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Endophysics, the fabric of time and the self-evolving universe

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Abstract

It is argued that a new understanding of time arises through a paradigm shift in physics, particularly in the areas of astrophysics and cosmology, viz. the change from the exo- to endo-physical perspective. This claim is illustrated/substantiated by discussion of some of the currently most pressing issues of theoretical physics related to the evolution of the universe: the nature of time and the interpretation of quantum mechanics. It is demonstrated that the endo-physical (or first-person) view is a fertile ground for getting important insights into the structure of the perceived/subjective aspect of time as well as for inferring a possible connection of the latter with its physical counterpart. Concerning quantum mechanics, the endo-physical perspective sheds fresh light on its interpretation and the measurement problem. This opens up a window for novel cosmological scenarios, such as a description of the universe as a self-evolving quantum automaton.

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1. Introduction

Our view of the world is generally made up of a set of *opinions* about various aspects of our perceived reality. In prehistoric times, much more so than for the purely intellectual reasons typical nowadays, these mental constructs were necessary as a basic instrument of survival. In order to hunt effectively, early humans would have needed to develop mental elaborations of the information they had acquired about the habits of animals, such as knowledge of the distribution of paths in a forest, or of the caves in the mountains where shelter from those animals could be found. These elaborations, linked to knowledge about light and climatic variations, are examples of *views* continuously updated upon the acquisition of new knowledge, resulting in the successful acquisition of food and the continued assurance of family security.

Since ancient times, man has spent much time and effort analysing and classifying all the causal relations between observed events. This has been necessary in order for him to connect his separate opinions of single aspects of reality into a more or less integrated interpretational scenario, allowing him to have as complete and as self-consistent a global view of his environment as possible. We find it useful to use the term *mental model of reality* (MMoR) for each of these integrated mental constructs [1].

With the emergence and development of human societies and language, individual MMoRs incorporated more and more new knowledge. They included all aspects of social co-existence, such as laws, traditions and communal activities, etc., always incorporating new relations between known events. The common feeling known today as *intersubjectivity* thus acquired a firmer footing, which created a basis for the construction of a consensus (or objective) global view of the world, valid within a given society.

There are two, strictly interconnected, basic characteristics of each individual MMoR: its constant updating with new data in order to follow the continuous and irreversible variations of the environment, and the interaction with other individuals and with the rest of nature. It would be difficult to discuss any *view* without any reference to the observed variations of the environment, from which new information is acquired. These two phenomenological items, *change* and *interaction*, are at the frontiers of our present knowledge of the world and are particularly important in the current wide-ranging use of highly advanced scientific methods. In spite of this fact, these two characteristics have always appeared to have little relevance in the development of physics. There are two reasons for this. First, the unceasing and irreversible variation of all observed phenomena (the representation of which we call *time*) is still considered an illusion by most physicists, principally because conventional theories do not uniquely identify the enigmatic "*moment of the now*". Second, physics itself seems to assume almost dogmatically the possibility of man reaching a complete detachment from his environment and therefore being able to analyse it without any mutual interaction with it. As a consequence of such an *exo-physical* attitude, the results of scientific investigations have often been raised to the rank of absolute truths, resulting in a picture of the universe as a unique block, visible in its entirety from its remote past to its far future. In line with this view, current physics is deeply involved in a hectic search for a theory of everything (TOE), which would be able to define a complete and exhaustive set of relations among all phenomena, both known and unknown and in the past and in the future.

It is the opinion of many distinguished scientists and philosophers that both the arrow of time and the interaction of man with nature must find a proper place in modern science. In fact, ever since the intellectual revolution induced by the study of systems far from equilibrium, initiated by Ilya Prigogine, many international groups have been working hard to find new paradigms for science, a particular aim being to enrich the conventional linear and reversible time of physics with the observed irreversible arrow of time. We too believe in the necessity of investing more time and effort in looking for new paradigms, also with the aim of overcoming the stalemate situation in which physics appears to have been in for such a long time. Given this line of thought, we propose reconsidering the irreversibility of time and the function of interaction between all elements in nature. This requires us to consider a change in paradigm, such that the exo-physical attitude is replaced with the *endo-physical* view. In this picture, change and interaction are essential and intrinsic components of a universe that, on the one hand, includes human beings looking for the laws of nature, and on the other hand, behaves like a self-referential quantum automaton evolving in an unpredictable way through a sequence of self-determined stages governed by the laws of quantum mechanics [2-4].

