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Observer, Collapse of events and parallel worlds in Quantum Gravity

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Abstract

Theories such as causal sets and causal dynamic triangulation teach us that, the world we live in, composed by the causal sets. It is shown that, an information probability type can be attributed to born probability of the timid children in the causal set, but, due to the causal structure of the theory, the probability can be replaced by the topos truth values, and in consequence, the probability will be appeared as an emergent and non-fundamental concept. Accordingly, we introduce three generalized principles, called contextuality, equivalence, and absolute cause and probable effects. Based on the generalized contextuality principle, an eternal non-causal universe exists. The creation of observer-dependent causal (worlds) sets (called collapse of events) is the result of the interaction between the concisions observers and the universe which can be explained mathematically through introducing a pyramidal operator. Using the metric of conscious observers and the Green function of causal sets, we show how one can define the pyramidal operator. Based on this vision, time and time evolution are emergent and non-fundamental concepts. Also, the transition between the eternal universe and non-eternal worlds or between parallel worlds only occurs when the observer's consciousness changes. It can be assumed that the essence of observers (or facts) is enteral and preserved

under the transition between the universe and the born worlds or between parallel born worlds, and as a result, it provided an appropriate answer to some philosophical ambiguities.

Introduction

It could be said that understanding the concept of time and defining it in a way that, on the Planck scale, can solve the problem of explaining the theory of the origin of the universe is one of the most obscure concepts and the most difficult scientific-philosophical activity facing scientists, nowadays. Apart from the philosophical problems facing the redefinition of the concept of time, the challenge from a mathematical perspective also stems from the fact that, according to the theory of relativity, the concept ultimately manifests itself in the form of a space-time field theory. Some scientists who accept this view believe that the quantum fluctuations of this field are the origin of the creation of the universe we currently live in, although they do not have a reasonable explanation for the origin of space-time field, life and consciousness. Also, from the perspective of quantum physics, an operator is defined for each physical quantity so that by applying it to the system state function, the possible observable values can be calculated. Expectation values are equivalent to the classical quantities and satisfy in the equations similar to the classical ones. As a result, we should be able to define the time operator according to these characteristics, which of course satisfies in the uncertainty relationship between energy and time.

But over time and with a little more thought, we realized that the main problems stem from the fact that we still do not have convincing and measurable answers (i.e., Answers that we can put to empirical test) to the following fundamental questions [1]:

- 1)- How to combine general relativity with quantum mechanics in the Plank scale?
- 2)- Some fundamental concepts of quantum mechanics do not make sense. How can one make a sensible theory?
- 3)- There are various particles and forces that are not covered by a unified theory. Can a unified theory be proposed?

4)- According to the Standard Model, there are physical constants in nature, but we don't know how nature chose them.

5)- Why do constants in the Standard Model of cosmology, such as dark energy, have such values?

Of course, it might be better to add the following questions to the above list:

6)- Why do we encounter the infinite values for some physical quantities in the theory of quantum physics and, in consequence, are forced to limit and determine them by the renormalization methods?

7)- Why do we encounter the infinite values for some physical quantities in the relativity physics and, in consequence, are forced to introduce some new concepts that are not sensible and create new problems for us to describe the causes of it?

8)- Some of us believe that, the vacuum fluctuations lead to the beginning of the Big Bang, the fusion of elementary particles at very high pressure and temperature is the origin of the formation of atoms and subsequently elements, after the Big Bang, and the creation of bonds between elements forms molecules and ultimately intelligent life is created [2]. This process shows a flow of time that represents at least five time periods (vacuum fluctuations, Big Bang, formation of elements, formation of molecules and finally the emergence of intelligent life). Is this the true reality of life or our perception of this world in which we live? If we lived in a parallel universe where the physical constants of its Standard Model were different, would we still reach the same understanding and conclusion?

These are the crisis of physics that we must overcome to reach the scalable and measurable future theory of the universe. Different solutions to overcome these crises have been introduced so far. Some of them focus on the reborn of the concept of time [3-5], while others focus on the disappearance of this concept and focus on the quanta of space [6,9]. It can be said that at present the main approaches to overcome the current situation are string theory [10,11], loop quantum gravity [12,14], and causal set theory [15,16]. Of course, other efforts have been made to preserve the structure and concepts of classical physics and establish the quantum theory based on it under the title of topo-quantum mechanics [17,19]. Questions

raised in the field of quantum gravity based on this perspective have also been explained and discussed [20,21]. Among the three main approaches to solving the problems [22], the third approach, which is based on the finding the new complete theories for both the quantum and relativity, is received more attention, nowadays.

The causal set theory belongs to the third approach, in which, it is possible to define the past and present time of an event [23-26]. Suppose we have a manifold M with a volume element, such that, its total volume, V_M , is finite. If we select a point from M in a random process, the probability that the point x is selected is $\frac{1}{V_M}\sqrt{-g}$ (in any coordinate system) [23]. Equivalently, the probability that x lies in the measurable region R is $\frac{V_R}{V_M}$. If we repeat this process n -time, we obtain a uniform random distribution of points with density $\rho = n/V_M$ [23]. If we forget the order of the points, we have a kind of unlabeled distribution of n -point. By randomly distributing n -point in M , the volume element $\sqrt{-g}$ statistically determines where they will fall. Given their positions, the causal structure determines the causal relationships between them [23]. The process is called sprinkling and for maintaining the Lorentz invariance, the sprinkling is done randomly using a Poisson distribution. Although, there are multiple methods of performing Poisson sprinklings and if they are performed appropriately they would be statistically equivalent, but it has been shown that some noticeable differences might still occur [27].

