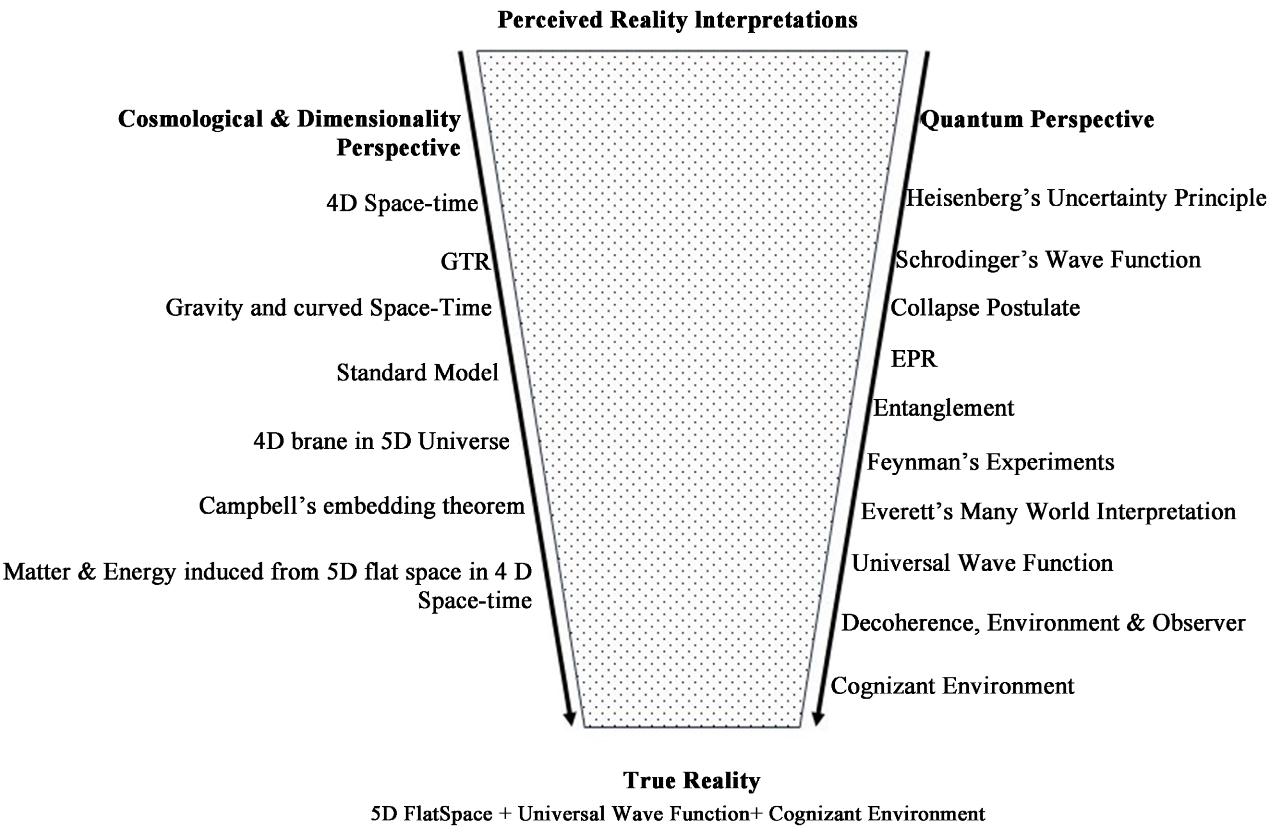

Figure 1. Visualization of idea filtration to arrive at true reality.

Our understanding of the perceived cosmic and microcosmic reality is based on two foundational fields of modern physics i.e., 1) *Cosmology*: the cosmic reality derived from the General Theory of Relativity (GTR), astrophysical observations and deductions such as Hubble's Constant (Hubble, 1929; Bahcall, 2015; Dainotti et al., 2021), red shift, and Cosmic Microwave Background (CMB) (Castelvecchi, 2020; Planck Collaboration, 2013), Standard Model of Cosmology (Robson, 2019; Peebles, 1993), the dimensionality of the universe etc., and 2) *Quantum Physics*: the understanding of the microcosmic reality arrived at and probed with the quantum theory, the standard model of particle physics (Mann, 2010), and the works of Hiesenberg, Einstein, Schrodinger, Born, Everett, Bell etc. In both the fields, the concept of the observer plays a central role. In general, the *observer* is either a participant in an experiment or an observational setup (e.g., Young-Feynman double slit experiments (Tavabi et al. 2019; Bach et al. 2013), Eddington's Experiment (Coles, 2019), or the CERN observations of Higgs Boson, etc.) or a thought experiment (also known as gedankenexperiment) in a theoretical framework such as Einstein's or Everett's thought experiments. Any formulation or perception of the so-called reality in physics, be it cosmology or micro-cosmology, has two equally important parts: The *observer* and the *observed*. However, the theoretical or experimental focus of any investigation in physics tends to focus on the latter aspect, i.e., the *observed*.

All physicists seek to answer one question, i.e., what is the true nature of the reality being perceived? With the success of modern quantum theory in explaining microcosmic reality, often in contradiction with the classical theory or even the general theory of relativity, this question has become all the more important and relevant. What we perceive as reality, based on the sensory apparatus and rationality that we evolved due to our macrocosmic existence, is not seen to be applicable in the quantum realm (discussed in section 2). On the other hand, since the entire existence is an aggregation of the quantum systems, the true reality must rest in the quantum realm.

Whether it is a macroscopic phenomenon being studied or a microscopic one, we have three fundamental elements – the observed system, the observer, and the environment. The observed system and the observer are always open quantum systems, immersed in a bath of the environment and exchanging information and energy with it.

In any problem of physics, there are also the elements, internal mechanisms, and abilities of the observer system, which are seldom dealt with in the problem except the part involving the measurement setup. More often than not, the observer is touched upon only as a theoretical necessity of the problem. With a few exceptions, no theory or treatment is dedicated exclusively to the *observer.* This, in turn, translates into various lacunae and difficulties in the logical framework as well as in our understanding of reality. On the other hand, from a classical mindset that we have naturally evolved due to our existence in macro settings, we find it rather difficult to comprehend the realities of the quantum world.

As we get into a deeper evaluation of the observer, observed system and the environmental interactions, we may, as a passing reference, draw upon all important Goedel's (1931) theorem, according to which even in elementary parts of arithmetic there exist propositions that cannot be proved or disproved within the system. Unprovability, in other words, also amounts to limitations in reasoning or even logical inconsistencies due to unexplainable elements. Going by this theorem, even with our best efforts and a lot of luck, we should still be prepared to face aspects of reality that are unexplainable. This, however, should not deter us from gaining as deep an understanding as possible of the reality.

If we imagine an ideal observer who is fully and seamlessly plugged into reality, which implies that this ideal observer is able to capture reality exactly as it is without any gaps in knowledge or understanding, then by Goedel's theorem, even such an ideal observer will confront questions that cannot be answered. In most problems in physics, the observer is almost treated as the ideal observer, though actually, every observer in real world has shortcomings because of the loss of information from the observed to the observer. In a later part of this section (Section 2.1), we discuss how "environment" can be treated as an "ideal observer".

In practice, however, it appears we have only real observers, who are far from the perfection of an ideal observer and face many obstacles between the reality of the observed system and the observation (or the perceived reality). These obstacles, to a large extent, can be assumed to be related to the abilities of the observer. To explain the "abilities of the observer" with clarity, we consider the example of the observers in the case of the fiction "Country of the Blind" by Wells (2023) in which all the inhabitants of the country are blind, which means they can neither see light nor have any idea about its properties, optics, spectrum, etc. Using only their senses towards heat (thermal radiation), sound, smell, and touch, they would evolve their own understanding of the universe and their own model of physics. Needless to say, they will have their own difficulties. On the other hand, we can imagine a country, that is just the opposite of the "Country of Blind", i.e., all the inhabitants are endowed with the capacity to sense or see Xrays, electron beams, neutrinos, etc., or through means and possibly radiations unknown to us, they can sense dark matter or gravitational waves, the reality they observe and the theories they construct will be different from the ones that we have.