Our proposal, besides being a consequence of the above considerations, is based on the results of the research of one of us [5,6], where for the first time the arrow of time (until now considered in physics as only a subjective feeling not worthy of scientific attention) is semi-quantitatively described by an algebraic-geometrical model (a language accepted by science), and is therefore objectified. In light of these findings, and within the framework of the endo-physical approach, the supposed illusiveness of change and time is itself ruled out. It is our belief that a general theoretical scenario (but not a theory of everything) can be built within the constraints of the approach taken here, with the final aim of linking the behaviour of both inert matter and living systems interacting with each other.

2. Exo- and endo-physical ways of thinking

The term *exo-physics* refers to the claim that observers may explore the world by looking at it as if they were outside it. In this conceptual schema, the human observer is assumed to achieve such a level of abstraction that all mutual interactions between him and the rest of the world can be neglected. In principle, the classical exo-physical observer could reach the limits of a-temporality, with a simultaneous perception of all events in both the past and the future of the entire universe, together with all their connections. These connections would be described by a unique theory of everything (TOE), valid always and everywhere in the universe, encompassing all the laws of nature already discovered together with those still to be discovered.

In contrast to exo-physics, the term *endo-physics* has been coined [7] in order to convey the concept of an investigation of the world from the *inside*, which is the actual situation of man with respect to nature. The two concepts, viz., exo- and endo-physics, have been extensively discussed and elaborated on by a number of authors and a fairly comprehensive treatment of the topic is given in [8], which also contains an exhaustive bibliography.

Exo-physics has been the adopted paradigm of all sciences since the very beginning of man's history. The ability of human beings to conceptualise and classify every aspect of perceived reality has always been assumed to be a reasonable sign that we can, in principle, achieve complete abstraction and construct with our imagination any sort of theory, capable of explaining and predicting all natural phenomena. Laplacian determinism and the search for TOE can be considered to be logical consequences of the exo-physical view.

This way of thinking has produced great achievements in our knowledge, reaching a climax during the last few centuries and, until the advent of quantum mechanics, there appeared nothing to complain about it. The exo-physical attitude has been of paramount importance for the development of science because it has allowed us construct amazingly advanced technologies supported by detailed theories about the behaviour of inert matter. For a number of decades, however, theoretical physics has found itself in a serious stalemate, with a lack of significant results in the effort to unify fundamental laws, possibly because the basic limits of applicability of the present approach have already been reached. We believe that the claim to find a theory of everything able to predict the future is inconsistent, because it involves the subject (man) of the prediction itself and ignores his full interaction with all the rest of the nature. Due, in fact, to the unavoidable man-matter interaction, there cannot exist a unique theory valid always and everywhere but all single theories can only find a reasonable application within the limits of interaction between the theorist and the object of his investigation. Typical extreme examples are, on the one hand, the classical gravitational laws describing with very high precision the movement of celestial bodies (where interaction with observers is negligible), and, on the other hand, the indeterminate quantum description of the movement of electrons around the nucleus (where the scale of the large mutual interactions would rule out observation of trajectories even on a classical level).

The exo-physical point of view has undergone strong criticism since the times of Immanuel Kant who, in his *Critique of Pure Reason*, stated that "the cosmic viewpoint (*sub specie eternitas*) had to be reduced to a human viewpoint (*sub specie homini*)." In 1982 Karl Popper, in his *The Open Universe: An Argument for Indeterminism*, wrote that "the Laplacian daemon must predict the system from within the system itself not from without it since no predictor can predict the results of his own predictions, based on the notion of information and velocity of information. The scientist cannot be considered any longer a disembodied spirit outside the world." More recently, George Kampis [9] observed that a "detached viewpoint provides a better and more global view but is in contrast with the man's role as an observer of a world with which he interacts heavily. There is the danger that, beyond certain limits, scientific theories be meaningless from a human viewpoint."