If all metrics have Lorentzian signature and satisfy the condition of separability of the future and the past, a partial order is created in each sprinkling and a n -element partial order $(l, \leq)$ can be defined [23]. The closed causal interval, between two elements $x, y \in l$, is defined as $[x, y] = \{z \in l; x \leq z \leq y\}$ while the open causal interval is defined as $(x, y) = \{z \in l; x < z < y\}$ [25,26]. Now, the past $(-)$ and future $(+)$ of an event $x \in l$ or subset $D \in l$ in the causet are given by $J^-(x) = \{y \in l; y \leq x\}$, $J^+(x) = \{y \in l; x \leq y\}$, and $J^\pm(D) = \bigcup_{x \in D} J^\pm(x)$, respectively [25,26]. For two elements $x, y \in l$ if $[x, y] = \{x, y\}$ then they are linked to another and denoted by $x <^* y$ [25,26]. A path between two element $x, y \in l$ is defined as $paths(x, y) = x <^* z_1 <^* z_2 <^* \dots <^* z_{n-1} <^* y$. A maximal path is a causet (i.e., the path has maximal cardinality among the elements of $paths(x, y)$) analogue of a time like geodesic in the continuum [25,26]. The past and future of a point can be partitioned into layers and ranks. The sets $L_k^-(x) = \{y \in J^-(x); |[y, x]| - 1 = k\}$ and $L_k^+(x) = \{y \in J^+(x); |[x, y]| - 1 = k\}$ are called the layer k past and future of a point $x \in l$, respectively, where $k \in \mathbb{N}_0$ [25,26]. The sets $R_k^-(x) = \{y \in J^-(x); rk(x, y) = k\}$ and $R_k^+(x) = \{y \in J^+(x); rk(y, x) = k\}$ are called rank k past and

future of an event $x \in l$, respectively, where $k \in \mathbb{N}_0$ and $rk(y, x) = \min_{p \in \text{path}(x, y)} |p-1|$ for $x \leq y$ and zero for otherwise [25,26]. These classifications are used for the definition of the discretized wave operators on the causal sets [25,26]. If the k -layer future (past) infinity of a causet l be the set $C_k^\pm = \{x \in l; \text{for } j \geq k \text{ then } L_j^\pm(x) = \emptyset\}$ then a preferred future (past) structure is defined as a map $\Lambda^\pm: l/C_2^\pm \rightarrow l$ such that $\Lambda^\pm(x) \in R_2^\pm(x)$ holds for all events $x \in l$ that are not in the two-layer future (past) infinity i.e., $x \in l/C_2^\pm$ [25,26]. For example, if Λ^- stands for a preferred past and $\phi: l \rightarrow \mathbb{R}$ be a scalar field, then the discretized Klein-Gordon operator $\square\phi: l/C_2^- \rightarrow \mathbb{R}$ is defined as $\phi(\Lambda^-(x)) - \frac{2}{|I_x|} \sum_{z \in I_x} \phi(z) + \phi(x)$ where $I_x = (\Lambda^-(x), x)$ is the open causal interval from the preferred past of x [25,26]. A spacetime $(M, g_{\mu\nu})$ is said to be strongly causal if, for all points $P \in M$ and for every neighborhood O of P , there exists a neighborhood V of P contained in O such that no causal curve intersects this neighborhood of V more than once [28]. It has been shown that the causal set is strongly causal if the growth dynamics is interpreted as a physical process [29].

However, it has been shown that if $(M, g_{\mu\nu})$ be a globally hyperbolic spacetime, a global time function f can be chosen such that each surface of constant f is a Cauchy surface (i.e., every world-line (time like curve) without endpoint intersects once and only once the hypersurface) [28]. Therefore, M can be foliated by Cauchy surfaces and the topology of M is $\mathbb{R} \times \Sigma$, where Σ denotes any Cauchy surface [28]. It means that, one can foliate $(M, g_{\mu\nu})$ by Cauchy surfaces Σ_t , parametrized by a global function, t [28]. Now, if n^a be the unit normal vector to Σ_t , and t^a be a vector field on M such that $t^a \nabla_a t = 1$, then one can decompose t^a into the normal and tangential to Σ_t by defining the lapse function, N , and shift vector N^a , with respect to t^a , such that, $N = -t_a N^a = (n^a \nabla_a t)^{-1}$ and $N_a = h_{ab} t^b$ where $h_{ab} = g_{ab} + n_a n_b$ [28]. Therefore, the vector t^a represents the flow of time through the spacetime [28]. If the event $p_0(x^a, t)$ and $p_1(x^a + dx^a, t + dt)$ are placed on the Σ_t and Σ_{t+dt} , respectively, then

$$ds^2 = (N^a N_a - N^2) dt^2 + 2N_a dx^a dt + \gamma_{ab} dx^a dx^b, \text{ and in consequence, } g^{\mu\nu} = \begin{pmatrix} -\frac{1}{N^2} & \frac{N^b}{N^2} \\ \frac{N^a}{N^2} & \gamma^{ab} - \frac{N^a N^b}{N^2} \end{pmatrix} [30].$$

Now, let us to consider a manifold M of topology $\Sigma \times [0, 1]$, with Σ a three-dimensional manifold. It implies that M has two boundaries $\Sigma(0)$ and $\Sigma(1)$ such that $\Sigma(1)$ is separated by a proper-time distance τ from $\Sigma(0)$. To better explain the subject, we will consider three cases. In the first case, suppose that instead of $\Sigma(0)$ and $\Sigma(1)$, we have two parallel straight lines. If we consider two triangles such that, the first of which has its vertex on $\Sigma(0)$ and its base on

$\Sigma(1)$ (called (1,2)-simplex), and the second of which has its vertex on $\Sigma(1)$, and its base on $\Sigma(0)$ (called (2,1)-simplex), one can cover the two lines by placing these two triangles together, provided that the sides of these triangles coincide whenever they are placed together and there is no gap between them. This is the topology $S^1 \times [0,1]$. In the second case, we place the base of a tetrahedron on $\Sigma(0)$ ($\Sigma(1)$) and its vertex on $\Sigma(1)$ ($\Sigma(0)$). It is called (3,1)-simplex ((1,3)-simplex). If the triangles of the lateral surfaces of these tetrahedrons coincide completely in the process of gluing them together, we can completely cover the hypersurfaces of $\Sigma(0)$ and $\Sigma(1)$ with the help of these two tetrahedrons. This is the topology $S^2 \times [0,1]$. In the third case, we can cover the hypersurfaces $\Sigma(0)$ and $\Sigma(1)$ with the help of (4,1) and (1,4)-simplex similar to the two previous cases. This is the topology $S^3 \times [0,1]$. It means that, each time-slice, with the topology S^{d-1} , is represented by a $(d-1)$ -dimensional triangulation, such that, by gluing together the $(d-1)$ -simplices whose links are all of (spatial) length $a_s=a$, the topology S^{d-1} is covered [31]. More precisely, the lattice construction contains spacelike links of length-squared a^2 and timelike links of length-squared $-aa^2$, $\alpha>0$ [31]. It should be noticed that, by keeping α variable, one allows for a relative scaling of space- and time-like length when the Wick rotation is used [31]. It is recalled that to simplify many calculations in quantum field theory, instead of using the real time, the imaginary time $t=-i\tau$ is used, where τ is a real parameter. This method is called the Wick rotation and τ is called the Euclidean time [32]. For example, if $ds^2=dt^2-dx^2$ be the Lorentzian metric then, by substituting t by $-i\tau$ (i.e., under Wick rotation) the Euclidean signature will be $ds^2=-d\tau^2-dx^2$ (apart from an irrelevant overall sign) [32].

