A Quantum Coherence-Recoherence-Based Model of Reality

Carlos Eduardo Maldonado

ABSTRACT

This paper discusses a coherence-recoherence-based model of reality and argues that the world and nature can be grasped as positive and negative loops of continuous coherence-decoherence-recoherence behaviors. In so doing, the paper presents a state-of-the-art about recoherence and claims that the world and nature can be taken as an unceasingly process of decoherence-and-recoherence. Non-linearity and non-equilibrium dynamics prevail in nature.

Key Words: Quantum Recoherence, Quantum and Classical World, Nature, Complexity

DOI Number: 10.14704/nq.2018.16.11.1858 **NeuroQuantology 2018; 16(11):44-48**

Introduction

Quantum science is a highly counterintuitive science – something that has produced serious troubles for those used to realism and determinism – the two most important and prevailing philosophies in the history of western thought.

Quantum recoherence has been observed both as a spontaneous event (de Ponte *et al.*, 2010), and experimentally induced (Chin *et al.*, 2013; Xu *et al.*, 2009). The origin of recoherence has apparently two distinct sources. Firstly, D. Deutsch proposes the concept during the Rank Prize Funds Mini-Symposium on Quantum Communication and Cryptography, Broadway, England, in 1993, based on a symmetrisation procedure (for details see BBDEJM: https://www.quantiki.org/wiki/basic-concepts-quantum-computation#Bibliography). On the other side, besides, in 1995 (Anglin *et al.*, 1995) introduce recoherence in the framework of the study of black holes.

In any case, quantum recoherence appears as a complementary stance vis-à-vis coherence, and decoherence. Surprisingly, the bibliography on the subject is not large, and only a number of papers and chapters in books have been devoted to it. In any case, there is no general agreement or consensus as to the interpretation of recoherence. This paper provides the state-of-the-art *en passant*, for it focuses on a different issue, namely after presenting the quandary of coherence-decoherence-recoherence, it aims at providing a model of reality. It will be argued that reality can be grasped as a sort of positive-and-negative loop that continuously re-creates itself, even though not in a linear way.

In any case, it has been demonstrated that the quantum Zeno effect, quantum dynamical decoupling and the strong continuous coupling can effectively suppress decoherence only if the frequency of the measurements or pulses is large enough or if the coupling is sufficiently strong (Xu *et al.*, 2009; Kauffman, 2016). By such suppression, at the same time recoherence is feasible and takes place.

This paper argues that a rather complete view of the world and nature entails the recognition that the classical world recoheres very

Corresponding author: Carlos Eduardo Maldonado
Address: Full Professor, School of Medicine, Universidad El Bosque
e-mail ✉ maldonadocarlos@unbosque.edu.co
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.
Received: 07 August 2018; **Accepted:** 27 September 2018

much as the quantum world decoheres. As it happens the traditional concern is about the relationships between the classical or macroscopic universe and the quantum or microscopic universe. To be sure, however, there are no two universes but only one. The trouble is that the wave function collapses; thus, as traditionally stated, decoherence stands at the hinge between one world and the other. Hence the question remains as to the explanation of how and when the collapse of the wave function gives rise to the classical world. However, this is half of the story, for the question is complemented with as to how recoherence shapes the world. It will be argued that coherence and recoherence happen within the same time lapse. As a consequence, the classical world is a case limit of quantum physics.

The interplay between the quantum and classical worlds

Quantum science – namely, quantum physics, quantum biology, quantum chemistry, quantum-based technologies, and even quantum social science - radically changed the traditional view of the world and nature in many concerns. This story has been told a number of times, and the reasons have been sufficiently provided.

At the heart of quantum systems is the idea of quantum entanglement. A system is entangled when two particles or photons are so intertwined that no one has a state of its own, but the connection between them provides both existence and meaning to both of them. Entanglement, however, has been experimentally developed to three and four bodies – usually subatomic particles (Gilder, 2009). Based upon entanglement, quantum physics has made teleportation possible. It is quantum entanglement that articulates both quantum mechanics and quantum waves.