The advent of quantum theory introduced into physics an intrinsic irreversibility and an unavoidable interaction between observers and the objects of their observation. The collapse of the wave function as the result of a measurement and the Heisenberg uncertainty principle could at first sight be read as supporting an endo-physical position, but the Copenhagen interpretation undermines this. By considering man's intrusion as a voluntary intervention on the unitary evolution of the rest of the universe, this interpretation actually reinforces the exo-physical detachment of man from nature, giving him a role in the determination of the evolution of the universe with the freedom to choose observations and measurements. This results in the paradoxical situation where man's free will is inconsistently mixed up with an all-pervading search for a deterministic TOE.

A possible solution to the paradox could come from Hugh Everett's many-worlds paradigm [10], which introduced the concept of the state of the universe evolving into a superposition of many physical states, corresponding to different, simultaneously existing mental states (in different simultaneously existing universes or branches). Due to decoherence, caused by the interactions of the observed system with the environment, we would be aware of only one of these states. The other states, hidden to our awareness, would be accessed only in other concurring universes. Such a hypothesis could reconcile, perhaps beyond the intentions of its inventor, exo- with endo-physics. The exo-physical unitarity of the evolution of the universe would be maintained, but on the endo-physical level of the different branches, there would be a probabilistic evolution of the universe, closely related to the continuous interaction between its parts, independently of the will of any observers.

The suggestion that the universe splits into three parts (subject, object and environment) made by Tegmark and Wheeler [11] also goes in this direction, despite their insistence in maintaining the search for a TOE, which is typical of the exo-physical approach. Studies on the physics of the brain and the anticipated construction of quantum computers may yet permit a test of the validity and the interpretation of Everett's paradigm.

3. Subjective and objective *views*

In the following discussion we will try to follow an endo-physical approach, based on the evidence that no theorist is alone in the universe. If we want to get a deeper understanding of the structure of the universe, we simply cannot avoid considering our mutual interaction with other individuals and with the rest of the environment. This is clearly a much more difficult approach than the exo-physical one, and new investigation and communication techniques will certainly be needed.

To our senses, the world appears as a collection of structures, incessantly and definitely moving or changing in shape and in their other physical properties. In our imagination, they correspond to separate objects with their own space localization and properties, mutually exchanging matter and information, their unceasing and irreversible changes being seemingly subject to laws governing their behaviour. Each of us is directly involved in this continuous interaction, which motivates us to invest great efforts looking for the rules that appear to govern these observed interactions. Little by little, we create within our space of consciousness a reasonable overall representation of the world, an MMoR, where all our knowledge is holistically linked on the basis of the countless relationships discovered between the known phenomena. Such a picture is usually built by combining knowledge obtained from everyday observations into a general framework comprising many other data and connections assumed to be true (by unconscious intuition or even by ideological, political or religious firm beliefs) and regarded as necessary for a complete and satisfactory overall view.

Systematic updating of MMoR's is generally done by filling in the gaps in knowledge by means of observations and experiments. Moreover, all individual MMoR's are continuously subject to reciprocal confrontations within human societies. This induces modifications by the addition of any new relationships discovered, including not only those derived from direct observation but also those coming from other individuals who, in turn, communicate links with third party MMoR's organically included in their own MMoR's. The strategy that we choose to fill in the gaps in our knowledge is not uniquely definable, however, because it depends on the personal needs of the individual, which are different for different individuals and may be different even for the same individual in different physical and psychical situations. It is therefore essential to keep in mind that what and how we ask and observe, and which indications we take into account from other people for inclusion into our own MMoR's, depends on many parameters, including our previous knowledge and beliefs. Due to this enormous variety of affecting data, all single MMoR's will exhibit both individual instabilities and large differences between each other, as regards their usefulness in satisfying the needs of the individual at any time [12].

Newly acquired knowledge, unfortunately, is not always compatible with the models we have already formulated, generating a need to eliminate any contradictions which may have arisen. New observations and inquiries may provide the desired answers, but at the cost of modifying, sometimes drastically, our already established models. In the long run, this process results in a reduction to a minimum of our *a priori* beliefs, which are those common to the whole of a society, and to a consensus representation useful for controlling nature.

