

# Theory of Ultimate Symmetry and the Idea of Multiverse

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**Abstract:** *While we are familiar with the concept of symmetry, 'Ultimate Symmetry' is a new and more profound concept. Ultimate symmetry can be termed as 'absolute neutrality'. Multipolarity of 'potentialities' entails absolute neutrality. Potentialities are 'beables' of the 'exo-systems' whose interactions give rise to the beables of the system under consideration, i.e. our universe. 'Beables' of our universe are the most fundamental quanta of space which are being continuously engendered following the law of 'conservation of ultimate symmetry'. This phenomenon gives rise to the continuous expansion of our universe. The concept of exo-systems stimulates the notion of many universes, or a 'multiverse' as the idea is currently known.*

**Keywords:** Ultimate Symmetry, Potentialities, Absolute neutrality, Exo-systems, Beables, Multiverse

## 1. Introduction

What is the most fundamental entity of the nature? What is the most fundamental relationship in our universe (or multiverse)? These questions can be posed from two different angles. From philosophical point of view, this is a very pertinent question to find a righteous way to unite whole mankind who are divided by various conflicting ideas and beliefs. From scientific point of view, the search for the most fundamental relationship and entity plays one of the most important roles in the quest for the ultimate and absolute truth of the nature and cosmos. In earlier times, space and time were considered to be the most fundamental structures of nature. Resounding scientific theories of classical and quantum mechanics, theory of general relativity – all these theories considered space and time (i.e. spacetime) to be the most fundamental things of nature. In quantum field theory, there is all-pervading quantum field which provides the basis for genesis of all the elementary particles. Then, there is string theory which proposes one-dimensional strings to be the most elementary physical structures. There are some quarters in both science and philosophy which consider 'causality' to be more basic in nature. Scientific theories in this field suggest causal sets to be more fundamental entities than both space and time. But on deeper analysis, it appears that all these theories are only parts of reality, not the whole picture.

The definition of reality is different to people from different fields in different contexts. Renowned scientist John Bell put forward the concepts of 'Beables' and 'Observables' which are of immense significance in understanding reality in scientific pursuits. The important points to be underscored here, as per Ian T. Durham, are noted below.

- 1) Bell refers to the beables of a theory as "those elements which correspond to elements of reality, to things which exist."
- 2) Bell recognizes that our fundamental window on the world is through observables, but he says that our observables must be constructed from beables.
- 3) In a sense, the problem of induction is concerned with just how we identify what actually is fundamental. After all, one assumes that there is some minimum set of

beables required for any final theory should such a theory even be attainable. To put it another way, one assumes that the universe, at its most fundamental level, consists only of those beables that are necessary to reproduce its manifest phenomena, i.e. there should be no extraneous beables.

In this article, I have shown that beables are born out of potentialities. When an entity comes into being (i.e. it becomes beable or observable), it becomes a part of reality in our universe. This phenomenon is a result of interactions of different potentialities. In this sense, reality corresponds to a large spectrum of potentialities. But what is the governing principle for reality to be engendered from the interactions of different potentialities? Here I introduce the concept of 'Ultimate Symmetry' or 'Absolute Neutrality' and the hypothesis of 'conservation of ultimate symmetry'. Before we delve into these new concepts, let us have a preliminary discussion on symmetry in the next section.

## 2. Symmetry- A Beautiful Concept

Symmetry is a manifestation of the functioning of nature at the most fundamental level. Nature expresses itself in so elegant and umpteen ways that each of the faculties of human intellect has its own unique way of adoration and appreciation. Be it art, paintings, music, architecture, sculpture or aesthetics – symmetry has a far-reaching influence across various fields. Symmetry seems to be a rudimentary language through which nature wishes to express itself. The grandeur, elegance and diversity of natural phenomena are manifestations of the deep-rooted symmetries in nature that are abound throughout the world – from the micro-domain of sub-atomic particles to the almost infinite vastness of cosmic scales.

Like the afore-mentioned different fields, symmetry is also conspicuous by its overwhelming presence in the field of science and mathematics. The scientific and mathematical approach to symmetry makes it a powerful tool to further our understanding of the nature's design in a more elaborate, objective and quantitative way. In scientific theories, symmetry has significant implications across various fields.

In particle physics, symmetry plays a crucial role in understanding the behavior of sub-atomic particles and forces. In condensed matter physics, symmetry is essential for understanding the properties of materials, such as crystals and magnets. In quantum mechanics, symmetry is necessary to classify the states of quantum systems and understand their behavior. In mathematics, symmetry is studied using group theory, which provides a mathematical framework for understanding symmetry operations. Symmetry is used to study the properties of algebraic structures, such as groups and rings. It has also extensive use in the study of geometric and topological shapes and spaces. In molecular chemistry, it is used to understand the structure and properties of molecules, whereas in crystallography, it is used to study the structure of crystals and their properties. In evolutionary biology, it is used to study the evolution and developmental processes of physiological structures of living organisms. In computer graphics, it is used to create realistic images and animations, while in machine learning, it is used to develop algorithms for image and signal processing.

Symmetry can be broadly classified into three categories with several sub-categories. The three broad categories are:

- 1) Translation symmetry,
- 2) Reflection symmetry,
- 3) Rotational symmetry.

Translation symmetry can be divided into two sub-categories:

- 1) Space translation symmetry,
- 2) Time translation symmetry.

Reflection symmetry can be further divided into three sub-categories:

- 1) Time reversal symmetry,
- 2) Space reflection symmetry (parity),
- 3) Matter-antimatter symmetry (matter reflection).

While it is obvious that the idea of symmetry is extremely important, the idea of broken symmetry is also important. Matter-antimatter asymmetry is a major example in this case. Matter and antimatter behave identically. But antimatters are very rare. We have sufficient experimental evidence that antimatters are not just rare on earth; they are rare throughout the entire universe. But it is almost certain that there had to be equal amounts of matter and antimatter at the big bang – in other words there was perfect symmetry between them. Then why antimatters are so rare today?

We do not know the actual reason behind it. But we believe that some time in the very early universe, probably within a fraction of a second after the big bang, the symmetry of matter and antimatter had to be broken. While, as has been said, we do not know why and how, we do know the size of asymmetry was very small, about one part in a billion ( $1: 10^9$ ). How do we know the size of this asymmetry? Remember that when matter and antimatter meet, they annihilate each other. If there were perfect symmetry between the two, then there would have been just enough antimatter to annihilate all the matter of universe so that there would be neither matter nor antimatter left in the universe – there would have been just energy everywhere in

the form of electromagnetic radiation (photon). In other words, the ratio between matter and energy would have been zero. But, of course, this is not the case in our universe where this ratio has been measured to be  $1: 10^9$ . Therefore, it can be said that this must be the size of matter-antimatter asymmetry which occurred in the very early universe.

If this symmetry were not broken, then there would have been no matter in this universe. No cosmic structures, stars, planets including living beings could come into existence. While, as it appears, we should be thankful to the matter-antimatter broken symmetry, we owe our existence to some others also. In 1956, Chien-Shiung Wu showed in his famous experiment that parity is not a good symmetry in weak nuclear interactions. The inspiration for this experiment came from the theoretical works by Tsung-Dao Lee and Chen-Ning Yang who proposed that parity might not be conserved in weak nuclear interactions. They were correct and were awarded Nobel Prize for that.

