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QUANTUM APPROACHES TO CONSCIOUSNESS.
THE HYPOTHESIS OF HENRY STAPP

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I. INTRODUCTION. CONSCIOUSNESS: CAUSALITY AND CORRELATIONS.

Several approaches can lead us to the core of the issue, which ultimately consists in being able to explain the correlations between mental phenomena, specifically and what most interests the subject of this paper, the phenomenon of consciousness and the bodily processes which are associated and temporarily coincident with them.

However, according to Chalmers, neuroscience offers such correlations, but it is not able to explain them.

According to Nicolas Gisin "Correlations claim an explanation"[1], as "once a correlation has been identified, the new task for science is to develop a theoretical model to explain it. This model takes the form of a story whose supports are mathematical equations. "

This means, as Gisin explains later in his paper, that any correlation of physical events described by science, should be explained in mathematical formalism and equations, namely causal models using both direct cause and common cause. This causation is broken both in explanations of correlations of quantum mechanics, which Gisin deals with in his article, as in consciousness, as observed by Chalmers, on the premise that consciousness is a fact of nature, but as the author says, runs "uncomfortably" along the border between science and philosophy.

Therefore awareness also would require a theoretical model.

According to Hawking and Mlodinov[2], an accurate model must satisfy the following requirements:

- be elegant
- contain few or adjustable arbitrary elements
- be consistent with existing observations or provide their explanation
- be able to make detailed predictions about future observations that allow refuting or falsifying the model, in case thy could not be confirmed.

In this paper we analyze the causal model of Henry Stapp, that even if it fails in fully complying with all these requirements, is based on the version of a model that entails empirical and demonstrable results as well as the possibility of a causal link between the two types of events or phenomena, being Stapp's hypothesis an hypothesis of consciousness based on quantum mechanics, which from the point of view of philosophy adopts a dualistic view of reality.

Also dualistic is the vision of Noë, which I will point out briefly, that contemplates consciousness as an entity that integrates the biological entity that perceives the world with the world itself.

Given that Chalmers also opts for a naturalistic dualism, I will stop briefly in the proposal that he carried out in 1996 about the causality of consciousness, that seeks to refute the physicalist reductionism or eliminativism "in any case" of consciousness as an existing entity, to then make an approach to other of the hypotheses of consciousness related to quantum theory.

[1] Nicolas GISIN, Quantum *correlations in Newtonian space and time: arbitrarily fast* communications *or non locality* 2012.

[2] Stephen HAWKING and Leonard MLODINOV, *The Grand Design* 2011 (p.68).

II. INTEGRATED CONSCIOUSNESS AND SUPERVENING CONSCIOUSNESS. ALVA NOË AND DAVID CHALMERS.

Alva Noë 2010[3] believes that those who underline that brain constructs an internal image of the world and that what we experience is an internal image and not the world itself, what they would evince is that the world, at least the world which the brain determines and not determined by the visual experiences, is a great illusion and what they bring (those who emphasize that the brain is an internal image of the world) to the stream of thought, is a new skepticism that insists that we can see just what it is given to us to see, although we believe otherwise.

The hypothesis of the "great illusion" for Noë is bad philosophy and cognitive science according to it is bad science.

Proponents of the new skepticism, including Daniel Dennett and Susan Blackmore, committed in fact, according to Noë, a serious mistake by not taking into account that it does not seem to us as direct perceivers, that the brain builds an internal model of the world, but what appears to us is that the world is there and that we are not only in it but that the world is at our disposal.

Not everything is psychology or neuroscience, as Frege said[4], because if so, they would contain all the sciences and would proclaim themselves the measure of all sciences. "We are not bearers of thoughts as we are bearers of our ideas".

Like Noë, Frege maintains an anti-reductionist perspective and considers that visual impressions are certainly necessary to see things, but not sufficient[5].

"So since the answer lies in the non-sensible, perhaps something non-sensible could also lead us out of the inner world and enable us to grasp thoughts where non sense-impressions were involved"[6].

"The apprehension of a thought presupposes someone who apprehends it, who thinks. He is the bearer of the thinking but not of the thought"[7].

Like Noë, Frege is also dualistic, as he discriminates between the thinking subject and the world (where the thoughts are).

Therefore, also in Frege we find out what it might be called dual capacity, the intrinsic and functional thinking and that that is able to capture the world.

According to Noë the phenomenon of consciousness is inclusive and interacts with the environment, necessarily, as the environment is an ontologically entity different than consciousness, but at the same time an "accessible" extension of it.

That the world is at my disposal means that “what guarantees its availability is, first of all, its actually being here, and second, my possessing the skills needed to gain access to it. (..) although I do not represent all the details at once, I have *access* to all the detail"[8].

And this does not mean for Noë that we are victim of a great illusion.