Numerous examples of this process can be found. For instance, in physics, the only way Planck found of explaining blackbody radiation was to abandon the established way of thinking and introduce the concept of quanta, which profoundly modified our classical picture of nature. From then on, the development of quantum mechanics was based on concepts and methods already known: De Broglie and (discrete frequencies of) waves, Max Born and the concept of probability, Heisenberg and matrices, etc. This is the process by which individual MMoR's evolve toward a model of reality that has a common part accepted by the majority of the members of the society concerned. This common part, in turn, affects individual MMoR's in a loop of increasing knowledge, whereby the objective model of reality becomes always more precise in collectively representing the world's behaviour. We shall call this collective representation the *common view* [12]. It entails all the current aspects of our picture of the world, including politics, morality, aesthetics, religion, science, etc. It is evident that there is no unique common view, neither in different societies nor within each discipline. In physics, for example, the description of nature is currently done by the use of many different theories, each valid within certain application limits. This is unavoidable due to the inherent endo-physical nature of the process of development of knowledge.

Together with the common view, the eventual expression of discourse within a society results in an agreed investigation methodology and an evolving communication language, made up of conscious and unconscious rules, aimed at bringing individual views under one roof. Of course, in order to facilitate the adaptability of the common view to those of the individual, the necessary schematisations implicit in any means of communication definitely limit the number and the quality of the details which can be involved. This lack of precision may add to the individual instabilities and inter-individual differences discussed above, thus requiring the continuous updating of the intercommunication process by the addition of new, commonly accepted rules. The formalised complete set of such rules can be seen as a rational aspect of the intercommunication between that society's members.

Historically, at certain stages of development, the continuous updating of rational language and methodology gave rise first to mathematics and then to science. Like any product of human intelligence, however, science and mathematics have undergone continuous evolution and, from time to time, when the necessity arose to perform deeper investigations or to express more complex laws, new scientific disciplines were established and new and more abstract mathematical tools were invented. New mathematical concepts and structures were often simple logical extensions of the old ones, based on the same main axioms (differential calculus, manifolds, tensors, non-commutative geometries, etc., to mention a few). In some cases, however, completely new principles were invoked (e.g., the origin of non-Euclidean geometries). In each case, however, the final goal has always been the need to describe in a precise, agreed quantitative way the phenomena under investigation.

Scientific theories, communicated using mathematics in addition to words, tables and diagrams, are examples of common views agreed within the scientific community, although each scientist (in the light of the individual differences discussed above) may have more or less different interpretations, almost always supported by some *a priori* beliefs and assumptions, generally different from one scientist to the next. It is interesting to note here that for many scientists, mathematics is seen, coherently with the exo-physical approach, as an absolute entity existing independently of us, whose hidden aspects are little by little discovered by the curiosity of man.

Within the endo-physical approach, such a view is meaningless, however. It is customary to refer to common views as *objective* views but, due mainly to the pervasive exo-physical attitude, the term "objective" has often been given a superior meaning and raised to the rank of "absolutely true." However, it is clear from the above discussion that the term "objective" cannot be synonymous with truth or independent reality, but only expresses the achieved consensus within the society. Individual subjective experience is primary, whilst a belief in the presence of something real outside us is secondary and comes from the consensus of many individual subjective experiences. The starting point of the process toward increasing knowledge is the individual subjective view which, after interaction with and feedback from others' individual views, is integrated into an ever more objective view, characteristic of the culture of the human society where the interaction takes place. It follows that the two terms, subjective and objective, do not represent a dichotomy: the term "objective" means no more than the term "subjective" when referred to a human society instead that to a single individual of that society [13].

From the point of view of endo-physics, the present long stalemate of physics seems to indicate that all the laws we have already found are an almost exhaustive part of an as yet unknown complete set of laws, each of them valid within well defined limits of applicability. More than that, we cannot attribute any feature of absoluteness to the laws already discovered or to those to be discovered in future, even if we improve our ways of reasoning and observing instruments. Any theories, within this outlook, can only be considered as working hypotheses which, as written by Friedrich Dürenmatt in his *Nachgedanke*n, "conform to human beings, at variance with enacted truths to which any human being must conform". A universal description of the world can only be an endo-description, asymptotically improving with time because of the continuous interaction between the various human groups and societies and between these and their members.