Another important example is time reversal symmetry. We know from our daily experience that this symmetry does not hold on macroscopic level. But time reversal symmetry holds on microscopic scale. It is one of rare cases where we cannot predict macroscopic behavior of matters from the atomic or sub-atomic behaviors, i.e. microscopic behaviors. It is interesting to note that in some way or other, the three reflection symmetries are broken. On the other hand, as far as we know, the translation symmetries are not.

### Ultimate symmetry or Absolute symmetry – a more profound concept

While we know the concept of symmetry, ‘Ultimate Symmetry’ is a totally new concept. What is ‘Ultimate Symmetry’ or ‘Absolute Symmetry’? Ultimate symmetry is nothing, absolutely nothing. But ‘Nothingness’ is not an inert concept in this context as it is often associated to in other discussions. In the present context, ‘nothingness’ is ripe and vibrant with infinite ‘potentialities’. It is a new concept altogether which is different from the idea of nothingness that has been alluded to at some length in some of the recent scientific literatures. In fact, in a more technical sense, ultimate symmetry can be termed as ‘absolute neutrality’. The idea of ‘nothingness’ has also been discussed from different angles elaborately by Lawrence M. Krauss in his well-written book ‘A universe from nothing’. There are some engrossing discussions about the idea of nothingness in this book. All the things of this universe that we observe and experience today, like atoms, stars and galaxies, have been there only for a finite time. A question naturally arises in our mind that where did they come from. While the obvious answer might seem to be ‘something’, it is not necessarily true. Many cosmologists today begin to realize that they may have arisen from ‘nothing’. But what does ‘nothing’ mean to a scientist in that context? Is it truly possible to create ‘something out of nothing’? These are some of the riddles which need to be addressed before we go deep down the subject.

At first, let us consider the idea of ‘nothing’ as a state where the ‘thing’ we are referring to doesn’t yet exist. We can’t have galaxies, stars, planets or any life forms without the particles necessary to build them. Everything we observe

today is made of subatomic matter particles which are the raw ingredients that our universe is built of. If we start with a matter-filled universe, we know how it can expand, cool and gravitate to evolve to the present stage. We know how stars are born (and die), leading to the heavy elements that allow the creation of stars with low mass, rocky planets, followed by organic molecules and eventually, the possibility of life. But how did the whole process end up with a matter-filled universe, instead of one with equal amounts of matter and antimatter? As it has already been mentioned, it is one of the biggest puzzles in cosmology today. If laws of physics allow only creation of equal amounts of matter and antimatter, then how do we live in a universe where every structure we see today is made of matter and not antimatter? Every planet, star or galaxy we have so far observed is known to be made of matter and not antimatter. So how, then, there is such an excess of matter over antimatter today if the universe was not born with one?

The origin of the matter-antimatter asymmetry in our universe – a problem known as ‘baryogenesis’ – is one of the greatest unsolved puzzles in physics today. Many ideas and mechanisms have been proposed for an explanation but still we do not know the answer. We do not know why there is something (more matter than antimatter) instead of nothing (equal amounts of matter and antimatter). But it is not an example of ‘nothing’ in true sense. Matter and antimatter annihilate each other to form energy. If there were equal amounts of matter and antimatter, there would have been just only energy following annihilation, i.e. our universe would have been filled with radiation only.

But if we prefer a definition of nothing that contains literally no things at all, then it is evident that the above definition is inadequate; it clearly contains something, i.e. radiation. In order to get a more accurate definition of ‘nothing’, one has to get rid of every quantum of radiation (photon) as well as every fundamental particle of matter. Particles or radiation, neutrinos or dark matter – everything must be removed to ensure that nothing is left behind except the empty space itself. With no fundamental particles of matter, no quanta of radiation, we have the void of empty space only. Some of the scientists consider this as the true definition of ‘nothingness’.

But even in this highly imaginative situation, certain physical entities still persist. The laws of physics still remain there, which means that quantum fields still pervade the whole universe. That includes the electromagnetic field, the gravitational field, the Higgs field, and the fields arising from the nuclear forces. Spacetime is still there - governed by General Relativity. All the fundamental constants of nature still retain their same values we observe them to have even in this highly restrictive scenario.

And perhaps most importantly, the zero-point energy of space, which is the energy of space itself, is still there with its present, positive, non-zero value. We do not know whether it is a true ‘ground state’ of our universe or whether a ground state with still lower energy of space is possible. It’s possible that we are currently in a false vacuum state and the true vacuum state is one with true lowest energy state, i.e. a ground state with zero-point energy closer to zero or

exactly zero. But the transition from the current vacuum state to such a true vacuum state would likely lead to a catastrophe for the universe – a phenomenon known as vacuum decay which would not be favorable for our existence. But this state provides a better definition of ‘nothing’ where the laws of physics are still valid (although some of the rules would be different). If it were possible to reach the true ground state of the universe – whatever that state may look like – and at the same time if we could have removed all the matter, energy, radiation, spacetime curvature and ripples etc. from the universe, we would have been left with a state of almost perfect ‘physical nothingness’.

But there is still a stage for the universe to play out on with no players on the stage. There would be no cast, no script and no scene in that play. The stage of play is nothing but a vast abyss of ‘physical nothingness’. The zero-point energy of the universe would be at its absolute minimum, making it almost impossible to extract work, energy or any real particles (or antiparticles) from it. But even in this highly imaginative scenario, we still have ‘something’ there, because space, time and rules of physics are still in place.

At this stage, one may point out that genuine nothingness occurs only when all of space, time and the governing rules of nature are removed. This is the most extreme case of nothingness. But scientists usually cannot make any sense of this sort of nothingness. If one follows this line of thinking, a number of questions arise with no definitive answers. These are –

- 1) How does spacetime emerge at a particular location or instant, when there is no such thing as space (location) or time (instant)?
- 2) How can we imagine something being ‘outside’ the universe if we don’t have space, or ‘having a beginning’ if we don’t have time?
- 3) From where the rules governing the universe arise?

Physicists have no definition for this final state of ‘nothing’, although it seems to be most satisfying philosophically. In fact, the concept of nothingness means different things to people from different fields in different contexts. But each of the definitions mentioned here is correct in its own way. Each definition has its own scope and range of validity, with applications to a wide range of physical problems; from the origin of matter in this universe to cosmic inflation, dark energy and the zero-point energy of space itself.

But ‘Ultimate Symmetry’ is a different concept altogether. As has already been said, ‘Ultimate Symmetry’ is nothing, absolutely nothing. But this concept of nothingness is not similar to the afore-stated different concepts of nothingness. (Actually it shows the limitation of human languages). ‘Nothing’ in this case is not the absence of something or everything. In the context of ‘Ultimate Symmetry’, ‘nothing’ is in fact teeming with infinite ‘potentialities’. The hypothesis of ‘conservation of ultimate symmetry’ is one of the most vital inferences that can be made from the concept of ultimate symmetry.