The point here, which we will also take up further in our discussion on quantum mechanics, is that there can be inherent shortcomings in the sensory or observational capabilities of the observer due to which the observed object or phenomenon will appear different from its reality. It should also not be assumed that we as lifeforms have evolved as "ideal observers" with all the sensory and cognizance apparatus needed to sense reality perfectly. This very likely is not the case. We term this effect "The Country of the Blind Syndrome (CBS)." Presumably, all life forms, including unknown or alien life forms will have CBS to a certain degree. In other words, the real-life observer will always have differences and deviations from an ideal observer and the degree of deviation would be proportional to the degree of CBS.

Therefore, the emphasis in physics on the observed system and not so much on the observer could be, in some measure, leading us to theoretical frameworks with logical incompatibilities such as those we see between quantum and classical physics.

2. Observer, Reality, and Cognizance

To a layman and even to a physicist, at a subconscious level, an *observer* is a person and the term *observation* is generally assumed to be human observation. One could, however, also assume the term *observer* to have a wider and more general and abstract meaning. (Dewitt & Graham, 1973; Barrett, 2018) introduce, as observers, systems termed servomechanisms that are conceived as automatically functioning machines, having recording devices that act as memory and are capable of responding to their environment. While Everett's observers relate to quantum theory, the concept also holds for any other framework in physics such as relativity. Whether such servomechanisms or similar automated mechanisms can suffice as observers would depend on how closely these mechanisms mimic real-life observers and undertake the process of observation. This is not without conceptual and philosophical challenges. Till a workable definition or description of the *observer* is arrived at, there will always be an element of ambiguity about the term and its use in the discourses and theoretical formulations in modern physics. For example, merely measurement of certain parameters may be termed as observation, whether an element of awareness of the measurement or its cognizance is involved or not. Some people may argue that this is a matter of "philosophy" rather than that of "physics", however, the fact remains that the concept of the *observer* has a direct bearing on the model of reality arrived at in modern physics.

In Section 2.1 below, we undertake a review of the developments in quantum theory, up to the development of many worlds and the decoherence models. Given that the observer occupies a central position in modern physics, in light of the review in Section 2.1, we examine the term *observer* with greater clarity in Section 2.2. Section2.3 examines the true reality from a relativistic and cosmological perspective.

2.1. The Quantum Perspective

Although quantum theory has advanced significantly and successfully, since the times of Max Planck, it could not shed itself of the aura of inexplainable and indeterminate aspects, when viewed from a classical physics perspective. This has continued to puzzle scientists till today. Physicists have faced conceptual challenges of objectification[2], localization, hidden variables, completeness, entanglement, causality, etc.

It is well established now that the principles that seem to work at the macroscopic level are either violated or are not strictly applicable in the quantum realm. Many such examples are discussed in the following discussions.

Over the last hundred years or so, an entire body of work has evolved including a mathematical framework that is different from the framework used to describe classical or macroscopic mechanics. These works include gauge theory, string theory, quantum field theory, Ket Algebra, etc. The basis of this framework is in conformity with the experimental results rather than a framework that is seen as logical by the human mind and can be derived or deduced within the logical framework of classical mechanics or even relativistic mechanics.

Planck's discovery that the radiation spectrum of black bodies occurs only with discrete energies or quanta given by "$h\nu$", (where "h" is Planck's constant and "ν" the frequency) is not only the beginning of quantum physics but also that of the "departures and contradictions" of the modern physics from classical physics. Yet, Planck's work addressed the problem of "ultraviolet catastrophe" (Robson, 2019) that one faced in classical physics. Planck's discovery led to the understanding that in the process of transition between two stationary states of an atom, radiation is emitted with an Energy content equal to "$h\nu$". The transition between the two states is discrete i.e., the atom does not exist in any state in between (say, states "E1" and "E2") in the transition but it either exists in state "E1" or "E2". The manner of transition is in contradiction with both, the classical and the relativistic theories as it, in a sense, violates the principles of continuity.

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[2] Visualising something in concrete form.

We quote Niels Bohr (1923) on this transition between the states:

> Among the conceivably possible states of motion in an atomic system, there exist a number of so-called stationary states which, in spite of the fact that the motion of the particles in these states obeys the laws of classical mechanics to a considerable extent, possess a peculiar, mechanically unexplainable stability, of such a sort that every permanent change in the motion of the system must consist in a complete transition from one stationary state to another.

Planck's work highlights the fact that classical physics is not applicable at the quantum level.

The Stanford Encyclopedia of Philosophy (Faye, 2019) lists various principles that govern classical mechanics namely—the principle of separated properties, the principle of value determinateness, the principle of causality, the principle of continuity, and the principle of conservation of energy. These principles in classical mechanics enable us to determine the future state of a system from the initial values or the values observed in the past.

In order to make these principles compatible with quantum theory, Bohr and Heisenberg banked on a principle of correspondence rule, which states that a transition between stationary states is allowed if, and only if, there is a corresponding harmonic component in the classical motion. However, Pauli's exclusion principle[3], which stated that two electrons with the same known quantum numbers could not be in the same state, challenged the correspondence rule.

Dirac (1947) highlights a number of conflicts between classical mechanics and quantum mechanics. For example, according to him, the stability of atoms and molecules and the physical and chemical properties of materials cannot be explained through a classical mechanics route. He also points out the conflict arising in the experimental evidence of specific heats. The observed specific heats at ordinary temperatures are well described by a theory that takes into account only the motion of each atom as a whole while not considering any internal dynamics of the atom. A conflict is also mentioned about the energy of oscillation of the electromagnetic field in a vacuum, which in accordance with classical mechanics should be infinite but is found to be finite.

Dirac points out that it was necessary to modify classical ideas even from a philosophical point of view. In classical mechanics, the matter is assumed to contain a large number of small constituent parts and even if we deduce laws for matter in bulk from the behavior of the smaller constituents, the question of the structure and stability of the smaller parts will remain unaddressed. An interesting possibility discussed by Dirac is that of a single photon being part of two or more beams! He states:

> "It would be quite wrong to picture the photon and its associated wave as interacting in the way in which particles and waves can interact in classical mechanics. The association can be interpreted only statistically, the wave

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[3] Bohr's Correspondence Principle, Stanford Encyclopedia of Philosophy https://plato.stanford.edu/entries/bohr-correspondence/.

> function giving us information about the probability of our finding the photon in any particular place when we make an observation of where it is.”

and

> “Such analogies have led to the name ‘Wave Mechanics’ being sometimes given to quantum mechanics. It is important to remember, however, that the superposition that occurs in quantum mechanics is of an essentially different nature from any occurring in the classical theory, as is shown by the fact that the quantum superposition principle demands indeterminacy in the results of observations in order to be capable of a sensible physical interpretation. The analogies are thus liable to be misleading.”

Dirac also agrees that in departing from the determinacy of the classical theory, a great complication is introduced into the description of nature although the “principle of superposition of the states” grants simplification to the theoretical and logical framework. In the context of the CBS described above, and the observer, we find this interesting concept from Dirac:

> “Quantum mechanics provides a good example of the new ideas. It requires the states of a dynamical system and the dynamical variables to be interconnected in quite strange ways that are unintelligible from the classical standpoint.”

The strangeness of the interconnections in the above quote points to the fact that based on the classical logical framework that we have developed naturally while making observations in a macro world, we are not able to relate to a quantum phenomenon indicating a quantum reality different from the one we perceive in the macro world.