The process of increasing knowledge in terms of a subjective-objective-subjective loop, closely connected with various features of our consciousness and with our physical and intellectual needs, is characteristic of the endo-physical viewpoint, where the capability of humans to achieve complete detachment from their interacting environment is excluded *per se*.

It is worth mentioning that the path to an ever more universal common view is generally signposted by innovative and appealing ideas elaborated by strong individual personalities with great communication skills and firm beliefs. These new ideas drive new common views, new elements for a more precise language of communication devoted to a better understanding of new ideas and updated ways of performing new experiments and observations in the new context. Quite often, however, new ideas, rather than accelerate the process toward a more universal common view, act as negative fluctuations producing dreadful conflicts with previously agreed views or biasing societies in wrong directions for long periods of time. Re-adjustments, however, always occur due to the anti-conformist role of heretics or, in extreme cases, to revolutions and counter-revolutions [12].

4. Objectivity of the arrow of time and psychopathology

The question of a proper understanding of reality seems to be intimately related to the fundamental question of how our mechanisms of perception and consciousness work. We have direct experience of the world only during a tiny interval of time, the moment of the present, the “now”, and our consciousness is able to recognize a unidirectional flow of events causally connected from before (the past) to after (the future). These two important elements of our subjective feelings concerning time, that is its directionality or arrow and the associated sense of “nowness”, have so far remained in the realm of phenomenology, i.e., beyond the grasp of the exact sciences. We argue that this can be ascribed to the sole use of the third-person, exo-physical point of view, one of the consequences being that most of the fundamental equations of physics are time-reversible, i.e., they do not distinguish between past and future. Moreover, the very concept of the present, the “now”, has no proper place in physics at all; this holds true whether one is talking of classical physics, quantum mechanics, relativity or string theories. Physics merely *quantifies* the points of the time dimension, thereby stripping the latter of its crucial experiential aspects. Physical time is thus a plain, quantitative mathematical abstraction and, as such, simply cannot account for the fine structure of subjective/psychological time.

In order to explain the latter, it will be, in our opinion, necessary to adopt the endo-physical line of reasoning and go well beyond merely quantifying data, considering a generalized mathematical concept of dimensions where a rigorous *qualitative* distinction between the individual elements can be implemented. This is unavoidable because of the inherently qualitative character of our perception of time. It concerns not only our ordinary “waking” experience of time, but in particular a large group of phenomena that are collectively referred to as the psychopathology of time, that is, all the “anomalous/peculiar/extraordinary” experiences of time that are repeatedly encountered and reported in various “altered” states of consciousness.

The peculiar fabric of psychological time comprises, alongside what can be regarded as rather subtle and qualitatively irrelevant deviations from our ordinary sense of time, such bizarre, paradoxical and mind-boggling forms as "eternity," "everlasting now," "arrested/suspended time," "time going backward," and even "disordered/fragmented" time, to mention the most salient ones [14-17]. The corresponding experimental data to be dealt with are based solely on first-person accounts/narratives, which are characterized by a lack of uniformity and reproducibility. Accordingly, in any rigorous mathematical description of the perception of time, we have to cope with a phenomenon, the individual's perception of change and motion, the quantification of which is impossible on the conceptual basis, since it depends on the particular status of the perceiver, who is the only one who could provide quasi-quantitative estimates. Physics has so far successfully avoided entering this domain of inquiry, simply ignoring it and relegating it to the category of illusions due to our limited senses. This attitude is, however, in a sharp contrast with that of many philosophers who, on the contrary, give vital importance to the human experience of change and motion (see, e.g., Bergson [18] for one of the most illustrative examples in this respect).

Saniga's algebraic geometrical model of the time dimension [5,6,14-17,19] is, to our knowledge, the first attempt at objectifying individual psychological experiences of time, providing us at the same time with conceptual clues about how the psychological and physical aspects of time could possibly be interconnected [19]. The debut model [5] and its simplest non-linear generalisation [15] are capable, at the semi-quantitative level, of accounting not only for the directionality of time and the sense of nowness, but also for a number of the most pronounced pathological time constructs, some of which have been mentioned above [14-17].