For an understanding of the above-mentioned concepts, let us take a more technical definition of ‘ultimate symmetry’.

In a more technical sense, ‘ultimate symmetry’ can be termed as ‘absolute neutrality’. The question of neutrality arises here as a result of ‘multi-polarities’ of the ‘potentialities’. What is ‘multi-polarity’? To investigate about this, we have to focus on ‘polarity’, which is a familiar concept for us. We all know about polarities of electrical charges. There are two types of electrical charges – positive and negative. The positive and negative electrical charges can exist in isolation. But to make a system electrically neutral, you need equal amounts of positive and negative charges. Electrical charges come in integral numbers (except in case of quarks). In this sense, electrical charges are quantized. We are also familiar with magnetic polarities. But magnetic poles are not found in isolation.

There is another form of polarity in the standard model of particle physics. Quarks – the sub-atomic particles – possess a very important property called color charge which is responsible for the strong nuclear force. Quarks come in three colors – red, green and blue (i.e. the names of the fundamental hues of white color). There are also anti-colors of these three color charges which are properties of anti-quarks. (Color charge is not related to visible colors we see in our everyday life. It is just a metaphor for the interactions of the strong force). The strong nuclear force binds quarks together inside hadrons (i.e. protons, neutrons etc.) and holds hadrons together inside atomic nuclei. Quantum Chromodynamics (QCD) is the theory which describes the strong nuclear force and the behavior of quarks and gluons (which are the particles that carry the color charge between the quarks). In case of color charges, neutrality is achieved when the three color charges – red, green and blue – combine to give white color (metaphorically), i.e. red + green + blue = white = neutral.

This is true in case of baryons. In case of mesons, neutrality is achieved when color charge of the quark is canceled out by the anti-color charge of the anti-quark, viz. red + anti-red = neutral. Color neutrality is an essential property of hadrons, ensuring that quarks are bound within hadrons and the strong nuclear force acts according to the symmetry criteria in a way that is consistent with experimental observations.

The study of cosmology at the cosmic scale demands study of the whole universe as a system. But to comprehend properly the concept of ultimate symmetry or absolute neutrality, at first we have to define certain specific ideas. Let us call the whole universe as the ‘System Under Consideration’ (SUC). The next question that arises here is - what is neutrality in the context of SUC? What is the entity whose neutrality is being considered here? To investigate about such questions, I found that the study of the SUC in isolation is not sufficient. The concept of exo-systems needs to be introduced here. The exo-systems to the SUC exist beyond the horizon of the SUC. But this horizon is not just a spatial horizon. It is something more than that. It is explained in details in appendix – 2. For now, let us focus on the entities for which neutrality is being discussed. The most fundamental entities of the exo-systems are their potentialities. They are called potentialities in respect of the SUC. But, actually, a potentiality is a beable which is the fundamental quantum of reality of the respective exo-

system. In fact, reality and potentiality are vice-versa. What is reality in a particular system is potentiality for another system. Reality in the SUC is potentiality for all exo-systems to it and vice-versa. All potentialities that belong to their respective exo-systems are distinct from each other. But at present, neither do we know about the distribution, variations and interrelations among potentialities of different exo-systems nor do we need the same for our current discussion. The point to be stressed here is that the polarity of potentialities is a fundamental property for all systems. In fact, multi-polarities of all potentialities are responsible to bring about the phenomenon of ultimate or absolute neutrality across all the systems (SUC and its exo-systems).

### Conservation of Ultimate Symmetry

To explain the concept of conservation of ultimate symmetry, let us take at first a simple case of two potentialities –  $P_1$  and  $P_2$ . Mutual causal interaction between these two potentialities  $P_1$  and  $P_2$  determines which one to become ‘beable’ or ‘observable’ in our universe, i.e. the system under consideration (SUC). According to the hypothesis of conservation of ultimate symmetry, we can write the condition of neutrality in terms of polarities of potentialities as follows -

$$P_1 + P_2 = 0 \text{ (= neutral)} \quad \text{---- (1)}$$

A particular potentiality  $P_1$  depends on another potentiality  $P_2$  to make its presence felt in our system, i.e. our universe. In this context, one may ask about the true nature of  $P_1$  and  $P_2$ . As has been said above, they are potentialities. Potentialities are ‘beables’ for their respective systems. What is a ‘beable’? ‘Beables’ are the fundamental entities which construct the reality of a system. According to John Bell, “--- our fundamental window on the world is through observables, --- but our observables must be constructed from beables”.

Let us now extend our simple case of two potentialities. According to the hypothesis of conservation of ultimate symmetry, we can generalize the condition of neutrality in terms of multi-polarities of potentialities as follows -

$$P_0 + \sum P_i = 0 \text{ (= neutral)} \quad \text{----(2)}$$

$$[i = 1, 2, 3, \dots]$$

Here,  $P_0 \rightarrow$  beable entity of the SUC,  
 $P_i \rightarrow$  potentialities belonging to the exo-systems which are responsible for genesis of  $P_0$ .

All potentialities ( $P_i$ -s and  $P_0$ ) are connected to each other through causality. This is internal causality of potentialities. This potentiality-causality network makes it possible for one of the potentialities to become a part of reality. Once a potentiality becomes a part of reality, i.e. it becomes beable in the SUC, it is then governed by the causal structure of our universe. The number of exo-systems can be infinite. Therefore, number of potentialities ( $P_i$ -s) also can extend to infinity. But for the sake of simplicity of the present discussion, the number of exo-systems (and, hence the number of potentialities) is taken to be a finite number.

The outcome of  $P_0$  (beable entity) is the result of two things – i) internal causal interactions among potentialities and ii)

the number of potentialities that are responsible for the genesis of  $P_0$ . But internal causal structures and interactions among different potentialities and distribution of potentialities are not known to us at present. Therefore, we cannot but concentrate on the number of potentialities for an elaborate analysis of  $P_0$  which is the most fundamental entity of our universe.

The concept of total internal energy is to be discussed more elaborately in this context. The internal energy of a system is essentially the summation of entire potential energy due to the relative position and configuration of the fundamental quanta of that system and the kinetic energy of the microscopic constituent particles which are in constant motion within the system. (There can be other forms of energy also including the rest mass of the constituent particles of the system, but they are not as fundamental as potential energy and kinetic energy.) In general, there are two fundamental forms of energy – potential energy and kinetic energy. Potential energy entails the ability to do work through different modes of interactions like attraction, repulsion etc., i.e. the ability to bring things into motion. Kinetic energy, on the other hand, is associated with the motion itself. Therefore, it can be said that potential energy, which resides in the relative position and configuration of the fundamental quanta of the system concerned, is a more fundamental concept than kinetic energy or other forms of energy. In this sense, in the context of total internal energy, it would be reasonable to explore the evolution of total internal potential energy of the system under consideration. At present, there is a problem to calculate definitely the total internal potential energy of a system on the basis of the relative position or configuration of its constituent quanta. But it should not deter our spirit to pursue the path leading to the discovery of ultimate truth. We must invent novel ways to solve this problem.

