Time and Consciousness in a Quantum World.

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Abstract

We address the relation between two apparently distinct problems: The quest for a deeper understanding of the nature of consciousness and the search for time and space as emergent structures in the quantum mechanical world. We also advance a toy-model proposal of emergence of time from a timeless unus mundus quantum-like space by using Aharonov’s two state formalism of quantum mechanics. We further speculate on these issues within a quantum cognitive perspective with particular interest in two recent papers on this emerging field of science. One (Aerts et al) entails (as we argue) a panpsychist top-down approach to the problem of consciousness. The second paper (Blutner et al) proposes a quantum cognitive model for Jung’s psychological type structure. We discuss these concepts and their relation with our main thesis, that time is a measure of individuality. One of our central motivations is to provide arguments that allows the mainstream physicist to take seriously a panpsychist worldview, a position that has been openly forwarded by many modern philosophers.

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According to Kant, space and time are *a priori* non-empirical representations and as such, they underlie all human mental constructions in order to organize and apprehend the sensorial data of physical reality [1]. One could make the case that Einstein’s relativity theory undermined this notion. We know since the early twentieth century that the inner workings of space and time can differ radically from the structure that our naive intuition leads us to. The Minkowski structure of spacetime was far from obvious and was discovered by studying carefully the discrepancy between the structure of electromagnetism (spawned by a large body of empirical evidence) and the Newtonian concept of space and time [2], [3]. One could well say that Maxwell’s equations already contains in itself the Lorentz spacetime structure and that Einstein and Minkowski were the first to fully understand this fact.

In the third decade of the twentieth century, the theory of a non-relativistic quantum theory (NRQT) of particles was developed by names as Heisenberg, Schrödinger, Born, Bohr, Jordan and Dirac [4]. This theory is *non-relativistic* in a serious way. Time and space
are treated in radically distinct ways: Time is a one-dimensional parameter and space is an observable, an Hermitian operator defined on an abstract infinite-dimensional quantum space of state-vectors. Of course, it was immediately recognized by the founders of quantum physics that it was imperative to extend the theory in order to make it compatible with relativity. Yet, the route to this approach was not so clear in the beginning. For instance, when Bohr was told that Dirac was working on a relativistic equation for the electron, he was surprised because he thought that Klein and Gordon had already achieved this [5].

After a while, it was recognized that no single particle equation would do the trick. The concept of a relativistic quantum field theory (RQFT) was introduced in order to describe elementary particles and their interactions. Particles were interpreted as elementary excitations of these quantum fields. The position operators of NRQT were ”downgraded” to a simple parameter along with time in Minkowski’s spacetime. And there were good reasons for this. First, Dirac observed that the opposite move (upgrading time as an observable) did not make much sense because then time and energy would both have semibounded by below spectrum like position and momentum observables. But this clearly conflicts with the stability of fermionic quantum systems as the hydrogen atom for instance. Yet, it was precisely this lack of stability of classical models for atomic systems that was actually one of the major driving forces behind the development of quantum mechanics in the first place. A second physical argument, consistent with the first can be made. The concept of a particle state with a well defined position does not make sense because of the intrinsic lack of an operational implementation of the measurement of its position with arbitrary precision. (This is only one instance of an ”operational-positivistic” argument that pervades the entire history of quantum physics). For example, consider an electron interacting with a classical electromagnetic (EM) field. In order to confine the electron inside a wave-packet with a width $\Delta x$ smaller than its Compton length $1/m_e$ (in natural units) one needs to set an EM field so strong that it would unavoidably create positrons and electron pairs implying a many-body formalism with a varying number of particles [6]. This provides a powerful reason for a quantum field description of particle interactions. Even nowadays, our most refined theories of physical reality accepted by mainstream physics is based on this construction. The standard model of elementary particles and even most attempts to go beyond it (supersymmetry and string theories as primary examples) are one way or another ultimately defined within this paradigm. Yet, there is something odd about this model. First,
this move of the role played by the position of quantum particles seems strange. Indeed, compare it to how the non-relativistic limit of relativistic classical mechanics (classical as non-quantum) is understood. In the latter, the passage from the relativistic regime to the Newtonian one is straightforward. It can be derived easily for relative speeds that are small compared to the speed of light. This "structural transformation" of the position operator to a simple parameter for relativistic quantum field theory is not sufficiently understood and many definitions of a relativistic position operator have been sporadically proposed in the literature [7].