An implication of this model is that, although manifestations of psychological time are diverse, unusual and fail to conform to any currently-favoured physical paradigm, they are accommodated by a definite algebraic geometrical pattern, i.e., can be classified mathematically. Any attempt to disregard these psychopathological temporal constructs as pure hallucinatory phenomena would then cast doubt about the role of mathematics in our understanding of Nature, because then we would have to explain why such hallucinatory phenomena appeared to be describable by mathematics. On the contrary, the applicability of mathematics here suggests that it is more natural to expect all these unusual perceptions of time to be as objective as our ordinary perception [14-17].

In view of these findings, those favouring the view that mathematics is an absolute entity and time is an illusion of our senses have to face a serious dilemma [20]: namely, either mathematics is an absolute entity and then the arrow of time has to be an intrinsic property of the universe, or the arrow of time is illusive and mathematics loses its absolute status too. It is worth stressing here that the model in question relies on the assumption that anecdotal, first-person descriptions of extraordinary senses of time are *on a par with* standard observational/experimental evidence in the natural sciences. This assumption is, of course, in sharp contrast with current operationalist psychology/ neuroscience, with their unilateral emphasis on third-person, objective behaviour, where subjective experience is systematically underemphasized, or even simply neglected, and all psychopathological phenomena, including the associated experiences of time, are conceived as nothing but disconnected and meaningless eruptions from, or failures of, malfunctioning cerebral modules. Nevertheless, we believe the approach discussed in [14-17] to be the inevitable and the only possible way to pursue research on the qualitative aspects of time, with profit to both psychology and physics. It is the abstract geometrization of the first-person perspective that gives the above-outlined approach a remarkable unifying and predictive power [17] and makes it a very promising conceptual step towards the ultimate unveiling of the riddle of time.

5. The universe as a self-evolving quantum automaton

Throughout the history of quantum mechanics there have been difficulties concerning the interpretation of what is meant by the concepts of *observer* and *measurement*. Collectively, these issues are known as the *measurement problem*. This problem may be seen as the confrontation between *exo* and *endo* in the quantum context. The traditional view advocated by Bohr is that quantum measurement can only be defined in exo-physical terms, with information about quantum systems being recorded by semi-classical observers standing outside of those systems.

Because the laws governing these observers are currently not understood, the conventional approach endows these semi-classical observers with free will, which means in effect using the mathematics of differential equations governed by boundary conditions dictated by factors external to the quantum systems under discussion. As a practical strategy this has worked extremely well, but even the most hardened practitioner of this approach to quantum mechanics eventually comes to realise its limitations. After many years working successfully with the standard approach, the great theorist Feynman began to explore the idea that the universe could be represented as some sort of vast quantum computation. He realised that the measurement problem represented an enormous hole in our understanding of the universe and wrote: “A very interesting question is the origin of the probabilities in quantum mechanics. Another way of putting things is this: we have an illusion that we can do any experiment that we want. We all, however, come from the same universe, have evolved with it, and don't really have any "real" freedom. For we obey certain laws and have come from a certain past." [21].

Feynman was in effect arguing the case for endo-physics. Despite the technical triumphs of modern theoretical and experimental physics, we still appear to know only about half of the laws of the universe; whilst we may be able to predict with great success the probabilities of the outcomes of any given quantum experiment, we have no real understanding why we find ourselves doing such experiments in the first place. It is not enough to say that physicists “want” to do their experiments; we should try to understand where this “want” comes from. In the above quotation, Feynman is clearly implying that all is not lost, however. If we the “observers” are ourselves subject to certain laws, as he suggests, then there is some hope that we may one day learn something about those laws. This is therefore a strong and positive rallying call from the most reputable of physicists for further investigation into quantum endo-physics.

Motivated by Feynman’s work, the E&J *stages* view of the running universe [2-4] provides a description of an evolving universe which takes into account the observed irreversibility and unpredictability of quantum change, consistent with the endo-physical paradigm. In this view, the universe is a self-contained, self-referential quantum automaton (or computation), organizing its own observations (or *tests* [22]) without the necessity of semi-classical observers standing outside it or its parts. It jumps serially from one stage to the next, each subsequent stage consisting of a new quantum state, a new information content and a new set of rules. These rules govern how each stage determines the next test of the universe, the quantum outcome of which then gives the next stage. A particularly subtle aspect of this is a hypothesis due to Buccheri which states that the rules must govern not only the quantum jump from one stage to the next but also any changes in the rules themselves [3]. This is because any truly endo-physical description of the universe cannot be influenced by any external factors. The rules, therefore, also have to be subject to what has been termed "the Rules of the Rules" [12].

