ON A POSSIBLE PHYSICAL METATHEORY OF CONSCIOUSNESS

Miroljub Dugic[1,4], Milan M. Cirkovic[2] and Dejan Rakovic[3,4]

[1]Department of Physics, Faculty of Science, P.O.Box 60, Kragujevac, Yugoslavia
E-mail: dugic@knez.uis.kg.ac.yu

[2]Astronomical Observatory, Volgina 7, 11160 Belgrade, Yugoslavia
E-mail: arioch@eunet.yu

[3]Faculty of Electrical Engineering, P.O.Box 35-54, 11000 Belgrade, Yugoslavia
E-mail: rakovic@net.yu

[4]International Anti-Stress Center, Smiljaniceva 11/III/7, 11000 Belgrade, Yugoslavia
E-mail: info@iasc-bg.org.yu; WWW address: www.iasc-bg.org.yu

Abstract: We show that the modern quantum mechanics, and particularly theory of decoherence, allows for formulating a sort of a physical metatheory of consciousness. Particularly, the analysis of the necessary conditions for the occurrence of decoherence, along with the hypothesis that consciousness bears (more-or-less) well definable physical origin, leads to a wider physical picture naturally involving consciousness. This can be considered as a sort of a psycho-physical parallelism, but on the rather wide scales bearing some cosmological relevance.

1. INTRODUCTION

In this study we would like to point out that modern quantum mechanics allows for formulating a physical metatheory (metaphysical theory) of consciousness. This observation comes from some recent progress in the foundations of the so-called decoherence theory (Dugic 1996, 1997a,b, 1998), as well as some cosmological discourses (Barrow and Tipler 1986). In addition, the same program is important in view of the contemporary heated debate of reductionism versus holism in the philosophy of science (e.g. Edmonds 1999).

We employ practically universally accepted hypothesis in physical considerations devoted to the issue of consciousness: *there is a physical background (and/or physical basis) of consciousness that, as a physical system, can be described and treated by the methods of the physical sciences.* This partially trivial assertion will later on prove useful for our considerations, finally leading to a wider physical picture naturally involving consciousness, and eventually pointing out something new as regards the connection between physics and (the physics of) consciousness. As will become clear below, this reductionist attitude is justified exactly because quantum mechanics (which we use as a physical basis for discussion) is generally perceived as introducing a substantial holistic element of modern physics. Therefore, by pointing out elements necessary for building a metatheory of consciousness, we may bridge the gap between these two positions, as well as explore the limits of the theory making process (Landauer 1967).

There is of course no big practical use of the metatheories, generally speaking. But the observations this way provided usually enrich and/or widen our point(s) of view. In our opinion, probably the main point of the present paper is that such a theory—metaphysical theory of consciousness—naturally follows from the foundations of quantum mechanics.

2. A BRIEF ACCOUNT OF THE THEORY OF DECOHERENCE

Decoherence is a real physical process partly investigated in the physical laboratories (Devoret et al. 1985a,b; Brune et al. 1996, Amman et al. 1998). It's history is long and rich of the different, both conceptual and methodological background. However, only recently the subject of decoherence met significant progress and has attracted significant attention of both theoreticians and experimental physicists.

Decoherence can be qualitatively defined as follows: *it represents a realistic physical process whose effect consists in establishing the (approximate) classical realism for the open physical systems*. Let us briefly discuss this definition. Quantum mechanics introduces the concept of *quantum indeterminism (quantum uncertainty)*, which consists in lack of the classical realism for some physical quantities of the quantum systems. E.g., the following statement does not have sense: 'electron in the hydrogen atom has a definite (relative) position'; rather, the electron's position is subjected to the famous uncertainty relations of Heisenberg. As opposite to this, the *classical reality* for a particle's position requires a definite value of the position in each instant in time generally - being the particle an isolated system, or in interaction with the surrounding physical systems. Therefore, existence of definite value of the electron's position *requires*, in quantum mechanics, an act of measurement of the position.

