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Vision of Oneness

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Preface

The Keys and the Door: For a Unitary Vision of the Physicists' Conception of Nature

This volume comes out from an informal discussion between friends and colleagues on the answer: *what topic do you think as fundamental in theoretical physics nowadays?* Obviously we received different answers according to the disposition and the different research areas, and answers in superposition state too.
And yet some attractors have emerged pointing out the keys for the Physicists conception of Nature, all of them converging towards a group of strongly interconnected problems.
Let's see them one by one:

- The concept of particle identity in QM and QFT;
- The relationship between QM and QFT, in particular the non –local aspects in Field Theory and the problem of non-perturbative solutions;
- The local/global problem in the relationship between particle physics and cosmology;
- The role of Renormalization group in describing the meso and macroscopic emergent behaviour;
- The possible extension of Poincarè symmetry group and Quantum cosmology;
- Higgs "mechanism" and the origin of mass.

Such topics show the centrality and extraordinary fecundity of Quantum Field Theory in describing the "thin" level of the World, and the "seminal" features of the mesoscopic and macroscopic emergence processes. On the other hand, they also show a strange "splitting up": QM is frozen to 1927, with all its interpretative problems, while QFT, hastily developed under the urge of subnuclear research, is regarded more as a "practical" tool rather than for its enormous theoretical and cultural potentialities. Till now QFT has not been allowed to be considered as a global vision of the World like it happened for relativity or Quantum mechanics. Such problem also affected formal language, when we speak of "first" and "second" quantization and, in general, the concept of "identity" of a physical object. The first step to take in order to bridge such conceptual gap is to bring out non-locality in QFT.
We know that an "everything theory" cannot exist without a history of the matter and energy. All that mixes cosmology and particle physics in a structural

way, and once again opens the problem of the relationships between local and global. It is impossible defining univocally a topology of the Universe both from GR and the different approaches to quantum cosmology. It is thus reasonable to ask if a global approach able to constraint QFT on cosmic scale is possible. And finally the Higgs mechanism. We call it so just to stress the phenomenological aspects. And yet the whole structure of Gauge theories with their about 30 free parameters depend on such mechanism. "Pathetic" Joao Magueijo writes in his magnificent Majorana biography "A Brilliant Darkness". Higgs boson inherits answers already active in Newton physics; but just like the absolute space-time of the English genius, also Higgs mechanism is probably the tip of the iceberg in a sea of not yet explored ranges from which to obtain what till now we hypnotise heuristically, such as Quantum gravity. Thus, once again, the complex and many-sided centrality of the Quantum Field Theory.
The dialogical style will make the reader find a lot of food for thought in these papers. We are convinced that they will show a "mean lifetime" quite longer with respect to the very quick times of theoretical physics nowadays.

I thank all the authors who enthusiastically joined to this project with their criticism and observations, so helping us to turn a via-mail modern Socratic dialogue into a book. The "middle-way" job between the ideas and the book would be impossible without the help of my friend Prof. Ammar Sakaji and the Editorial Board of EJTP.

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Visions Of Oneness
Space-Time Geometry and Quantum Physics

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Abstract

Over a span of few years, Theoretical Physics has widened its horizons. It has outlined new perspectives on classical and quantum systems, discussed the meaning of matter at Planck's wall and the role of Quantum Information. Nevertheless, we seem that such rapid colonization of new territories runs the risk to forget some foundational problems which the inner unity of Physics knowledge depend on. It is here taken into consideration the difficult relationship between geometry and dynamics established by the current epistemological arrangement of Quantum Mechanics (QM) and General Relativity (GR), as well as its impact on cosmological and informational questions.

1 Introduction

2 Classic and Quantum, Global and Local

General Relativity (GR) may be considered the highest achievement of classical Physics, a formidable synthesis of the notions of space and time as a theatre of coordinates, of the description of the field of gravity, and of the equations of motion. Moreover, it has furnished the modern conceptual approach to studying the large-scale structure of space-time and the processes that take place in hyperdense matter (Hawking & Ellis, 1975). The essential form of the tensorial equations of Einsteinian gravity can be written as:

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$$G_{\alpha,\beta} = 8\pi T_{\alpha,\beta} \quad (1)$$

With G being the Einstein tensor and T the stress-energy tensor.