But by using (m,n) -simplex, in fact, we construct a lattice structure on $\Sigma(0)$ and $\Sigma(1)$. Therefore, we should discretize the continuum Einstein-Hilbert action, $S^{EH}=\frac{1}{G_N} \int d^4x \sqrt{-\det g} (R[g, \partial g, \partial^2 g] - 2\Lambda)$, on the lattice construction. Here, G_N and Λ are the constant of Newton and the cosmological constant, respectively, and R denotes the Ricci scalar of the metric tensor g [33]. If $0 \leq i \leq 4$ and I stand for dimension and the subtype of simplices and $N_i^I(T)$ denotes the number of simplices, where T is a given simplicial manifold, the discretized action will be a linear combination of several counting variables $\{N_i^I\}$ [31,33]. For example, if four-simplices come in two different variants, (3,2) and (4,1), with corresponding counting variables $N_4^{(3,2)}$ and $N_4^{(4,1)}$, the discretized action can be written as $S^{CDT}[T]=k_b\pi\sqrt{4\alpha+1}N_0(T)+\mathbf{A}(\alpha,k_b,\lambda_b)N_4^{(4,1)}(T)+\mathbf{B}(\alpha,k_b,\lambda_b)N_4^{(3,2)}(T)$ where $\mathbf{A}$ and $\mathbf{B}$ are specific linear combinations of the bare inverse Newton's constant k_b and bare cosmological

constant λ_b , N_0 is the number of vertices, and $\alpha > 0$ is a finite, fixed parameter which is described above [33]. The theory, which is a non-perturbative path integral approach to quantum gravity and belongs to the third approach, is called Causal Dynamical Triangulations (CDT) [31,33-35]. An important advantage of this method is that it is possible to test this theory using the Monte Carlo numerical calculation method [36].

Whether in the method of causal set theory, where the precedence of events actually introduces the concept of time and its evolution, or in the CDT theory, where the time foliation of manifold does the same thing, the important issue is defining the time variable and time evolution in a theory that is supposed to explain and describe physics in the Planck scale. For example, consider a spin- $\hbar/2$ system in z -direction then the probability of having spin- $\hbar/2$ system in φ -direction will be $(\cos(\frac{\varphi}{2}))^2$. Both $\hbar/2$ -system in z - and φ -direction are facts and in consequence the quantum mechanics provides the probability amplitude between facts i.e., we deal with a relational theory, called Relational Quantum Mechanics (RQM) [37,38]. It should be noted that, unlike the classical systems, the dynamical evolution laws of quantum facts are genuinely probabilistic, the spectrum of possible facts is limited by quantum discreteness, and the facts are sparse and relative [38]. Sparse means, the facts are realised only at the interactions between (any) two physical systems and relative means they are labelled by the interacting systems i.e., the facts are relative to the systems that interact (was called contextuality, by Bohr) [38]. Therefore, the insight of RQM is that the transition amplitudes $P(a,b)$ must be interpreted as determining physical probability amplitudes only if the physical facts a and b are relative to the same systems. i.e., all facts are labeled by the systems involved in the interactions [38]. Of course, after each measurement, collapse of wave function is occurred and in consequence a subset of all relative facts becomes stable due to the decoherence [38]. Therefore, the conventional laboratory “measurement outcomes” are a particular case of stable facts [37,38]. There are three approaches to the relational quantum dynamics (RQD) which are relational observables in the clock-neutral picture of Dirac quantization [38], Page and Wootters’ (PW) Schrodinger picture formalism [38,39], and the relational Heisenberg picture obtained via symmetry reduction [38]. It has been shown that there is an equivalence between three approaches [38]. In these approaches, the time will be an emergent concept by separating the system from its environment [40]. Also it will be well known that, we are finding the actual observation of universe by correlating measurements at different positions in the late universe. By introducing a cosmological history for giving a rational accounting of these spatial patterns, it has been shown that the cosmological time is

an auxiliary one, which is not present in the observables themselves. In consequence, there should be a description of physics that focusses only on the observed static correlations, and in which, time evolution becomes a derived concept [41].

In this article, we intend to explain how the current situation of our universe can be explained based on assuming three generalized principles called contextuality, equivalence, and absolute cause and probable effects. Based on the generalized contextuality principle, an eternal non-causal universe exists. In our interpretation, due to the interaction between concisions observers and the eternal ono-causal universe, the time-dependent phenomenon manifests itself. Therefore, time is a concept that arises after the collapse of non-causal set of primary eternal events in interaction with the observers, and the time evolution is nothing but a change in the observer-dependent induced causal set. Therefore, a pyramidal operator can be defined that is specific to each observer. This operator acts on the primary eternal non-causal set of events and forms the causal set of each observer. In this way, the philosophical infinite regress and circular reasoning problems that arises in defining the starting point of the world also becomes irrelevant.

The structure of article is as follows. The important principles are provided in section II. The basic idea of collapse of events is presented in section III and in section IV the pyramidal operator is defined and its operation and the concept of time and time evolution are explained. The conclusion is provided in section V.

Basic principles

Since, all objects in a gravitational field fall with the same acceleration, their trajectory is independent of their mass and composition. It is called the weak equivalence principle. By assuming that the laws of physic are the same in the uniform gravitational field and in the uniformly accelerating reference frame, one can generalize the weak equivalence principle and call it as strong equivalence principle. For our model and explanation, we generalize the strong equivalence principle as below:

- **Generalized contextuality principle:**

A non-causal eternal universe exist which is composed by the non-causal events (facts). Through the interaction of consciences observers with the non-causal set, an observer-

dependent causal set (partial order set) of events (facts) is induced. It means that the events (facts) are relative to the systems that interact.