Each quantum state of the E&J universe is an element of a vast quantum register, i.e., a Hilbert space *H* which is the tensor product of an enormous number *N* of quantum subregisters, such as quantum bits (qubits). A simple estimate suggests that *N* must be much greater than 10^{180} [3], so we are clearly dealing with a Hilbert space of truly vast dimension (given by 2^N in the case of qubits). Because of the mathematical properties of tensor product spaces, each state in *H* can be either entangled or separable. If a state is separable, then it is the tensor product of some factor states, each of which lies in a different factor subspace of H. When very large numbers of subregisters are involved and individual factors appear to persist over many jumps, separable states can be discussed in familiar terms such as systems, observers and environments (we recall that in standard quantum mechanics, complete states representing systems and observers are tensor products of states representing these objects separately). Such a description should emerge in certain contexts, typically involving large numbers of subregisters, but this is not inevitable. Moreover, because of the nature of the mathematical description, there is no inherent difference between systems, observers and environment, and in principle they have the same mathematical status.

As a cosmological model, the E&J universe is always *necessarily* represented by a pure state, never a mixed one, because there are no external observers for which the classical probabilities associated with mixed states could be defined. This is the first and most important consequence of taking an endo-physical approach to quantum cosmology.

A fundamentally non-classical feature of quantum mechanics is entanglement. This is at the heart of quantum strangeness, because entanglement is the point at which quantum systems lose any prospect of a classical interpretation in terms of their subsystems. Any classical discussion of subsystems generally requires them to be distinguishable in one form or another. For example, otherwise identical classical subsystems can be distinguished by their spatial positions alone. Space itself, therefore, can be regarded as no more than a particular classical way of distinguishing subsystems of systems, rather than as an entity in its own right. Once we move to a fully quantum approach, however, we should expect to lose even the concept of space as a fundamental component of the universe, in the same way that we no longer have an intrinsic notion of observer or system.

In the E&J model, entanglement and separability are two equally important sides of the same coin, both being essential for an understanding of quantum endo-physics. Consider cosmology. We imagine that at a time before the Big Bang, the universe found itself in a completely entangled pure state. This would be equivalent to a state of utter chaos, devoid of any classical structures such as matter, observers, space or even any internal measure of time. Then, after some unspecified (and unmeasurable) number of jumps, the rules and information content at some critical stage happened to be such that the hitherto completely entangled state of the universe jumped into a new state which was separable into two or more factor states. This would represent a sort of "quantum Big Bang". If the subsequent dynamics dictated by the rules were such that the state of the universe became more and more separable, then the conditions would be appropriate for a discussion in more familiar terms, such as an expansion of space. From this point of view, the Big Bang is not associated with any singularity, but represents only one of many points in the evolution of the universe where separate expanding sub-universes could arise from an increase in the number of factor states.

Once the state of the universe became more and more factored, this would give eventually rise to the emergence of reasonable stable patterns of factorisations and entanglements equivalent (in information theoretic terms) to observers, systems and environments embedded in classical space, the dimensions of which could depend on scale and context. In the long run, a far-reaching interpretation would be to consider the spontaneous emergence of semi-classical observers with a sense of free will, aware of themselves and looking for the rules governing the universe itself.

The jumps which produce stages with updated information content occur over discrete temporal intervals called quantum ticks (or q-ticks); these are the elementary markers of change in the quantum universe and define time in terms of the ongoing jumping process. There is no uniform scale of time attached to a q-tick, such as a Planck scale unit, however. Q-ticks have meaning only in terms of the discrete topology arising from the concepts of *before* and *after* which are intrinsically associated with quantum state reduction. Moreover, it is possible for jumps to occur such that some of the factors in the initial state remain unaltered. In such a case, those factors which do not change over the jump experience a so-called *null test* [2] and appear to remain frozen in time whilst the rest of the universe changes.

