Consciousness and quantum mechanics of macroscopic systems

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Abstract

We propose the quantum mechanical description of complex systems should be performed using two types of causality relation: the ordering relation \((x \prec y)\) and the subset relation \((A \subseteq B)\). The structures with two ordering operations, called the causal sites, have been already proposed in context of quantum gravity (Christensen and Crane, 2005). We suggest they are also common to biological physics and may describe how the brain works. In the spirit of the Penrose ideas we identify the geometry of the spacetime with universal field of consciousness. The latter has its evident counterparts in ancient Indian philosophy and provides a framework for unification of physical and mental phenomena.

Key words: consciousness, quantum measurement, spacetime

1 Introduction

The creation of quantum mechanics at the beginning of the previous century was, perhaps, the most significant event when the discovery of particular physical effects resulted in global change of human understanding of the world. The radical point of view suggested by quantum mechanics consists in complete disclaim of the objective reality: for the state of object – as declared by quantum mechanics – depends on what the observer knows. Later, the widely accepted statistical interpretation of quantum mechanics pacified the situation by assertion that quantum mechanical probability describes an ensemble of quantum particles rather than a single one, and so it statistically predicts the share of particles to be found in a given state in certain experiment. Using this paradigm
one can surely do a lot of quantum mechanical calculations with a good agreement with experiment without paying serious attention whether the world exists or not.

In our days the attitude to the problem of consciousness and measurement in quantum mechanics has changed, basically due to the studies related to quantum computations [1, 2]. It becomes utmost evident, or at least very attractive, to assume that final observation on any quantum system is performed by consciousness – the ultimate observer. At the same time, the research in brain science and the attempts to simulate complex brain wave dynamics by dynamical systems, in particular by neural networks [3], reveal a deep parallelism between the hypothetical procedure of quantum computations and information processing in human brain [1, 5, 6]. Alternatively it seems utmost impossible to explain tremendous amount of information processing per second, performed by human brain at room temperature, without significant thermodynamic heat losses, those should be of order \( \Delta Q = kT\Delta I \ln 2 \), that is about \( 3 \cdot 10^{-21} \text{J/operation} \) at \( T = 300^\circ K \). Qualitatively the parallels between quantum phenomena in micro-world and psychological phenomena in brain science are quite well known. For instance, asking a person what he is thinking about this very moment, will cause a process similar to wave function collapse: from all thoughts superposed in his mind before being asked he will select only one thought and formalise it in his answer – that is an einselection process [7].

The importance of consciousness in quantum physics was understood much earlier than the question of brain information processing arose. In quantum physics the result of measurement can not be described independently of the observer, i.e. cannot be described “objectively” [8, 9]. If a quantum system has two possible states, \( |\psi_1\rangle \) and \( |\psi_2\rangle \), their linear superposition
\[
|\psi\rangle = c_1|\psi_1\rangle + c_2|\psi_2\rangle
\]
is also a possible state of the same system. The states of quantum system, defined as vectors in abstract Hilbert space, are determined only relatively to certain process of measurement: if there is a Hermitian operator \( A^\dagger = A \), such that
\[
A|\psi_1\rangle = a_1|\psi_1\rangle, \quad A|\psi_2\rangle = a_2|\psi_2\rangle, \quad a_1 \neq a_2 \in \mathbb{R},
\]
the states \( |\psi_1\rangle \) and \( |\psi_2\rangle \) are referred to as eigenstates of the physical observable \( A \). Spin, momentum, energy, coordinate, etc. are physical observables.

The process of measurement, i.e. determination of the state of quantum system leads to the collapse of the linear superposition of states (1) to the measured state – either of possible ones. The probability of certain result of measurement is given by squared complex amplitude:
\[
|\psi\rangle = c_1|\psi_1\rangle + c_2|\psi_2\rangle \rightarrow \begin{cases} |\psi_1\rangle, & p_1 = |c_1|^2 \\ |\psi_2\rangle, & p_2 = |c_2|^2, \end{cases}
\]
where the initial state is normalised \( |c_1|^2 + |c_2|^2 = 1 \). The equation (3) is the simplest form of the von Neuman reduction postulate, that states the collapse of the wave function (1) from a linear superposition of possible states to a definite state.

