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THE WORLD AS A QUANTUM INFORMATION PROCESSOR

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Abstract

It is impossible to fully grasp reality and the universe without a sound understanding of quantum science, i.e. theory. The aim of this paper is twofold, namely first presenting what quantum information processing consists of, and then consequently discussing the implications of quantum science to the understanding of reality. I shall claim that the world is fully quantum, and the classical world is but a limit case of the quantum world. The crux of the argument is that quantum information can be taken as a living phenomenon. Quantum information processing (QIP) has been mainly the subject of computational approaches. Here we take it as the way in which information allows for a non-dualistic explanation of the world. In this sense, quantum information processing consists in understanding how entanglement stands as the ground for a coherent reality yet highly dynamical, vibrant and vivid. Information, I argue, is a living phenomenon that creates itself out of nothing. Quantum information is a relational view of entities, systems, phenomena, and events (Auletta, 2005).

Keywords: *Philosophy of Science; Epistemology; Living Systems; Non-algorithmic Information; Complexity Theory*.

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El mundo como procesador de información cuántica

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Resumen

Es imposible comprender cabalmente el universo y la realidad sin una comprensión de la ciencia o teoría cuántica. Este artículo tiene dos propósitos: primero, presentar en qué consiste el procesamiento cuántico de la información, y luego también discutir, consiguientemente, las implicaciones de la cuántica para la comprensión de la realidad. Argumento que el mundo es plenamente cuántico, y que el mundo clásico es un caso límite del mundo cuántico. La base del argumento aquí es que la información cuántica puede ser vista como un fenómeno vivo. El procesamiento cántico de la información (PCI) ha sido principalmente objeto de explicaciones computacionales. Aquí, ésta es tomada como el modo en que la información permite una explicación del mundo que no es dualista. En este sentido, el (PCI) consiste en la comprensión acerca de cómo el entrelazamiento emerge como la base para una realidad coherente y sin embargo altamente dinámica, vibrante, vívida. La información, se argumenta aquí, es una visión relacional de entes, sistemas, fenómenos y eventos (Auletta, 2005).

Palabras clave: *filosofía de la ciencia; epistemología; sistemas vivos; información no-algorítmica; teoría de la complejidad.*

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THE WORLD AS A QUANTUM INFORMATION PROCESSOR

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I. Introduction

This paper argues that the universe or reality can be adequately grasped as a quantum information processor. Two main arguments support the claim, thus: on the one side, quantum information is an interpretation of quantum mechanics (QM), however not equal to any of the other more than fifteen interpretations existing so far; on the other side, the world is fully quantum, and conventional reality is a limiting case of the quantum realm. In order to introduce and discuss these two claims, this paper opens up with a short state-of-the art about the interpretations of QM, and how the door is to be open for quantum information as an interpretation (Auletta, 2005; Fuchs, 2002).

Accordingly, a discussion with the classical view of reality is necessary to rightly understand what quantum reality is about (Storey, *et al*., 1995; Li & Luo, 2008). This is the subject of the second section of this paper in which it is assessed that we live in a quantum world. On this basis, quantum information processing is studied and discussed, and a distance is set out regarding the classical world. The third section argues that the universe or the world is a quantum information processor. We end with a consideration of biological information where it is said that cognition is a biological process; however, previously to the biological processes we have information processing. At the end, some conclusions are drawn.

Nonetheless, a further justification of the structure of this paper is needed. The claim here is that the world is a quantum is to be taken in its broadest sense, namely the world, or nature or the universe is a quantum processor; this means that it processes information non-locally, in distributed and parallel modes, non-sequentially and non-hierarchically (Damasio, 2018). The crux is not the binary language of information – which is here a trivial fact, but the very processing. Information does not exist before being processed and neither after being processed. Information only exists as long as it is being processed. Processing information simply means that A is transformed into B, quite a different phenomenon. As Wheeler put it: *it from bit from qu-bit*; plainly said things are nothing by themselves; they are the information set upon; moreover, things are quantum information, not just sheer information in the sense of Shannon & Weaver.

Based upon the main claim, the problem is to framed as an issue pertaining an interpretation of quantum mechanics (Plotnitsky & Khrennikov, 2015; Ruyant, 2018). A table is hereafter provided that shows that there are currently more than fifteen interpretations of quantum mechanics. Instead of a hurdle, such variety of interpretations is a clear sign of a vital question. This paper takes on one lead to tackle the question, namely, quantum information processing, a field opened independently by Bennet and Shor.