Therefore, the process of quantum measurement establishes (D'Espagnat 1971) the classical reality for the measured physical quantity (quantum-mechanically: observable), and at heart of the quantum measurement process proves to be (Zurek 1982, Giulini et al. 1996) the process of decoherence. Needless to say, the transition from quantum uncertainty to classical reality in due course of the quantum measurement assumes external intervention on the measured object (i.e., of the measurement instrument (apparatus) on the object of measurement), which justifies referring to the measured object as to an "open" quantum system. In general, by an "open" physical system one assumes a system whose behavior and dynamics (evolution in time) are substantially determined by its interaction with its environment.

Therefore, one may say that the effect of decoherence establishes at least approximate classical realism for some of the open system's observables, and is usually considered (Zurek 1991, Giulini et al. 1996) as the main candidate for resolving the long standing problem of the "transition from quantum to classical" (Zurek 1991, Omnes 1994).

In the "macroscopic context", i.e. as regards the macroscopic physical systems, the effect of decoherence is expected to meet the following criteria/requirements: (a) providing a definite border line between the open quantum system and its environment, (b) establishing at least approximate classical reality for some observables of the open system as a whole, and (c) to represent a comparatively quick physical process. Keeping in mind that the classic-physics world is at the "macroscopic context", it is usually, albeit only plausibly assumed that the process of decoherence should bear ubiquity and universality in the context of the "transition from quantum to classical".

However, recently (Dugic 1996, 1997a,b), existence of the necessary conditions for the occurrence of decoherence has been proved. It particularly means that interaction between the open system (S) and its environment (E) should be of certain kind as to provide the occurrence of decoherence. As regards the "microscopic" physical systems (elementary particles, atoms, molecules), this result does not mean much; e.g., the interactions that are not of the kind required are widely used in quantum mechanics. However, in the "macroscopic context", this result opens some questions.

In the "macroscopic context", the occurrence of decoherence is sometimes (Zurek 1993) plausibly considered as a necessary condition for fulfilling the above criterion (a), and consequently the other criteria (b) and (c). Particularly, it can be plausibly stated (Zurek 1993) that the decoherence provides us with the definite border-line between the two systems, S and E. Keeping this in mind, one directly concludes that in the "macroscopic context" nonoccurrence of decoherence (as pointed out in Zurek 1993) *contradicts our macroscopic experience and intuition*. Therefore one may state the question of physical relevance, meaning and importance of the necessary conditions for the occurrence of decoherence in the "macroscopic context".

3. THE ROOTS OF THE PHYSICAL METATHEORY OF CONSCIOUSNESS

Prima facie, the nonoccurrence of decoherence is not physically relevant and can be interpreted as a pathology of the theory itself[1]. However, this is not really the case. A deeper physical/ interpretational analysis offers an interesting interpretation naturally involving consciousness.

As it was distinguished in Dugic (1996) and further elaborated in Dugic, Rakovic and Cirkovic (2000), the decoherence theory allows for the following analysis: Let us suppose that the two systems, an open system S and its environment E are in mutual interaction not leading to decoherence. Then, according to the plausible assumption (Zurek 1993) distinguished above, one cannot determine the border-line between S and E. But suppose that there exist such coordinate transformations as to allow for redefining the interaction and leading to the definitions of the new physical systems—the new open system S' and its environment E'. Now, relative to the coordinates of the new systems, S' and E', one may say that there occurs the decoherence effect leading to unambiguous definitions of both systems, S' and E', and simultaneously defining the desired border-line between the two systems. This transformation is substantial (cf. Appendix I for some mathematical details, and for a strict treatment see Dugic et al 2000), in the sense that the "old" systems, S and E, cannot be even in principle defined or observed.[2] That is, one deals with the same composite system, S+E (identical with S'+E'), but the two definitions of the subsystems (the "old" one, S and E, and the "new" one, S' and E') are mutually *exclusive*! The process of decoherence, which establishes the classical reality only for the "new" subsystems, S' and E', clearly states: the open system S' bears classical reality, and can be defined only simultaneously with its environment, E'. The composite system cannot be considered decomposable into the "old" "system" S and its "environment" E: they simply do not bear classical reality, which is generally expected in the "macroscopic" world.