The process of measurement takes place by means of interaction of the system with the environment, but is not caused by that interaction only. Indeed, if the measuring device was in a state
$|\phi\rangle$ before the measurement, and works so, that depending upon the detected state of the measured system $|\psi\rangle$, the device undergoes either of quantum transitions,

$$
\begin{aligned}
|\phi\rangle &\to |\phi_1\rangle, & \text{if the system was in the state } |\psi_1\rangle, \\
|\phi\rangle &\to |\phi_2\rangle, & \text{if the system was in the state } |\psi_2\rangle,
\end{aligned}
$$

then the result of measurement is that the state of the combined system (“system + device”) undergoes a transition from factorisable to non-factorisable superposition state:

$$
|\psi\rangle|\phi\rangle \to c_1|\psi_1\rangle|\phi_1\rangle + c_2|\psi_2\rangle|\phi_2\rangle.
$$

The latter is called an entangled state, emphasising the fact, that the states of the system and that of the measuring device are no longer mutually independent after the measurement. The transformation (4) itself does not lead to the collapse of wave function, since it retains the superposition of states. The collapse happens at the moment when the states of the the measuring device are discriminated by observer; that means that different states of the measuring device should be mutually orthogonal

$$
\langle \phi_1 | \phi_2 \rangle = 0;
$$

if it is not the case the linear superposition will survive after the measurement.

The entanglement arising in course of measuring introduces two essential problems into quantum measurement: (i) the problem of nonlocality, and (ii) the problem who is the observer. The former makes the events separated by space-like intervals causally connected: measuring the projection of spin of one EPR particle we know the projection of its counterpart [10]. The latter drives the final observer, who discriminates the states of measuring device, out of physical reality: a state of the measuring device $|\phi\rangle$, which is entangled with the state of the studied quantum system $|\psi\rangle$, is measured by the other device $|\phi_1\rangle$, which becomes entangled with $|\phi\rangle$ and so on, including human vision system, parts of brain etc. , – also described by quantum mechanics, – but all these systems themselves cannot discriminate. So, it should be something beyond this to say “this and not this” and record the result. This something we define as an ultimate observer, the function of which is the awareness.

Therefore before the observer became aware of the result of measurement he describes the system by wave function (1), but when he became aware of its state he starts to use either with $|\psi_1\rangle|\phi_1\rangle$ or $|\psi_2\rangle|\phi_2\rangle$. This means the result of measurement is dependent upon whether or not the observer sees the measuring device.

To summarise these strange facts of quantum reality, from very beginning of quantum mechanics, it was suggested that the wave function of a quantum system may evolve in two essentially different ways: (1) exhibit linear unitary evolution, governed by the Schrödinger equation; (2) exhibit quantum collapse when being observed; (3) the wave function in quantum mechanics describes not a quantum system per se, but our perception of that quantum system. This three points comprise the Copenhagen interpretation of quantum mechanics, developed by N.Bohr, V.Heisenberg and W.Pauli. According to Copenhagen interpretation [11], the task of science is to extend the range of our experience and to predict the results of our sensations after certain actions. The
quantum mechanical amplitudes describe therefore the probabilities of our sensations. For this very reason the Copenhagen interpretation has been attacked many times as denying the existence of the external world. The description of our sensations instead of material world is not bad itself: it simply means there should be something beyond our sensations, which is not less important than the matter, and which should be included in our picture of the world. It can be referred to as universal consciousness.

In present paper we tried to consider the matter and the consciousness as equal constituents of the world, trace their roots in cosmology, and compare the present view on consciousness and the geometry of the spacetime with ancient Vedic philosophy. The remainder of this paper is organised as follows. In section 2 we consider the relation of consciousness to cosmology and topology in view of ancient Indian philosophy. It is claimed that a hierarchic type of causality (causal sites) should be used instead of point causality. In section 3 we discuss our perception of the world as macroscopic quantum effect. An hierarchic Hilbert space formalism is proposed in section 4 to generalise the idea of hierarchic information states, proposed to describe the brain dynamics in terms of dynamical systems. A few general remarks on consciousness and causality in living and non-living matter are presented in Conclusion.