A second and much more serious "positivistic flavoured argument" can be made. Consider a full RQFT explanation of particle interactions. For example, suppose (for the sake of simplicity) that the world is comprised only by electrons, positrons and photons. We have an electronic field and the "photonic field" which mediate the interaction between the electronic leptons. Given a state of the electronic/EM field all one can compute and "ask experimentally" are things like "For this particular event of spacetime, what is the probability of finding a certain number of electrons, positrons or photons with such and such momenta, spin, helicity, etc.?" The typical scattering experiment is one where there is a global field state characterized by a given number of incoming particles far away with well defined momenta, spin, etc. and outgoing particles (long after the interaction) again with a well defined number of particles with given states. One then computes and measures the transition probability. What is curious about this full-blown quantum field description is that since the particles are only excitations of quantum fields, there is no room for any individuality of a single particle. This is a well-known fact, but it seems that the full depth of the fundamental consequences of this issue has not been pursued far enough. Take, for instance, a simple non-relativistic quantum system as the hydrogen atom. In this case, one has an electron quantum mechanically bound to a proton by its classical electric field. The electron can be in this or that energy state with this or that spin. But we think of the electron as being the same particle that happens to be in different possible states over time. From the point of RQFT, this is a "linguistic liberty", so to speak. What really happens (according to RQFT) is that the (classical) EM field in this case is not strong enough to create more particles/excitations with appreciable probability, thus, the individuality of this particular field excitation is emergent. This poses the following question: how do we measure time operationally? The obvious answer is: with a clock. But a clock is nothing else but a periodic phenomenon of some sort. For instance, the rotation of the Earth around its
axis or its translational orbit around the sun were once considered excellent clocks. Today we apply atomic clocks to GPS technology. A necessary condition in order to an arbitrary system be considered a clock is that it must maintain its \textit{individuality}. If an object now is supposed to be a clock, one must be able to recognize this system as the same object in a further moment. How is it then that we have a full-blown RQFT with a previously defined spacetime? Einstein changed our understanding of spacetime when he thought carefully about how one can operationally define the synchronization of clocks in a way compatible with electromagnetism. It seems that what quantum mechanics is telling us about the nature of spacetime is that its structure should be \textit{emergent} in some strong ontological sense that still remains to be unravelled. The structure of RQFT is a ”superstructure” in this sense. Time and space are artificially included ”by hand” in the theory. For this reason it is natural to claim that, in some sense to be made more precise in the future, one can state that ”\textit{Time is a Measure of Individuality}”. We address a few suggestions of how this may be accomplished in the following sections. In the last section, we conclude with some closing remarks. We visit now a concept that is possibly even more controversial than that of the nature of time or spacetime.

II. \textbf{TIME AND CONSCIOUSNESS: THE TRUE ”ASTONISHING HYPOTHESIS”}

Francis Crick, one of the 1962 Medicine nobel-prize winners for co-discovering the double-helix structure of DNA (together with James Watson and Maurice Wilkins) published a book in 1994 called ”\textit{The Astonishing Hypothesis: The Scientific Search for the Soul}” \footnote{8}. In his book, he advocates a physicalist and reductionist explanation of the mind and other attributes of consciousness. From the perspective of the History of Science, Newtonian Physics was followed by an increasingly number of new developments over the past three or four centuries together with amazing advances of the hard and biological sciences. It would seem that one could conclude today that the reductionist point of view is completely vindicated. From a mainstream scientific standard, all attempts of a vitalist philosophy have been purged from science and as so, the reductionist hypothesis (sometimes called the \textit{bottom-up} approach) for explaining consciousness actually looks anything but astonishing.

It fact, it is the opposite approach, the hypothesis that the concept of consciousness is
somehow a primitive ontological feature of reality is nowadays what deserves to be called astonishing. If one looks at the history of science, though, a much more intertwined complex intellectual zigzag between both metaphysical positions becomes evident. Some of the most important founders of the age of reason were not so convinced themselves of this extreme form of "naive physicalism". Descartes advanced his well-known dualistic approach, where mind can affect matter, but not the contrary [9]. His point of view is now considered almost universally unacceptable given our present knowledge of science. Neither did Newton believe in a completely mechanical universe that obeys deterministic laws (that were essentially discovered by himself.) As a matter of fact, he somehow was able to maintain a metaphysical view with enough room to accommodate a God that could once in a while "intervene" in the workings of the great machine [10]. Leibniz argued in his "Monadology" that there is an inescapable "explanatory gap" between the purely mechanistic explanation of the world and the true functioning of the "mind" [11]. Yet, many of Newton’s later followers become much more "Newtonian" than himself. Take Laplace’s famous words [12]:

"We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes."