When extended to *complex systems* consisting of a set of *mutually interacting* (open) macroscopic systems plus their environments, this notion obtains unexpected element. Actually, in a set of such systems, the local interaction on one place determines interaction (and therefore definition of the systems) at spatially distant place(s), thus making the macroscopic piece of the Universe (MPU) as an interconnected physical system, in which definition of each of its part (element) depends on the definition of a *local* system and its environment; and this can be rigorously proved (Dugic 1997b; Dugic et al 2000). It cannot be overemphasized: even for the complex systems, the different definitions of the MPU are mutually exclusive, in so far as only one of them bears classical reality.

However, one may ask if the composite system as a whole, can—in due course of its time evolution—survive transition of the classical reality from one to another definition[3] of the MPU. But this is nonphysical transition, for *it cannot be observed*. Actually, the conscious observer could never be aware of this transition, for the simple reason: according to the assumption (cf. Introduction) that consciousness bears a macroscopic (Rakovic and Dugic 2000; Dugic and Rakovic 2000) physical system as its origin, the transformation from one definition of MPU as a realistic system to another definition of the MPU bearing classical reality equally refers to the physical system which is the physical basis of consciousness. In other words, the different Universes define

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[1] More precisely: one can expect that quantum mechanical formalism, as usually, gives us more than we can expect and/or interpret in terms of the classical physics, and particularly in terms of the classical reality. To this end, one may expect that only those physical models referring to the occurrence of decoherence could be considered physically relevant or realistic, putting aside the non-realistic and irrelevant models for which decoherence does not take place.

[2] As regards the whole system (S+E = S'+E'), the canonical transformations distinguished in Appendix I represent just the change of representation. However, as to the "subsystems", this change is substantial: it transforms the interaction hamiltonian from a nonseparable form (for which decoherence does not occur), to a separable form (for which decoherence can occur). Having in mind the Zurek's phrase "no systems-no problem", we emphasize that the canonical transformations allow for defining a system for which decoherence may occur—the system S' and its environment E'—while leaving the "border line" between S and E indefinable.

[3] Using the above definitions: the "new" system S' and E' looses classical reality, while the "old" systems, now, bear classical reality.

the different, mutually exclusive definitions of the systems, which the consciousness originates from.

This gives us a clue for the physical metatheory of consciousness: The different definitions of the MPU, bearing classical reality or not, in principle, define the different consciousness. The physical bases of consciousness in the different Universes (MPUs) are *mutually exclusive*, bearing the following substantial characteristics for each Universe: (i) consciousness (through its macroscopic-physics origin) can be defined only simultaneously with defining the rest of the MPU, and (ii) the different Universes define the different, mutually exclusive consciousness.

Therefore, consciousness, treated as a physical system, in the context of universally valid quantum mechanics is only a relative concept, its physical characteristics being determined by even remote pieces of the actual Universe. In practice, it means that observations in a given Universe can be performed only by the conscious beings physically (in the sense of our considerations) belonging to that Universe. This, *the relative-metatheory of consciousness* is a sort of *psycho-physical parallelism* bearing the holistic nature of the physical Universe, which naturally incorporates consciousness as its part (Wilber 1980; Hoyle 1982; Barrow and Tipler 1986).

In their lucid and instructive analysis of the collapse problem in quantum mechanics, Barrow and Tipler (1986, pp. 464-471) offer five basic avenues for solution. Apart from unattractive solipsism and Everett's "no-collapse" theory (which does offer a host of interesting physical and philosophical issues, but is uninteresting from our present point of view), these authors suggest that either any being with consciousness can collapse the wave function by observations, or a "community" of such beings can collectively collapse it, or there is some sort of "ultimate Observer" who is responsible for the collapse. From the point of view exposed above, it is clear that the nature of MPU and its link with consciousness implies that we may reject the first option also. Moreover, it could be argued that our proposal accommodates both the second and the third options.[4]

In a sense, our suggestion is antithetical to the famous proposal of Eugene P. Wigner (i.e. Wigner 1967) that the linearity of the Schrödinger's equation fails for conscious entities, and that there is some inherently non-linear procedure taking place inside those entities. As pointed out by Penrose (1979, p. 295), this reductionist picture leads to a rather disturbing view of the reality and actuality of the universe, since according to this view, by far the largest part of the universe will exist only as a network of linear superpositions. Our picture, on the contrary, automatically implies complete realism, even when applied to those parts of the universe not observed by us, but only implied in the definition of MPU.[5] This is certainly a strong merit in the holistic approach to both quantum mechanics and cosmology.