2 Hierarchical systems: How the geometry emerges

The positive solution of the problem of measurement may be given by understanding of common source of matter and consciousness. Such ideas have been proposed since long ago, at least since Pythagoras, but mostly at the level of metaphysics. Rather recently a participation of gravity in the wave function collapse in brain has been proposed by R.Penrose [5]. This idea is very attractive mathematically: both the gravity and the consciousness impose certain sets of relations on matter, and it is natural to suggest these two types of relations have common source. To illucidate that common source let us borrow the picture of the origin of the world drawn in ancient scriptures, in particular in Indian philosophy. As it is said in Rig Veda [12 page 13]:

There was neither being nor non-being,
Without breath breathed by its own power That One
RV.10.129, Creation hymn

In Sanskrit language “That One” is denoted by the term brahman. Non-differentiable Brahman is the source of differentiated (i.e. comprised of more than one entity) world. In Chandogya upanishad (Chand 4.10.5) [12 page 16] we read “brahman is void”. In modern terms this can be understood as vacuum.

According to Rig Veda the creation of the world – “creation of many from One”, “manifested from non-manifested” – results in three fundamental entities

Prakriti – the term close to our word “matter”

Atman – there is no exact English equivalent to it – it is often translated as “universal soul”, “objective soul”, or “pure consciousness” [12 page 27]
**Purusha** - eng. “Person” – that, who realise its identity to atman ("I am He") – the term related to human consciousness.

The hymns of Rig Veda are written in an ambiguous manner, and their unique interpretation is quite difficult [13, 14]. Here we cite the Rig Veda text basically for illustration – the same question on the origin of the present Universe from something one and unique could be asked in purely physical settings: How present continuous space has emerged? The Big Bang theory does not answer this question for it is based on continuous spacetime itself. To get a continuous space from something discrete it is required to have (i) sufficiently big discrete set of objects (ii) with sufficiently big set of relations on that set. Typical example is the spatial grid – a set of vertexes (balls) with binary neighbouring relations between them; depending on the number of neighbours we have different dimensions of the space.

However the neighbouring relations are not the only possible relations. The other type of possible relations is the part – the whole relation. It is related to the fragmentation of a single object into a number of parts (subsets). Such relations are described by hierarchic trees. In view of this we can assume the existence of universal set of relations between objects (prakriti) understanding this set as a universal consciousness (atman).

The term purusha, mentioned above, is more complex. By definition, purusha is “that who realises its identity to atman”; it is the source of ego, free will, etc., and is attributed to the field of psychology, rather than physics. It is important, however, that atman – the objective consciousness – is the universal set of relations. Therefore the purusha should be subset of it. This means in the final end of any observation the final observer is the universal consciousness – atman. (Some authors considering the matter-consciousness dualism in view of Indian philosophy use the prakriti-purusha dihotomy, restricting the consciousness to observer’s consciousness.)

Assuming the atman to be a universal set of relations imposed on matter let us consider a mathematical toy-model of the origin of continuous world from a non-discriminated brahman (|0⟩), which we understood as vacuum.

The formation of matter (prakriti) could be described by action of creation operators to vacuum state |i⟩ = a_i^+|0⟩, i = 1, N. This results in a tree-like process which yields a discrete, but not necessarily countable set of excitation

\[
\begin{align*}
|1⟩ & \rightarrow |11⟩ \quad \cdots \\
\vdots & \quad \downarrow & \vdots \\
|0⟩ & \quad \vdots & |1M⟩ \\
\vdots & \quad \downarrow & \vdots \\
|N⟩ & \quad \vdots & \quad \cdots
\end{align*}
\] (5)

The tree-like process (5) can be continued or not with either of the first generated excitations \{|i⟩\}_1, N. We assume it is the way the prakriti emerged from brahman, but not the geometry. It is important, that in physical sense the prakriti is understood as pre-matter, rather than matter. The matter fields of observed elementary particles can be combined of pre-matter elements: this requires certain relations to combine those elements into a set – the geometry is required. These relations
are to be imposed by atman. What kind of relation those could be? Definitely the relations that distinguish between “this and not this” and binary relations between elements. The most trivial topology will be the space of all possible subsets of the set of prakriti elements, with each subset being understood as an open set. Interestingly, the “atoms” introduced by Democritus philosophy were derived from the non-differentiable absolute by imposing the relation that distinguish between “this and not this”. However, this construction deals with a discrete set of objects, and we need something more to explain how the continuous geometry emerges from a discrete set, and how this set is ordered to explain the observed causal phenomena.