**Bridge between Potentiality and Reality**

We need to develop a bridge, i.e. a causal and logical connection, between potentiality as described in the previous section and the reality in our system, i.e. our universe. We need to explore the Relation-2 of the foregoing section to investigate elaborately the nature of relationship between potentiality and reality (i.e. beable or observable).

$$P_0 + \sum P_i = 0 \quad \text{---- (2)}$$

Where,  $P_0$  ----> quantum beable entity which is the fundamental quantum of reality in SUC.

$P_i$  ----> quantum potentialities which are responsible to generate  $P_0$ .

As discussed earlier,  $P_0$  is the most fundamental beable entity of the SUC.  $P_i$ -s are also the most fundamental beable entities of their respective systems which are exo-systems to SUC. It has also been discussed that the genesis of  $P_0$  depends on two factors – 1) internal causal interactions among  $P_i$ -s, and 2) the spectrum of potentialities, i.e. the number of  $P_i$ -s that are responsible for the genesis of  $P_0$ . At present, internal causal structures among  $P_i$ -s are not known to us. Therefore, we have to concentrate mainly on the number of  $P_i$ -s in our present discussion.

It is evident from the foregoing discussion that the onset of  $P_0$  in the SUC increases the total internal potential energy of the system due to reorientation of the relative position and configuration of the fundamental quanta of that system. Again, onset of  $P_0$  depends on the number of potentialities. Let us now introduce the following relation between total internal potential energy of a system and the number of quantum potentialities.

$$E = f ( P_n ) \quad \text{---- (3)}$$

Where,  $E$  ----> total internal potential energy of the system under consideration (SUC)

$P_n$  ----> total number of potentialities responsible for the genesis of  $P_0$   
(the number of exo-systems  $N \leq P_n$ ).

It is evident from equation (1) of the foregoing section that

$$P_n \geq 1 \quad \text{---- (4)}$$

The number of potentialities  $P_n$  can be a large (finite) number with a lower bound equal to 1. (Here we take  $P_n$  to be a finite number for simplicity of our discussion).

Let us now explore the nature of interactions of different systems (SUC and exo-systems) on the basis of equation (3). If we consider two isolated systems with internal potential energies  $E_1$  &  $E_2$ , then we get the following two equations

$$E_1 = f ( P_{n1} ) \quad \text{---- (5) (for system 1)}$$

And,

$$E_2 = f ( P_{n2} ) \quad \text{---- (6) stem 2)}$$

Total internal potential energy ( $E$ ) of the two systems is

$$E = E_1 + E_2 \quad \text{---- (7)}$$

If these two systems come into causal contact with one another, then there will be causal interactions between all the quantum potentialities of those two systems. The total number of quantum potentialities responsible for the genesis of  $p_0$  (i.e.  $p_n$ ) is then given by

$$P_n = P_{n1} \cdot P_{n2} \quad \text{---- (8)}$$

Combining equations (3), (5), (6), (7) and (8), we get

$$f ( P_{n1} ) + f ( P_{n2} ) = f ( P_{n1} \cdot P_{n2} ) \quad \text{---- (9)}$$

Differentiating with respect to  $p_{n2}$ , we get

$$\frac{df(P_{n2})}{dP_{n2}} = \frac{df(P_{n1} \cdot P_{n2})}{dP_{n2}} = \frac{df(P_{n1} \cdot P_{n2})}{dP_n} \cdot \frac{dP_n}{dP_{n2}} = \frac{df(P_{n1} \cdot P_{n2})}{dP_n} \cdot P_{n1}$$

Differentiating again with respect to  $p_{n1}$ , we have

$$\begin{aligned} 0 &= \frac{df(P_{n1} \cdot P_{n2})}{dP_n} + P_{n1} \frac{d}{dP_{n1}} \left( \frac{df(P_{n1} \cdot P_{n2})}{dP_n} \right) \\ &= \frac{df(P_n)}{dP_n} + P_{n1} \cdot \frac{d}{dP_{n1}} \left( \frac{df(P_n)}{dP_n} \right) \cdot \frac{dP_n}{dP_{n1}} \\ &= f'(P_n) + P_{n1} \cdot P_{n2} \cdot f''(P_n) \left( \frac{dP_n}{dP_{n1}} = P_{n2} \right) \\ &= f'(P_n) + P_n \cdot f''(P_n) \quad (P_n = P_{n1} \cdot P_{n2}) \\ &\Rightarrow P_n \cdot f''(P_n) = - f'(P_n) \\ &\Rightarrow f''(P_n) / f'(P_n) = - 1 / P_n \quad \text{---- (10)} \end{aligned}$$

On integration, we have

$$\begin{aligned} \text{Log}_e f'(P_n) &= - \text{log}_e P_n + \text{log}_e K \quad (K = \text{constant}) \\ \Rightarrow f'(P_n) &= K / P_n \quad \text{---- (11)} \end{aligned}$$

Again integrating the above expression, we get

$$f ( P_n ) = K \text{log}_e P_n + \text{log}_e P_{nc} \quad (P_{nc} = \text{constant})$$

From equation (3), we get

$$E = K \log_e P_n + \log_e P_{nc} \quad \text{---- (12)}$$

where E is the total internal potential energy of the combined system.

From equation (4), we get the minimum value of  $P_n$  to be 1. This boundary condition (lower boundary) can be applied in the equation (12). As  $P_{nc}$  in equation (12) is any arbitrary constant, we can take the value of  $P_{nc}$  to be equal to 1, i.e. the boundary condition given by the relation (4).

In that case, the equation (12) is reduced to the following form

$$E = K \log_e P_n \quad \text{---- (13) } (\log 1 = 0)$$

Relation (13) shows that the total internal potential energy (E) of a system depends on the spectrum of potentialities, i.e. the number of quantum potentialities of the exo-systems to which they belong. The governing principle here is the hypothesis of conservation of ultimate symmetry. It shows that the theory of ultimate symmetry or absolute neutrality is valid not only for the SUC (i.e. our universe), but it also takes into account the exo-systems of SUC within its ambit.

The energy E in equation (13) can be computed in two different ways. If we consider the conventional unit (i.e. S.I. unit) of energy for E, then we have to assign the same unit to the constant K also. It is the usual practice of getting the physical relations. But there is an alternative way also. Energy can also be computed on the basis of numbers using the relation (13) in an equivalent way. In that case, relation (13) is to be expressed in terms of generalized Log  $P_n$  with respect to any base suitably chosen for the specific purpose.

$$E = \text{Log}_b P_n \quad \text{---- (14) } (b = \text{any arbitrary base})$$

If the fields of potentialities are taken to be quantum fields, then potentialities are excitations of those fields arising out of the interactions among the fields of potentialities of different exo-systems. Energy is a conserved quantity for the conventional quantum fields, but not for the fields of potentialities. The fields of potentialities are governed by the conservation of ultimate symmetry or absolute neutrality.