The result is that two sorts of time appear to govern the evolution of the E&J universe. From a mathematical, exo-physical perspective, the universe appears to jump in a regular serial way according to a universal, global and absolute discrete exo-time which labels successive stages. From a physical, endo-physical perspective, however, different parts of the universe appear to evolve at different rates, so that in effect local endo-time is non-integrable. An analogy here is with time in special relativity. On the one hand we may use co-ordinate time, which is mathematical and external to systems embedded in spacetime, or proper time, which is a non-integrable intrinsic (i.e., co-ordinate independent) measure of change local to those subsystems.

As an example of the independence of q-ticks in the jumping processes of separate parts of the universe, we refer to the decay of a radioactive atom. Such an atom appears to be frozen (from the Heisenberg picture point of view [2]) from the time of its preparation to the time of its decay, whilst innumerable other quantum jumps associated with other parts of the universe may have occurred. Indeed, according to the most subtle and disturbing interpretation of quantum mechanics given by Bohr and supported by the Kochen-Specker theorem, it is not correct to imagine the atom as really "being there" in a classical sense during that q-tick. Q-ticks in separate parts of the universe are not necessarily linked with each other, which is in agreement with Smolin's view that time is a natural feature of a world with many highly organized structures, whose different evolution can be used as reference clocks in each local context.

In the E&J model, the rules are involved in determining the quantum tests of the universe, the outcomes of which are new states of the universe. There may well be jumps which result in states of increasing complexity (as measured by their patterns of factorisation and entanglement), which lead to significant changes in these rules. This could then lead to an onset of complexity in the universe as a whole, such that the latest rules appeared to be uncorrelated with ancient ones. This leads to a picture of an *ontological emergence of the laws of physics*. This is not such a controversial issue as it seems at first sight. In conventional cosmology, for example, it is known that atomic and molecular physics are not applicable or relevant in the very early universe, when temperatures were too high to permit the formation of stable bound states of protons and electrons. More recently, some cosmologists have taken seriously the proposition that the so-called "constants of nature" such as the speed of light could vary with the age of the universe.

Looking at the current stage of our universe from the E&J standpoint, it seems to be one which is highly factorised and describable in terms of an apparently stable classical space and time in which matter is embedded. This accounts for the almost perfect classical nature of the universe as seen on human scales of activity. With advanced technology, fortunately, we can still observe a residuum of quantum processes in action. This alerted us first to the existence of quantum principles underlying the evolution of the universe and then more recently, validated their correctness, as shown in numerous violations of Bell-type inequalities and other evidence of entanglement.

In the E&J approach to the quantum universe, only one stage can be taken to be real in the conventional sense in any discussion or calculation. This stage is known as the *current present*. Relative to this stage, we can only talk of other stages as those which *were* real (relative to the current present) and whose rules lead to the current present, or potential future stages (again, relative to the current present) which have not yet occurred, relative to the current present. This is very much in line with the language of conditionality used in conventional quantum mechanics. It is stimulating to think of a possible relationship between this concept of current stage with the concept of the subjective *now* used widely in the conventional non-scientific description of human experience and activity.

6. Conclusions

In this article we have argued the case for an endo-physical approach to science, from the point of view of social interactivity, the psychopathology of time and of quantum physics. In each case, advances have come once differentiated approaches based on external observers are complemented by more holistic ones.

The greatest problem facing any paradigm shift in science is the need for mathematical expression. It is the case, unfortunately, that mathematics has traditionally been formulated to suit the needs of exo-physics. Quite possibly, no true endo-physical approach to mathematics can be developed. This would be the case if the Platonic view of the world of mathematical truth existing independently of the physical universe were correct. Even that most basic concept in mathematics, the set, is phrased in the language of the exo-physical observer. A set is traditionally defined as a "well-defined collection of objects". We may well ask, "*well-defined by whom*?"

These difficulties with mathematical expression need not deter us, however. It need not be the case that the exo-physical language of mathematics cannot be used to describe endo-physics, provided it is kept in mind at all times for whom this description is intended. Ultimately, endo-physics relates only to the endo-physical observer and not to any thing or anyone standing on the outside.

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