The concepts of particle-wave duality led Schrodinger to derive the equation that governs the matter wave function, given by:

$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2}\partial^2+V(x,t)\Psi(x,t)=\iota\hbar\frac{\partial\Psi(x,t)}{\partial t} \tag{1}$$

where $\hbar$ is the reduced Planck constant given by

$$\hbar^2=\frac{h}{2\pi}$$

and, $V(x,t)$ is the potential energy function, $\Psi(x,t)$ is the wave function.

The general wave function of the type shown in Equation (2) can only be a solution to Schrodinger’s Equation (1), if $\gamma=\sqrt{-1}$, which can be seen in the imaginary part on the R.H.S of Equation (1).

$$\Psi(x,t)=\cos(kx-\omega t)+\gamma\sin(kx-\omega t) \tag{2}$$

The imaginary part is associated with the time derivative. Interestingly, the imaginary part also appears in the theory of relativity in a four-dimensional space-time metric where the fourth dimension is “ιct”, which then flows into all of the relativistic treatments.

The link between the theoretical description given by Schrodinger and experimentation was provided by Max Born (Born, 1926), according to whom, if the wave function of a particle has the value Ψ at some point x, then the probability of finding the particle between x and $x + dx$ is proportional to $|\Psi|^2 dx$. It is important to note that the wave function is not a physical wave that we are used to seeing such as a water wave or a wave in a string, rather it is a wave of probabilities, where the position x in $\Psi(x,t)$ is related to the probability of finding the particle.

Generally, we tend to focus on the real part such as $|\Psi|^2$ in quantum mechanics and ds^2 (separation squared) in the theory of relativity because the squared value is real, can be measured, can be validated through experimentation, and is easy to manipulate in mathematics. However, it is important to be aware of the fact that, mathematically, a part of reality is an imaginary part both in Schrodinger's equation and in relativity.

The probability, however, cannot be defined without invoking the observer. In the quantum theory, which has its basis in the probability wave function or the Schrodinger's equation, the *observer* is embedded in the theoretical framework because the very concept of probability has to do with observations and it is the fundamental and underlying aspect of uncertainty. Probability comes into play only when there is an *observer* and in its absence, it has no meaning. In a wave function, the probability for any outcome is given by the Born's rule i.e., square of the amplitude. In the absence of an *observer*, the very nature of the wave function comes into question. Quantum theory, as we know it, cannot be framed, if we take the observer out.

This situation is very different from the one in classical mechanics where the observer remained outside the subject of observation. However, in modern physics, as seen above, it occupies a central place next to the subject or is even mingled with it.

The "measurement problem" or the "wave function collapse problem" emanates from the fact that the amplitude of the quantum mechanical wave function describing a particle, relates to probabilities but a measurement leads to finality and hence is seen as a collapse of the wave function. This leads to many questions e.g., how and why a reality that is fundamentally probabilistic, leads to a deterministic result and that of the "cut-off", i.e., the precise point where the probabilistic nature converts to a deterministic one. The problem is clearly related to the *observer* as on the one hand we have probabilities that are *observer* centric and on the other hand, the "eigenstate" or the so called "collapsed function", which too, is assumed to have collapsed by the act of observation. "The collapse" concept has also remained a bone of contention in physics. According to Everett (Ball, 2022) (as quoted by Phillip Ball), wave function collapse is an illusion.

Feynman Lectures (2022) in his famous lectures conducts a thought experiment (Vol III) with an electron gun and two holes. The experiment concludes that if we are tracking an electron (or looking at it), it behaves as a particle but if we are not looking at it, it exhibits wave-like behavior. Obviously, when we are looking at the electron, there is an interaction with the photon, which causes it to behave in a particle-like fashion. However, if it is not being tracked and there is no interaction with the photon, it flows through, what appears to be its natural undisturbed state, which is a wave. Now "tracking" amounts to the observation of the electron with a light (or electromagnetic) source and no observation is possible without the use of the light source. Thus we can conclude that the observer has a role not only in seeing reality but also, interestingly and importantly, in the formation of the reality we observe. We may put it as follows –reality has dual nature – one nature when it is being observed and another one when it is not being observed. Feynman also highlighted the fact that the light source should have a certain minimum energy associated with it (frequency) below which it will not cause the electron to behave in a particle-like fashion or in other words, we would not have observed the electron. Thus interestingly, observation has also something to do with energy and below a certain threshhold of energy in the light source, an observation will not take place. In recent years, Feynman's thought experiments of Vol III have been verified through actual experiments (Bach et al., 2013).

According to Heisenberg's uncertainty principle (Busch et al., 2007; Martens, 1991; Heisenberg, 1925), the position and momentum of a particle cannot be simultaneously measured. EPR (Einstein et al., 1935) point out that when the momentum of a particle is known, its coordinate has no physical reality. EPR lay down the sufficient condition of completeness of a theory as:

> every element of physical reality must have a counterpart in the physical theory
>
> And that of reality as:
>
> If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity.

They (EPR) conclude that the quantum-mechanical description of *reality* given by the wave function is not complete and in order to complete it, one needs to supplement the theory with unknown variables, also generally termed the "hidden variables".

Interestingly, EPR comes up with a description that leads to entanglement. They consider two systems that are allowed to interact for a period of time and are then separated. However, in the thought experiment they conduct after the interaction, EPR go on to prove as quoted below:

> "as a consequence of two different measurements performed upon the first system, the second system may be left in states with two different wave

> functions. Since at the time of measurement, the two systems no longer interact, no real change can take place in the second system in consequence of anything that may be done to the first system."

This amounts to entanglement. EPR prove that Schrodinger's wave function leads to entanglement, which in their view is paradoxical and hence according to them, quantum theory is incomplete. Yet it is found that entanglement exists and therefore, they seem to have made an important discovery while trying to prove the counterpoint. This also proves the point that there exists what some scientists (Sean Carrol, Brian Greene, others...) call the *hidden reality* in the quantum realm, an idea that even Einstein seems to have resisted.

In the theoretical evolution at the beginning of the 20th century, a fact that was not emphasized to the extent required was that at the center of these investigations was the "*observer*". In the later developments of the theory of relativity and Heisenberg's uncertainty principle, the aspect of the observer becomes more important. It was conjectured that the "state of a system" (Wesson, 2012) being observed was not a pre-existing state but also depended on the observer.

Given that quantum theory presents a probabilistic and indeterminate view of the microcosm, it has led to serious contradictions and divergent viewpoints on the very nature of reality. Many scientists including Einstein, as we see in EPR remained uncomfortable with quantum theory.

According to Stephen Hawkings (1998), *"Heisenberg's uncertainty principle is a fundamental, inescapable property of the world."* This statement is meant to convey the fact that the uncertainty is not arising from our inability to observe microcosmic phenomena or due to perturbation of the experimental setup but was a fundamental property of microcosmic reality.

In response to EPR, Heisenberg talks of the 'cut' between what is counted as part of the system to be observed and what is counted as part of the means of observation (translation by Crull & Bacciagaluppi (2022)). He asks:

> At what place should one draw the cut between the description by wave-functions and the classical-anschaulich description?

And then concludes that:

> the quantum mechanical predictions about the outcome of an arbitrary experiment are independent of the location of the cut

With respect to the debate between classical and quantum physics, Heisenberg comments:

> …Quantum mechanics has thus revealed to us here a new property of nature that was unknown to classical physics.

As one of the main architects of the quantum theory, Heisenberg seems to strongly defend the quantum theory and even acknowledges that quantum mechanics has revealed a new property of nature that was unknown in classical physics, which is the wave function. Thus he points to the fact that the reality that classical physics is trying to address is different from the underlying reality that quantum theory had stumbled upon.