- **Generalized equivalence principle:**

A set of observer-dependent events (facts) can be represented by using a causal set. Although in different causal sets (partial ordered sets), the first member, the last member, the Hasse diagram, and the minimum and maximum paths between the first and the last elements may be different, at least far enough away from the Planck scale, the physical laws governing these causal sets are the same in each related non-eternal causal world. Of course, if the observers move with different velocity respect to each other the laws of physics might not be the same for these observers around the Planck scales. It means that different physical laws govern the observer-dependent causal sets. It is called the violation of Lorentz invariance [42]. It should be noted that the eternal universe can collapse into parallel worlds, each governed by its own laws of physics. Therefore, the violation of Lorentz invariance around the Planck scale means that, the universe at that scale, is in the transition phase from the eternal universe to the observer-dependent non-eternal world. In the other words, the Planck scale is the critical point of transition from the eternal universe to the non-eternal world. However, after the formation of each worlds and away from the critical point, the physical laws governing the causal sets existing in each world are invariant and independent of the induced causal sets.

- **Generalized absolute cause and probable effects principle**

In any causal set (Hasse diagram), the first member is the first cause and the last members are the last effects. Each effect member (called timid child) is born with a probability that is not necessarily the same in the successive births. With the successive birth of the timid children, the causal set grows. The birth probability $P(a,b)$ must be interpreted as determining physical probability amplitudes since, both the mother a and the timid child b belong to the same causal set [38]. If Ω stands for sample space, one can choose sample A_i from Ω with the probability P_i and construct the event space E . If

$$P_i \geq 0, \sum_i P_i = 1 \quad (1)$$

and

$$P(\bigcup_{i=1}^{\infty} A_i) = \sum_{i=1}^{\infty} P(A_i) \quad (2)$$

then (Ω, E, P) is called the measure space and P_i (number of choices A_i /total choices) is called the Kolmogorov probability [43]. However, if $|\psi_1\rangle$ and A stand for state vector and observable operator, respectively, such that $A|u_j\rangle = a_j|u_j\rangle$, a family of probability densities

$$\Pi(\psi_1, a_j) = |\langle u_j | \psi_1 \rangle|^2, j \in J \quad (3)$$

where, J belongs to an index set, can be defined for the emergence of an eigenvalue a_j of the observable A when a measurement is performed in the state $|\psi_1\rangle$. If τ_A stands for the total algebra of events on a_j , then $(a_j, \tau_A, \Pi(\psi_1, A))$ will be the measure space and the whole quantum mechanical probability chain corresponding to the measure space can be represented by the map [44]

$$(|\psi_1\rangle, A) \rightarrow (a_j, \tau_A, \Pi(\psi_1, A)) \quad (4)$$

But for measuring the observable A , a macroscopic device with the physical aspect D_A should be used. The set of all values V_j of the physical aspect A of D_A is denoted by $V_A(D_A)$. Now, the factual space is specified as $[V_A(D_A), \tau_A, \Pi(\psi_1, M_A)]$ where τ_A and M_A are the total algebra on the set $V_A(D_A)$ and the measurement process $\{M_A(\psi_1, D_A)\}$ performed on the state $|\psi_1\rangle$, respectively [44]. Of course, it is postulated that [44]

$$\Pi(\psi_1, M_A, V_j) = \Pi(\psi_1, a_j) = |\langle u_j | \psi_1 \rangle|^2 \quad (5)$$

Therefore, the formal probability density $\Pi(\psi_1, a_j) = |\langle u_j | \psi_1 \rangle|^2$ is a predictional law for observing the measuring device at the physical aspect D_A [44]. It should be noted that, based on the Bohr-complementarity, if two observables with physical aspects D_A and D_B belong to the same sub-ensemble M_X , then their eigenvalues can be measured simultaneously. After each measurement we find a set of some eigenvalues of the complementary observables and by repeating the measurement on the same initial conditions (same state vector), which is called the identically reproducible procedure P , one is able to find the set of all eigenvalues of the complementary observables. Since we assign a probability to each measurement, we will find a probability chain after repeating the experiment for finding the set of all eigenvalues of the complementary observables. It means that, we can establish a relationship between the identically reproducible procedure P , algebra of events τ , probability Π and the quantum mechanical formal descriptions, state vector $|\psi\rangle$, observables A , eigenvectors $|u_j\rangle$, and eigenstate a_j [44]. The probability defined in this way is called informational probability [44,45]. Therefore, the quantum mechanical probability is the informational probability and

not the Kolmogorov probability [45]. In consequence, the above mentioned birth probability $P(a,b)$ which is interpreted as determining physical probability amplitudes, is a quantum mechanical probability. It means that for constructing a causal set and assigning a probability to each causal link between two elements, one should repeat a set of similar experiments and construct the factual space $[V_A(D_A), \tau_A, \Pi(\psi_1, M_A)]$. In the other words, it is assumed that an absolute cause always exist which has a set of timid children, called probable effects. Each timid child (probable effect) is born with a probability equal to p_i , which is defined based on the quantum probability (information) theory such that the sum of the probabilities associated with the timid children, $\sum_i p_i$, is equal to one i.e., at least one timid child born (expect the last elements of a causal set). It should be noted that for the growth of a causal set, it is necessary, at least one of the timid children to play the role of absolute cause. It is called the absolute cause and probable effects principle.

Now, two questions can be asked:

- (i) whether the probability is a fundamental concept or is a derived concept?
- (ii) We receive the data of early universe, for example as background radiation. How can one prepare the similar situations to the early universe for doing the similar experiments?

For answering to the first question, let us to consider the operators

$$S_z = \begin{pmatrix} 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -2 \end{pmatrix} \quad (6)$$

and the function $f: X \rightarrow X^2$, such that

$$f(S_z) = S_z^2 = \begin{pmatrix} 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 \end{pmatrix} \quad (7)$$