#### Nature of $P_o$

What is the nature of  $P_o$ ?  $P_o$  is the quantized form of the most fundamental entity of SUC. But what is the nature of that fundamental entity?  $P_n$  is the number of the quantized potential fundamental entities belonging to the exo-systems which give rise to quantized fundamental entity  $P_o$  in our universe obeying the relationship for 'conservation of ultimate symmetry'

$$P_o + \sum P_i = 0$$

$P_o$  is the outcome of this conservation relationship which manifests itself as quantum of space in our universe. It is the fundamental quantum of space. It shows that space is quantized at the most fundamental level.

This equation for conservation of ultimate symmetry is also a relationship between reality and potentiality. This reality-potentiality relationship begets quanta of space ( $P_o$ ) in our universe. If this potentiality factor, i.e.  $P_n$ , is not well

understood or ignored, then the reality factor, i.e.  $P_o$ , may seem to be self-generated. In that case, it may seem to be an amazing phenomenon that more and more space is coming into existence on its own. This whole event gives rise to the idea of dark energy which occupies the centre-stage of the current cosmological debates and discourses. Therefore, to resolve the conundrum of dark energy and to investigate about the accelerating expansion of our universe, we have to concentrate on the conservation of ultimate symmetry.

The theory of ultimate symmetry indicates that at the most fundamental level, space is a quantized entity. When a quantum of space ( $P_o$ ) comes into existence in our universe obeying the law of conservation of ultimate symmetry, then the total configuration or orientation of the already existing quanta of space including the new one changes. As the space is quantized at the most fundamental level (i.e. at the most microscopic level), certain interesting as well as puzzling phenomena now seem to have a convincing explanation finally. Let us first consider the phenomenon of 'dark energy'. As per cosmological data available so far, it is the most abundant component our universe is made of. Almost 68% of our universe is dark energy, 27% is dark matter and only about 5% is the aggregate of ordinary (observable) mass and energy. Therefore it is but natural that the scientific literatures around the world are replete with various attempts to explain the dark energy. Some of them are enumerated in details in the website of NASA.

One explanation of dark energy comes from the quantum theory of matter. In this theory, there is a case of vacuum energy or zero-point energy where all the quantum states have values zero or they are not observable. Virtual particles are popping up and disappearing after their fleeting existence continually in this scenario. But when scientists attempted to calculate how much energy this would contribute to the empty space, the findings have gone astray by a lot – by a factor  $10^{120}$  which is certainly unacceptable.

Another explanation for dark energy is that it is the property of space. Currently scientists are beginning to realize that space itself has amazing properties. When Einstein incorporated 'cosmological constant' in his equation of general relativity, he had the idea that empty space can possess its own energy. As it is an inherent property of space itself, energy density of space won't decrease as space expands. If more of space somehow comes into existence, more energy of space would cause the universe to expand faster and faster.

Some of the scientists had the idea that it is possible for more space to come into existence. But it remained to be explained what could be the mechanism behind it. Finally, we have the answer in the form of 'ultimate symmetry'. If the phenomena of ultimate symmetry and conservation of ultimate symmetry are not well understood, generation of more space on its own may appear to be an amazing phenomenon. According to the principle of conservation of ultimate symmetry, potentialities ( $P_n$ ) beget reality ( $P_o$ ) in our universe. Potentialities belonging to the exo-systems beyond our universe are responsible for genesis of  $P_o$ , i.e. quanta of space in our universe. Expansion of universe is driven by the continuous genesis of  $P_o$  in our universe.

Therefore, it can be inferred from the foregoing discussion that existence of exo-systems is validated by the expansion of universe.

Let us now investigate what is the basis of the relationship between the total internal potential energy of our system under consideration (SUC), i.e. our universe, and the number of potentialities as expounded in this article.

$$E = f(P_n)$$

How the total potential energy of our universe (E) is dependent on the number of potentialities ( $P_n$ )? In other words, why the total internal potential energy content, i.e. E, of our universe is a function of the number of potentialities, i.e.  $P_n$ , which are entities of exo-systems beyond the SUC (i.e. our universe)? As mentioned in the previous section of this article, the outcome of  $P_o$  depends on two factors – 1) distribution and internal relationship of the potentialities and causal interactions among potentialities, and 2) number of potentialities ( $P_n$ ) that are relevant for  $P_o$  (i.e. responsible for genesis of  $P_o$ ). But the nature of internal causal relationship among potentialities is not known to us at present. Therefore we have to concentrate only on the number of potentialities ( $P_n$ ) responsible for the genesis of  $P_o$  in our universe. As soon as a quantum of space  $P_o$  comes into existence in our universe obeying the conservation of ultimate symmetry, the volume of space of the universe increases. This is the reason for the expansion of universe.

At each stage, the genesis of the quanta of space in the universe brings about a change or re-orientation of the configuration or relative positions of the existing quanta of space. As the number of quanta of space increases in the system, the total configuration of all the quanta of space of that system undergoes a change. This alters the relative positions of all quanta of space within the system. As the relative positions of all the quanta of space change due to integration of the new quanta of space, the total potential energy possessed by all the quanta of space increases due to the new relative positions of the quanta of space of the universe (due to the increased number of the quanta of space).

Some scientific discourses refer to the inherent energy of space. It is not the inherent energy of space. It is the potential energy that the quanta of space possess due to their relative positions and configuration within the system, i.e. our universe. Potential energy is the most basic form of energy, especially when we talk about a system like our universe. We have already discussed that the onset of  $P_o$  depends on the number of potentialities, i.e.  $P_n$ , and the total internal potential energy of the system under consideration (SUC, i.e. our universe) increases due to onset of  $P_o$  (i.e. quantum of space which is the basic building unit of space). Therefore, we can justify the relationship

$$E = f(P_n)$$

E on the left hand side of the equation denotes the total potential energy possessed by all quanta of space of the universe. What is called 'dark energy' is nothing but the total potential energy (E) of all the quanta of space due to

their relative configuration in our universe. It is not any mysterious inherent energy of space.

The other features manifested by the phenomenon of the expansion of universe can also be explained in the light of the theory of ultimate symmetry and conservation of ultimate symmetry. The expansion of the universe or the increase in volume of the universe does not decrease its density. Here the increase in volume of the system under consideration (i.e. our universe) takes place due to addition of the basic building blocks of the system which is the quanta of space ( $P_o$ ) as elucidated in this article. Integration of the most fundamental constituents of a system to the existing ensemble or body of the system does not reduce the density of the system while increasing the volume of the system. This mechanism generates the expansion of the system. This is what happens in case of our universe. Quanta of space ( $P_o$ ) are continuously engendered in our universe which triggers the accelerated expansion of the universe without diluting the density of it.

Another important feature of the expansion of universe is the restoration of homogeneity and isotropy of the whole universe during the process of expansion. As the generation of  $P_o$  in our universe is equally likely in all the directions and everywhere of the universe, therefore it is but natural that homogeneity of our universe is restored during its expansion and it is isotropic.