Framing the problem allows for arguing that quantum information processing is a clear sign of life, for living beings as-we-know-them, process information non-algorithmically. In other words, living beings are not a Turing Machine, whatsoever. Such an argument adamantly shocks with classical view of the world, that is grounded ion the principle of the third excluded; hence, the classical world is seen as an array of distinctive different things so that one cannot be another at the same time. Without hesitation, the conclusion emerges hereafter that we live in a living world, something that brings us quite close to pantheism, panpsiquism or biocentrism – an astounding counterintuitive if not iconoclastic draw.

Along such a stance, quantum biology allows us to assess: biology in general can see realities that physics ignores (Kauffman, 2020; Carroll, 2017), namely life, i.e. living beings. I leave quantum biology aside in order to highlight biological information as such. Finally, some conclusions are sketched out.

II. Framing the problem

Quantum information processing (QIP) has been mainly the subject of computational approaches (Long, 2006). Here we take it as the way in which information allows for a non-dualistic explanation of the world. In this sense, (QIP) consists in understanding how entanglement stands as the ground for a coherent reality yet highly dynamical, vibrant and vivid (Zeilinger, 1999).

Information, it will be argued here, is a living phenomenon that creates itself (Vedral, 2010) out of nothing. Quantum information is a relational view of entities, systems, phenomena, and events.

Information is processed in the quantum world as a state of superposition, in terms of non-duality, non-locality, and as entanglement (Vedral, 2003). The processing of information in the quantum realm is an unceasing source of particles, anti-particles, photons, and even phonons in such a way that particles are continuously changed into waves and the waves into particles (Schwindt et al., 1999). As consequences, the concept of "force" disappears. A "force" is the outcome of the continuous exchange among particles and the change from particles to waves, and vice versa: A physical force has been transformed into a field. Hence, we talk about electrodynamic fields, quantum field theory, gravitational field, or the Higgs field, for instance.

Translated into biological terms, (QIP) can adequately be understood as metabolization i.e. as transforming one thing, say A, into another, say B. Metabolization are processes of energy transformation, storage and release of energy – energy that can be used by other molecules within the same metabolic system. Not ultimately probably the most tenable hypothesis about the origin of life reads: "metabolization first". Metabolization actually consists of a highly complex network of networks that make any living organism possible.

Usually when a bond is created bringing forth a larger molecule, energy is stored. Now, when the molecule is broken down energy is released. In any case, energy is never lost, for it can be harnessed by another molecule with the same metabolic network. In a mechanical system the efficiency is low. Yet, when the system is a cell, the efficiency is highly efficient. Such efficiency is due to quantum processes (Sanjeevi, 2019; McFadden & Al-Khalili, 2016). We can call this as quantum efficiency. In the quantum realm there is no loss of energy, no matter what.

There is an array of interpretations about quantum mechanics (Auletta, 2001). Table No. 1 summarizes them, even though some interpretations are still being developed to-date.

Table N. 1: Interpretations of Quantum Mechanics

Interpretation	Author
Classification adopted by Einstein	Albert Einstein, 1905
Ensemble interpretation, or statistical interpretation	Max Born, 1926
The Copenhagen interpretation	Niels Bohr, 1927
von Neumann/Wigner interpretation: consciousness causes the collapse	John von Neumann 1932; Eugene Wigner 1967
Quantum logic	Garrett Birkhoff, John von Neumann, 1936
Broglie–Bohm theory	Louis de Broglie, 1927; David Bohm, 1952
Many worlds	Hugh Everett, 1957
Stochastic mechanics	Edward Nelson, 1966
Many minds	H. Dieter Zeh, 1970
Modal interpretations of quantum theory	B. van Fraassen, 1972 and 1974; Bryce DeWit, 1970;, Dennis Dieks, 1988, and others
Consistent histories	Robert Griffiths, 1984
Objective collapse theories	Girardhi-Rimini-Weber, 1986; Penrose interpretation, 1989
Transactional interpretation	John Cramer, 1986
Relational quantum mechanics	Carlo Rovelli, 1994
Quantum information theories	Charles Bennett, Peter Schor, 1998
Branching space–time theories	Mark Sharlow, 2006
Time-symmetric theories	Ognyan Oreshkov and Niolas Cerf, 2015
The Montevideo Interpretation	R. Gambini and J. Pullin, 2018
Other interpretations	