Often scientists and even Einstein felt that there were unknown variables in quantum physics, which if they are discovered, will enable deterministic approaches in quantum theory as in classical physics. Heisenberg in his response to EPR, strongly resists this thinking.

The conclusions of Bell's proof (Bell, 1964) on hidden variables as a rebuttal to EPR are profound. Bell's theorem has shown that no "hidden variable" interpretation of quantum mechanics is possible and that there must be a mechanism that allows the setting of one measuring device to influence the readings of another instrument, however remote it might be. Clauser et al. (1969) (CSHS) propose experiments to test the violation of Bell's conditions of "hidden variables". Aspect (1976) describes experiments to test realistic local theories and concludes that there is strong evidence against the whole class of realistic local theories.

Aerts (2001), who proposed the "creation-discovery" hypothesis, would liken *reality* observed to some outer or higher reality, which we cannot directly observe in our 4D spacetime. The act of observation is "as if" the higher reality is being observed through a window. The idea is similar to CBS example given above.

He cites the example of Rauch's work (Rauch et al., 1974) on neutron interferometry and remarks:

> It is 'as if' the single neutron is present simultaneous in both places, in the small cube in Vienna and in the small cube in Copenhagen, and that it can be acted upon from both these places as though it really and truly be there

In the above description, it appears as if a particle is simultaneously present in two places. This translates into a phenomenon (a quantum effect) of "non-locality", which also goes against the principles of classical theory. Aert comes up with a hypothesis, which we present here as yet another viewpoint:

> We shall assume that quantum entities are not permanently present in space, and that, when a quantum entity is detected in such a nonspatial state, it is 'dragged' or 'sucked-up' into space by the detection system

The discord with classical theory and contradictions among different schools of thought have been such that they have resulted in the seemingly bizarre conclusions of many worlds by Everett.

In the context of this paper's one of the main themes on the examination of the Observer's role in physics, Everett's work is worthy of a more exhaustive description. For Einstien, when he conducted the thought experiment with observers, it was sufficient to use the classical concept of the observer and he made no attempts to further define or go deeper into the concept of what exactly an observer means in physics. However, given the importance of the observer to Einstein's formulations in the theory of relativity, it would perhaps have been worthwhile to delve deeper into the meaning and concept of the observer. In section 2.2, we have linked the term "observer" to "cognizance". Everett, in his treatment, seems to give an equal emphasis to the physical realities and events and their observation. Everett's theory has one of the rare treatments of mathematical formalism for the observer. His full-blown theory of many worlds rests essentially on his mathematical formulations of the observer.

Everett defined observer as:

> "…automatically functioning machines, possessing sensory apparata and coupled to recording devices capable of registering past sensory data and machine configurations. We can further suppose that the machine is so constructed that its present actions shall be determined not only by its present sensory data, but by the contents of its memory as well."

These machines are close to the concept of observer defined in Section 2.2. The term "*actions*" in the above definition conveys the idea that the machine will take "action" and in the context of Everett's work, this "action" should be more measurements. However, any "action" by the machine based on measured data amounts to the cognition of the measured data.

We briefly present some of the aspects of Everett's theory:

According to Everett, fundamentally, there are two different ways in which the state function can change:

Process 1: The discontinuous change brought about by the observation of a quantity with eigenstates Φ_1, Φ_2, …, in which the state ψ will be changed to the state Φ_j with probability I ψ, Φ_j I^2.

Process 2: The continuous, deterministic change of state of the (isolated) system with time according to a wave equation $\partial\psi/\partial t = U\psi$, where U is a linear operator.

Everett presents a thought experiment with two observers to prove that if more than one observer is considered, the interpretation of quantum mechanics becomes untenable and leads to paradoxical conclusions that if there are more than two observers, they may have no objective existence, but their existence may depend upon the future actions of yet another observer.

According to Everett (Einstein, 1905b; Dewitt & Graham, 1973; Barrett, 2018) –

> From interaction of the systems, and from our point of view all measurement and observation processes are to be regarded simply as interactions between observer and object-system which produce strong correlations.

i.e., The continuous, deterministic change of state of the (isolated) system with time according to a wave equation $\partial\Psi/\partial t = U\Psi$, where U is a linear operator. Ψ is also referred to as the universal wave function.

In Everett's thought experiment one observer A is performing measurements on a system S and assumes he obtains results according to process 1, however, another observer B has the combined state function of A + S and according to B, everything is happening according to process 2 till he makes the measurement.

Thus while A was under the impression that he was observing S, he was in fact entangled with S and a Schrodinger's wave function described A+S and there never was a process 1. To get around the paradox, Everett proposes five alternatives:

1) A universe, in which there is only one observer and each person holds the view that he is the only observer

2) Quantum mechanical description fails when applied to macro systems

3) To deny the possibility that the second observer is in the possession of the combined state function of the first observer and the rest of the system

4) To abandon the position that the state function is a complete description of a system.

5) To assume the universal validity of the quantum description and Process 1 is completely rejected along with the wave collapse concept.

Alternatives 1-5 are not the only alternatives, and there could be many more. Everett prefers Alternative 5, which means that in reality, only Process 2 is in force, and that the entire universe has a universal wave function. There is no collapse of the wave function as was assumed in the Copenhagen Interpretation. While each observer seems to experience Process 1, in reality, the observer and the system are not defined by separate state functions. The process of observation is captured within a composite system including both, the observer and the object system and the composite system is described by the state function of the composite system. The composite system cannot be represented by a single pair of subsystem states but only by a superposition of such pairs of subsystem states. i.e., Schrodinger's equation for a pair of particles ψ (x_1, x_2) cannot be written in the form $\psi = \phi(x_1)\eta(x_2)$ but only in the form $\psi = \sum_{i,j} a_{i,j}\phi^i(x_1)\eta^j(x_2)$, which represents the superposition of particles x_1 and x_2. Everett proves that the subjective experience of these observers is precisely in accordance with the predictions of the usual probabilistic interpretation of quantum mechanics.

Everett calls this the "theory of universal wave function". According to him:

> "this concept of a universal wave mechanics, together with the necessary correlation machinery for its interpretation, forms a logically self consistent description of a universe in which several observers are at work."

In this theory, since in reality, there is no collapse of the wave function but is only seen as such by individual observers, all the probable outcomes of the wave function actually happen or are branched out and this leads to the many world concept. In other words, if a particle described by a probability wave function was being observed, it is not as if the probability wave function collapsed on the observation but rather replicas of the same observer saw the particle in different parallel worlds.

It is important to note that the splitting of the world into multiple branches does not involve a division or dilution of mass or energy. The branching occurs due to quantum effects, and each branch represents a different possibility rather than a fraction of the total mass or energy.

Interestingly, if we think of layers of observers, with the first one observing the object system, the second one observing the first one observing the object system, the third one observing the 2nd observer observing the first observer observing the object system, and so on and so forth. If the entire system (universe) is finite, we are then, in the end, or ad-infinitum, led to a single universal wave function, and a single observer at the highest layer.

Carrol's insightful book (Something Deeply Hidden) (Carrol, 2022), which can also be seen as a defense of Everett's thesis, addresses many aspects of Everett's theory. We list some of them here.

- Everett's theory is more simplistic and elegant than the conventional quantum theory as it does away with the need for the collapse of the wave function, which had been introduced without any sound rationale other than an attempt to explain the deterministic macroscopic experience
- Essence of Everett's theory is that reality is a smoothly evolving wave function and nothing else
- "That simple process—*macroscopic objects become entangled with the environment, which we cannot keep track of—is decoherence, and it comes with universe-altering consequences. Decoherence causes the wave function to split, or branch, into multiple worlds.*"
- "*After branching, each copy of the original observer finds themselves in a world with some particular measurement outcome. To them, the wave function seems to have collapsed.*"

Zurek (2003, 1998) contributes to the fundamental idea of decoherence. Entanglement of the quantum state with the environment in an irreversible process so that it loses its interference properties is termed decoherence. Zurek makes the following insightful comments about "what's going on":

> "Relaxation and noise are caused by the environment perturbing the system, while decoherence and einselection are caused by the system perturbing the environment."

and

> "The observer and the environment compete for the information about the system. Environment—because of its size and its incessant interaction with the system—wins that competition, acquiring information faster and more completely than the observer"

Again Zurek's concepts, in a departure from Everett's theory, seem to talk of the survival of one preferred superposition state through what he terms as *einselection* and labels it as quantum Darwinism. Weak decoherence has been experimentally confirmed (Beierle et al., 2018).