The peculiarity of eqs (1) leads to an effect of non-linearity – gravity gravitates! – which makes it very difficult to apply the traditional "local" processes of quantization to Einstein's space-time curve. Moreover, a much more radical effect of non-locality is at the center of Quantum Mechanics (QM), the theory that threw many of the certainties of the classical image about the World into crisis and that provided the tools for the investigation of Particle Physics and condensed matter (see for ex. Hughes, 1992). In the EPR-Bell phenomena, in fact, objects separated in space and time show space-like correlations that are inexplicable in classical terms, and that characterize the quantum statistics from which the most interesting properties of the structure of matter derive. Since the non-local correlations do not transport energy, they do not violate Relativity but nonetheless remain outside the bounds of the classical picture of the world. This situation goes under the name of "pacific coexistence" between Relativity and Quantum Physics (Shimony). The problem of reconciling the classical image of Einstein's space-time and quantum non-locality is that of constructing a dynamic model of space-time in which the quantum processes also find a place, or that of developing a quantum geometrodynamics. This line clearly takes its inspiration from the philosophical and geometrical approach of General Relativity.

3 Quantum Potential and Active Information

The most recent attempts at a geometric approach to quantum processes are owed to Wheeler (Wheeler,1990) based on Weyl's geometry, and then to Wood and Papini (Wood & Papini, 1995) using a modification of the Weyl-Dirac theory. These theories have suggested that QM could be incorporated as a corresponding "deformation" of space-time. More recently Sidharth (Sidharth, 2002) has proposed a geometric interpretation of QM on the basis of non-commutative and non-integrable geometries. Nonetheless, all of these attempts seem to elude the epistemological core of QM Standard Interpretation. As Heisenberg observed at the dawning of quantum theory, Copenhagen's interpretation is radically a-causal, and quantum processes cannot therefore be retraced to a space-time vision. This profoundly limits every attempt to understand Quantum Physics within the traditional Einsteinian space-time arena, however “extended” it may be.

In recent years interest in D. Bohm’s realist interpretation of QM has grown. Here let’s recall that Bohm’s interpretation reproduces all the results of QM without any ambiguity regarding the role of the observer and allows an easy extension to the Field Theory formalism (Bohm & Hiley, 1995; Durr et al. 2004; Nikolic, 2007). In this interpretation non-locality is not an “unexpected visitor,” as in the standard interpretation, but derives directly from quantum potential Q, a necessary term for the conservation of energy in Schrödinger’s equation:

$$Q = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R} \tag{2}$$

The form of potential (2) reveals some interesting properties: it depends on the amplitude R of the wave function and its action is like-space, exactly that called for in the EPR-Bell processes. Quantum potential contains global information of physical processes, defined as “active information” by Bohm, or the contextual information of the system under observation and its environment, information that is not “external” to space-time but should rather be considered a type of geometric information “woven” into space-time itself. It is, further, a dynamic entity. Paraphrasing J.A.Wheeler’s famous saying about GR, we can say that the evolution of the state of a quantum system changes active global information, and this in turn influences the state of the quantum system, redesigning the non-local geometry of the universe.

4 Geometries of Non-Locality

The geometry subtending quantum potential has been explored by various authors (see Carroll, 2006). One very interesting result is that of Shojai & Shojai (Shojai & Shojai, 2004), who studied the behavior of particles at spin 0 in a space-time curve, demonstrating that quantum potential contributes to the curvature that is added to the classic one and that reveals profound and unexpected connections between gravity and quantum phenomena. All of this is expressed by a metric conformal such as:

$$\tilde{g}_{\mu\nu} = \frac{M^2}{m^2} g_{\mu\nu}, \tag{3}$$

Where the expression for mass is: $M^2 = m^2 \exp Q$, with Q as the quantum potential.

This is a perfect image of quantum geometrodynamics that combines the gravitational and quantum aspects of matter, at least in terms of the level of macroscopic description of physical processes. In reality, once again, things are not so simple. Non-locality remains a phenomenon that rests uncomfortably with a "mechanical" vision of the universe, and it is not by chance that Bohm referred to QM and its interpretation as *quantum non-mechanics*, to reiterate that they could not be in any way understood as a return to the classical, but rather as the partial recovery of a "fuzzy realism." Taking up the ideas of Heisenberg and G. Chew, the Birbeck group (Hiley & Monk, 1998; Brown, 2002) demonstrated that the entire symplectic non-commutative geometry identified by quantum potential can be derived from Weyl's discrete algebra. In more directly physical terms, this means that there are two epistemological interventions to do towards Eddington's quantum sheet of geometrodynamics:

a) it is taken as primary and non-local, and therefore it is necessary to introduce additional hypotheses about its deep structure, or

b) the space-time manifold must be considered an emergence of the deepest processes situated at the level of quantum gravity. We have to remember here, at least, the original proposal of Sacharov of deducing the gravity as "metric elasticity" of quantum vacuum (Sacharov , 1968; Visser, 2002) and more recent one by Consoli on ultra-weak excitations in a condensed as a model for the gravity and Higgs mechanism (Consoli, 2009).