4. SOME COSMOLOGICAL CONSIDERATIONS

The view that macroscopic parts of our universe play a central role in physical understanding of consciousness may not be so surprising *ultimo facie*, especially if one takes seriously numerous anthropic "coincidences" playing a role in both classical and quantum cosmology (Carter 1974; Barrow and Tipler 1986). It is a well-known property of the universe that many of the model parameters in an envisaged complete physical description must be fine-tuned in order for life and sentience to be possible; among those are the total cosmological mass density Ω, magnitude of the cosmological constant Λ, and strengths of various couplings (including the celebrated example of the fine-structure constant α). For instance, it is well-known that Ω (*prima*

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[4] Interestingly enough, these are the two options which—Barrow and Tipler lament—"have not been explored to any extent" (Barrow and Tipler 1986, p. 469).

[5] This applies to those parts of the universe unobservable by us *in principle*. For instance, if our universe possesses a particular kind of horizon, often called event (or de Sitter) horizon, galaxies, stars and possible intelligent beings beyond this horizon will be unobservable by us *at all times*, both at present and in arbitrarily distant future. However, our cosmological theories do suggest that such unobservable galaxies (and an infinite number of them!) are *real.*

facie a random variable) has to be in a rather small interval between 0.1 and 10 for life (and, contingently, intelligence and self-awareness) as we know it to be possible.[6] Other parameters are even more tightly constrained: it has been argued that a change in magnitude of nuclear interaction coupling of only about 10% would make nucleosynthesis of elements necessary for life utterly impossible.

All these and many other examples testify on the fine-tuning present in the cosmological initial conditions, i.e. close to the Big Bang singularity. The similar, although less obvious conclusion applies to the issue of the arrow of time. As was first discussed by Wiener (1961), the existence of the time arrow as we perceive it around us is the necessary requisite for intelligence, and therefore presumably consciousness as well (see also the discussion in Barrow and Tipler 1986). However, there emerged a sort of consensus in last several decades on the crucial role played by cosmological initial conditions in determination of the arrow of time (Penrose 1979; Price 1996). Initial low-entropy state is a necessary requisite for subsequent flow of time; however, the real issue then becomes how such low-entropy state did come into being? The Penrose's estimate of the probability of spontaneous regularization of Big Bang in order to match the low-entropy initial conditions—evolving towards the observed state—is astonishing (see Appendix II for technical details)

$$1 \text{ part in } 10^{10^{123}} \ (!) \tag{1}$$

This stupendous volume of the parameter space *not* leading to emergence of intelligence and consciousness cannot fail to emphasize the highly special nature of the initial cosmological conditions. This result represents a good basis for our view of the role of cosmological boundary conditions in the future physical theory of consciousness.

However, this is not the end of the story. The role of MPU in the considerations above suggests that specific cosmological boundary conditions of some sort are necessary for the *continuous* existence of consciousness as we know it. Our conclusion is in accordance with the Empedoclean picture of contingency between physical and biological processes in the universe (Cirkovic 2000). One example of such boundary condition is the Wheeler boundary condition, requiring that intelligent life selects out a single branch of the universal wave function from "smeared out" universe existing prior to the first measurement interaction. This serves as a physical basis for Wheeler's so-called Participatory Anthropic Principle, which states that *observers are necessary to bring universe into being* (cf. Barrow and Tipler 1986). However, even a much weaker assumption could serve the same purpose in our picture.