A comparison of Everett's Many Worlds Interpretation and Zurek's decoherence model extracted using Chat GPT is given below:

> Interpretation of Measurement: In Everett's MWI, the measurement process does not collapse the quantum superposition into a single outcome. Instead,

the universe splits into multiple branches or "worlds," each corresponding to a different outcome of the measurement. All possibilities encoded in the superposition coexist in parallel, leading to a branching tree of universes. In contrast, Zurek's Decoherence Theory does not involve multiple worlds but focuses on the interaction between a quantum system and its environment. According to decoherence, the system and environment become entangled during measurement, leading to a rapid and irreversible suppression of interference between different outcomes. The system appears to "collapse" into a particular state due to the interactions with the environment, but there is no branching into multiple worlds.

Role of Observer: In MWI, there is no special role assigned to the observer. The observer is also part of the quantum system and undergoes superposition and branching like any other quantum entity. Each observer experiences a specific outcome corresponding to their branch of the wave function. Zurek's Decoherence Theory, on the other hand, acknowledges the importance of the environment and considers it as a "passive" observer that causes the system to decohere. The environment can be any macroscopic system with many degrees of freedom, such as a measuring apparatus or a collection of particles. The theory focuses on the interactions between the system and its environment, leading to the emergence of classical-like behavior.

Nature of Reality: MWI asserts the reality of all the branches or worlds that result from the splitting of the wave function. Each branch represents a different possible outcome of a measurement, and they all exist simultaneously in separate but parallel realities. In MWI, reality is fundamentally a vast ensemble of parallel universes. Decoherence Theory, on the other hand, does not posit the existence of multiple worlds. It explains the apparent "collapse" or classical behavior by considering the system-environment interaction and the loss of coherence between different states. According to Zurek, the classical world emerges from the quantum realm through decoherence, but there is no need to postulate the existence of separate parallel realities.

Mathematical Framework: Both theories are based on the mathematical formalism of quantum mechanics. MWI uses the standard mathematical framework of quantum theory, where the evolution of the wave function is described by the Schrödinger equation. Decoherence Theory also employs the same mathematical framework but places emphasis on the density matrix formalism and the concept of entanglement between the system and its environment.

The most significant contribution of Zurek is on the role of the environment in decoherence, which we also discuss in Section 2.2. It is important to keep in mind that even experimental detection of decoherence does not rule out Everettian MWI because the many worlds are mutually exclusive possibilities and cannot be detected from one world to the other.

An indicator of compatibility with thermodynamic concepts and the "arrow of time", if not the proof of the Everettian model, is in the second law of thermodynamics and the increase in entropy. Once a branching out happens from a mother universe to many child universes, the overall entropy increases. Moreover, branching and increase in entropy can also be linked to the arrow of time.

2.2. Observer and Cognizance

There is no clear definition of the "*observer*" in Physics and there are different perceptions and functionalities under different frameworks and settings. For example, in classical physics, the "*observer*" is clearly outside the observed system while in relativity the "*observer*" is relative to the frame of reference and different observers may obtain different values for measurement of the same entity (for example mass or length) depending on their relative position and speed. Still, in relativity, prima facia the "observer" appears to be outside the observed system. However in quantum physics, the term "*observer*" is often used to describe a system or apparatus that interacts with a quantum system to obtain information on it. This interaction leads to outcomes that are superpositions of observer's and the observed system's wave functions. Often the way the "*observer*" is described or treated, leaves it open to interpretation, which brings the entire theoretical framework into question. Ideally, in physics, there should be a standard definition of the *observer*.

Delving deeper into the term "*observer*" or rather dissecting it, one finds that the term has different elements and sub-elements, which we summarily described below:

1) Measurement

Measurement is always in the context of the parameters of a *system* or an *object* and can be defined in many ways in science. In our context, we define it as the value discovery of a physical parameter of the state of a "system" through a probe, device, experimental setup, or, process. The process invariably leads to an interaction between the observer and the observed system and after the interaction, the two are described by a superposition of their pre-interaction states, which in quantum parlance is also known as entanglement. The "value" discovered through measurement is also termed the eigenstate or the pointer state (Brasil & de Castro, 2015). Measurement is not only a link between the observer and the observed system but also an interaction between the two. However, it is important to keep in mind that the "observer" (who has to be cognizant – discussed below in sub-section 4) may not always be aware of the true source or nature of the parameter measured as the parameter measured may be a manifestation of some unknown or unseen property of the observed system. For example, if we return to the CBS analogy, a blind man may be able to sense the heat of the sun but will not know of its true source. On the other hand, while there might exist a number of parameters pertaining to the observed system, the observer can only measure those parameters of which it has the knowledge. In the same example as above, people in the "Country of the Blind" cannot possibly measure the luminosity of the sun or for that matter any light source. Interestingly, the treatment of 5D space by Wesson and others (section 2.3), wherein "mass" is seen as a manifestation of the flat 5th dimension in 4D space-time could be yet another example of CBS or the measurement of something that is a manifestation of yet another unknown reality.

Measurement has to do with observation and interestingly it is not only dependent upon the bodies or systems being measured but also on the observer, his abilities, and the frame of reference. Needless to say, the simplest of measurements, even that of the distance between two points cannot be made without the observer. This fact highlights the central position of the observer in all theoretical constructs in physics.

On the other hand, as per Zurek's treatment of observer and "environment", given that both observer and the observed system are open quantum systems immersed in the "environment", the knowledge of the measured parameter and its value is available to the environment even at a time Δt ($\Delta t \rightarrow 0$) before it is measured. Moreover, while the observer may receive a value based on the accuracy of the measurement set-up, the "environment" has with it, not only the exact value measured but also the loss in the measurement setup.

2) Sensor

The observed system's state parameters are eventually measured by some kind of sensors, which can either be biological, such as eye, skin, tongue, leaves of a plant, etc., or manmade transducers, detectors, and measuring devices and systems. An absolutely essential part of the *observer*, the *sensor* enables measurements of the parameters and has to be compatible with both the observed and the observer. The accuracy of the sensor would determine how closely we determine the reality. While man-made sensors or devices can provide nearly precise (in a macro context) and quantifiable values of the parameters measured, biological sensors such as the skin can give a good assessment, for example of temperature in terms of cold, pleasant, warm, hot, or unbearable or in case of other parameters such as distance in terms of close, near, far, very far, etc. We give these examples of biological sensors to highlight the fact that apart from man-made sensors and measuring devices, there can exist other sensory apparatus in nature.

3) Intelligence

Measurement leads to a record and a series of records constitute a dataset, which can be processed for intelligence. For example, the position of an asteroid in a coordinate system given by x_1, y_1, z_1 at a given point of time t_1 is a record R_1, and x_n, y_n, z_n at t_n can be a series of records R_n that provide us with the intelligence about the path or trajectory of the asteroid. Huge datasets are created in experiments with facilities such as Large Hadron Collider (LHC), that take years to analyze. For example, analysis of the mass of W boson has been going on for more than 12 years[4]. The point here is that a single measurement or a series of

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[4] https://home.cern/news/press-release/physics/improved-atlas-result-weighs-w-boson (accessed on 26th March 2023).

measurements form a data set, which contains intelligence about the state or form of the system observed. This intelligence, once analyzed, provides us with an understanding of the reality of the observed system. Whether that "arrived at" reality reflects true reality and is precise or not so precise, depends on the analysis, observer, and measurement system.