Using the now famous image of complementarity in D. Bohm's version, we can say that the entire connected and local structure of both space-time and the Shannon-Turing information we use to compute the events in it is the explicit order of a hidden, implicit order, which acts as a "fabric of reality" at a sub-quantum level, fundamentally discrete and non-commutative (Licata, 2008).

5 The Quantum Foam of Implicit Order

The idea of a structure of relations subtending the observable forms of matter, energy and space-time was defined by J. A. Wheeler as "quantum foam," with the precise intent of evoking the erosion of traditional notions toward the Planck scale typical of quantum gravity. Despite the ongoing lack of a strong unifying principle, the various versions of String theory have had a certain success in overcoming some of the impasses of Particle Physics, and it has been suggested that space-time manifold is the result of the interaction between pbranes, and that the acquisition of the masses in Higg's Ocean finds its natural explanation in the mechanisms of uncurling and compactification (see Riotto, 2000; Sundrum & Randall, 1999). In reality, the majority of the versions of strings works, just like Quantum Field Theory, which is its closest relative, with a flat Minkowski space-time, while a correct, authentically relativistic (in the sense of GR) theory should be independent from the background, or not presuppose any metric signature. Various theories have these requirements. One is Penrose's Twistor theory (Huggett & Todd, 1994). To use Penrose's own words, "a twistor is an object similar to the two-faced Janus, unitary but with one face turned toward QM and the other toward GR." More precisely a twistor is and object without mass and charge and with spin, invariant for the conformal group, so as to find again the light-cone of Minkowski's space-time. The famous representation by Robinson is based on a stereographic projection of Clifford's algebra that defines the structure of twistors and allows the essential characteristics of the dynamic non-local "fragments" of space-time to be intuitively taken from it. Another very elegant theory that has the right relativistic requirements is Rovelli and Smolin's "Loop quantum gravity" (Rovelli, 2007). The loops are closed field lines that do not depend on the coordinate system and therefore provide the basis for a relational description of space-time in the spirit of Leibniz. The theory presupposes a very particular space-time structure at the Planck scale: the operators associated with area and volume in fact have a discrete spectrum, giving birth to a complex and fascinating graph structure and thus furnishing a discrete combinatorial view of Physics.

We have to mention also some interesting attempts to model a quantized space-time as a crystal lattice (Kleinert et al. 2010) and the Preparata Plank Lattice where the quantum foam structure itself acts as the Higgs mechanism and allows the emerging of a spectrum of masses selected by the lattice (Preparata & Xue, 1994).

6 A Radical Criticism to "Everything Theories"

Holger Nielsen has directed a radical criticism at Everything Theories in his Random Dynamics (Nielsen, 1989; Gaeta, 1993). The key idea is quite simple, in his own words: "Could the fundamental physical "laws" be enormously complicated, but our well-know laws come out in a limit?". Nielsen observed that any directly verifiable statement about physical world – from experimental view-point - is structurally connected to Yang-Mills Theories and Gauge Symmetries. Consequently, what we can say about the "fundamental constituents" of the world at an actually inaccessible range is they are compatible with some very general mathematical structures. The same essential lesson seems to come out of Garret Lisi's "Exceptionally Simple" Theory of Everything (Garret Lisi, 2007). In the frame of a radical emergentist approach, Robert Laughlin starts from the instability of Yang-Mills equations to criticize any fundamentalist nomological attitude: *if a strategy to solve such equations is adopted, it should be better not to speak of a Theory of Everything, but just of patenting a technology) to calculate them.*

A reasonable and provisional conclusion deriving from such reflections is that we should not to think the world structure in terms of fundamental objects, but rather as informational patterns acting as matrices generating the physical processes.

7 Who Needs QM Interpretations?

We could now ask whether it is not the case to examine the QM foundational problems from another viewpoint. It is not from the past that a modern conductor reaches Mozart – however good as a philologist he may be - , but from the historical understanding of his legacy. Analogously we should maybe analyze QM from its ripest fruit: the Quantum Field Theory (QFT) that is indeed considered the nucleus of the early "Theory of Everything" (Srednicki, 2007). Most of the interpretative debate is still centered on 1927 Schrödinger equation that is surely a very useful formulation but loaded with a classical burden responsible for the so-called wave-particle dualism. Recently, M. Cini (Cini, 2003) proposed to come back to the P. Jordan original approach, so deriving all the QM characteristics from Planck's field quantization and the consequent uncertainty principle. The traditional statistical properties thus derive from the Wigner-Feynman pseudo-probabilities without any reference to "first quantization" and its tough conceptual problems (see Feynman, 1987).