Now, as it has been traditionally interpreted, the classical world is the outcome of the quantum world, and we only face in the conventional reality the effects of the quantum realm. The Copenhagen interpretation argues that the classical world is the outcome of quantum effects – calling the attention to the measurement problem.

The appearance, hence, is that there are two worlds, one based on quantum behaviors explained by three levels, thus: quantum mechanics, quantum waves, and entanglement. That world is the subject of a number of interpretations –over fourteen- all of which have as common ground the trouble about the interplay or the relation with the classical world. The other world is the classical – that was traditionally the subject of science, philosophy, and culture, as we know it from the past until the emergence of quantum science. The first one is highly counterintuitive, whereas the second is rooted on common sense and human perception (Haven and Khrennikov, 2013).

From a logical standpoint, the classical world is ruled by the principle of third excluded set out originally by Aristotle; that is, it is impossible for one proposition (about the world) to be true and its negation to be also true. Either the proposition is true or the negation is false. Such a principle simply is untenable within the framework of quantum theory – something that was already set clearly out by Th. Young's double-slit experiment.

As it is well known, the core problem is the divide between both worlds. One classical explanation has been the wave function collapse, one more time, a contribution from the Copenhagen interpretation. During the last few decades, with the development of quantum information theory, quantum measurement has been understood in the framework of quantum decoherence theory.

If so, the issue then becomes about the relationship among coherence, decoherence, and recoherence. We now turn to this.

Coherence, decoherence, recoherence: A non-linear dynamic

Two basic but different approaches to decoherence and recoherence appear in the bibliography. On the one side, there is recoherence as the reversal of propagation-induced decoherence in laboratory. In this case, the concern is about recovering lost information. On the other side, focused mainly on quantum biology, coherence has been observed that coexists with energy transport or also with light harvesting. Non-trivial quantum behaviors in living systems have been observed in DNA mutations, photosynthesis, electron transfer in proteins, magnetic sensing (birds navigation), enzyme catalyzed reactions, ranging from femtoseconds to picoseconds, and even nanoseconds (Maldonado and Gómez, 2014). Non-equilibrium processes lead to the spontaneous creation and sustenance of (electronic) coherence.

Decoherence can be safely taken as the interaction of a quantum system with an external environment. The entanglement is therefore broken, and singular and local entities appear on their own.

Correspondingly to the various timescales identified, recent studies have even also identified some range of temperatures where coherent oscillations occur – at 77 K, and 277 K. The recoherence time can also be taken as the time scale of the thermalization process.

In any case, biology, i.e. quantum biology seems to open the door widely for a better understanding of open quantum systems. Put differently, non-equilibrium systems may generate or maintain quantum entanglement.

Now, as it is well known, the quantum world is essentially probabilistic and heavily marked by randomness, whereas the conventional reality is bivalent and solid. Such a view, however, is only apparent, for there is a continuous process of decoherence and recoherence that shapes reality, as it happens.

The interpretations about the decoherence-recoherence behaviors are varied and no consensus can be seen herein. Table No. 1 shows the various positions about it. This table also serves as a state-of-the-art about the subject of this paper. It is a short matrix with a twofold consideration, thus: either recoherence is total or partial or, besides, recoherence is induced in laboratory or spontaneous in nature.

Table 1. Interpretations and Observations about Recoherence

Total Recoherence	Partial Recoherence	Induced recoherence	Spontaneous Recoherence
Refs. (1), (6), (7), (10), (11)	Refs. (2), (3), (4), (8), (9), (13), (14), (16)	Refs. (1), (3), (4), (5), (7), (8), (9), (14), (16)	Refs. (2), (5), (6), (10), (11), (13)

Even though important, a series of technical arguments support each position mentioned in table No. 1. I leave aside those technicalities mainly pertaining the role of the reservoir, and the detector field system; I refer to the bibliography for further details. The focus here lies in depicting a general view of reality thanks to the interplay between decoherence and recoherence.