There is a question how the discrete set of relations can result in a continuous differentiable manifold. The first way to answer, suggested by combinatorial topology, is that a set of binary relations between points (elements of prakriti) can be considered as a complex, with points being the vertices. For instance, a set of 3 points \{A, B, C\} with the set of binary relations \{\chi(A, B), \chi(B, C), \chi(C, A)\} is equivalent to the \(S^1\) sphere; similarly, the set of 4 points \{A, B, C, D\} with corresponding binary relations

\[
\{\chi(A, B), \chi(B, C), \chi(C, A), \chi(A, D), \chi(B, D), \chi(C, D)\},
\]

i.e. a three-dimensional simplex, is equivalent to the sphere \(S^2\), see Fig. 1 The metrics on this space can be introduces as \(\rho(x, y) = \) the shortest path from vertex \(x\) to vertex \(y\) of the graph, with the distance between neighbouring, i.e. those subjected to the relation \(\chi(\cdot, \cdot)\), vertexes considered as unity. To introduce a chronological-like ordering a more complicated set of relations is required. First, the partial ordering like that described in [15] or [16] can be introduced by regarding the formation of the Universe topology a multiplicative process of diversification (5). The idea of multiplicative process as the origin of the Universe with fractal Cantorian geometry has been discussed by many authors [17, 18, 19, 20, 21]. However, as to my knowledge, it was not considered as a source of causality relations.

We assume that the vertical ordering (shown in Fig. 2) corresponds to \(\subset\) and the horizontal ordering corresponds to \(\prec\) of [16]. In quantum description of pre-spacetime the evolution can be observed by changing the number of entities and the quanta of time is just an action of the next creation operator on the already existed level \(a_i^+(t + 1)a_j^+(t) \ldots a_k^+(1)|0\rangle\). This quanta of time are presumably equal to \(\tau_{Pl} \sim 10^{-42}\)sec. If there are no changes - there is no time. The observer of course observe not the pre-atoms, or regions, shown in Fig. 2 but some groups of them together with certain relations – all this is perceived as fields. The horizontal ordering \(\prec\) corresponds to the signal propagation. Where we understand a signal can be generated by any change of physical fields.
On a discrete set generated by a multiplicative process from a single parent object we have two kinds of relations:

a The neighbouring relations make this space metrisable:

if \( \chi(a, b) = true \& a \neq b \) then \( \rho(a, b) = 1 \). The distance between points which are not direct neighbours is counted as a shortest path composed of neighbouring pairs:

\[
a, x_1, x_2, \ldots, x_n, b : \chi(a, x_1) = \chi(x_1, x_2) = \ldots \chi(x_n, b) = true.
\]  

(6)

The neighbouring relation \( \chi(\cdot, \cdot) \) implies the equivalence relation \( a \sim b \& b \sim c \Rightarrow a \sim c \), where \( a \sim b \) means the existence of a path between \( a \) and \( b \). Therefore the neighbouring relation defines the partition of the initial set into disjoint classes. If the neighbouring relation is equipped with a partial order

\[
a \prec b \& b \prec c \Rightarrow a \prec c,
\]  

(7)

with closed loops avoided, then the manifold constructed from the neighbouring relations will inherit that partial order. Physically, the partial order corresponds to the time ordering. A signal can propagate from point \( a \) to point \( b \) only if there exists a causal path

\[
a, x_1, x_2, \ldots, x_n, b : a \prec x_1 \prec x_2 \prec \ldots \prec x_n \prec b.
\]  

(8)

b The inheritance (parent-child) relation is another type of causal relations, not related to the causal paths of the type “a”. Inheritance is a relation between parent and child objects, the whole and the part. A typical physical example is the EPR pair: two fermions, being produced by a single (parent) boson retain quantum correlations between their states, regardless the fact that they are not connected by causal path of type “a”. The inheritance from parent to child \( (C \subseteq P) \) also implies a partial order

\[
A \subseteq B \& B \subseteq C \Rightarrow A \subseteq C.
\]  

(9)
The causal relations of type “a” are purely classical – they are common to differential geometry, Newtonian mechanics and general relativity. The type “b” causal relations can not be found in classical physics, in which the coordinates can be measured with arbitrary high precision. The partial order $\subseteq$ describes the refinement of the measurement: one can measure (affect) a part of something only having affected the whole first; but not reverse. In EPR experiments the states of two different fermions are measured only after the state of the parent boson have been affected. In this way the multiplicative process (5) with two ordering relations, $\prec$ and $\subseteq$, unifies the geometry and the theory of measurement. The question is how these two relations are imposed on the discrete set generated by a multiplicative process. An interesting point of view is considering the Universe in terms of information theory, as big processor which includes all, where the matter fields are computational elements immersed in computational media – consciousness \cite{22}.