Needless to reaffirm, this increasing hard-core belief in mechanism as an ultimate description of reality was supported by an extraordinary number of successful applications of physics and mathematics to all kinds of natural phenomena. Yet, a reaction against this prevailing attitude from the intellectual world did not have to wait much: already in the late eighteenth century, a number of different schools of thought (much later collectively coined as the Counter-Enlightment movement) advocated a more anti-rationalist worldview where vitalist and organic ideas were welcomed as a cure for the excessive cold and mechanistic metaphysics of the times. These ideas were closely related to German Romanticism and many thinkers and artists (Goethe for instance) defended many anti-enlightenment positions [13]. We dwell into these historical upturns only to point out that the resurgence of panpsychism and monist related philosophies in the last few decades are far from being something 
new in the history of science. In the twentieth century, many founders of quantum mechanics also dived into some related concepts. Bohr, Schrödinger, von-Neumann, Wigner and Pauli all considered the idea of consciousness (or significantly close ideas) playing a fundamental role in quantum mechanics. Bohr introduced the philosophical concept of complementarity in order to deal with apparently logical contradictions found in quantum descriptions as the famous wave-particle duality. He believed that this concept could be extended to many other fields far from quantum physics as the complementarity between science and religion, for example. Bohr was also convinced that the so called measurement problem could be solved by imposing that a state vector of a quantum system collapses when it interacts with a classical measuring system. Thus, in his view, classical reality should have an ontological status equal to quantum reality. But the circular logic implied by the fact that classical reality should also obviously be some kind of classical limit of the quantum description of the world did not seem to bother him at all. Bohr was also influenced by Taoist philosophy. Indeed, when Frederick IX conferred him the Order of the Elephant, he designed his own coat of arms which featured the yin/yang symbol together with the Latin motto contraria sunt complementa, “opposites are complementary” [14]. Schrödinger was pretty much influenced by the philosophy of Schopenhauer and like him also had strong interests in Eastern philosophies. In his book What Is Life? (curiously the book that decisively influenced Watson and Crick in their pursuit of the structure of DNA) he speculates about the possibility that individual consciousness could be a manifestation of some kind of universal consciousness [15], [16]. It is also well-known that both von-Neumann and Wigner suggested the introduction of a conscious observer in order to solve the measurement problem in quantum mechanics [17]. Yet, it is fare to say that it was Pauli and his friend Jung that pushed these ideas to an unprecedented level [18].

Jung was a Swiss psychiatrist who founded the discipline of analytical psychology. One of its main concepts is that of individuation, a process of integrating the conscious realm with the unconscious one in order to provide a healthy human development of the psyche. He introduced a number of concepts like psychological types: the extrovert and introvert attitudes together with the psychological functions of Sensation, Intuition, Thinking and Feeling. He also developed the concept of archetypes, collective unconscious, the ego and the shadow, the animus and the anima and synchronicity. This last concept involved the idea of non-causal relations between events with psychological significance. This greatly
influenced Pauli (that was his patient) and they become collaborators and friends. They developed together the notion of the *inus mundus* in connection to non-local and non-causal synchronistic phenomena. The *inus mundus* can be thought as a deep "undifferentiated sea" of unconscious possibilities where common elementary archetypes of the human race resides and that occasionally surfaces through the particular individuation of human beings.

Jung developed these conceptual constructs after many years both of clinical observations of his patients and personal introspection. Both thinkers believed that the *jective world and the subjective world were equally *real and important and that a proper understanding of the relation between these distinct ontological realms was a matter of great urgency. They were convinced that physics (and science in general) would evolve towards this path in the future.

These indeed are extraordinary and truly astonishing claims. After all, the beginning of modern science was shaped during the Renaissance and the Enlightenment when a clear cut between objective and subjective reality was devised. How could it even be possible to consider going back to the superstitious, religious and "magical thinking" of medieval times? Today, most thinkers that consider panpsychism seriously are considered as anti-rationalists by mainstream physicalists. Probably a superficial "new-agism" together with some exaggerated post-modern relativism did not help much in this matter. The work of Philosophers and Cognitive Scientists varying from Gregory Bateson to David Chalmers, Liane Gabora and Ignazio Licata are, unfortunately, not sufficiently appreciated, in general, by the current hard materialistic paradigm.

We distinguish *four* main distinct philosophical positions on this issue. To make this point clear, let us quote a famous line of Wittgenstein from his *Tractatus Logico-Philosophicus*: "*Whereof one cannot speak, thereof must one be silent.*" The first view is that of the pure hard-core materialistic and physicalist thinker. He would interpret Wittgenstein’s words as meaning that all there is about reality are precisely *only* those things that can be said about it. This position represents such a naive view that it almost excuses us from further commentaries. It is enough to say that this represents precisely the opposite of what Wittgenstein was trying to communicate. This impoverished philosophical stand is commonly found to be behind a certain kind of revived old-fashioned discourse coined pejoratively as "scientism". Yet, many contemporary mainstream scientists go along with this metaphysical position. The second view is probably much more akin to Wittgenstein’s original vision.
This is the view of the mainstream scientist that does not negate the existence of things in the world that are beyond science, but believes that since these matters belong (by definition) out of the domain of scientific discourse, they should be dealt exclusively by non-scientific disciplines like ethics, religion, etc. This is a respectable and pragmatic position and there are good reasons for taking this metaphysical position seriously. A third view envisages a philosophy of monism in order to describe reality where the nature of consciousness and that of material reality are one and the same. This philosophy of panpsychism can be seen as a top/bottom approach to the mind/body problem where consciousness is a primary ontological feature of the world and where any element of material reality has at least some degree of consciousness [28]. Yet, there is a fourth view that can be considered as being somewhat between views number two and number three. This stems from the fact that one may formulate the following question (about view number two): if there is a clear division between those things that we can speak about and those that we cannot, how can we talk about the division itself? How can one recognize it? One possible answer is that we talk about the "unspeakable" indirectly through metaphors, art, religion and cultural expressions in general. But, the cultural forms and language that we use in order to express science (and in particular, physics) also evolves in time. As an example, take Faraday’s concept of force fields that he introduced in the nineteenth century. This represented a major step away from the local particle interaction model of Newtonian mechanics. It was difficult for the physicists to understand this new form of thinking. It was Hertz that finally accepted the fact that Maxwell equations were the EM theory, paving the way for Einstein. All the other main physicists of the day (including Maxwell himself) tried to construct mechanical models for a luminiferous ether. Today any child is familiar with the idea of a "force field". It is commonly depicted in many contemporary cartoons, TV shows and science-fiction movies. Who knows what people will think about wave-functions and quantum entanglement in a couple of hundred years from now? Richard Feynman in his famous Lectures on Physics that he delivered back in the sixties to undergraduate students at Caltech has a section named "Scientific imagination". Some excerpts from the original text are quoted below [29]:

"...I have no picture of this electromagnetic field that is in any sense accurate. ...When I start describing the magnetic field moving through space, I speak of the $\vec{E}$ and $\vec{B}$ fields and wave my arms and you may imagine that I can see them. I’ll tell you what I see. I see some kind of vague shadowy, wiggling lines—here and there is an $\vec{E}$ and $\vec{B}$ written on them
somehow, and perhaps some of the lines have arrows on them—an arrow here or there which disappears when I look too closely at it. When I talk about the fields swishing through space, I have a terrible confusion between the symbols I use to describe the objects and the objects themselves. ...We use a lot of tools, though. We use mathematical equations and rules, and make a lot of pictures. What I realize now is that when I talk about the electromagnetic field in space, I see some kind of a superposition of all of the diagrams which I've ever seen drawn about them...

...Perhaps the only hope, you say, is to take a mathematical view...We are unfortunately limited to abstractions, to using instruments to detect the field, to using mathematical symbols to describe the field, etc. But nevertheless, in some sense the fields are real, because after we are all finished fiddling around with mathematical equations—with or without making pictures and drawings or trying to visualize the thing—we can still make the instruments detect the signals from Mariner II and find out about galaxies a billion miles away, and so on.”

Feynman gives us here a vivid and pedagogical example of how striking the influence of historical and cultural contexts can exert upon scientific discourse.

It is our firm belief that there in no such thing as a completely neutral philosophical thinker. Everyone carries their own prejudices and bias. At this point, the reader probably has guessed that the author has sympathies towards views number three and four. Yet, it is absolutely imperative to recognize that there is presently no hard scientific facts capable of distinguishing any of these metaphysical positions. In fact, for view number two thinkers, it is even impossible to distinguish them in principle. The view number one physicalist (clearly also a kind of an extreme monistic and materialistic thinker) believes that the "explanatory gap" can be closed when the workings of the human brain become sufficiently understood someday in the future.

We propose some concrete pathways where one can look for an intellectual construct that can accommodate views three or four. Firstly it is important to acknowledge that there is a large and ancient historical body of evidence of knowledge from the "subjective realm". This may seem a contradiction in terms because we are used to think that only objective facts are capable of being communicated and that deserves being recognized as science. Take physics and mathematics as a typical example. The laws of Newton are the same in Europe or Asia and relativity theory is the same in the Northern or Southern hemispheres. The famous
number theorists Hardy and Ramanujan could work perfectly together on mathematics in the early twentieth century, but the first was a typical European rationalist and the second was a religious Hindu that believed that his uncanny mathematical skills were delivered to him by his family goddess Mahalakshmi. Yet, ”softer” sciences (as sociology and psychology, for instance) are much more ”cultural dependent” than it is for ”hard sciences”. Still, their disciplines are commonly considered as part of the scientific enterprise in general.

We put forward the idea of looking more carefully to what is called ”perennial philosophy”, a term introduced by Agostino Steuco and later by Leibniz. Modernly, this concept was recovered by names as Jung, Joseph Campbell and Aldoux Huxley. Perennial philosophy can be thought as a tradition which states that the psychological structure of consciousness (different states of consciousness and in particular, mystical experiences) stem from a universal concept. Yet, these ideas take different configurations based on distinct historical and cultural contexts, thus shaping a variety of schools of thought and organized religions in all places and times of mankind history. We assume that the concept of consciousness and states of consciousness (as a working hypothesis) are real in the sense that they have equal ontological status as mainstream scientific concepts like time, space, energy, matter, etc. The evidence that allows us to pursue this approach results from a vast and long time literature based on introspection and exploration of subjective experiences both in Eastern and Western philosophies. Yet, there is only on true test that can prove if this or any other scientific working hypothesis is worthwhile. This is the ultimate pragmatic test where the fruitfulness of an idea is measured by the number of facts it can explain and practical usefulness it can provide. It should also be consistent with the body of science that we already know. There is one particular characteristic of these altered states of consciousness that we are specially interested in. This is the phenomenon that is sometimes called ”mindfulness” obtained through meditation and mind-altering substances. There is a long tradition of statements that converge to a few ideas about these states: a feeling of a ”loss of ego” and an altered sense of the flux of time. There seems to be a continuous spectrum of states between our ordinary state of consciousness related to a usual sense of psychological time and a complete loss of ego together with a feeling of ”timelessness” for extreme states of consciousness. For example, a somewhat ”lighter” change of the ordinary state of consciousness is the so-called ”day-dreaming”. This is a common experience that usually occurs spontaneously followed by a sense of a lack of passage of time and immediate
The chain of thought processes that happens continuously for all of us when we are in our ordinary state of consciousness basically "defines" our sense of an "ego" and even a mild interruption of this process changes our sense of individuality and our sense of a passage or flux of psychological time. The striking parallel with our analysis of physical time in the previous section is obvious. Hence, we may rephrase that somehow "time is a measure of individuality". In the next section we deliver a more concrete face to this idea by studying a quantum mechanical "toy model" that may help shed some light on this issue.