As a consequence, one could conjecture that consciousness might be the essential property of Nature at different structural levels (macroscopic and microscopic, animate and inanimate), as widely claimed in traditional esoteric knowledge (Wilber 1980)—which might be supported by analogous mathematical formalisms of the dynamics of Hopfield's associated neural networks and Feynman's propagator version of quantum mechanics (Peruš 1996)—implying that "collective consciousness" of Nature itself behaves as a giant nonlocal quantum neural network with distributed "individual consciousness" processing units. Such nonlocal pantheistic idea of consciousness is also supported by Rakovic´s physical model of altered and transitional states of consciousness, explained in the Appendix III. In addition, this model might provide additional route to the physical

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[6] The total cosmological density Ω is a dimensionless quantity defined as the ratio of actual density of matter (including radiation and any yet-unknown matter particles and fields) to the critical density necessary for universe to recollapse under its own gravitational pull. Therefore, the universe will expand forever if $\Omega \leq 1$, and recollapse for $\Omega > 1$ (which should be taken with the grain of salt, since the matter fields with "exotic" properties may make the actual situation more complicated). That Ω is surprisingly close to unity (within one order of magnitude uncertainty) was first noted by Dicke in early 1960-ies (famous "Dicke coincidences" from cosmological textbooks). This is the source of ambiguity which dominated XX century cosmology concerning future of the universe: will it expand forever, or recollapse to future singularity of "Big Crunch". The best contemporary evidence strongly suggests the former alternative, although this can not yet be firmly established.

solution of the problem of the wave-packet reduction in the quantum measurement theory (Rakovic 1995a, 1997; Rakovic and Dugic 2000).

This picture also offers significant new insights in the nascent field of physical eschatology—a rather young branch of astrophysics, dealing with the *future* fate of astrophysical objects, as well as the universe itself. Landmark studies in physical eschatology are those of Rees (1969), Dyson (1979), Tipler (1986) and Adams and Laughlin (1997). Some relevant issues were also discussed in the monograph of Barrow and Tipler (1986), as well as several popular-level books (e.g. Davies 1994). Since the distinction between knowledge in classical cosmology and physical eschatology depends on the distinction between past and future, several issues in the physics and philosophy of time are relevant to the assessment of eschatological results and *vice versa*. In addition, we need to take into account the almost trivial conclusion, explicitly formulated and defended by Dyson in his classical paper (Dyson 1979):

> It is impossible to calculate in detail the long-range future of the universe without including the effects of life and intelligence. It is impossible to calculate the capabilities of life and intelligence without touching, at least peripherally, philosophical questions. If we are to examine how intelligent life may be able to guide the physical development of the universe for its own purposes, we cannot altogether avoid considering what the values and purposes of intelligent life may be. But as soon as we mention the words value and purpose, we run into one of the most firmly entrenched taboos of twentieth-century science.

Future of the universe containing life and intelligence is *essentially* different from the past of the same universe in which there were no such forms of complex organization of matter.[7] Consciousness is admittedly the most complex such form known, and therefore the issue of the future of the universe is inseparable from our understanding of the relationship between consciousness and the (macro)physical world. In particular, the relative definition of consciousness exposed above is subject to evolution describing large-scale structure of the universe, as studied in the eschatological discourse (cf. Tipler 1986).

5. DISCUSSION AND PROSPECTS

The process of decoherence is a realistic (objective) physical process. It particularly means that no 'observer' is required either for its unfolding, or for the final effect as it is strongly confirmed by the existing experiments (Devoret et al. 1985a,b; Brune et al. 1996; Amman et al. 1998). Therefore, our considerations refer to the objective effect of decoherence, and the above mentioned "psycho-physical parallelism" is not the one introduced by von Neumann and Wigner which assumes substantial role of consciousness in the process of quantum measurement. Particularly, in the von Neumann-Wigner interpretation of the measurement process it is assumed that consciousness is an external agency necessary and sufficient for the occurrence of the quantum-mechanical "collapse" of the quantum state of the object of measurement. In our considerations, consciousness is (cf. Introduction) treated through its physical basis as a macroscopic, i.e. an open quantum system, thus being a part of the "macroscopic piece of the Universe", not the "external agency" as in the von Neumann-Wigner theory (Wigner 1967). Therefore, in the context of the universally valid quantum mechanics (which is precisely the context of the decoherence theory), one may not expect such a role of consciousness as regards the "collapse". Rather, a new fundamental physical law is expectable with this regard (Leggett 1980; Prigogine 1997).