4) Cognizance

An important and essential step between the processing of records and the making of observation is taking *cognizance* of the intelligence provided by the observed parameters. The values obtained from the process of measurement must be recognized in their raw or processed form and attributed to the measured parameter for the process of observation to be completed. This process requires an understanding of the measured parameter w.r.t. the observed system. If we dissect observation into different elements as above, the last but essential element to complete the process of observation is cognizance. It may be understood as analysis, recognition, and acknowledgment of the measurement. Since we cannot complete the process of observation without *cognizance,* we also cannot complete many of the theoretical formulations of modern physics, that invoke the observer, without in turn invoking cognizance.

Though it appears that to be cognizant is a capacity of the human mind, to a certain extent and in a rudimentary sense, it can also be attributed to animals and other biological systems, automated systems, or even feedback loops in nature that can be termed as cognizant. To give a few examples—i) a predator can track the speed and path of the prey and act on that intelligence and sometimes vice versa; ii) biological systems respond to the environment, and climatic systems respond to greenhouse gas emissions. There can be many examples that are non-human.

It is difficult to say that the current state of instrumentation and information technology with its algorithms, software, and recording mechanisms has the capacity of cognizance, though it may emerge in futuristic AI technologies. Whether machines—AI, other non-life systems, and other biological systems can have cognitive capacity is something that is debatable but is also a subject of ongoing research (Chalmers, 2011; Baluška, 2009). Therefore, in practice, it might be difficult to attribute observer status to servomechanisms proposed by Everett though for the purposes of a thought experiment, this may work, assuming that in the future a technology will emerge with a capacity of *cognizance*.

In the absence of *cognizance*, the process of observation is not completed and in spite of measurements and records, no observation can be said to have taken place.

Interestingly as described by Zurek, the environment has all the knowledge of all the parameters of the observed system and of the observation being carried out by the observer including all the knowledge residing within the observer. This, one can say also includes the design of the measurement system along with sensors, the recording mechanism, and the analytical and cognizance capacity of the observer. This is for no reason other than the fact that both the observed system and the observer are immersed in a bath of the *environment* and are open quantum systems. Thus the environment is cognizant and this conclusion flows from the fact that the observer, who has to be cognizant, is always embedded in it. It is a significant, simple and elegant conclusion.

In totality, the observer-observed system-environment system constitutes the multiverse described by a single Schrodinger's equation or a universal wave function.

Thus for "observation" to take place and for "observer" to exist in a given setting, all the four elements described above should have been involved i.e., Measurement, Sensors, Intelligence, and Cognizance.

Fields (2018) discusses decoherence in the context of Schrodinger's cat example and carries out a comprehensive review of different types of observers that surface in quantum physics-related literature. He quotes Hartle's (Hartle, 2011) definition of the observer—"*information gathering and utilizing systems (IGUSes)*". According to Hartle:

> As human IGUSes, both individually and collectively, we are described in terms of quasiclassical variables.

Fields also quotes Schlosshauer (2007):

> "We simply treat the observer as a quantum system interacting with the observed system"

Even the term "observation" is not fully understood or well described. According to Sassoli de Bianchi (2013) *observation is not interpretation* but at the same time, he is of the opinion that a radical distinction between observation and interpretation is not possible.

Scientists and Philosophers have often used the term *consciousness* to describe a certain aspect of the ability to observe or that of cognition. However, there is a distinction between the *observer* and the *consciousness*, the latter being a broader term including thoughts, intelligence, etc. and the "*ability to observe*" could be a subset of it. It seems that consciousness must necessarily accompany the observation for the process of observation and its cognizance to be completed.

Stuart Hameroff and Roger Penrose (2014) have presented three alternate theories on consciousness:

a) Has a basis physical evolution explained by Science/Materialism
b) Basis in Dualism/Spirituality
c) An essential ingredient of physical laws, not fully understood.

Interestingly, Hameroff and Penrose mention consciousness as an essential ingredient of physical laws.

2.3. Relativistic and Cosmological Perspective

In this section, we examine the question of the true reality from a different perspective, that of cosmology and the dimensionality of the universe. That the universe in 4D spacetime has probably originated with a big bang (inflation) from a minuscule Planck scale universe some 13.8 billion years ago is the prevalent and widely accepted theory of cosmology. This theory has been a subject of debate and reassessment, to some extent, in the light of the Hubble's constant tension, which is the discrepancy, of more than 4σ, between the value of the Hubble constant estimated through the local probes and the one arrived at through cosmological value inferred with the power spectrum of the CMB (Dainotti et al., 2021). The recent James Webb images of high red shift early universe galaxies has not resolved the Hubble's tension and in fact has resulted in new interest in correctly assessing the age of the universe, which was earlier assessed at 13.8 billion years. These observations, the dimensionality of the universe, its structure, its age have implications on the extent and form of the universe, in other words, the cosmic reality. Einstein, for whom the *observer* was at the center of his theory, came up with the concept of a 4D spacetime continuum. By default, the *observer* becomes intrinsic to all extensions of GRT including the standard model of cosmology (Robson, 2019; Peebles, 1993).

That gravity is well described by the geometry of spacetime has been well established through the General Theory of Relativity (GTR) (Ryder, 2009; Robson, 2019; Peebles, 1993), and many of its treatments. On a stellar and cosmic scale, GTR in a 4D framework is reasonably well established and confirmed in the perihelion of mercury (Janssen & Renn, 2021), deflection of light by the sun (Dyson, 1920), gravitational wave observation (Abbott et al., 2016a; Abbott et al., 2016b) and relativistic redshift observations (Do et al., 2019; Angélil & Saha, 2010).

The 4D spacetime as in GTR is the widely accepted geometrical framework to describe the observed universe. However, parallel theories have also been put forward to establish a case for a 5D universe. These are works of Weyl (1918), Kaluza (2018), Klien (1926), Wesson (2012), Wesson (2015), Wesson (2008), Wesson & Overduin (2013), Wesson & de Leon (1995), Lidsey et al. (1997), Randall and Sundrum (RS) (1999), Arkani-Hamed et al. (1998), Hossain (2022), and others. These works propose a 4D spacetime embedded in a 4D+n universe and matter (mass and energy) as a manifestation of the 5th dimension. Some of the key pointers on 5-dimensional theory of spece-time are:

- Kaluza established that a GTR in 5D universe included GTR in 4D universe in addition to the electromagnetic field.
- According to Wesson (2012), Einstein's Equivalence Principle (EEP) could be a direct consequence of the existence of an extra dimension and that energy density and pressure (matter) is a property of 4D spacetime, owing its existence to the fifth dimension.
- Wesson and others (Lidsey et al., 1997; Aubrun et al., 2011) refer to Campbell's embedding theorem, which implies that all solutions to the n-dimensional Einstein field equations with arbitrary energy-momentum ten-

sor can be embedded, at least locally, in a spacetime that is itself a solution to (n + 1)—dimensional vacuum GTR.

- According to Wesson (2008) Einstein's equations with the matter in 4D are a subset of the Ricci-flat equations for apparently flat space in 5D. Ricci Tensor defines the curvature of spacetime manifold. Wesson has proposed, the rest mass as an analogue of the proper distance in the fifth dimension.
- Wesson and Overduin (2013) suggest that the cosmological constant Λ scales with mass
- Randall and Sundrum (RS) (1999) and Arkani-Hamed et al. (1998) have also considered a higher 4 + n dimensional spacetime to address the hierarchy problem (Bhattacharya, 2017).
- Hossain (2022) has proposed a model of 4D multi branes in a 5D universe

Wesson comments that the objection to 5D universe construct is that after many years of investigation, there is still no empirical proof of the existence of the extra dimension. However, we feel it is a matter of interpretation of Wesson's own work. The fact that we can observe "Matter/Mass and gravity", which according to Wesson are a manifestation of the 5th dimension is an evidence of the 5th dimension in itself.