III. THE EMERGENCE OF TIME

A. The Partial Trace and the Emergence of Temperature

Feynman discusses in his text-book on Statistical Mechanics [34] a concept that is known as the improper density matrix. Suppose one is interested in studying a certain physical quantum system defined by a finite dimensional space of state-vectors $W_S$. (We consider only finite dimensional spaces in order to avoid inessential analytical technical details). Feynman then introduces the "rest of the universe" described by $W_R$ so that the "whole universe" is described by the tensor product $W = W_S \otimes W_R$. Suppose further that an observer has physical access only to system $W_S$, then given a pure state-vector $|\Psi\rangle \in W$ of the "universe", one can define a unique operator $\hat{\rho}_{|\Psi\rangle}$ that acts upon $W_S$ defined by the following equation:

$$\langle \Psi | \hat{O} \otimes \hat{I} | \Psi \rangle = tr \left( \hat{\rho}_{|\Psi\rangle} \hat{O} \right)$$

for every observable $\hat{O}$ of $W_S$. This operational definition singles out a map between the space of rays defined by $W$ and the space of positive unit trace operators in $W_S$. One recognizes this map as the well-known partial trace operation

$$|\Psi\rangle \langle \Psi | \rightarrow \hat{\rho}_{|\Psi\rangle} = tr_R (|\Psi\rangle \langle \Psi |)$$

commonly used in modern quantum information theory. Feynman, of course, was not meaning anything "cosmological" with his choice of words. He meant simply that given a particular physical system that we are interested in, say a gas confined by a piston in a cylinder, the "rest of the universe" could be any amount of the environment relevant to the physics of the system. (A heat bath, for instance). In order to characterize the system to be in thermal equilibrium, it is natural to suppose that the density matrix must commute with the
Hamiltonian $\hat{H}$ of the system, so that the density matrix is a function of the Hamiltonian $\hat{\rho} = \hat{\rho}(\hat{H})$. We further assume that the entropy $S = -tr(\hat{\rho} \ln \hat{\rho})$ is maximized together with the further constraint defined by the internal energy $E = tr(\hat{\rho} \hat{H})$. This leads us to the well-known Boltzmann-like density operator

$$\hat{\rho} = \frac{1}{Z} e^{-\beta \hat{H}}$$

with

$$Z = tr(e^{-\beta \hat{H}})$$

where $\beta$ is thermodynamically identified with the inverse temperature (in natural units). The Hermitian operator $e^{-\beta \hat{H}}$ looks similar to the unitary time evolution operator $\hat{U}(t) = e^{-it\hat{H}}$ if one makes the identification $\beta \rightarrow it$. This formal analogy allows thermal averages of systems in equilibrium to be computed from RQFT with imaginary time. If a solution to the latter is analytic in time, a thermodynamic solution can be obtained by Wick rotation. Thus it is a mainly a mathematical technique for calculating thermodynamic partition functions. Speculations that there may be some deeper foundational reason for these results have been made in the literature but there is not yet any hard evidence for these claims. Yet, we may speculate about the possibility of "deriving a emergent notion of time" in an analogous manner. At a first glance, it seems difficult to find a way to somehow derive an unitary time evolution operator instead of the Hermitian Boltzmann operator. In the following subsection we suggest how to circumvent this problem.

B. Aharonov’s Two-State Formalism

The Two-Time formalism for Quantum Mechanics developed by Aharonov, Bergman and Lebowtiz (ABL) in 1964 was initially proposed in order to remove the apparent time asymmetry from the usual formulation of Quantum Physics due to the projection postulate. This formulation advocates that in order to provide a complete information for a given quantum state of a system one needs to know not only the previous pre-selected state of the system obtained by a strong measurement but also a post-selected state given also by a strong measurement. This is a time-symmetric refinement of the ensemble given only by a given pre-selected state. This concept led in the eighties to the discovery of a new element of reality, the so-called Weak Value (WV) of an observable for a particular two-time state. Given non-orthogonal pre and post selected states $|\alpha\rangle$ and $|\beta\rangle$ (the two-time state is usually represented by the tensor product $\langle \beta | \otimes |\alpha\rangle$) then the WV $\langle \hat{O} \rangle_w$ of an observable
\( \hat{O} \) is the complex number

\[
\langle \hat{O} \rangle_w = \frac{\langle \beta | \hat{O} | \alpha \rangle}{\langle \beta | \alpha \rangle}
\]

It can be shown that the WV can be effectively measured by conducting a great number of experiments with the same chosen two-time boundary conditions. This can be achieved through an infinitesimally small coupling of the system of interest with a measuring system within a von-Neumann pre-measurement setup.