3 Consciousness and brain

Turning to biological science we face the problem of relations between brain and consciousness. If the universal consciousness (atman) is as fundamental as matter is, if the geometry of the world exists by virtue of it, what is its relation to the personal observer’s consciousness, or mind? Mind (sanscr. chitta), viz. a human mind, is a category of much less generality than atman, and is subjunctive to the latter. Mind is the “software” that works in brain. Its task is to process the sensory inputs, to form response, and to control its execution. The dynamics of neuron firings, as emphasised by Tegmark \cite{23}, can be described by classical or semiclassical approximation, however the potential and the forces related to the activity of neurons are governed by the field of consciousness, in the sense, that neurodynamics works in highly unequilibrial regime \cite{3}, and it is the consciousness that drives the neuron system to either of its possible attractors. Thus the trajectory of an atom in a living cell can be evaluated only at time intervals much less than the typical times of the consciousness dynamics.

The difference between living and non-living systems lies in the fact, that living systems have something, perhaps what was called purusha in ancient Indian philosophy, that makes them different from just a mechanical collection of parts. It is said in Rig Veda scriptures, that each living being has its separate, but identical purusha. For non-living matter, which does not have it, – say for a stone, the product of wave functions of all atoms in that stone completely determines its quantum state of that stone. For a living object, in contrast, the state of the whole defines the state of the parts, but not vice versa. That is why the entropy of a living system does not increase according to the second law of thermodynamics. The individual consciousness, purusha, is the field that determines the dynamics of a living system and decreases entropy. It was even suggested by a physicist N.Umov a hundred years ago to introduce the third law of thermodynamics specially for it to meet Darwin’s evolutionary ideas.

The “mind”, in contrast to consciousness, is something more special to psychology and can be attributed only to living creatures, if not only for humans. The problem of mind and consciousness have been studied by philosophers from ancient times, and it seems be helpful to recall certain functions of mind to understand how the brain works \cite{24, 25}. According to ancient Indian philosophy
the mind (chitta) has at least three functional components: manas – the recording facility, buddhi – the intellect, and aharnkara – the ego. This three functions enables the data acquisition about the state of the environment and the state of body, develop possible plans of action and control their execution. All those provide the survival of the organism. For instance, the manas registers (by sense organs) a fast moving object, the buddhi evaluates its size and possible trajectory and finds out it will soon approach my personal position and transmits the information to aharnkara. If it is the case the aharnkara commands the body to change position in an appropriate way to avoid the collision.

If the work of the manas - the recording facility - can be explained physically, at least in principle, in a way similar to the operation of digital camera, the operation of buddhi is more complex. Here we use Sanskrit word buddhi instead of English “intelect”, for very often the intellect is understood is purely algorithmic decision taking, but buddhi includes both algorithmic and non-algorithmic evaluation of input information. The former is described by formal rules and can be implemented on computer, the latter cannot be implemented in such a way and it is the place for quantum aspects of consciousness.

To understand how the brain works different models have been proposed, see for review. Generally the brain is considered as an information processing unit that maps certain input information into certain output information. However, the word “information” requires definition itself. First, according to the amount of information is a number of dichotomy questions (to be answered yes/no) we have to ask to describe the system completely. Therefore the definition of information implicitly requires consciousness – the reader of the yes/no answers. Even having known the state of each neuron in the brain, we do not have a unique way to determine what thoughts are going on. The situation is similar to traditional computing: having measured the currents in microprocessor we still can not say what software is running. The consciousness in a wide sense, atman, as was already mentioned, is out of material world by definition: it is a set of relations imposed upon material objects. In a narrow sense, the consciousness, or more exactly the mind, keeps the scheme of the organism (body), makes the scheme of the external world and maintains the body-world interactions. Being a part of the universal consciousness (atman), the mind (chitta) is also capable of observing its own state.