The distinction and even opposition between the alternatives presented in Table No. 1 are not a hurdle for the aim of this text: reality recoheres and then decoheres, and on and on – creating thus a sort of wave that is defined in terms of degrees of freedom.

Certainly, it appears, the quantum coherence cannot be fully recovered. However, according to some authors (9) (xyz) all of the quantum coherence will recover *in the end, after a much longer relaxation time* (highlighted, C.E.M.). As it has been stated, the quantum Zeno effect with continuous measurements can be used to preserve the coherence of specific states (Kauffman, 2016).

The diagram No. 1 below offers a picture of what a model of reality based on coherence-recoherence would look like.

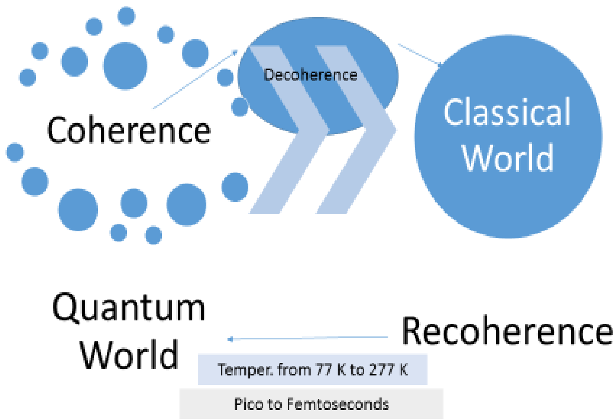

Diagram 1. Coherence and Recoherence with Timescales and Temperatures, Depicting Reality
Source: Own Elaboration

Nature loves to hide, apparently

Reality originates from the quantum realm, i.e. quantum scale. No question about this. Cosmology has already set this out clearly enough. In the conventional wisdom of the quantum research community, the classical world is the outcome of the wave function collapse. There is, as yet, not enough clarity as to why and how the collapse happens, even though a number of good interpretations are being brought to the fore. The classical world, it appears, is a limit case of quantum behaviors and phenomena.

The novelty about recoherence is that it allows for a two-way bridge "departing" so to speak from the classical world, and going to the quantum scale, and on again to the conventional reality, and so forth. Recoherence has been both induced and observed spontaneously in a number of cases. The kernel, though, is that recoherence never offers a 100% identical system as it was the case when coherence happened. Recoherence offers an "attenuated" copy of reality, as it has been said (de Ponte *et al.*, 2010).

In recoherence the entanglement is reversed by (unitary) spatial propagation, and the original state recovered. Moreover, though the reversal of any quantum mechanical process must always be theoretically possible, these findings demonstrate that any reversibility can be observed, even for decoherence phenomena (Bouchard *et al*., 2015).

The discussion remains open as to whether the initial quantum state can be recovered (period), or else, just partially recovered, say by 75% - larger than the classical limit 66.7%. The concepts range from "a certain recovery", to "fully recovered". Further research and reflection will shed better lights in some close future.

In one way or another, the core issue remains the very fact that reality is information, rather than sheer matter (mass) or energy (Vedral, 2010). If so, information is never completely lost, and if the knowledge about it is the very knowledge about the continuous dephasing of reality and re-phasing – as a wave that vanishes and appears once and again but never in the same way (i.e. never exactly in the way it has been grasped once). It seems true, after all: we never step on the same river twice – for it is not the same river, and it is not the same man, as Heraclitus once pointed out.

Recoherence can be understood as the decay of the degree of entanglement or also as the restoration of the degree of quantum coherence – two different ways of stating the issue. The system after decoherence evolves toward equilibrium: the spontaneous recoherence of quantum states (Bouchard *et al*., 2015). Over against the concern about the loss of information (whether in quantum computation, or in black holes) a metaphor was introduced by some authors (Bouchard *et al.*), namely nature does not erase information: it just shuffles it – in the environment.

Now, apparently, it is an asymptotic view of time that allows a full understanding of recoherence. The question regarding the role of time in the coherence-decoherence-recoherence behaviors does not discharge the possibility that the distinction between past and future be contingent.