This concept is indeed time-symmetric and the temporal inversion operation can be implemented by swapping the pre and post-selected states together with the complex conjugation of the WV. Consider now the following operationally definition: take two distinct maximally entangled states \(| \alpha \rangle, | \beta \rangle\) of the "whole "universe" \( W = W_s \otimes W_R \) analogously as discussed in the previous subsection. In this case both \( \hat{\rho}_{|\alpha\rangle} \) and \( \hat{\rho}_{|\beta\rangle} \) have maximum von-Neumann entropy \( S = -tr (\hat{\rho}_{|\alpha\rangle} \ln \hat{\rho}_{|\alpha\rangle}) = -tr (\hat{\rho}_{|\beta\rangle} \ln \hat{\rho}_{|\beta\rangle}) = \ln N \), where \( N = \min(\text{dim } W_s, \text{dim } W_R) \). One can then prove that the partial trace of \(| \alpha \rangle \langle \beta |\) (up to the proportionality constant \( N \)) is an unitary operator \( \hat{U}_{\langle \beta | \otimes | \alpha \rangle} \): (proof in appendix).

\[
\hat{U}_{\langle \beta | \otimes | \alpha \rangle} = Ntr_R (| \alpha \rangle \langle \beta |) \quad \text{with} \quad \hat{U}_{\langle \beta | \otimes | \alpha \rangle}^\dagger = \hat{U}_{\langle \alpha | \otimes | \beta \rangle}
\]

Is is tempting to identify somehow the "whole Universe \( W = W_s \otimes W_R \)" in this case with the timeless unus mundus of Jung and Pauli.

IV. QUANTUM COGNITION

The emerging field of quantum cognition advocates the use of a mathematical formalism inspired by quantum mechanics in order to model certain human cognitive structures and other complex phenomena. Most researchers of quantum cognitive sciences are rather pragmatic and careful about the worldview behind their practice [38], [39], [40]. They make it clear that they do not assume that the human brain is quantum-like as claimed by a few scientists [41]. Their starting point is the assumption that some systems (as certain human cognitive and psychological features) have such a degree of complexity, that it is impossible to study its behavior without taking into account contextuality in the form of non-Kolmogorovian probability models like the one provided by quantum physics. Many applications have been pursued successfully for subjects as decision theory and human judge-
ment in general, conceptual composition, linguistics and memory recognition. Recently, Dieterik Aerts, after a thorough investigation on how concepts can compose and interfere with each other in a ”quantum-like” manner, advanced an intriguing proposition that contrasts strikingly from the prevailing view [42]. He set forward the position that quantum entities may actually be nothing else than ”conceptual entities” themselves. One argument for this is the striking parallel between the non-local, non-causal quantum channel of two entangled quantum systems and the idea of ”meaning” of the composition of two distinct concepts. He further theorizes that space (or spacetime) is a macroscopic emergent structure and the so-called non-locality of entangled elementary particles are a consequence of the fact that they somehow ”exist beyond space and time”. This view resonates obviously with some of the ideas that we discussed in previous sections. Aerts also discusses two widely different metaphysical interpretations of this worldview: The first (which he chooses to call an ”antropomorphic” interpretation) views quantum entities and their interactions as an extreme instance of conceptual entities interacting through ”meaningful communication” embodied by other quantum entities (and their compositions) just as like humans communicate concepts through ordinary language. A second interpretation that Aerts asserts to be a somewhat less radical and less antropomorphic philosophical position is a semiotic version of these ideas: here, the quantum entities are nothing but signs exchanged between macroscopic classical systems like the communication between living creatures and also between inanimate objects as computer interfaces. Again, we believe that we have here the possibility of an intermediate choice. If one considers the concept of consciousness as a primary ontological feature of reality then the danger of an antropomorphic interpretation vanishes. After all, human consciousness may be only one instance of the general phenomena of consciousness. Thus, the human species does not need to play any special role in the nature of reality.