Source: Own elaboration

From a philosophical standpoint the situation of there being more than seventeen different interpretations about quantum mechanics is very meaningful (Laloë, 2012). Indeed, in the history of science, philosophy and philosophy of science there were usually two rival interpretations; empiricists versus rationalists, for instance. Rather than this being a signal of weakness, it can be taken as a sign of vitality. Something has been going on that suggests a rich variety of interpretations (Fuchs & Peres, 2000). The

Holy Grail of science, to so speak, is not the set of observations or data, the experiments or the calculi, but the very interpretations of reality, of the models brought out, of the set of data. Interpretation – this is when scientists step on to philosophical issues, as it happens (Halpern, 2018).

Quantum information processing (QIP) can be safely said to be an interpretation of quantum mechanics (Smolin, 2019). It is namely the assessment that the world and the universe are strongly entangled and in a constant superposition (Zwirn, 2017). Moreover, the universe and reality are an unceasing process of transformations (Ellis, 2011) – very much in the tenure of the first law of thermodynamics. As it has been pointed out, quantum coherence breaks down into decoherence, but then decoherence recoheres further on (Maldonado, 2018a). As a consequence, the world is entirely quantum and the conventional or classical reality is just a moment in the dynamics of coherence-decoherence-recoherence. Information, i.e. information processing is the very transformation – say, from plasma to energy to matter to life, in the history of the universe (Walker, *et al*., 2017), so much so that t is never lost; rather, it is unceasingly transforming. The story of the transformation of information is the very story of the universe and of living beings, including human beings.

III. We live in a quantum world

From the quantum standpoint, reality is a large realm of processes, fluxes, and dynamics – over against the idea that there are states, objects, and entities. From a philosophical point of view, the classical world has been grasped as a set of equilibria, steady states, and permanence (Modi, *et al*., 2012). However, from a quantum perspective the universe is a buoyant set of change, becoming, and unceasing creation and destruction of particles and waves.

Quantum science has the merit that it introduces a view of the world in a large range, in a deep and wide horizon in which time and space are dissolved, so to speak, and yet can be said to be discrete phenomena. Such a horizon is said to be coherent. Time and space are not distinguished and do not exist as consistent systems. However, quantized time and quantized space remain a puzzle (Rovelli, 2018).

In any case, we do not see the quantum world, for it is highly counter-intuitive. We just grasp it by its effects. The classical world can be said to be the effect of quantum behaviors (Ollivier & Zurek, 2001). Those effects have been traditionally understood as the outcome of the wave collapse. The quantum coherence is broken down, it decoheres, and classical reality emerges. This is the standard view of the world.

Nonetheless, there is no wave collapse but a number of instances in which the quantum system decoheres. The entire universe, as it is well known by now, is one single wave; i.e. wave function; as a whole it never collapses – the collapses are sheer instances that end up being recohered, at the end of the day, so to speak. Rightly said, the classical world is a case limit of the quantum world. Moreover, the classical world is an idealized limiting case of quantum behaviors and phenomena (Li & Luo, 2008).

Due to the advancement of spearhead science at large and the contributions of quantum science in particular, from a cognitive point of view, reality and natural perception do not coincide any longer. Reality is not perceived any more, but imagined, modeled, simulated, or intuited. Along this process reality and the world are conceived not so much in terms of mass (as after the 18th Century) or just as energy (as after the 19th Century), but as information (as after the second half of the 20th Century) (cfr. Englert, 1996). Information is a physical stance un-material and intangible, though. Definitely, it from bit from qubit – which has come to be a common acknowledgement in the field by now.

IV. The trouble with the classical view of reality

The classical world relies entirely on the logical principle of third excluded. This means, the classical world has been taken in terms of either- or – i.e., in terms of a bivalent reality (Mermin, 1985). Dualism is the consequence of such an understanding. Dualism, however, has produced numerous troubles, problems, and unwanted outcomes in the history of science and mankind (Chefles, 2000). Quantum science allows for overcoming a dualist view of the universe.

Indeed, absolutely nothing within the conceptual framework of quantum theory allows for a distinction, and even less an opposition between the microscopic and the macroscopic dimensions (Maldonado, 2019). In the same tenure, ontology and epistemology cease to exist as distinguished stances (Plotnitsky & Khrennikov, 2015; Maldonado et al., 2020). Positively said, epistemology and ontology are one and the same thing in quantum science. Dualism is henceforth untenable. This is the rationale for assessing that the world is quantum (not even quantum-like, as many claim).