The eigenvalues (spectrum) of S_z and S_z^2 are $[-2, 0, 2]$ and $[0, 4]$, respectively. Also, we can define the maps

$$V_{\vec{\psi}}(S_z): S_z \rightarrow [-2, 0, 2] \quad (8)$$

and

$$V_{\vec{\psi}}(S_z^2): S_z^2 \rightarrow [0, 4] \quad (9)$$

which are called the valuation function. It is obvious that

$$f(V_{\vec{\psi}}(S_z))=[4,0,4] \quad (10)$$

$$V_{\vec{\psi}}(f(S_z))=[0,4] \quad (11)$$

Therefore

$$f(V_{\vec{\psi}}(S_z)) \neq V_{\vec{\psi}}(f(S_z)) \quad (12)$$

Generally, if $V_{\vec{\psi}}$ be the map from the set of all bounded self-adjoint operators $\hat{O}$ (which belong to the Hilbert space whose dimension is greater than two) to the set of real number $\mathbb{R}$, and $f:\mathbb{R} \rightarrow \mathbb{R}$, there is no $V_{\vec{\psi}}$ for all $\hat{A} \in \hat{O}$ such that $V_{\vec{\psi}}(f(\hat{A})) = f(V_{\vec{\psi}}(\hat{A}))$. If the condition $V_{\vec{\psi}}(f(\hat{A})) = f(V_{\vec{\psi}}(\hat{A}))$ is satisfied, it is called that the Functional Composition Condition (FUNC) is satisfied [46]. Now, if one substitutes $\mathbb{R}$ with the probability distribution $P(\mathbb{R})$ and write

$$V_{\vec{\psi}}:\hat{O} \rightarrow P(\mathbb{R}) \quad (13)$$

then FUNC reads

$$pr(V_{\vec{\psi}}(f(\hat{A}))=a) = pr(f(V_{\vec{\psi}}(\hat{A}))=a) \quad (14)$$

where pr stands for probability [46]. But, if $\hat{P}_m$ be the projection operator then $\hat{A} = \sum_m a_m \hat{P}_m$, such that $\hat{P}_m^2 = \hat{P}_m$ and, in consequence, FUNC reads

$$V_{\vec{\psi}}(\hat{P}_m)^2 = V_{\vec{\psi}}(\hat{P}_m^2) = V_{\vec{\psi}}(\hat{P}_m) \quad (15)$$

Therefore, $V_{\vec{\psi}}(\hat{P}_m) = 1$ or $V_{\vec{\psi}}(\hat{P}_m) = 0$. It means that, one can assign the number one (true), only and only, to one of the element of the set $\{\hat{P}_m\}$ and he/she should assign zero (false) to other remained elements of the set $\{\hat{P}_m\}$. It means that, only one of the probable states will be observed, finally. This value assignment (zero or one) is not only mutually exclusive (i.e., a value can be true from a given moment) but also collectively exhaustive (i.e., at least one of the values must be true at a given moment) [46]. Based on this value assignment, the Kochen-Specker (KS) theorem can be stated as [44]:

“If the dimension of Hilbert space be greater than two, does not exist any valuation function $V_{\vec{\psi}}:\hat{O} \rightarrow \mathbb{R}$, such that, FUNC for all $\hat{A} \in \hat{O}$ is satisfied and valid” or equivalently as:

“given a Hilbert space $\mathcal{H}$, such that $\dim[\mathcal{H}] > 2$ and a set O of self-adjoint operators $\hat{A}$ which represent observables, then the following two statements are contradictory:

- All observables associated with projection in O have values simultaneously.
- The values of observables follow the FUNC principle”.

Therefore, the implications of KS theorem are that one or both of the following two assumptions must be dropped [46]:

- The set of truth values is represented by $\{0,1\}$.
- The FUNC principle

But in quantum physics, if $\hat{P}_m$ be the projection operator such that every bounded abelian operator can be written as $\hat{A} = \sum_m a_m \hat{P}_m$, then one is able to assign a set of eigenvalues of the projection operators to $\hat{A}$, which is called the family spectrum. Here, FUNC is satisfied and a values between $\{0,1\}$ is assigned to each proposition [46]. In this approach, the proposition b or its negation, $\neg b$, which is denoted by $(b \vee \neg b)$, has values between zero and one i.e., $b \vee \neg b \leq 1$. It means that, we break quantum physics into the classical temporal slices to give a classical picture of it. Then, we put these pictures and slices together so that the no information is lost [46]. In fact, this is what we do in causal set theory and CDT. In topos approach to quantum physics, the idea that the set of truth values is only $\{0,1\}$ is abandoned and a multivalued logic (intuitionistic logic) is utilized [46]. In this approach, for both open and closed systems, a logical interpretation and internal logic in terms of truth values are presented. In consequence, the truth value is the fundamental concept and the probability is the derived concept [46]. Therefore, instead of assigning the information probability domain to each link between causes and effects, one can assign the set of truth values. It means that, the absolute cause and probable effects principle can be explained based on the set of truth values instead of the probability concept.

But, we have no enough laboratory capabilities for simulating the condition of early universe, nowadays (except LHC, which is used for studying the creation of some fundamental particles and their decay). Therefore, we cannot provide the set of similar causal sets of early universe and study the born-probability of different timid child, nowadays.

Basic idea of collapse of events

The basic idea is shown in Fig.1. As the figure shows, an eternal universe, composed by eternal non-causal events (facts), is in front of every consciousness observer. His/her consciousness is considered as a pyramidal operator which refracts the non-causal set of the eternal universe to the causal set. The refraction depends on the consciousness observer similar to the refraction of light which depends on the material characteristic of refraction pyramid.

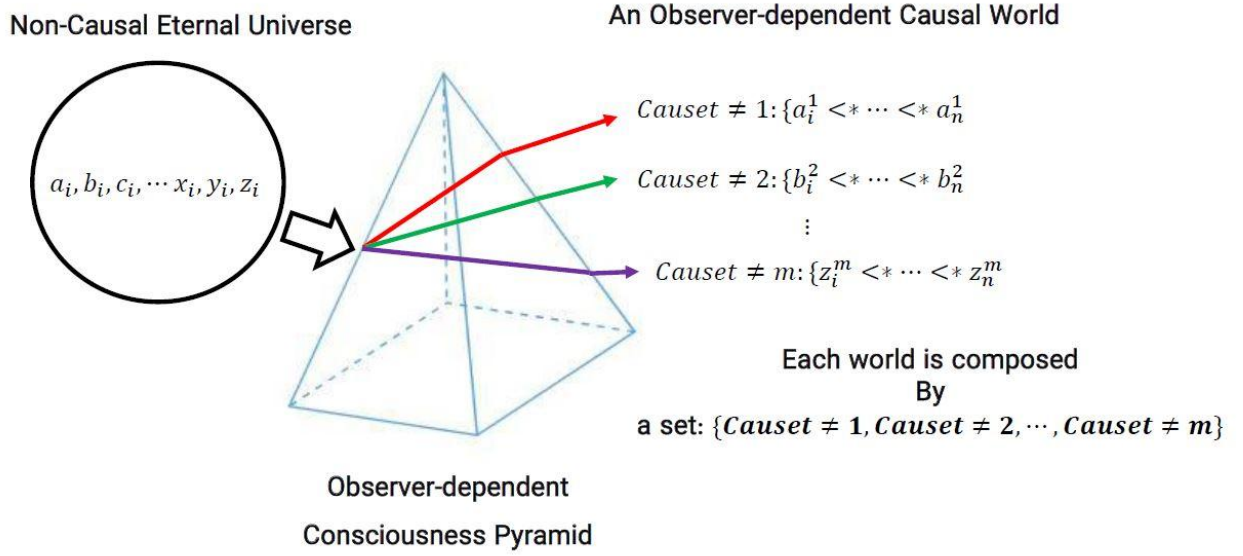


Fig.1 (color Online) Observer-dependent consciousness pyramid refracts the non-causal eternal universe to the different causets. Each observer belongs to each world has own causet but all of observers obey the same physical laws. The physical laws between different worlds are different from each other i.e., we encounter the parallel worlds.