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[7] In addition, the premise that MPU generates a particular form of consciousness immediately obviates the common form of counterfactual cosmological analysis of (tacitly assumed) "lifeless" universes. In this sense our statement agrees with the abovementioned continual presence of consciousness; while counterfactuals are essential to theoretical reasoning in physical sciences, it is crucial that they are *understood as such*.

Starting point of our considerations is the issue of (non)occurrence of decoherence (of (non)establishing the classical reality for open quantum systems). It brought the relative-theory of consciousness. But now, in turn, one may note that consciousness is able to justify classical reality of the MPU as well as of the measured quantum observables. Methodologically speaking, this "two-direction" relation between classical reality and consciousness justifies consistency of our conclusions, and represents the main characteristic of "psycho-physical parallelism" as discussed above.

Interestingly enough, similar holistic thoughts and sentiments have been expressed (and rather conventionally disregarded) by undoubtedly one of the greatest physicists of all times, Erwin Schrödinger in his 1924. paper entitled "Bohr's New Radiation Hypothesis and the Energy Law". His words, in the colorful language of those formative years of modern science, sound appropriate for the conclusion of the present study (Schrödinger 1924):

> Thus one can also say: a definite stability of the state of the world *sub specie aeternitatis* can only occur through the *connection* of each individual system with the whole rest of the world. The separated individual system would be, from the standpoint of the unity, a chaos. It requires the connection as a permanent *regulator*, without which, energetically considered, it would wander about at random. Is it an idle speculation, to find in this a similarity to social, ethical and cultural phenomena?

APPENDIX I

To illustrate the transformations we have in mind (the so-called canonical transformations) we will use a simplified, unrealistic example (model).

Let us suppose that the (open) system S is defined by its "coordinate" x_S, while its environment is defined by its "coordinate" x_E. The transformations we have in mind are such that define the new (open) system S' and its environment E' that are defined by their "coordinates":

$$\xi_{S'} = \xi_{S'}(x_S, x_E)$$
$$\xi_{E'} = \xi_{E'}(x_S, x_E)$$

(I.1)

which states (mathematically) analytical dependence of the "coordinates" of the "new" systems, S' and E', on the "coordinates" of the old systems, S and E. We further suppose existence of the inverse relations:

$$x_S = x_S(\xi_{S'}, {}'\xi_{E'})$$
$$x_E = x_E(\xi_{S'}, \xi_{E'})$$

(I.2)

in full analogy with (I.1). Needless to say, the composite system is one and the same, i.e. one may state: S+E = S'+E'.

Let us suppose that the interaction in the composite system, when expressed in terms of "coordinates" of the "old" systems (S and E) proves not to lead to decoherence, while when expressed in terms of "coordinates" of the "new" systems (S' and E'), this interaction leads to decoherence, thus establishing (approximate) classical reality for the open system S' (and, simultaneously, for its environment E'). Then the transition:

$$(x_S, x_E) \xrightarrow{\text{canonical transformations}} (\xi_{S'}, \xi_{E'})$$

(I.3)

is physically substantial: due to the lack of classical reality of the "old" system (and its environment), it states that the inverse transformation to (I.3) is physically meaningless.

Furthermore, due to the fact that the "new" composite system's observables are subject to quantum uncertainty, the "old" composite system' observables are unobservable.

Actually, the (quantum) measurements of the "old" observables, x_S, x_E require simultaneous measurements of the "new" observables $\xi_{S'}, \xi_{E'}$ - which is forbidden by the uncertainty relations of the "new" observables.

Therefore, even if one may ascribe the (approximate) classical reality to the "new" system's observables, this is not the case with the observables of the "old" systems in so far as the interaction between S and E does not lead to decoherence.

APPENDIX II

In this Appendix we would like to show how one obtains the most profound example of fine tuning, the one dealing with the regular nature of the Big Bang singularity discussed by Penrose (1989) and quoted above in (1).