However, we cannot simultaneously see or grasp the world as classical and quantum. Suggestive as it is, this means that the standard view of "quantum-like" phenomena is rather a weak argument in that it is flurry or sloppy. We can safely say that classical behavior is a degradation of quantum behaviors. Classical behavior is post-quantum, for at the very beginning of the universe its behavior was quantum. Such idea can be extended to our environmental crisis saying that the degradation of our planet makes it (roughly) classical. Without further ado, we are currently facing a metamorphosis of the very nature of knowledge, a story in-process.

What brings us, indeed, all into peril regarding the climate emergency is not the second law of thermodynamics but the first law because we have not been able to use other forms of energy, and have not been able to change one form of energy into another harnessing the various forms of it. The issue that emerges here is quantum thermodynamics, namely the understanding about how energy can be used and transformed at the quantum level, which is the real ground out of which it can be harnessed at the macroscopic level.

From the standpoint of cosmology and astrophysics, the classical world emerges when the transition from energy to matter takes place, and, later on, from matter to life. High energy or temperatures become cooler, and the classical world begins to have a shape, so to speak. Due to the decrease of the initial high temperatures for the new emerging condensate objects temperature becomes a trouble, and it needs to be cooled. The arrow of time arises (Hands, 2017). Life is a wet, warm and sticky phenomenon amid an extremely cold universe – a most thrilling emergence, indeed.

The measuring problem was originally considered as the interaction between a quantum and a classical system. This however is not true any longer. To-date a measurement can consist of the interaction among quantum systems, and the measuring apparatus can be a quantum system (Luo, 2008). There are no measures free of interaction (Long, *et al*., 2014). As a consequence, the measure is always an interaction that entails an entanglement.

There is no need of a conscious agent for a measure to be possible – no matter the nature of the agent. Once we have attained or gained quantum entanglement the measuring problem in the way in which the Copenhagen debate conceived it, disappears: either the wave function is constantly collapsing or else an escape door to the discontinuity of wave function is to be sought. That is exactly what happens with the second quantum revolution, namely quantum information processing (QIP), along with several other interpretations of quantum mechanics. The conclusion is that the Copenhagen interpretation is not unique and becomes irrelevant to some extent in the framework of the other interpretations.

The permanent process that was called the collapse of the wave function becomes now full of jumps or discrete changes; there happen sudden outbreaks unceasingly.

V. Quantum Information Processing

Quantum information processing (QIP) can be adequately taken as a living phenomenon on its own. Information is processed by other stances, indeed, but it is also created out of nothing, and consists in an everlasting process of transformation, enrichment, complexification. Information allows for low entropy to remain low and makes that high entropy becomes low making thus life possible in the universe. Living beings downgrade entropy as well as high energies into low energies and make thus possible the transformation on non-living matter and energy into living matter and energy – a most crucial transformation. (QIP) can rightly be taken as parallel with homeostasis (Damasio, 2019), which is the exact complement of metabolization. Plainly said, life is a self-organizing phenomenon, namely radically an autopoietic process.

Indeed, the world has not been created by any creator, but it can be said to be its own work, a non-linear, surprising, self-organizing, autopoietic and emerging world, though. Indeed, taking up the world as a quantum information processor firmly sets the ground for self-organization and self-catalytic sets or loops.

A number of consequences follow from the considerations above. Probably the most puzzling one is the fact that the doors to panpsychism are being wide open (Maldonado, 2018b). Pansychism, namely, the assumption that consciousness pervades reality from one extreme to the other, can also be understood as a sort of pantheism; in other words, the idea that life is not just a particular case in the universe. On the contrary, ultimately, the universe itself is alive, a most striking claim when seen from the eyes of tradition in the western world.

The idea can be expressed in computational terms saying that the universe does compute (Lloyd, 2006). Or also, that the information is processed from the abiotic stance on to the biotic one, even though in a variety of ways. Panpsychism, pantheism, biocentrism, or also hylozoism, have never encountered a starring role in the history of science or philosophy. A most compelling consequence, as it happens. Computing, I should like to highlight it, properly means transforming one thing into another, i.e. metabolizing, as it is already said above. Computing should not by any means be reduced to something like "analyzing" (Fuchs & Hodges, 2016).

The world is an information processor radically quantum since the very explanation of what matter does, energy carries out and information is about are quantum behaviors and phenomena. Quantum behaviors ground the very shape, expressions and behaviors of the world at large.