In fact, Observer-dependent consciousness pyramid refracts the non-causal eternal universe to the different causal sets. Each observer belongs to each non-eternal causal world has own causet but all of observers, belong to same world, obey the same physical laws. The physical laws between different worlds are different from each other i.e., we encounter the parallel worlds. The formation process of non-eternal causal world from the eternal non-causal universe is called the collapse of events (facts).

According to this interpretation, we have an eternal universe and non-eternal parallel worlds that arise due to the consciousness of the observers. From now on, whenever we talk about the universe, we mean the eternal non-causal universe, and whenever we talk about the non-eternal causal world, we mean the world in which we live and will live. Since consciousness is the reason for refracting universe into the parallel worlds, the transition from one world to another one is possible only when the consciousness of the observer changes. Therefore, in fact, the temporal slicing of events arises due to the consciousness of the observer, and time and temporal evolution are emergent concepts which depend on the conscious observer and are not fundamental concepts. The universe is eternal and always remains eternal, and our perception of the non-eternal causal world appears as a temporary parallel world.

Although it is not customary to provide a metaphysical interpretation in a physical theory, based on the idea of the collapse of events, it can be said that death is a stage of change in the observer's consciousness, and a person after several changes in his/her consciousness, finally returns to the original eternal universe. In fact, the essence of events is a preserved and constant quantity and does not change in the process of sequential collapse. This means that the essence of events is eternal and always remains in this state. The characteristics of events which are attributed to each essence change in each collapse and then evolve in time based on the specific physical laws, while the essence of the events does not change. Therefore, our essence is always in a state of eternity and death is only a type of collapse in the characteristics of events related to us. It is precisely because of this characteristic that the self within us does not change from the time of birth to the moment of death and beyond, and we know that although we have become older in the non-eternal world we live in, our inner self is the same as it was from childhood. Of course, this transition from the eternal universe to the non-eternal parallel worlds has different stages in different religions, but the discussion of which is beyond the scope of this article.

Pyramidal operator, concept of time, and time evolution

As we explained in the section III, we deal with cause and effect. Green function is the main function which connects cause and effect in the classical physics. It describes how a dynamical system evolves from position $(\vec{r}_0, t_1)$ to the position $(\vec{r}, t_2)$ under specific conditions called causality and reciprocity [47]. Of course, for finding a unique physical solution to a differential equation boundary and/or initial conditions are required, too. In quantum physics, we deal with wavepacket for bringing together the particle- and wave-concept i.e., wavepacket has properties of both particle and wave. Wavepacket oscillates with small frequency Δf , i.e., it is spread over large time Δt , such that, the size of the wavepacket moves with velocity v . Therefore, based on the bandwidth theorem [47]

$$\Delta f \Delta t \geq 1/4\pi \quad (16)$$

However, since the energy is related to the frequency, e.g. $E = hf$, the bandwidth theorem appears as the uncertainty principle. In quantum physics, one deal with the time evolution operator $U(t_2, t_1)$ such that

$$\psi(t_2) = U(t_2, t_1)\psi(t_1) \quad (17)$$

and

$$U(t_2, t_1) = T e^{-i \int_{t_1}^{t_2} V(t) dt} \quad (18)$$

where T and $V(t)$ stand for the Dyson time ordering operator and the interaction that causes the system to change, respectively. Of course, T is proportional to the step function, $\Theta(t_2 - t_1)$, which is one for $t_2 > t_1$ and zero for $t_2 < t_1$. In consequence, the quantum time ordering corresponds to the classical causality [47]. Also, the unitary time evolution operator can be written as

$$\hat{U}(\tau) = \exp\left[-\frac{i\hat{H}\tau}{\hbar}\right] \quad (19)$$

where $\hat{H}$ is the Hamiltonian of system. The Green function is defined as

$$G(x_1 t_1, x_2 t_2) \equiv \left\langle x_2 \left| \exp\left[-\frac{i\hat{H}(t_2 - t_1)}{\hbar}\right] \right| x_1 \right\rangle \quad (20)$$

Now, if the Green's function at time t_i is considered as the cause of the Green's function at time t_{i+1} , the interpretation that, the Green's function connects cause to effect, is still a correct interpretation [48-50]. Of course, if there is no dissipation in the system, we can replace i by $-i$ for reversing the time direction in quantum physics. The overall reversal time, which is done by applying the time reversal operator on the Hamiltonian of system, corresponds to the classical reciprocity [47]. It means that we are still dealing with the causality and reciprocity concepts, although their definitions have been changed based on the fundamental principles of quantum theory.

Based on the above and previous descriptions, it can be concluded that:

- Every observer has own essence which lives in the non-causal eternal universe.
- After collapsing the events by concisions pyramid, he/she experiences an observer-dependent causal, non-eternal, and temporal world, such that, he/she sees his/herself at the center of a causal set, in which, some events have occurred before him/her and the rest will occur after him/her. Now, the concept of spacetime is an understandable concept for him/her. In other words, spacetime has been born.
- The causality relation, between causes and effects, can be explained by using the Green's function method. Now, the concept of time evolution is an understandable concept for him/her and has been born.

- The concisions pyramid can be considered as a projection operator from enteral universe to the causal, non-enteral and temporal world which depends on the location of observer in spacetime of the non-internal world.