Another interesting paper on quantum cognition is that of Blutner et al where a quantum-like model is proposed for the structure of Jung’s psychological type theory. This is one of the most important parts of Jung’s concept of the structure of the self [43], [44], [45]. The authors consider a two-qubit structure where one of the qubits accommodate a two-dimensional representation of the introversion/extroversion attitude. When a person faces an object from the world, the introvert personality tends to direct his libido inwards (towards the images that the object elicits in the subjective world) and the extrovert directs his libido towards
the object. The second qubit models the four psychological functions (thinking, feeling) and (sensing, intuition) as two mutually unbiased orthogonal bases. The first pair of opposite functions assesses and judges information either logically or emotionally. The second pair involves perception of information, either sensorially or intuitively. According to Jung, every human being is born with a primary function which is independent of race, gender, social class or any other cultural context. A secondary or auxiliary function necessarily has to be sorted out from the other pair in order to ”support” the primary function. Clearly the third and fourth choices of psychological functions are then uniquely determined. The third and fourth functions must respectively be the opposites of the secondary and primary functions. The ”upper” hemisphere of this Bloch sphere is related to the conscious realm while the ”lower” hemisphere represents the unconscious. It follows that the eight possible choices of the psychological functions together with the two attitude types implies a total of sixteen different psychological types. The structure of an individual personality type is therefore described by a state vector belonging to a four-dimensional space given by the tensor product of these two qubits. Blutner et al argue that the richer topology of the two-qubit model is capable of a much more adequate and refined explanation of the results obtained from some well-known methodologies for psychological tests designed to classify which Jungian type a particular subject belongs to. Jung claims that the psychic dynamics of a human being takes place through the exchange of libido (psychic energy) between the conscious and unconscious realms. The primary and secondary functions belonging to the first realm and the remaining ”inferior functions” related to the latter. A normal and healthy subject must have a balanced and integrated relation between these distinct structures and the role of the analyst is to bring back this balance and develop their integration through the process of individuation. One cannot achieve this directly from the superior function to the inferior one. It must always be intermediated through the secondary function. Thus, the path is from the superior to the secondary function and from there to its opposite. This is the first phase of an individuation which may be conducted with the help of an analyst. Yet, a full integration of the superior and inferior functions and therefore the integration of unconscious elements with the conscious is a personal life-time task. Jung also speaks of a further classification of the psychological functions depending on rather they are or not of a fundamentally static or dynamic nature. These four ”kinds of realities” as he coined them are the static reality that comes through sensation, the dynamic reality revealed by intuition, the static images
provided by thinking and the dynamic images perceived by feeling. As an example, consider
the static images generated by thinking. These are the timeless Logos of Platonic idealized
world of perfect ideas. Yet, feeling has a superficial resemblance to the thinking process.
Let us consider some illustrative examples chosen by Jung himself. For instance, take the
concept of freedom. It can be a highly abstract and static concept but it also can convey a
strong (potentially dynamic) feeling. In a similar manner, consider the concept my country.
It clearly can also be taken either abstractly or emotionally. Another example is the abstract
idealized and static definition of God as the ”unchanging totality of all changing processes”
or rather imagine God as a powerful dynamic image identified with Eros. It may prove to be
worthwhile to design and implement some cognitive tests on concept composition like those
conducted by Aerts and others but also accounting somehow for the psychological type of
the subjects. Aerts also observed the complementarity of the opposing ideas of abstractness
versus concreteness in his analogy between quantum and conceptual entities. He asserts that
the level of ”abstractness” of a given concept is somewhat the measure of its generality. For
instance, the concept animal is more abstract than the concept dog which in turn is more
abstract than my dog. The concept mine in this last example was used to give a context to
the concept dog in the sense that it provides further restrictions for the examples of dogs
that can come to a subject’s mind. Aerts compares the opposition of the abstract/concrete
concept with the complementarity between position and momentum of quantum particles.
Indeed, the more concrete a concept is, the more ”individuality” the concept conveys. In
fact, the more restrictions (contexts) are imposed over it, the more the level of concreteness
of the given concept will increase. Plausibly this could always be carried on until the ulti-
mate level of concreteness is reached when ”every mind” should agree on its ”uniqueness”.
We have then an individual object.

How can this conception relate to Jung’s type theory? It is important to recognize here
that the quantum-like modeling of conceptual space by Aerts and collaborators entails an
impersonal view of the ”collection of human minds” that deals with these concepts. On
the other hand, Jung’s psychological type theory seeks the means to understand specific
subjects, not only their ”minds” but the complete structure of a subject’s ”self”. There also
seems to be a kind of complementarity between these two approaches. Indeed, one approach
studies the space of concepts determined by the ”general mind set” of human beings. The
other focuses on the specific ways the psychic structure of an individual person perceives
and accesses concepts and images that are caused by external objects. From a naive point of view, one may think that the decision to study both processes within the same mathematical structure would be a methodological mistake. But the beauty of this conception is the fact that this allows one to describe within this same quantum-like structure both "the things that are thought" together with "those things that think them up". This should be expected when one realizes that this division must be (in a certain sense) an arbitrary splitting of the timeless unus mundus between an observed world and the world that observes it.

Jung firmly believed that causality alone is not sufficient to describe the full phenomena of the psychology of the self. He asserted that the psychic structure of the self is a self-regulating system with purposiveness. We wonder if there is a chance that this teleological characteristic may be related to the two-state boundary formulation of the unus mundus.

V. CLOSING REMARKS AND FUTURE PROSPECTS

We have tried to put forward some thoughts and speculations on how one could approach a unified and scientific panpsychist approach to the problem of consciousness and the emergence of time (and spacetime).