### 3. Conclusion

It transpires from the discussions of this article that the genesis of the fundamental quanta of space depends on the number of potentialities which are beables for their respective systems. It also alludes to the fact that this is a process where the fundamental quanta of space of the system under consideration (SUC), i.e. our universe, are being engendered due to interactions among potentialities. But how this theory can be validated by experiments? Expansion of the universe is the most important phenomenon which provides validation of the theory of ultimate symmetry. But we need some experiments which can be conducted right here on the earth. One possible experiment would be to verify the red-shift of the light from very distant sources. If the source of light is nearer, the red-shift effect due to the genesis of fundamental quanta of space would be too small or feeble to be detected decidedly. The experiments should be so designed as to nullify the effects of receding sources (red-shift), approaching sources (blue-shift) and the red-shift due to gravitational time dilation for very distant sources. In this set-up, we can get the red-shift of light only due to the genesis of fundamental space quanta obeying the theory of ultimate symmetry.

In this article, two distinct and different types of systems are taken for study. One is the system under consideration in which the smallest quanta of the most fundamental entity of the system (i.e.  $P_o$ ) are being generated under the influence of potentialities. The potentialities (i.e.  $P_n$ ) themselves are the smallest quanta of the most fundamental entities of their respective systems which are all exo-systems for the system under consideration (SUC). These exo-systems may all be

distinct and different types of systems from one another. Two distinct types of systems are classified as given below.

- 1) System under consideration (SUC),
- 2) Exo-systems of SUC.

In this discussion, our universe is the system under consideration. If our universe is taken to be an isolated system, the genesis of the smallest quanta of the most fundamental entity of our universe ( $P_0$ ) seems to violate the law of conservation of energy. We know that total energy for an isolated system is conserved. If the system has no interactions with its surroundings, total energy of this system remains conserved. But it is clear from the present discussion that our universe must have interactions with a large number of exo-systems (perhaps infinite number of exo-systems). These exo-systems may be other universes. Identification of these exo-systems requires more elaborate research and investigation and more data and information. But one thing is clear from the present discussion that all these systems (SUC and exo-systems) are causally interconnected through the conservation of ultimate symmetry (i.e. absolute neutrality). So it is clear that our system, i.e. our universe, is not an isolated system. At present we do not have evidence whether these exo-systems are spatially connected or disconnected to our universe, i.e. they exist beyond the periphery of our universe or not. In fact, the true nature of the potentialities is beyond our scientific knowledge and comprehension at present. Also, the question of spatial connection or disconnection seems to be irrelevant and ambiguous from the point of view of genesis of the quanta of space in our universe. How can we imagine something being 'outside' the universe when potentialities beget the fundamental entity what we perceive as space in our universe? All these facts point to the possibility that our universe is not an isolated system – it is just a part of an extended system comprising of a large (possibly infinite) number of exo-systems. Therefore, conservation of energy does not seem to be a valid proposition as far as the whole universe is concerned. (Conservation of energy for our universe has been discussed in details in Appendix – I).

Do the exo-systems specified in this article belong to our universe? What is the definition of universe in the first place? According to Ian T. Durham, if we define the universe as the totality of everything that exists, then "it is not clear how a universe would be defined within the context of any theory that admits multiple universes, particularly in such a manner that they could be distinguished in some meaningful way. The nature of what we mean by a universe in such instances remains largely unsettled. It is inherently ambiguous in regard to both 'totality' and 'existence'. The totality of all that exists to a proponent of an Everett – De Witt multiverse, for example, includes an infinite number of universes. This definition is simply too vague to qualify as a beable for any realistic theory.

Alternatively, an operationalist might define a universe as the totality of all that can be measured. Wheeler's participatory universe takes this idea to its logical extreme by suggesting that only things that can be measured can exist. ---- In Bell's conception, the observables corresponding to measurements are constructed from beables. This implies that full knowledge of certain beables

may not be possible. If our knowledge of the world is limited to observables and observables are built from beables, it is not inconceivable to imagine that there are aspects of beables we won't – and possibly can't – ever know. It leaves open the possibility that there might be more to the world than merely what we can measure -----."

Does the theory of ultimate symmetry need the concept of 'Multiverse' to be incorporated in its discussion? In this context, it is to be mentioned that the discovery that the empty space has non-zero energy inspired many physicists to have a rethinking about what is the key factor in nature that would ensure the possibility of life in a universe like ours. Investigations and researches in this field suggest that had the value of the vacuum energy been different – smaller or bigger – than the currently estimated value, there would have been no one around today to estimate or measure it. A question naturally arises at this point that what is the implication of this fact. Is it hinting at some deeper underlying truth about the nature and cosmos? If the value of the zero – point energy of space is 'anthropically' selected, i.e. if there were many universes with each universe having a randomly chosen value of energy of empty space based on some probability distribution among all possible energies, then only the universes, in which the values of vacuum energy are not that different from the one of our universe, would be able to sustain life as we know it. To put it in simple terms, we live in a universe which makes it possible for life to have evolved in it.

This line of thinking can be justified logically and mathematically only if there is a possibility that there are many different universes having different random values of the energy of empty space. The mathematical and theoretical arguments in favour of the existence of many universes, or a 'multiverse' as the idea is now known, are perhaps much stronger than simply a possibility. The idea of multiverse is not just an imagination or conjecture today. The current ideas of particle theory that drive much of the researches in this field at present seem to support the concept of multiverse.

It is to be noted here that validity of almost all the laws and theories of science are limited only to our universe. But the law of 'conservation of ultimate symmetry' is true over entire multiverse. In this sense, it is a more profound and more fundamental law of nature than those laws which are true only in our system, i.e. only in our universe. Many scientists, even those who believe in the multiverse theory, are of the opinion that universes which comprise the entire multiverse are causally disconnected. Here we have the 'theory of ultimate symmetry' which provides a unique causal and logical connection between all universes. In fact, all universes belonging to the entire multiverse are connected with each other through conservation of ultimate symmetry.

All these facts point to the possibility that our universe is not an isolated system – it is just a part of an extended system comprising of a large (possibly infinite) number of exo-systems which has now come to be known as Multiverse. The novelty of the foregoing analysis is that the concept of ultimate symmetry is valid for the whole multiverse and the

law of conservation of ultimate symmetry holds true across the entire multiverse. In this sense, the law of conservation of ultimate symmetry seems to be more fundamental than any other theories of science which describe the nature in our universe.

### Appendix – 1

#### Expanding Universe and A Review of Energy Conservation

(From Big Think, May 02, 2023 – Article by Ethan Siegel)

One of the most important laws of science is the conservation of energy. In simple terms, it says that the total amounts of initial and final energy in any physical system must always add up to the same value. It seems to be a book-keeping exercise for an isolated physical system. But there is an underlying reason for why energy is always conserved. It is because there is a physical symmetry that corresponds to the conserved quantity of energy. It is time translation invariance. This means that the physical properties and laws don't evolve with time. It is the proof of a profound theorem by a renowned mathematician Emmy Noether. Noether's theorems showed that if we have a physical system with conservative forces at play and whose 'action' has a differentiable symmetry, then for such a differentiable symmetry, there must be a corresponding conservation law and an associated conserved quantity. For example, if we have a moving system which is symmetric under rotations, regardless how it is oriented, then the angular momentum of the system is conserved. Another example is that if we have a moving system that is symmetric under spatial translations, then the linear momentum of that system is conserved.