- If ds_i^2 stands for the metric of the observer (i) in the spacetime, then the pyramidal operator can be defined as:

$$\widehat{PO}_i \equiv \Theta(ds^2 - ds_i^2) \{x_0 <^* x_1 <^* \dots <^* x_i <^* x_{i+1} <^* \dots\} \quad (21)$$

where, $\Theta(ds^2 - ds_i^2)$ is the heavy side function and $\{x_0 <^* x_1 <^* \dots <^* x_i <^* x_{i+1} <^* \dots\}$ is the causal set whose center, (x_i) , is the location of observer on his/her worldline. If the enteral universe is shown by the non-causal set $S = \{a_i, b_i, \dots, y_i, z_i\}$ whose elements are facts, then

$$\widehat{PO}_i(S) \equiv \Theta(ds^2 - ds_i^2) \{x_0 <^* x_1 <^* \dots <^* x_i <^* x_{i+1} <^* \dots\} \quad (22)$$

As we have seen above, the causality relation can be written as a Green function between each cause and its effect. Therefore, one can write

$$\{x_0 <^* x_1 <^* \dots <^* x_i <^* x_{i+1} <^* \dots\} \equiv G^r(x_1 - x_0) \dots G^r(x_i - x_{i-1}) \dots G^a(x_i - x_{i+1}) G^a(x_{i+1} - x_{i+2}) \dots \quad (23)$$

which, $G^{r(a)}$ stands for retarded (advanced) Green's function i.e., G^r stands for the information flow from past to future while G^a stands for the information flow from future to past [50]. Therefore, the pyramidal operator can be defined as

$$\widehat{PO}_i(S) \equiv \Theta(ds^2 - ds_i^2) G^r(x_1 - x_0) \dots G^r(x_i - x_{i-1}) \dots G^a(x_i - x_{i+1}) G^a(x_{i+1} - x_{i+2}) \dots \quad (24)$$

But, what is about $G^{r(a)}$?

It has been shown that, if $G_0^r(x_1, x_2)$ and $G_m^r(x_1, x_2)$ stand for the massless and massive scalar retarded Green's function, respectively, then [50]

$$G_m^r = \sum_{k=0}^{\infty} (-m^2)^k G_0^r * G_0^r * \dots * G_0^r \dots ; (k+1 \text{ times}) \quad (25)$$

where,

$$(G_0^r * G_0^r)(x_3 - x_2) \equiv \int d^d x_1 \sqrt{-g(x_1)} G_0^r(x_3 - x_1) G_0^r(x_1 - x_2) \quad (26)$$

Now, if $K_0^r(x_3, x_2)$ and $K_m^r(x_3, x_2)$ stand for the retarded massless and massive Green's function on a causal set, by replacement

$$\int d^d x_1 \sqrt{-g(x_1)} \rightarrow \rho^{-1} \sum_{\text{causal set elements}} X \quad (27)$$

one can write [50]

$$K_m^r = \sum_{k=0}^{\infty} \left(-\frac{m^2}{\rho}\right)^k K_0^r \cdot K_0^r \cdots K_0^r; (k+1 \text{ times}) \quad (28)$$

which, ρ is the sprinkling density in a volume V of d -dimensional spacetime [50].

For example, in two-dimensional Minkowski space M^2 , a massive retarded Green function on every causal set, can be written as

$$K_m^r(x_2, x_1) = \sum_{k=0}^{\infty} \left(-\frac{m^2}{\rho}\right)^k \left(\frac{1}{2}\right)^k C_k(x_2, x_1) \quad (29)$$

where, C_k 's are called k -chain and are powers of the causal matrix i.e.,

$$C_k(x_2, x_1) = C_0 \cdot C_0 \cdots C_0; (k+1 \text{ times}) \quad (30)$$

and

$$C_0(x_2, x_1) := \begin{cases} 1 & \text{if } x_1 < x_2 \\ 0 & \text{Otherwise} \end{cases} \quad (31)$$

Conclusion

Based on the results of causal-effect interaction-based theories (such as the causal set theory) or theories based on the temporal slicing of spacetime manifold (such as the CDT theory), it can be concluded that the structure of our non-eternal world is causal. Based on the Big Bang-Inflation theory, this causal structure is created due to the simultaneously and sudden phase change in the expanding vacuum, which creates the Big Bang event. The Big Bang event leads to the creation of elementary particles, and subsequently, the fusion of elementary particles leads to the formation of nucleus and the stability nucleus by adding electrons leads to the formation of atoms. As the process continues, the current world is formed, finally. In order to provide a suitable interpretation for Inflation-Big Bang theory, we have to accept the philosophical regression or the philosophical cycle, although despite their acceptance, the concept of time and temporal evolution still remain ambiguous.

In this paper first, we have introduced the generalized version of three principles called contextuality principle, equivalence principle, and absolute cause and probable effects principle. Based on these principles, we have shown that how a concisions observer (called observer, for simplicity) belongs to a causal and non-eternal world (called world, for simplicity) interacts with the universe, and in consequence, non-causal events collapse to the causal one. In consequence, the born causal set is observer-dependent. While, these different

causal sets which belong to the same world might have different first and last elements and minimum and maximum path but, they are satisfied the same physical laws. Of course, in different parallel worlds, different physical laws are satisfied by the causal sets, due to the different interaction between their observers with the universe. It has been shown that the causal relationship between different elements of a causal set can be explained by using the concept of Green's function. Also, it has been shown that, one is able to define a pyramidal operator for explaining the interaction between observer and universe. The operator depends on the place of observer on his/her worldline and the Green's function of the born causal set.

Although it is not customary to study metaphysical issues in the scientific articles, we have shown that if we attribute an enteral essence to any observer (event or fact), the essence is a preserved and constant quantity during the transitions from universe to world(s) or sequential transition from one world to another world. Therefore, it is only because of his/her self-concisions that he/she perceives a non-eternal causal world which is that is time-dependent. Of course, the transition between parallel worlds and the return to the universe occur when his/her self-concisions has changed. However, the interpretation of this issue differs among different religions and is out of the scope of this article.

Data availability

The data that supports the findings of this study are available inside its text

References:

- [1] Lee Smolin," The trouble with physics" (Mariner Books, 2007).
- [2] G. F. Giudice," Before the Big Bang" (Springer, 2025)
- [3] Lee Smolin," Time Reborn" (Mariner Books, 2013).
- [4] Lee Smolin," Einstein's Unfinished Revolution" (Penguin Press, 2019).
- [5] R. M. Unger and L. Smolin," The singular universe and the reality of time" (Cambridge University Press, 2015).
- [6] Julian Barbour," The End of Time" (Oxford University Press, 2001).
- [7] Carlo Rovelli," The order of time" (Riverhead Book, 2018).