Information – and not any longer just matter or energy – can be viewed as the physical concept that best captures the nature of the world, namely processing, change, and creation. Yet, information does not exist before the processing, and neither after processing. Information exists as and in the moment of the processing. The outcome is adamantly, namely the world, that is nature or the universe, is not just a state, but a process – and unceasing and never ending process.

Living beings and the universe do not just read the environment, if allowed. Besides and even better, they continuously create new information. Information is created in a manifold of ways, thus: as behaviors, signs, networks, actions, interactions, or more information. We are then faced with an increasing complexity, which is the landmark of the world in general. We all live in an increasingly complex universe that creates and transforms information unceasingly. The universe is anew at each moment, once and again (Kauffman, 2016; Kauffman, 2020).

One more puzzling consequence is the recognition that new information corresponds to new surprises. Indeed, the meaning of information is proportional to the randomness and surprise that are entailed. The lower the randomness and surprise, the more predictable information is (Vedral, 2010). Unpredictable information points out straightforwardly to novelty, ingeniosity, and creativity. The universe is the name for the creation and appearance of new information – quantum information processing.

Hereafter, the non-deterministic behavior of the world manifests itself in many aspects. We turn to the next argument.

VI. Biological information

Translated into biological terms, (QIP) can adequately be understood as metabolization i.e. as transforming one thing, say A, into another, say B. Metabolization are processes of energy transformation, storage and release of energy – energy that can be used by other molecules within the same metabolic system (Djordjevic, 2016; McFadden & Al-Khalili, 2016). Usually when a bond is created bringing forth a larger molecule, energy is stored. Now, when the molecule is broken down energy is released. In any case, energy is never lost, for it can be harnessed by another molecule with the same metabolic network. In a mechanical system the efficiency is low. Yet, when the system is a cell, the efficiency is highly efficient. Such efficiency is due to quantum processes. We can call this as quantum efficiency.

In the quantum realm there is no loss of energy, no matter what. Now, the fact that there is no loss of energy can be more adequately stated saying that there is no loss of information. Information transforms itself into other forms of information, and thus, metabolization and life are unceasing ever-lasting processes and dynamics; i.e. complex dynamics.

It can be safely said that cognition is a biological process, and yet, previously to the biological processes we have information processing (Auletta, 2011); in other words, information processing begins at some point long before the emergence of life, but it crosses and constitute living beings. Information does not exist before it is processed, and does not exist after it is processed. Information is the very outcome of its being processed, which highlights the importance of a process-linked mindset. Now, the processing means its change and transformation, which go on from the very stage in which an atom is excited and goes inwards or outwards of its orbit, up to the very enriching, transformation, and change in and by living beings (Maldonado & Gómez-Cruz, 2015).

Given the distinction between classical information and quantum information, it is more than reasonable to assess that information is quantum and that it has been studied thoroughly in a number of biological levels and processes (birds migration, magnetic field of the Earth, the human brain, and many other cases). Quantum effects are now widely recognized at the macroscopic level in living beings (Sanjeevi, 2019; Hobson, 2013).

VII. Conclusions

There are not hyletic (or material) differences among biotic and abiotic stances (Walker *et al*., 2017). The differences can be said to be only qualitative, of degrees or of organization. Reality as a whole is a process of unceasing unfolding and re-configuration. The main title for such an unfolding can be seen as coherence-decoherence-recoherence. Somewhere in the midst of such a process the classical or conventional world emerges – as an idealized limit of the quantum world.

In the hardcore of quantum science there is not one single argument allowing juxtapose the microscopic and the macroscopic dimensions of the world. They are just a difference of time-speed, thus: the macroscopic world is slow whereas the microscopic one is rapid and increasingly vertiginous. As it is well known, the scales of the microscopic world are: mili, micro, nano, pico, femto, atto, and yocto – scales, to-date (Barbour, 1999). Time emerges from microscopic scales but is densified in the macroscopic world as seconds, minutes, hours, days, months, years, centuries, and ultimately, millennia. The crux about linking the macroscopic and the microscopic world is not just a question of masses or volumes, but of timescales. Digging into such a a question is nonetheless the subject of a different paper.

Ultimately the very origin of life consists in processing information, i.e. processing quantum information. The issue that emerges here apparently points to the mathematics of symmetry. This point sets out the horizon for further research and is to be left here aside.

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