Now, what Noether's theorem has to say about the conservation of energy? According to Noether's theorem, the symmetry that leads to the conservation of energy is time translation invariance. This means that the laws of physics, or the rules that govern the particles and fields, remain unchanged whether we move any physical system forward or backward in time. This appears to be a profound property of all the quantum laws of physics, governing individual particles as well as all quantum fields. It governs particles in isolation as well as particles' interaction. It governs the creation and annihilation of particle-antiparticle pairs. And it governs every gravitational experiment we have ever performed – be it on the earth, in the solar system or even within the Milky Way galaxy. As long as the laws of physics remain unchanged with time for any physical system, then energy is always conserved for that system. And it's true for the strong nuclear force, the weak nuclear force, and the electromagnetic force also.

But it's not always true for the gravitational force – it's only true for gravitational force sometimes. For all of the physical forces of this universe other than the gravitational force, the same laws and rules apply all the times, under all conditions, at all locations. For example, when particles with electric charges move apart, it's because either some conservative force (like the electric force) is pushing them apart from one another, or some external force is being applied over a distance, performing work on those particles in order to move them. Since work done is equivalent to energy and the equal and opposite forces that act on these charges conserve the total (kinetic + electric potential) energy, it's easy to see that energy conservation holds in these cases.

But for the gravitational interaction, this is only true – under Einstein's General Relativity – in a spacetime that has a static, unchanging structure with time. The structure of our universe wouldn't change over time if we consider the Schwarzschild solution of the Einstein's field equations where the mass is assumed to be non-rotating and concentrated at a single point with no spatial extent. If we write down the equations governing this scenario, the coordinates, the laws, and the rules of that spacetime don't change. Because they are invariant under time translation, that means energy must be conserved within that spacetime as well.

Unfortunately for the ardent followers of energy conservation, however, this is no longer true if the universe expands. In our realistic universe, the curvature of spacetime is determined by the presence and distribution of matter and energy, and that curved spacetime then tells matter and energy how to move. If the universe is uniformly filled with matter and energy, as our universe is observed to be at the largest of cosmic scales, then the spacetime that describes it isn't Schwarzschild spacetime anymore-neither is it static nor is it unchanging. Instead, that spacetime is known as 'Friedmann-Lemaitre-Robertson-Walker' (FLRW) spacetime. The most important feature of this spacetime is that it must expand or contract over time; all static solutions are inherently unstable.

It has been observed and measured that our universe is expanding. All the galaxies within the observable universe are receding from each other at an accelerating rate. It means the relative positions and distances within our universe change over time. As a consequence, the energy dependent quantities that vary with distance, such as gravitational potential energy, also change. The distance between the galaxies isn't related to how much energy is consumed to pull them apart. Instead, the distance between them is only a function of how much time has passed while the universe has been expanding as well as how rapidly it has been expanding over that time. The expansion of the universe is simply occurring as a consequence of the galaxies continuously flying apart over time.

And because the expanding universe – through the very act of expanding – is no longer the same at all times, that means it isn't time-translation invariant. Hence, energy is not conserved in an expanding universe.

### Appendix – 2

#### Time and Dimension

I think there is a scope to examine the relationship between space, time and dimension in the context of the theory of ultimate symmetry. Let us explore how the notion of exo-systems is related to the interactions between time and dimension. At the outset, it is to be stressed that the notion of time is totally embedded with the change of situation. The concept of time would not have come into being had there been no change of situations in this universe. The continuous changes that are taking place around us give rise to our perception of time. From a more realistic point of view, time (as well as space) can be analyzed on the basis of 'causal set

theory' which forms an important part of current science research around the world.

Causal set theory combines discreteness and causality to create a more fundamental physical entity. In fact, causality is a more fundamental organizing principle than the one which gives rise to the conventional concept of space-time. According to this view, the elements that constitute space-time can be regarded as momentary events which are causally related between themselves. Such events are claimed to be 'more basic than objects extended in time (in conventional sense) like particles, the latter being understood as persistent patterns of events rather than enduring substances.' The idea of spacetime was first developed by Minkowski – a teacher of Einstein. In his spacetime structure, an interval between two points (which is known as Minkowski metric) depicts a connection between those points through an exchange of photons. In other words, this process shows how a photon propagates through the three spatial coordinates  $x$ ,  $y$ ,  $z$ , over a time  $t$ . Einstein formulated his field equations in terms of tensors. This ensures that these equations are unaffected by the choice of coordinate systems. All these highlight the fact that space and time can be fused together to form an admixture called spacetime.

It seems that to arrive at a better understanding of the subject of time, the familiar and conventional idea of time will not be very helpful. Instead of that, we need to introduce the concept of temporal interval. As mentioned earlier, a change of situation of a physical system gives rise to the notion of time. If a physical system transforms from a particular situation A to another situation B, then this transformation from A to B marks a definite interval which generates the perception of time. Let it be called 'temporal interval' – partially to recognize the genesis of the concept and partially to make it distinct from the conventional idea of time. Any theory which seeks to explain time (and space as well) must take into account this aspect of nature. At this point, it seems to me that a discrete theory will be more helpful in exploring the intimate relationship between time and space but not in the way expounded by the continuum theorists. In this context, the causal set theory has a distinct advantage over other theories because the concept of temporal interval is in-built in formation of this theory. The ontological concept behind the discrete theory of causal sets can be traced back to the writings of the scientists like Bernhard Riemann and Albert Einstein. The idea of discreteness of space came very early even within relativity through the recognition that "almost all the geometrical properties of Minkowski space could be reduced to order theoretic relationships among point events." Riemann wrote in 1854 – "The question of the validity of the presuppositions of geometry in the infinitely small hangs together with the question of the inner ground of the metric relationship of space. In connection with latter question . . . the above remark applies, that for a discrete manifold, the principle of its metric relationship is already contained in the concept of manifold itself, whereas for a continuous manifold, it must come from somewhere else. Therefore, either reality which underlies physical space must form discrete manifold or else the basis of its metric relationships should be sought for outside it (. . .)."

Here Riemann's point of view is that the discrete space has an in-built metric information right from the start. Einstein, who had adopted Riemann's concept of continuous curved space for his theory of general relativity, also doubted whether, deep down, continuity could persist. "In any case, it seems to me that the alternative continuum--discontinuum is a genuine alternative, i.e. there is no compromise here. In (a discontinuum) theory there cannot be space and time, only numbers (. . .). It will be especially difficult to elicit something like a spatio-temporal quasi-order from such a scheme. I cannot picture to myself how the axiomatic framework of such physics could look (. . .). But I hold it as altogether possible that developments will lead there (. . .)." Here Einstein called 'discontinuum' what Riemann had described 'discrete manifold'.