The real thinking process includes along with the verbal information space, which is processed classically, certain images, associations, etc., that can not be formalised using a finite and universal alphabet. By analogy with quantum computations, we can consider such space as a Hilbert space of images. This seems to agree with the Copenhagen interpretation of quantum mechanics, that says the wave function describes our perceptions, rather than reality itself. This does not contradict the statement, that between two “measurements” the evolution of mind can be fairly well described by a dynamical system. In the space of all states of consciousness such dynamical system forms a trajectory – the stream of consciousness.

It is not rather clear, at what lowest neurophysiological level the quantum state reduction correlates with consciousness. One of the candidates is the level of cytoskeleton. Penrose also suggested the so-called single-graviton criterion, that means the quantum gravity effects may be essential at the level of the single neuron. However the final detector of any quantum measurement is the observer’s consciousness and therefore the quantum collapse happens at the
level of macroscopic brain activity \cite{25}. The usual role of the observer’s consciousness (chitta) is registering the state of a macroscopic device, a pointer, – say a light pointer, or a digital indicator. The latter (possibly via a long chain of intermediate mesoscopic devices) interacts with the measured quantum system. The whole chain should exhibit linear evolution according to the Schrödinger equation. The von Neuman collapse happens because the states of the pointer device are utmost mutually orthogonal for the tremendous number of degrees of freedom involved

$$\langle i|j \rangle \sim e^{-N},$$

where $N$ is the number of degrees of freedom in the device. Because of this orthogonality the reduction \cite{3} takes place.

Let us imagine the quantum system interacting with very few degrees of freedom of human observer. Such effects do really take place: a human eye in dark-adapted state is capable of detecting a single photon \cite{34,35}. A photon registered \textit{in vivo} by human observer may be the cause of entanglement between a quantum system and remote observer. Indeed, if a photon is emitted in Raman scattering, the observer’s consciousness becomes entangled with the molecule which scattered the photon. To some extent, this means the observer becomes aware of the state of that molecule. The important point of such consideration is that the measurement process, performed by human consciousness, consists of two stages \cite{7}. The last is the quantum transition, but the first is \textit{taking attention} of the system to be studied. The quantum transition is described by the probability amplitudes, while taking attention is a voluntary act, and is not described by the probability amplitudes – it just imposes certain relations upon neurons. This means, that if a person concentrates on an external system, and wish to observe it, he makes his consciousness entangled with that system.

The difference from a standard observation in visual range, – when the observer receives a lot of photons with uncorrelated phases from the studied object, – is that a volition to observe a system makes the observer’s consciousness and the system into a combined system, but does not necessarily lead to a collapse. The \textit{collapse} happens when the observer \textit{records} his impressions in verbal form – thoughts, – doing so he destroys the coherent superposition and makes it into a single information state of his consciousness, which corresponds to a definite pattern of neural activity.

If the consciousness and the topology of spacetime have the same origin – both are sets of relations imposed on matter, – the measurement performed by direct perception, i.e. by brain being entangled with the studied system, can also change the state of observed system. The possible mechanism is the same as for the EPR-pair: having measured the projection of spin of one particle of the pair we, therefore, fix the projection of its counterpart on another end. Such hypothesis is implicitly supported by the fact, that most significant effects of intended change of state by paranormal inductors (psi-phenomena) were observed for semiconductor devices, where the number of half-spin excitation over forbidden zone is easily controlled \cite{36}.
4 Hierarchic structure of information states

“... however the complex object may be, the thought of it is one individual state of consciousness.”

William James

The term *state of consciousness* in the above phrase requires clarification. If the object is really complex, i.e., it contains a number of hierarchic levels, the knowledge of that object is acquired by taking snapshots of different hierarchic levels by means of sequential quantum measurements. That is why it is natural to assume the state of consciousness, which is a representation of that object, to be a hierarchic tree. This coincides with the definition of information state as a \( p \)-adic tree given in [32]. If the information is coded in a string written in \( m \)-letter alphabet, possibly a chain of neurons with \( m \) states [37], and

\[
x = (x_0, x_1, \ldots, x_i, \ldots), \quad x_i = 0, m - 1, \quad m \in \mathbb{N},
\]

is an information vector, where the coordinate \( x_0 \) is the most important, \( x_1 \) is less important, and so on, then different information states can be labelled by \( m \)-adic trees, or \( m \)-adic integers \( x = x_0 + x_1m + x_2m^2 + \ldots \).