The above discussions lead us to the Space-Time-Matter (STM) theory, in which matter and energy in four dimensions are induced from flat space in higher dimensions. However, on a micro-cosmic scale, matter comprises innumerable different fundamental particles that emanate from the underlying fields after quantization (Tong, 2006). Therefore, as far as matter is concerned, its original reality is in the fields. In the theoretical frameworks, these fields and particles emanate from different dimensions or branes. In string theory, up to 26 dimensions are considered.

However, in cartesian and gaussian space, an "n" dimensional space can be treated as "n − m + 1" dimensional space where "m" dimensions are clubbed together and treated as a single dimension, as in the case of spacetime wherein the resultant of the three space vectors (x_1, x_2, x_3) and time (x_4) can be treated as two-dimensional field (4 − 3 + 1, where m = 3). Then, all the higher dimensions in the gauge theory or the string theory can also be treated as "clubbed together" as a single dimension that is perceived as matter with its properties, induced from the 5th dimension.

Moreover, in any n-dimensional space, we can always imagine an n − 1 curved hypersurface (see Hossain, 2022). This aspect is adequately demonstrated in the influence that matter has on spacetime in the form of gravity. Hossain has pointed out that an "n" dimensional curved spacetime continuum can only exist at least in an "n + 1" flat space. Therefore, 4D curved spacetime can only exist in 5D flat space.

There are enough grounds to assume that the totality of the universe is at least 5 dimensional. According to Wesson, while the universe may be flat in 5D, it can contain matter of complicated forms in 4D. If we go with this conclusion, the reality of matter could be in a geometric representation of one or more external dimensions in spacetime.

Investigation into dimensionality seems to indicate that the reality of what we perceive as matter and curved spacetime in the 4D universe could be emanating from a flat 5D universe. Therefore, the true reality could be that of a flat 5D or 5D + n universe.

3. Conclusion

What then exactly is the true nature of reality, we see and observe, or that of the models of the universe that we have developed? Is the four-dimensional spacetime curvature based on GTR, all that is there or is there some underlying deeper reality? In the review and analysis carried out above, we have seen that developments in modern quantum physics and the work carried out on 4D + n (n > 0) universe, point towards a deeper underlying reality that we have not clearly understood so far. Moreover, discussions on quantum theory indicate that what we see and perceive as macro beings in a macro world, may not be the true reality but a formation with a hidden structure to it.

We have seen above how from the times of Planck almost 120 years back till today, the world of atomic and sub-atomic particles defies classical mechanics and our sense of a deterministic universe that we perceive in our day-to-day life. Copenhagen Interpretation, Heisenberg's uncertainty principle, EPR, Schrodinger's equation, entanglement, Feynman's experiment, Everetts MWI, and Zurek's decoherence and many other aspects of quantum physics, all of these backed by many successful experiments point towards the fact that true nature of reality is not directly perceivable to us and in that sense is a hidden reality.

An important but lesser-understood aspect of this reality is the *observer*, which is a term that has been used but hardly ever defined with clarity and can have different meanings and interpretations. However, in the discussion above, we find that the term "observation" must include measurement, sensory apparatus, intelligence, and cognizance. Moreover, we find that the environment can be the ideal observer and has more intelligence than the observer and a complete and deeper cognition of the events.

Here we attempt to paint a picture of true reality based on developments in quantum and relativistic theory discussed above:

The observer-observer system-environment system constitutes the universe in totality described by a universal wave function. The wave function has all the outcomes i.e., Everett's many worlds. Our perceived reality is that of a decohered universe, which is only one of the many (infinite) outcomes and all other outcomes possibly exist. Possibly, because to date, parallel universes have not been confirmed experimentally but EPR, Feynman's experiments, Everett's theory and, Zurek's decoherence establish a strong case for the parallel worlds. It is difficult to conceive or visualize these different parallel universes but keeping in view the law of conservation of matter and energy, these cannot be physically

Table 2. A summary of deviations and departures of quantum theory from classical theory.

Date	***Conflict***	***Type of Conflict***	***Description***
1900	*Ultraviolet Catastrophe: Classical theory fails to account for blackbody radiation at high frequencies* (Planck, 1900)	*Theoretical*	*Classical physics predicted that the energy emitted by a blackbody would increase without bounds as the frequency of the radiation increases, known as the ultraviolet catastrophe. Planck introduced the idea of energy quantization to explain the observed spectrum of blackbody radiation. Discrete emission and absorption is in conflict with the principles of classical physics*
1905	*Photoelectric effect: Classical theory cannot explain the energy dependence of electron emission from metal surfaces* (Einstein, 1905a, 1905c; Arons & Preppard, 1965)	*Experimental*	*The photoelectric effect is the phenomenon where electrons are emitted from a metal surface when exposed to light. Classical theory predicted that the energy of the emitted electrons would increase with the intensity of the incident light, but not with its frequency. Einstein proposed that light behaves as discrete packets of energy (photons) whose energy is proportional to their frequency, which successfully explained the observed energy dependence of the photoelectric effect.*
1913	*Bohr Model of the Atom: Classical mechanics cannot explain the stability of atoms and atomic spectra* (Bohr, 1913)	*Theoretical*	*Classical mechanics failed to explain the stability of atoms and the spectral lines they produced. Bohr developed a model of the atom based on the quantization of atomic energy levels, which explained the discrete spectra of elements and introduced the idea of quantum jumps between energy levels.*
1925	*Pauli's Exclusion Principle: Two electrons with the same quantum number cannot be in the same state* (Pauli, 1925)	*Theoretical*	*Pauli's Exclusion Principle has no basis in Classical Physics and is also in conflict with Bohr's correspondence rule*
1923	*Wave-Particle Duality: Classical mechanics cannot explain the behavior of particles as both waves and particles* (Davisson & Germer, 1927)	*Experimental*	*The wave-particle duality is the concept that particles, such as electrons, can exhibit both wave-like and particle-like behavior. Classical mechanics was unable to explain the diffraction and interference patterns observed with electrons in the Davisson-Germer experiment.*
1926	*Schrodinger's Equation: Probability Wave Function*	*Theoretical*	*A matter wave function, which is not possible in classical mechanics*
1927	*Uncertainty Principle: Classical mechanics cannot simultaneously measure the position and momentum of a particle with arbitrary precision* (Heisenberg, 1927)	*Theoretical*	*Classical mechanics assumed that it was possible to measure both the position and momentum of a particle with arbitrary precision. Heisenberg's uncertainty principle states that the more precisely the position of a particle is known, the less precisely its momentum can be known, and vice versa.*
1928	Dirac Equation: Classical mechanics cannot describe relativistic quantum mechanics (Dirac, 1928)	*Theoretical*	Classical mechanics is non-relativistic and cannot describe the behavior of particles traveling at high speeds. Dirac's equation describes the behavior of relativistic particles in a quantum mechanical framework..
1935	EPR Paradox: Classical mechanics cannot explain quantum entanglement (Crull & Bacciagaluppi, 2022)	*Theoretical*	The EPR paradox is a thought experiment that highlights the apparent contradiction between quantum mechanics and classical mechanics. It involves the entanglement of two particles, where a measurement on one particle seems to instantaneously affect the other particle, even if they are separated by large distances. This led to the development of the concept of quantum entanglement, which is a fundamental concept in quantum mechanics.