The relevant measure of gravitational entropy is given, for the case of black hole, by the famous Bekenstein-Hawking formula (Bekenstein 1973; Hawking 1975):

$$S_{BH} = \frac{kc^3}{G\hbar} \frac{A}{4}, \tag{II.1}$$

where A is the black hole horizon surface area, and the rest are fundamental physical constants observed in the universe: k is the Boltzmann constant, c – velocity of light, G – Newtonian gravitational constant, and $\hbar$ is the Planck constant. We perceive that the entropy of matter enclosed within horizon (not entering at all into a physical problem of the state of such collapsed matter) is proportional to the horizon surface area. In the simplest case, the one of spherically-symmetric black hole, horizon is the sphere with area $A = 4\pi R^2$, where the relevant radius R is the Schwarschild radius, given as

$$R = \frac{2Gm}{c^2}. \tag{II.2}$$

In this formula, *m* is mass of the black hole (observable, for instance, through its gravitational attraction of other objects or even deflection of light rays). Combining this result with (II. 1), we obtain the following expression for gravitational entropy as a function of mass:

$$S_{BH} = \frac{2\pi Gk}{\hbar c} m^2. \tag{II.3}$$

Now we are in position to calculate the gravitational entropy of the matter within our visual horizon if we could somehow collapse it into a single gigantic black hole (since we can reasonably estimate the mass of all matter within the horizon). It will be the *maximal* entropy state, since, as shown by Bekenstein, the state of matter in the black hole is the most probable one, as far as gravitational interaction is concerned. Any other state (for instance the one we observe at present, where matter is clumped in galaxies, stars, planets, etc. and there is just a small number of black holes) is a priori *less probable*. It is worth noticing, however, that in the context of contemporary relativistic cosmological models, such situation actually occurred in the past: all matter within our visual horizon today was within the initial Big Bang singularity, which has much in common with the (local) black hole singularities.

Finally, to establish quantitatively how much less probable is the observed entropy in comparison to the (II. 3), we need the historically all-important Shannon formula, giving the relationship between entropy and information (Shannon 1948):

$$S = -k\sum_i p_i \ln p_i, \qquad (\text{II.4})$$

where p_i is the probability of system considered being in state i.[8] Even on a qualitative level, it is clear that the presence of logarithm in (II. 4) is the source of huge exponential terms such as the one in eq. (1). It gives us a proper lever to compare our universe with the case in which all matter within our horizon is located in black holes. It comes out that, as Penrose (1989) discusses, our universe is of so small entropy compared to the generic one, that the probability of its reaching the observed state is stupendously small, as in (1). This is, as correctly emphasized by Penrose and Price, not only a source of cosmological, but probably all other arrows of time as well, and a profound example of fine-tuning to be accounted for by unified field theories of the near future.

APPENDIX III

The goal of this Appendix is to qualitatively sketch the model of transitional states of consciousness developed by Rakovic (1995a,b; Rakovic et al. 2000). Namely, these states might be deeply connected with the role of "collective consciousness" (as a composite quantum state Φ of all "individual consciousness" ϕ_k: $\Phi \sim \prod_k \phi_k$) in the quantum theory of measurement, where "collective consciousness" with its assembling (equivalent to convergence of Feynman's propagator quantum mechanics to one of its propagators, Φ_i) contributes in channeling reduction of initial wave function Ψ into one of (possible) probabilistic eigenstates Ψ_i - which implies that "collapse" could be related with generation of microparticles' local wormholes in highly noninertial microparticle's interactions in quantum measurement situations (fully equivalent to extremely strong gravitational fields according to Einstein's Principle of equivalence, where relativistic generation of wormholes is predicted; cf. Morris, Thorne and Yurtsever 1988; Thorne 1994). In a similar vein, in the Penrose's gravitationally induced collapse (e.g. Penrose 1994) the very mechanism for this process could be continuous opening and closing of local microparticle's wormholes, addresses of their exits being related (probabilistically) to one of (possible) eigenstates Ψ_i of corresponding quantum system—and everything being related to corresponding (probabilistic) assembling $\Phi \to \Phi_i$ of "collective consciousness", thus channeling the collapse $\Psi \to \Psi_i$.