For this goal, we have discussed some attributes from the emerging field of quantum cognition combined with the world view of analytical psychology developed by Carl Jung (and to an extent Wolfgang Pauli).

Recent work of Aerts, Blutner and collaborators are fundamental to this proposed program. It is clear to our mind that the burden of scientific proof lies on the side of those that advocate the panpsychist view and we hope that the ideas presented here may somehow help to reach this objective.

A possible future program is the search for a model of the dynamics of the "structure of the self" discovered by Jung. The physicist’s approach to model the dynamics of a quantum system is to discover a time evolution rule (to find a Hamiltonian) either empirically or stemming from some more fundamental theory. It is our opinion that, in the case of the structure of the self, it would be constructive to realize that one should rather seek for a model with the notion of an emerging time (or psychological time) as we have discussed.

Presumably this should be accomplished together with the "individuation" of a particular subject starting from an undifferentiated unus mundus identified with the collective
unconsciousness. One can also envisage an empirical path towards this goal. The testing of a psychological sense of time of subjects under some mind-altered states of consciousness could be interesting. Consider, for instance, how two persons usually communicate by conversation. This only occurs because they share a common language and vocabulary. Communication often becomes easier when these persons know each other and have developed a sharper set of common words and cultural expressions as jargon, slangs, etc. It is a familiar feeling that sometimes in a close relationship one almost can “guess” the others words or thoughts. It is fair to say that in these cases one could state that there is almost an “extension of the ego” of each one of the subjects in prejudice to each other’s individual ego-centered conscious. After all, a person’s ego is whatever this person identifies itself with. It can be his body, his job, an ideal, his family, his country, etc. The ego construct is continuously changing and it can even be determined by the actual momentarily relationship with another person like talking to a friend, for instance. Suppose these two friendly subjects are submitted to a test where they are both initially under the influence of an extreme altered state of conscious. Plausibly at the beginning moments there will not occur any conscious communication between them since each one will be deeply immersed into their own personal unconscious and even their shared collective unconscious together with a great decrease of an ordinary sense of flux of time. Gradually, one expects that some sparse attempts of conscious communication will happen and the frequency of these ephemeral attempts probably would slowly increase under the initially mild conscious-will of each subject together with the withering effects of their mind-altered states. An impartial noninvasive and thorough observation of this process may provide an important insight of the inner functioning of some plausible kind of ”shared individuation” of the two subjects. The struggle to communicate and the gradual increase of common words and concepts may slowly allow the construction of some kind of ”clock ritual” between them. One expects that this progressively feeling of individualization should be accompanied with a conjoint perception of a psychological time. Many other ingenious cognitive experiments may be devised in order to study time perception under altered states of consciousness and the loss and gain of individuality. Multiple cognitive time scales of the functioning of the brain have been proposed as an interplay between quantum-like and classical random electrodynamical signals from neurons [46, 47]. Also, some experiments have already been conducted to study the bistability of perception under ambiguity [48]. This maybe a particularly interesting venue
of investigation with regard to Jung’s psychodynamics of mental pathologies because it is well-known that one of the characteristics of neurotic behavior is the incapability to deal with ambiguity [33].

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VII. APPENDIX

Given two distinct maximally entangled states \(|\alpha\rangle, |\beta\rangle\) of \(W_s \otimes W_R\), we may suppose without loss of generality that \(\dim W_s = N < \dim W_R = M\) so that we can expand these states as

\[
|\alpha\rangle = \frac{1}{\sqrt{N}} \sum_i |u_i\rangle \otimes |w_i\rangle \quad \text{and} \quad |\beta\rangle = \frac{1}{\sqrt{N}} \sum_j |v_j\rangle \otimes |t_j\rangle
\]

where \(\{|u_i\rangle, |v_\sigma\rangle\}\) and \(\{|w_i\rangle, |t_\sigma\rangle\}\) \(i = 0, \ldots, N - 1\) and \(\sigma = 0, \ldots, M - 1\) are pairs of orthonormal basis respectively in \(W_s\) and \(W_R\). We have then that:

\[
|\alpha\rangle \langle \beta| = \frac{1}{N} \sum_{i,j} |u_i\rangle \langle v^j| \otimes |w_i\rangle \langle t^j|
\]

the partial trace gives us then

\[
\hat{U}_{\langle \beta| \otimes |\alpha\rangle} = \sum_{i,j} |u_i\rangle \langle t^j| w_i\rangle \langle v^j| \quad \text{and} \quad \hat{U}_{\langle \alpha| \otimes |\beta\rangle} = \sum_{k,l} |v_k\rangle \langle w^l| t_k\rangle \langle u^l|
\]

then an easy computation proves indeed that

\[
\hat{U}_{\langle \beta| \otimes |\alpha\rangle} \hat{U}_{\langle \alpha| \otimes |\beta\rangle} = \hat{I} \quad \text{with} \quad tr\left(\hat{U}_{\langle \beta| \otimes |\alpha\rangle}\right) = N \langle \beta|\alpha\rangle
\]
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