The causal elements that constitute space can be regarded as events which are causally related between themselves. Discrete dynamical models incorporating causal ordering have been developed by several scientists in recent times. One of the most notable models among them has been developed by D P Rideout and R D Sorkin. They developed a model of 'sequential growth dynamics' for causal sets. It is the usual practice to describe the dynamical law by specifying a Hamiltonian which is the generator of time evolution in that framework. But it needs the pre-condition of existence of a continuous time variable. Causal set theory doesn't need any such pre-condition. (There is also no need to assume a fictitious 'external' time as mentioned in the article of Rideout and Sorkin). In the paper of Rideout and Sorkin, "evolution is envisaged as a process of stochastic growth to be described in terms of probabilities of forming designated causal sets and dynamical law is a rule which assigns probabilities to suitable classes of causal sets". A causal set is defined as a locally finite, partially ordered set whose elements are linked by a particular order relation ( $<$  i.e. preceding). The dynamics in question is called 'transitive percolation' in which "each new element forges a causal bond independently with each existing element with probability, say  $P$ , where  $P \in [0, 1]$  is a fixed parameter of the model". The exponents of causal set theory introduced causal sets as the elementary events which are the basic building blocks of space-time. In contrast to the continuum theory where space-time is described by the intimate commingling of space and time coordinates which is manifested by the relationships among point events carrying information about contiguity, curvature, distance and time; in the discrete theory of causal sets there are only causal elements which are related by partial order ( $x < y$  or  $y < x$ ). Despite its simplicity, "this structure has the remarkable potential to reproduce everything that we mean by the geometry of space to a high degree of approximation". But until now, its focus on temporality (or temporal interval) is inadequate though it has immense potential to provide a sound theoretical framework for an in-depth study of temporality and to elicit a sound theoretical relationship between temporal interval and spatial dimensions.

There are four physical requirements for the dynamics of the causal sets, according to Rideout and Sorkin. They are –

- 1) The condition of internal temporality.
- 2) The condition of discrete general covariance.
- 3) The Bell causality condition.

## 4) The Markov sum rule.

Among these four conditions, the first one, i.e. the condition of internal temporality, is in-built in the definition of growth process as expounded by Rideout and Sorkin. It is not merely a condition for dynamics, but it is the generator of the perception of time. It is in itself a very strong condition for viability of the whole causal set network and there is no need to assume any 'fictitious external time' in this network. An addition of a causal element to the already existing network of causal sets marks a change in the whole network of causal sets. But this change of network should not be confused with the change of space-like configuration of any discrete spatial manifold. It must be understood solely on the basis of causal nature of the relationship among the elements that is the essence of the whole causal set theory. In this sense, addition of a causal element to the already existing set of causal elements results in a re-orientation of the whole set. If the former set gives a particular situation A, then the latter set marks another situation B in the total causal network. The genesis of the notion of time lies in this change of situation from A to B within the causal network. Then the interval A --- B can be called an interval on a 'causal hypersurface' or simply 'causal interval'.

It is evident from the foregoing discussion that the causal set network as described here generates both temporality and spatiality. A question naturally arises then what is the relationship between the temporality and spatiality within this framework? A close investigation of the above discussion reveals that as the situation A transforms into situation B, the relevant set now contains more causal elements. Now additional element can be incorporated to the existing set either in a linearly independent way or in a linearly dependent way (with respect to the already existing elements of the basis of the causal set). If the new element that enters in the set combines in a linearly independent way with the existing elements of the basis of that set, then the basis of the set is extended.

From set theory, we know that basis of set is the generator of the whole set. In case the basis of a set is extended (i.e. it contains more elements), the dimension of the set is changed (augmented). So, addition of an element to the existing causal set can increase the dimension of the set. In broader sense, the dynamics of causal set sets in motion a process which has the potential to alter (augment) the dimension of the whole causal set network.

It is obvious from the aforesaid discussion that, for an evolving physical system which obeys the laws of dynamics of causal sets, there is a definite relationship between the temporal interval and the changing dimension of the system. In my book 'Time, Space and Dimension', I derived the following relation between temporal interval and dimension of a system.

$$t_n / t_{n-1} = K \cdot t_1$$

Where,

$t_n$  ----> temporal interval of n-th dimension (n = 1,2,3,4,5,6,----)

K ----> rate of growth of causal sets (its unit is s<sup>-1</sup>)

The above relation shows that temporal interval increases when dimension of the system increases. It increases by a factor which is the product of the rate of growth of causal set network and the temporal interval of the base dimension (here dimension one, i.e.  $t_1$ ). If the temporal interval of the base dimension ( $t_1$ ) and the rate of growth of causal set network (K) are taken to be fixed, then temporal intervals of two consecutive dimensions bears a fixed ratio, i.e. the relationship is independent of the order of dimensions. Moreover, this is an expression purely in numbers which is advantageous for inter dimensional transformation of physical equations.

How this theory can be validated by experiments? The systems which evolve over time provide an opportunity to verify and validate this relationship between temporal interval and dimension. In this context, we have to keep in mind that dimension is, in true sense, a mathematical concept based on set theory. The spatial dimensions (the three dimensional space) are just a construct of human mind. Any experiment for testing the theory of time and dimension as elucidated in this article must adhere to the set theoretic definition of dimension. There are numerous systems which evolve over time. The whole universe is a system which evolves over time. But we have to choose such a system on which we can make experiments right here on earth. We can choose biological systems – particularly the ones which are important from medical point of view. The growths like tumors and cancers evolve over time. We can compare the growth rate of tumors when they are placed under the influence of an external field, say an electric field, with its usual growth rate (i.e. not under any external influence). The growth rate of the tumor must be slower under the influence of an electric field than its natural growth rate. It will be the verification and validation of the relationship between temporal interval and dimensions as elucidated in this appendix.

As has already been discussed earlier, the genesis of the quanta of the most fundamental entity of the system under consideration (SUC), i.e. our universe, depends on the interactions among potentialities which are quanta of the fields of potentialities of their respective exo-systems. The most fundamental entity of our universe is the quantum of space which is continuously engendered obeying the law of conservation of ultimate symmetry. At present we don't know the true nature of exo-systems and potentialities. But there is no mystery in their existence and influence on our universe. Exo-systems exist beyond the world perceivable by the usual sensory capabilities by humans or the instruments constructed by them so far. But humans are endowed with a unique intellectual capability which makes them distinct from other animals of this planet. The faculty of mathematics provides a powerful extra-sensory ability through which humans can comprehend an augmented reality of this physical world. In this sense, exo-systems and potentialities belong to the realm of augmented reality.

Physical reality is something which is perceivable by human sensory organs or detectable by instruments made for specific experiments. At present, exo-systems and potentialities are not directly perceivable or detectable through experiments. We require mathematical and

theoretical methods for their thorough comprehension. As already discussed in this article, space is an emergent entity of our universe. Therefore, anything ‘outside’ our universe doesn’t bear any meaning scientifically. The three dimensional description of space is something devised by human mind which has nothing to do with physical reality. Therefore, searching for extra-spatial dimensions is also a futile exercise as far as scientific study of physical reality is concerned.

The study of dimensions bears significance and actual relevance in connection with set theory. In set theory, we know the basis of the set is the generator of the set. The number of linearly independent elements that form the basis of the set gives the dimension of the set. If nature, i.e. our physical world, can be described by a suitable set theory, then this mathematical treatment of dimensions becomes relevant in defining dimensions of physical reality. In this sense, this mathematical treatment of dimensions entails an augmented reality which is the domain of exo-systems.

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