Conclusions

Quantum mechanics does not provide a comprehensive worldview. Nonetheless, it can be seen as replete with suggestions (Malin, 2001). A coherence-recoherence-based model of reality is reasonable and tenable interpretation.

The understanding of reality is an essentially incomplete enterprise, for it depends on the advances of research and reflection. Each epoch tries to fulfill a more complete picture of nature than the previous ones. The task of achieving a complete view of the world, however, remains open-ended. This should, though, not be taken as a relativistic or eclectic take. Each generation re-writes the story of the world, very much as science, research, and reflection depict an always more complete understanding and explanation of reality as the story unfolds. Culture is shaped in such interplay.

Conventional reality is the outcome of decoherent quantum behaviors. However, classical reality does recohere. The discussion remains whether it does partially or fully – a question that is to be better clarified in some future to come. Nonlinear dynamics infringes the interplay between the quantum world and the classical one. Definitely, non-equilibrium states seem to be the landmark of the world and reality.

References

Anglin JR, Laflamme R, Zurek WH, Paz JP. Decoherence and recoherence in an analogue of the black hole information paradox. Physical Review D 1995; 52(4): 2221-31

Bacciagaluppi G. Probability, arrow of time and decoherence. Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics 2007; 38(2): 439-56.

Barenco A, Berthiaume A, Deutsch D, Ekert A, Jozsa R, Macchiavello C. Stabilization of quantum computations by symmetrization. SIAM Journal on Computing 1997; 26(5): 1541-57.

Bouchard F, Harris J, Mand H, Bent N, Santamato E, Boyd RW, Karimi E. Observation of quantum recoherence of photons by spatial propagation. Scientific Reports 2015; 5: 15330.

Chin AW, Prior J, Rosenbach R, Caycedo-Soler F, Huelga SF, Plenio MB. The role of non-equilibrium vibrational structures in electronic coherence and recoherence in pigment–protein complexes. Nature Physics 2013; 9(2): 113-18.

de Ponte MA, Cacheffo A, Villas-Bôas CJ, Mizrahi SS, Moussa MH. Spontaneous recoherence of quantum states after decoherence. The European Physical Journal D 2010; 59(3): 487-96.

Gilder L. The age of entanglement. when quantum physics was reborn. New York: Vintage Books, 2009.

Haven E, Khrennikov A. Quantum Social Science. Cambridge: Cambridge University Press, 2013.

Kauffman S. Humanity in a Creative Universe. Oxford: Oxford University Press, 2016.

Lin SY, Hu BL. Entanglement, recoherence and information flow in an accelerated detector—quantum field system: implications for the black hole information issue. Classical and Quantum Gravity 2008; 25(15): 154004.

Maldonado CE, Gómez-Cruz NA. Synchronicity among biological and computational levels of an organism: quantum biology and complexity. Procedia Computer Science 2014; 36: 177-84.

Malin S. Nature loves to hide. Quantum Physics and the nature of reality, a western perspective. Oxford: Oxford University Press, 2001.

Manrique PD, Rodríguez F, Quiroga L, Johnson NF. Nonequilibrium quantum systems: Divergence between global and local descriptions. Advances in Condensed Matter Physics 2015; 2015(615727): 1-7.

Tempelaar R, Halpin A, Johnson PJ, Cai J, Murphy RS, Knoester J, Miller RD, Jansen TL. Laser-limited signatures of quantum coherence. The Journal of Physical Chemistry A 2015; 120(19): 3042-48.

Vedral V. Decoding Reality. The Universe as Quantum Information. Oxford: Oxford University Press, 2010.

Xu JS, Li CF, Gong M, Zou XB, Chen L, Chen G, Tang JS, Guo GC. Measurement-induced quantum coherence recovery. New Journal of Physics 2009; 11(4): 043010.

Web pages:

http://www.nature.com/nphys/archive/subject_nphys_s17_2013.html

https://www.quantiki.org/wiki/basic-concepts-quantum-computation.

*e*ISSN 1303-5150