In quantum mechanics, if we have a system \( A \) consisting of two parts, – say, a meson consisting of quarks and anti-quark, – the wave function of the whole \( A \) is completely determined by direct product of the constituents wave functions:

\[
\Psi_M = \bar{q} \otimes q.
\]

Such system is unconscious: there is nothing extra in meson, that can not be found in the product of its components wave functions. However, it is formally possible to represent the state of meson in the hierarchic form [38]

\[
\{|A\}, \{|Ai\}, \{|Aj\}\},
\]

see Fig.3. The possible spin states of meson are \(|\uparrow\rangle, |0\rangle, |\downarrow\rangle\); the spin states of quarks are \(|\uparrow\rangle, |\downarrow\rangle\). If there are two states of meson, say \(|A\rangle = |\uparrow\rangle, \quad |B\rangle = |\downarrow\rangle\) their linear superposition

\[
\Psi = \alpha \{|A\}, \{|Ai\}, \{|Aj\}\} + \beta \{|B\}, \{|Bi\}', \{|Bj\}'\}\}
\]

is also allowed state. Perhaps, for a nonliving matter, such as meson, the index \( A \) in (10) is redundant – for the state of the whole is just a product of the states of its constituents. For biological systems the presence of the state of the whole as an independent argument is important. To some extent the same is required for any open system. The wave function of an electron in molecule is not the same as the wave function of a free electron. One can argue that formally we can take into account all other electrons and nuclei degrees of freedom of that molecule and calculate the wave function of the whole molecule, but this is practically impossible: the interaction with environment and, finally, the wave function of the whole Universe should be taken into account. So, for hierarchic systems, such as atoms, molecules and bigger complexes, it is quite reasonable to treat the state of
the whole as independent argument. Strictly speaking, the measurement procedure itself demands to keep the state of the whole as separate independent argument when studying the behaviour of the parts. Say, the measurement of the spin state of quark in meson can be performed only after the whole meson was prepared in a certain quantum state.

In biological settings, the state of the whole is controlled by consciousness and cannot be expressed as a product of its constituents states – so it must be kept independently. Reproducing the classical consideration of [32], we can make the same statement about thinking process: we can retrieve details of a thought only when it was first grasped as a whole, and then we go down to the parts (details). Each step on this thought-tree corresponds to a measurement procedure.

Generally the thoughts of material objects have hierarchic structure. If before the measurement took place the studied object was in a superposition of quantum states

$$|\phi\rangle = \alpha_1|[x^{(1)}]\rangle + \alpha_2|[x^{(2)}]\rangle + \ldots \alpha_n|[x^{(n)}]\rangle,$$

(11)

where $$|[x^i]\rangle$$ correspond to different information states, then after the measurement only one of the alternatives will survive, let it be the $$i$$-th state, survived with probability $$|\alpha_i|^2$$: it will form a classical information state defined in hierarchic tree. This coincides with the definition of information state as a $$p$$-adic tree. If $$[x^{(i)}]$$ is a classical information state, i.e. the string of integers $$x_0^{(i)}, x_1^{(i)}, x_2^{(i)}, \ldots, x_k^{(i)} < p$$, the corresponding $$p$$-adic tree can be labelled by a $$p$$-adic integer

$$x^{(i)} = x_0^{(i)} + x_1^{(i)} p + x_2^{(i)} p^2 + \ldots.$$

(12)

The vector in hierarchic Hilbert space [33], which corresponds to $$p$$-adic tree (12), will be written as

$$|[x]\rangle = \{p^0|x_0\rangle, p^{-1/2}|x_0 x_1\rangle, p^{-1}|x_0 x_1 x_2\rangle, \ldots\},$$

(13)

with scalar product, norm etc. being defined component-wise:

$$\langle [x]| [y]\rangle = \langle x_0 | y_0 \rangle + p^{-1} \langle x_0 x_1 | y_0 y_1 \rangle + p^{-2} \langle x_0 x_1 x_2 | y_0 y_1 y_2 \rangle + \ldots.$$

(14)
Figure 4: Spatial domains corresponding to piecewise constant behaviour of wave-function in $p$-adic norm, $p = 2$.