- [8] Carlo Rovelli, "The seven lessons on Physics" (Penguin Press, 2012).
- [9] Carlo Rovelli, "Relativity is not what it seems" (Riverhead Books, 2017).
- [10] Barton Zwiebach, "A First Course in String Theory" (Cambridge Press, 2004).
- [11] Joseph Conlon, "Why String Theory?" (CRC Press, 2016).
- [12] R. Gambini and J. Pullin, "Loops, Knots, Gauge Theories and Quantum Gravity" (Cambridge University Press, 2000).
- [13] Carlo Rovelli, "Quantum Gravity" (Cambridge University Press, 2007).
- [14] C. Rovelli and F. Vidotto, "Covariant Loop Quantum Gravity" (Cambridge University Press, 2014).
- [15] Sumati Surya, "The Causal Set Approach to Quantum Gravity" (Springer, 2025).
- [16] Sumati Surya, "The Causal Set Approach to Quantum Gravity", arXiv:1903.11544v2 [gr-qc] 28 Aug 2019.
- [17] Cecilia Flori, "A First Course in Topos Quantum Theory", (Springer, 2013).
- [18] Cecilia Flori, "A Second Course in Topos Quantum Theory", (Springer, 2018).
- [19] Cecilia Flori, "Group Action in Topos Quantum Physics", arXiv: 1110.1650 [quantph].
- [20] Hamidreza Simchi, "General Formulation of Topos Many-Node Theory" (BP International, New Frontiers in Physical Science Research, Vol. 9, DOI: 10.9734/bpi/nfpr/v9/9580F).
- [21] Hamidreza Simchi, "Topos Many-Node Theory: Roots, Foundations, and Predictions", arXiv:2306.00030v1 [gr-qc] 31 May 2023.
- [22] Lee Smolin, "Three roads to quantum gravity" (Basic Books, 2000).
- [23] Luca Bombelli, "Statistical Lorentzian geometry and the closeness of Lorentzian manifolds", *J. Math. Phys.* **41**, 6944–6958 (2000).
- [24] Luca Bombelli, "Space-time as a causal set" (PhD Thesis, Syracuse University, Italy, 1978).
- [25] E. Dable-Heath, C. J. Fewster, K. Rejzner, and N. Woods, "Algebraic classical and quantum field theory on causal sets", *Phys. Rev. D* **101**, 065013 (2020).

- [26]C. J. Fewster, E. Hawkins, C. Minz, and K. Rejzner, “Local structure of sprinkled causal sets”, *Phys. Rev. D* **103**, 086020 (2021).
- [27]A. Deshpande, R. Pitu, and D. D. Reid, “The effect of Poisson sprinkling methods on causal sets in 1+1-dimensional flat spacetime”, *J. Emerge. Invest.* **8**, 1 (2025).
- [28]Robert M. Wald, “General Relativity” (University of Chicago Press, 1984).
- [29]S. Baron, and B. Le Bihan, “Causal Set Theory is (Strongly) Causal”, *Foundations of Physics* **55**, 63 (2025).
- [30]A. Corichi, and D. Nunez, “Introduction to the ADM Formalism” arXiv: 2210.10103v2 [gr-qc] (2023).
- [31]J. Ambjørna, A. Görlich, J. Jurkiewicz, and R. Loll, “Nonperturbative quantum gravity”, *Physics Reports* **519**, 127 (2012).
- [32]V. F. Mukhanov and S.. Winitzki, “Introduction to Quantum Fields in Classical Backgrounds” (Cambridge University Press, 2007).
- [33]R. Loll, “Quantum Gravity from Causal Dynamical Triangulations: A Review”, arXiv:1905.08669v1 [hep-th] (2019).
- [34]J. Ambjorn and R. Loll, “Causal Dynamical Triangulations: Gateway to Nonperturbative Quantum Gravity” arXiv:2401.09399v1 [hep-th] (2024).
- [35]R. Loll, “Nonperturbative Quantum Gravity Unlocked Through Computation”, arXiv:2501.17972v1 [hep-th] (2025).
- [36]R. Roll, “The emergence of spacetime or quantum gravity on your desktop”, *Class. Quantum Grav.* **25**, 114006 (2008).
- [37]A. Di Biagio and C. Rovelli, “Stable Facts, Relative Facts”, *Foundations of Physics* **51**, 30 (2021).
- [38]Carlo Rovelli, “The Relational Interpretation”, arXiv: 2109.09170v3 [quant-ph] (2021).
- [39]D. N. Page and W. K. Wootters, “ Evolution without evolution: Dynamics described by stationary observables”, *Phys. Rev. D* **72**, 12 (1983).
- [40]S. Gemsheim and J. M. Rost, “Emergence of Time from Quantum Interaction with the Environment”, *Phys. Rev. Lett.* **131**, 140202 (2023).

- [41]N. Arkani-Hamed, D. Baumann, A. Hillman, A. Joyce, H. Lee, and G. L. Pimentel, “Kinematic Flow and the Emergence of Time” *Phys. Rev. Lett.* 135, 031602 (2025).
- [42]G. Galanti and M. Roncadelli, “Is Lorentz invariance violation found?”, arXiv: 2504.01830v2 [astro-ph.HE] (2025).
- [43]A. Kolmogorov, “Foundations of the theory of probability” (Chelsea Publishing Company, 1933).
- [44]M. E. Carvallo, “Nature, Cognition, and System II” (chapter 7) (Springer, 1992).
- [45]H. Simchi, “Bell’s inequality and Quantum Probability Trees” arXiv: 0209095 [quant-ph] (2000).
- [46]Cecilia Flori, “A First Course in Topos Quantum Theory” (Springer, 2013).
- [47]J.H. McGuire, A. L. Godunov, Kh. Kh. Shakov, Kh. Yu. Rakhimov, and A. Chalastaras, “Quantum time ordering and degeneracy I: Time ordering in quantum mechanics”, arXiv: quant-ph/0312179v1 (2003).
- [48]E. N. Economou, “Green’s Functions in Quantum Physics” (Springer, 2006).
- [49]Nomaan X, F. Dowker, and S. Surya, “Scalar Field Green Functions on Causal Sets”, *Class. Quant. Gravity* **34**, 12 (2017).
- [50]X. Nomaan, “Quantum Field Theory on Causal Sets” (*Handbook of Quantum Gravity*. Springer, 2023).