G. Preparata (1942 – 2000) has followed the same line by his "realistic interpretation" completely based on QFT (Preparata, 2002).It is shown that QM is a discrete approximation of QFT for dilute systems, but has extremely significant effects on the instability of quantum vacuum for the emerging of condensed states of coherence.

The above-mentioned two simple cases show not only that QM gets rid of any "Alice-in-wonderland" features if we look at it from the superior viewpoint of

QFT, but also that it has a greatly explicative potential. The old wave/particle dualism simply becomes the consequence of continuity/discontinuity aspects between the field modes, non-locally "intertwined" and obviously subjected to superposition and interference phenomena. The detection of a quantum object ("collapse") is nothing but the "local" click of a quantum within an apparatus according to Planck. Let's remember that it is due to the heuristic images of Einstein and Thompson if the idea to consider a quantum as a localized particle became was established as tradition.

In this way QM, far from being a baffling puzzle, is the unsteady historical and conceptual passage unifying the early Quantum Theory to the strongly powerful QFT. So the fundamental questions shift to cosmological level, on the origin, the boundary conditions and the evolution of the quantum informational fabric of the Universe.

8 Quantum Information and Cosmology

Any theory of interactions is not complete without a general scenario where to set it. The importance of cosmology for the physics of elementary particles has become evident with the developing of Gauge theories, where the unification project strictly depends on the ranges of the temperatures of the Universe history.

Recently, one of the fundamental goals for theoretical physicists has been to merge Einstein cosmology and Quantum Physics into a single frame (Hartle & Hawking, 1983; Vilekin, 1984). Different attempts *ad hoc* have shed a new light on the De Sitter model and the cosmological constant role (Einstein biggest mistake!). Although a general agreement has not been reached yet, the old Big Bang conception as a "thermodynamic balloon" seems to be irreparably compromised by now. We just quote here the Author and L. Chiatti work on Archaic Universe where the starting point is the quantum improvement of Fantappiè-Arcidiacono group approach based on DeSitter Universe. The elimination of the initial singularity and the adoption of DeSitter 5 hypersphere as the quantum vacuum's geometrical shape make possible a very concise description of the boundary conditions necessary for the evolution of the observed physical universe. Such "pre-space" we define as "archaic" has not to be considered as antecedent to "Big-Bang", but rather as a spatial and a-temporal substrate of the usual space-time metric containing *in nuce* all the evolutionary possibilities that the General Projective Relativity (GPR) equations indicate. After eliminating any geometrical singularity with Euclidean substrate, the description of the Universe evolution can be seen as an extended nucleation from a coherent state with very high non-local information to an observable mix of matter-energy. The passage from the archaic to the evolutionary state is defined by a sort of "holomovement" (Bohm, 1995) due to a Wick rotation which characterizes the appearence of the dynamics and time arrow starting from the general constraints on the pre-dynamic, archaic condition. It is remarkable that the structure itself of the theory simplifies any speculation about dark matter and inflation, and gives a purely geometrical description to the cosmological constant (Licata, 2006; Licata & Chiatti, 2009, 2010).

So, Archaic Quantum Information fixes the broadest "matrix of reality" compatible with experimental observations, requires a derivation of the usual field theory from an algebraic and topological theory and preludes to an ambitious project of 5-dimensonal unification between space and matter.

Such scenario is not incompatible with a recent suggestion by A. Valentini (2002; 2009). The quantum phase we observe now, characterized by the Born rule $\rho = |\psi|^2$, could be the fossil of a previous very high correlation phase where non-locality could has allowed the hypercomputational processes and played a decisive role in the formation of "frozen" structures nearly to the threshold of the physics of living systems. Besides, it is patent by now that as soon as we remain within the "Turing Cage" the morphogenic possibilities of quantum information will not be fully comprehended (Licata, 2008; 2010; Blume-Kohout & Zurek, 2006; Davies et al., 2009).

9 Beyond: Heraclitean and Parmenedian Aspects of Contemporary Physics

A rapid review of the relationships between the explicate order of space-time manifold and the theories that investigate the fine structure of quantum foam invites interesting reflection, both epistemological and cognitive. The entire history of Physics may be considered a progressive refinement of the models of space-time, from Newton's absolute one to non-Euclidean and conformal geometries of the various classical and quantum geometrodynamics. All of these theories are characterized by the notion of "process," understood as the evolution of a set of observables in space and in time. Quantum Physics has created an irreversible leak in the self-cohesion of such kind of view of the world, and the exploration of quantum gravity seems to propose the introduction of new geometric and algebraic structures that identify the weaving of relationships in the implicit order from which the very concepts of space, time, and evolution emerge. A unitary vision of the relationship between GR and QM will require, therefore, new conceptual terms to describe the deep complementarity between the Heraclitean and Parmenedian aspects of the physical world.

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