Continued

1947	Lamb Shift: Classical mechanics cannot explain the energy shift in the hydrogen spectrum (Lamb & Retherford, 1947)	*Experimental*	The Lamb shift is the small energy shift observed in the hydrogen spectrum that could not be explained by classical mechanics. It was a significant confirmation of the predictions of quantum electrodynamics, which is the relativistic quantum field theory that describes the interactions between charged particles and
1955	Double-Slit Experiment with Electrons: Classical mechanics cannot explain the interference pattern of electrons (Davisson, 1955)	*Theoretical/ Experimental*	The double-slit experiment with electrons demonstrated the wave-like nature of particles and the interference pattern they produce, which could not be explained by classical mechanics. The experiment provided further evidence for the wave-particle duality of matter and established the foundation for quantum mechanics.
1964	Bell's Theorem: Classical mechanics cannot explain the correlations between entangled particles (Bell, 1964)	*Theoretical*	Bell's theorem is a mathematical proof that shows that classical mechanics cannot explain the correlations between entangled particles. It states that if particles have definite properties before being measured, as classical mechanics assumes, then the results of a series of measurements must satisfy certain mathematical inequalities. However, these inequalities are violated by the predictions of quantum mechanics, indicating that particles do not have definite properties before being measured. This led to the development of quantum information theory and the study of quantum entanglement.
1972	Aharonov-Bohm Effect: Classical mechanics cannot explain the behavior of particles in the presence of electromagnetic fields (Aharonov & Bohm, 1959)	*Experimental*	The Aharonov-Bohm effect is a phenomenon where the behavior of a particle is affected by the presence of an electromagnetic field, even when the particle does not directly interact with the field. This effect cannot be explained by classical mechanics, which assumes that the behavior of a particle is determined solely by the forces acting on it. The effect is a consequence of the non-locality of the electromagnetic field, which is described by the electromagnetic potential, and is a fundamental concept in quantum mechanics.
1982	Quantum Teleportation: Classical mechanics cannot explain the transfer of quantum information (Bouwmeester, 1997)	*Experimental*	Quantum teleportation is a process where the quantum state of one particle is transferred to another particle due to quantum entanglement, without involving any travel.
1986	Quantum Hall Effect: Classical mechanics cannot explain the quantization of electrical conductance (Klitzing et al., 1980)	*Experimental*	The quantum Hall effect is a phenomenon where the electrical conductance of a two-dimensional electron gas is quantized, meaning that it can only take on discrete values. This effect cannot be explained by classical mechanics, which assumes that the behavior of electrons can be described using classical equations of motion. Instead, the effect is a consequence of the quantum mechanical properties of electrons, such as their wave-like nature and quantization of energy levels. The quantum Hall effect has important applications in metrology and the determination of fundamental physical constants.
2001	Bose-Einstein Condensation: Classical mechanics cannot explain the behavior of ultra-cold atoms (Anderson et al., 1995)	*Experimental*	Bose-Einstein condensation is a phenomenon where a gas of ultra-cold atoms collapses into a single quantum state, forming a macroscopic quantum object. This phenomenon cannot be explained by classical mechanics, which assumes that the behavior of particles is described using classical equations of motion. Instead, Bose-Einstein condensation is a consequence of the wave-like nature of particles and their quantum mechanical properties, such as indistinguishability and coherence. The observation of Bose-Einstein condensation was a major breakthrough in the field of atomic physics and has led to the development of new technologies, such as atom lasers and ultra-cold atom interferometry.

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2010	Quantum Computing: Classical mechanics cannot explain the speedup achieved by quantum algorithms (Shor, 1994)	*Theoretical*	Quantum computing is a type of computing that uses quantum mechanics to perform certain types of calculations much faster than classical computers. This speedup cannot be explained by classical mechanics, which assumes that the behavior of particles is described using classical equations of motion. Instead, quantum computing relies on the principles of quantum mechanics, such as superposition and entanglement, to perform multiple calculations simultaneously. The speedup achieved by quantum algorithms, such as Shor's algorithm for factoring large numbers, has important applications in cryptography and other fields.
2015	Quantum Biology: Classical mechanics cannot explain the role of quantum mechanics in biological systems (Lambert et al., 2013)	*Theoretical*	Quantum biology is an emerging field that explores the role of quantum mechanics in biological systems, such as photosynthesis, neurology etc.
2018	Quantum Mechanics vs. Realism: Quantum mechanics violates the principle of local realism	*Theoretical*	The principle of local realism states that the properties of a particle are predetermined and independent of any measurement or observation. This principle is violated by quantum mechanics, which predicts that the properties of a particle can only be determined through measurement and that the act of measurement can affect the state of the particle. This conflict was first described in the famous EPR paradox paper and was later formalized by John Bell in his inequalities. Experimental tests of Bell's inequalities have consistently shown that quantum mechanics violates the principle of local realism, confirming the predictions of quantum mechanics and ruling out any local hidden variable theory. This conflict has important implications for our understanding of the nature of reality and the fundamental laws of physics.
2021	Quantum Mechanics vs. Relativity: Quantum mechanics does not account for gravity	*Theoretical*	Quantum mechanics and general relativity are the two most successful theories in physics, but they are incompatible with each other. While general relativity describes the behavior of gravity on a large scale, quantum mechanics describes the behavior of particles on a small scale. The problem is that quantum mechanics does not account for the force of gravity, making it impossible to describe the behavior of particles in a gravitational field. This conflict is known as the problem of quantum gravity, and it is one of the biggest unsolved problems in physics. In 2021, a team of researchers demonstrated a way to simulate quantum gravity in the lab using quantum teleportation, which could lead to new insights into this problem.
2021	Quantum Mechanics vs. Reality: The measurement problem (Schlosshauer, 2004)	*Theoretical*	The measurement problem is one of the most famous and controversial conflicts in quantum mechanics. It refers to the paradoxical nature of quantum mechanics, where the act of measurement can collapse the wave function of a particle and determine its state. This conflict arises because the wave function describes the probabilities of different states, but measurement seems to force the particle to take on a definite state. There are many interpretations of quantum mechanics that attempt to resolve this conflict, including the Copenhagen interpretation, the many-worlds interpretation, and the pilot wave theory. However, the measurement problem remains an open question and a subject of intense debate among physicists.

Note: Generated with help of Chat GPT.

different universes, splitting into infinite worlds every fraction of a second. This scenario would violate the conservation of matter and energy. Then what meaning can we assign to the concept of "parallel worlds"? The reality of the parallel worlds can only be understood as an analogy and we present here the analogy of a multi-faceted crystal, a crystal with infinite faces, with each facet representing a different world. The analogy is not in a geometric or physical sense but a conceptual one. We have seen that the universal wave function, in a sense is also the environment that contains the observer-observed system which renders it as cognizant.

From the above discussions, three very interesting conclusions can be drawn, two from the quantum theory and the other from cosmology and dimensionality streams respectively:

1) Observation cannot take place without cognizance and therefore, the observer is cognizant. As a result, the environment too has got to be cognizant because the observer is embedded in it. Lastly, if there is no cognizance, there will be no observation, no entanglement, and no decoherence, which means we will not perceive the decohered universe as we do.

2) There is a universal wave function with entangled observers, environment, cognizance, and probably multiple worlds. The multiple worlds have to be understood in a conceptual analogy with different facets of a crystal, each facet representing a different world

3) The other conclusion on reality is arrived at from a cosmological and spacetime dimensionality perspective. According to Wesson and many others, mass and energy in the curved 4D spacetime are manifestations of a flat (4D + n) space. The (4D + n) space itself could be a spacetime continuum (where n > 0) perceived by us as 4D spacetime.

To sum it up, keeping in view the understanding arrived at so far, the true reality is a flat 4D + n (n > 0) space (possibly 5D spacetime continuum), cognizance, and a universal wave function.

Table 2 summarizes the contradictions of quantum theory from the classical theory, as they have arisen, till today.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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