The question how it is possible that these highly noninertial microparticles' processes with inevitable relativistic generation of microparticles' wormholes and other envisaged quantum-gravitational effects were not taken into account within quantum mechanics which is yet extremely accurate theory—might be answered as it was, but within the ad hoc von Neumann's "projection postulate" (von Neumann 1955) to account for quantum-mechanical "wave packet collapse" in quantum measurement situations (implying also that this *ad hoc* procedure is based on quantum gravitational phenomena, as suggested by Penrose, being on deeper physical level than quantum mechanical ones!). On the other hand, the nonlocality of usually conceived "collective consciousness" provides additional evidence for the nonlocal nature of quantum mechanics—otherwise demonstrated by tests of Bell's inequalities and the Einstein-Podolsky-Rosen effect (Bell 1987; Aspect, Dalibard, and Roger 1982).

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[8] It is worth noticing that there is some ambiguity in the literature, which concept of entropy is the more "fundamental" one and therefore (II. 4) is sometimes written without the Boltzmann constant k, and it is said that the Shannon entropy for thermodynamical systems is equal to the fine-grained entropy in units of k. We neglect this rather semantic issue in the present discussion.

It should be also pointed out that the above "collective consciousness"' assembling Φ_i ($i = 1,2,3...$) in quantum theory of measurement should be interpreted as purely probabilistic (with relative frequency of their appearance given by quantum-mechanical probability $|a_i|^2$ of realization of corresponding microparticles' eigenstates Ψ_i, where $\Phi\Psi = \sum_i a_i \Phi_i \Psi_i$), depending not on the previous history of the repeatedly prepared quantum system. However, this might not be the case for biological "individual consciousness"' assembling, being history-dependent deterministic one (resulting in deterministic convergence of the consciousness-related-acupuncture electromagnetic/ionic microwave ultra-low frequency-modulated oscillatory holographic Hopfield-like associative neural network to the particular attractor in the potential hypersurface (Jovanovic-Ignjatic and Rakovic 1999; Rakovic et al. 2000), or equivalently to deterministic convergence of Feynman's propagator quantum mechanics to the particular propagator corresponding to ϕ_k, fixedly determined by "individual consciousness"), implying that strong preferences in individual futures might exist, governed by individual mental loads, as widely claimed in Eastern tradition (Wilber 1980; Vujicin 1996). The same may apply to collective futures Φ_i, also governed by interpersonal mental loads (Rakovic 2000). It should be also noted that these preferences in individual and collective futures might be anticipated in transitional states of consciousness that might be the basis of intuition, precognition and deep creative insights (Jahn 1982). What is really anticipated in transitional states of consciousness of "individual consciousness" might be the evolved state of cosmic "collective consciousness" $\Phi(t)$ (to which our "individual consciousness" ϕ_k has access, being the presumed constituting part of cosmic "collective consciousness"), which is quantum-mechanically described by deterministic unitary evolution governed by the Schrödinger equation.

A hypothesis that nonlocal individual/collective consciousness re-assembling ($\Phi \rightarrow \Phi_i$) is possible, with direct influence on the collapse of the observed system ($\Psi \rightarrow \Psi_i$), might be also supported by Princeton PEAR human/machine experiments (Jahn and Dunne 1988), where (even distant) human operators, solely by volition, have been able to influence the sophisticated machines with (otherwise) strictly random outputs, in a statistically repeatable effects (of the order of a few parts in ten thousand) - but individually not reproducible at any moment, which is a standard request in contemporary scientific experiments. All this can be accounted by intentional transitional transpersonal biological (non-Schrödinger governed) quantum gravitational tunneling of the "operator's individual consciousness" with mental addressing on the "machine's content of collective consciousness", channeling intentionally the "operator/machine composite state of collective consciousness" ($\Phi \rightarrow \Phi_i$), thus automatically influencing the machine output ($\Psi \rightarrow \Psi_i$) in the non-Schrödinger quantum-gravitationally governed collapse-like process ($\Phi \Psi \rightarrow \Phi_i \Psi_i$). As a consequence one could further support the conjecture that consciousness might be essential property of Nature at different structural levels, macroscopic and microscopic, animate and inanimate, being presumably related to the unified field itself (Hagelin 1987).

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[9] In connection with this reference, see also many archival publications and technical reports by PEAR (Princeton Engineering Anomalies Research); relevant pointers are on the following WWW address: www.princeton.edu/ ~rdnelson/pear.html.

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