The representation (13) of $p$-adic trees states for the oriented string of characters: $x_0$ is more important than $x_1$, and so on. If instead one would try to use

$$|x⟩ = \{ |x_0⟩, |x_1⟩, |x_2⟩, \}$$

the orientation will be lost.

The link to the quantum mechanics of $c$-valued wavefunctions of $p$-adic argument normalised as

$$\phi : \mathbb{Z}_p \to \mathbb{C} : ∥\phi∥^2 = \int_{\mathbb{Z}_p} |\phi(x)|^2 dx < ∞$$

might be given by setting the scale behaviour of the hierarchic wave function to

$$\phi(x) \sim |x|^1_p \leq 1, x \in \mathbb{Z}_p.$$  (16)

This corresponds to geometric interpretation: smaller $p$-adic norm means smaller spatial scales. On the larger scale the domain of piece-wise constant behaviour is larger, see Fig.4.

In our hierarchic formalism the function $\phi(x)$ is understood in terms of hierarchic states

$$\phi(x) \equiv \langle [\phi] | [x] \rangle,$$

where $[x]$ and $[\phi]$ belong to the space (13) and the space conjugated to it, respectively. The measurements on such a system should be described by a tree of operators, each of them corresponding to its particular scale – from the most rough to the finest:

$$\hat{A} \equiv |x_k⟩A_0^{kl}⟨x_l| + \frac{1}{p} |x_k x_m⟩A_1^{klnn}⟨x_l x_n| + \ldots$$  (17)

We ought to say that hierarchic representation of external world in brain in the form of hierarchic trees – information states – stems from the discriminative feature of consciousness: discrimination...
between “this” and “not this” leads to a tree-like structure. In any observation (measurement) we start from rough and continue with subtle details. There is no account for this fact in standard quantum mechanics. According to Copenhagen interpretation quantum mechanics predicts our sensations after certain actions. We infer that our representation of the external world is correct if our predictions coincide with observations. An important property of consciousness is its ability “to be aware of itself”. This means consciousness can observe (measure) itself. Thus the dynamic of thinking, and the brain activity, constrained by that dynamics, can be described by quantum mechanics of information states represented by vectors in hierarchic Hilbert space (13). Such dynamics be relevant to the brain thinking processes on intervals between measurements. In the same way as the geometry of spacetime defines the laws of motion for unconscious matter, the consciousness defines the laws of motion for living matter. It makes relations between subparts of living systems in such a way that the living matter acts against the second law of thermodynamics.

5 Conclusion

In traditional approach to quantum mechanics, declared by N.Bohr, life is considered as something complementary to the procedure of quantum measurement. If we measure position of an atom in living cell with a high accuracy, the energy, required to achieve this accuracy, will kill the cell. According to this paradigm, the physics study interactions between objects, which are separable, i.e., may be discriminated from each other. Biology, in contrast, studies the effect of changing the state of the whole (organism, organ, cell) to the functioning of its parts. Those two methods have been considered as complementary to each other. We suggest, that this seeming complementarity stems from the fundamental structure of the world imposed by universal consciousness.

The separate existence of the mind and the matter has been proclaimed even by Descartes. The new finding, made by R.Penrose, was that consciousness, which is responsible for the measurement, and the geometry, which is responsible for the constancy of laws of nature, may be just the same.

In our paper, basing on ancient Indian philosophy along with modern physics, we claim there are two types of consciousness: objective consciousness, which can be identified deterministic laws of physics, and subjective consciousness, which is responsible for the behaviour of living beings. The geometry of spacetime that we observe is formed by those two types of consciousness, by imposing two types of causal relations, preceding (≺) and inclusion (⊆). The former is more known in physics, the latter – in biology; both, in fact, constitute a general causal structure, known as causal site. Our individual consciousness, which process the information on the external world and is also capable of observing itself, represents the results of observations in hierarchic trees, or information states. This hierarchy is comes from the general structure of the objective consciousness – the structure of causal site. Mathematical description are hierarchic quantum states corresponding to information states.
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