He does not even locate the mind in the brain, privileging the position of the environment in any act

[3] Alva NOË, *Out of our heads* 2010 (p. 140).
[4] Gottlob FREGE, *The Thought: a Logical Inquiry* ,1956 (p.307).
[5] Ib. (p.308-309).
[6] Ib. (p. 309)
[7] Ib. (p. 308)
[8] Alva NOË, *Out of our heads* 2010 (p.140-141).

of perception, but he integrates the perceiving being in the environment.

Our "perceptual awareness of the world as a predictable place depends on how the world actually works" and on the other hand, our perceptual skills have evolved to be able to give up life on earth based on evolution.

The world, Noë declares, is not a mental construct, and our conscious mind operates in active consonance with the world. All around us determines the nature of our experience and it is not only our perceptual system, even though many scientists assume this premise and although the science of vision, as an emblematic example of perceptual activity, has not yet demonstrated that the visual world is engineered by the brain[9].

Noë reminds us, emulating Descartes[10], that every conscious scientist is aware of the implicit fallacy of this occurrence, at least until we could be able to explain how the mental eye "sees" the retinal image.

David Chalmers[11], unable to prove the causation on the basis of logical supervenience of conscious experience based on fundamental physical phenomena, also opts for a naturalistic dualism.

His line of argument is not based on an inferential analysis of direct causes or common causes but it is a modal argument and focuses on the notion of logical supervenience, although his analysis goes further and explores other arguments that could make possible a theory of consciousness, as the arguments derived from the information theory.

He adopts the notion of departure, supervenience, as an explanatory framework of a series or concatenations of facts and of relevant physical interdependent properties that would instantiate the so called causal closure of the physical.

Thus biological properties supervene on physical properties and microscopic properties on macroscopic properties.

Generally, if properties B, be water or have a particular physical form, supervene logically on A properties, be H2O or to own certain genetic combinations, we can say that events A entail facts B and when an event involves or is inferred from another, it is logically impossible for the former to exist without the second. Hence, logic supervenience and possibility go hand in hand.

However, Chalmers believes that supervenience can exist in the physical world without logical supervenience is given. There are correlations in the natural world, albeit of weaker nature than logical supervenience. If these correlations are systemic and nomic, their dependence relationship must endure counterfactual situations[12].

Another relevant issue is that logical supervenience implies natural supervenience which is the only empirically verifiable, as Chalmers believes.

If A properties (basic or fundamental) determine B properties in all logically possible situations, this applies to all naturally possible situations and not vice versa. Thus, the pressure of a gas mole naturally depends on its volume and temperature based on a constant k, but this is not a logical

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[9] Ib. (p.142-144).

[10]Note: The author refers to the *homunculus fallacy:* extracted from *Doptrics*, it is to devise the existence of a little man located in our brain that observes through his eyes all what happens in the retinal image.

[11]David CHALMERS, *The Conscious Mind* (Chapter II.4).

[12]Ib. (p.38).

dependence, since we could imagine a world where this constant is logically different. Therefore, natural supervenience does not imply logic supervenience.

Chalmers thinks that cases of natural supervenience without logical supervenience are very difficult to find in the physical world.

Consciousness is one of them, due to the necessary connection between physical structures and experience, given only by the laws of nature and not by logic[13], contrary to what happens in the (reductionist) explanations of physical phenomena, both structural and functional, that occur above the microphysical level, as the case for breeding or as, at cognitive level, the case of learning.

However, as Chalmers declares, all these phenomena can be causally analyzed by functionalist or cognitive theories, but they are nothing more than functionally useful descriptions and none of them is able to explain how, and especially why, they affect our phenomenology.

In each mental concept involving a phenomenal or experiential element, an explanatory gap is consistently yielded. "Explaining how a causal role operates is not enough to explain consciousness"[14].

The failure of logical supervenience of consciousness on the physical indicates that reductive explanation of consciousness can thrive. However, there shall not be excluded, in the author's opinion, the physical facts from its explanation. In fact, one possible solution could be to proclaim that all facts that supervene logically are a combination of physical and phenomenal facts or that logical supervenience on the physical facts is yielded by the means of conscious experience[15].

Thus as far as he the hypothesis of "new physics"[16]is concerned in his paper, he does not exclude the possibility that a fundamental physical theory such as quantum mechanics can play a key role in the theory of consciousness.

Even if this option does not seem to be the bet of Chalmers, who throughout the text seems to favor a theory of consciousness based on the information structure of the process of knowledge, in the final part of the book dedicated to quantum mechanics and its possible linkage with consciousness, favors the interpretation of Everett 1957.

III. THE NEW PHYSICS.

In the words of Chalmers[17]: "the problem of quantum mechanics is almost as hard as the problem of consciousness. Quantum mechanics gives us a remarkable successful calculus for predicting the results of empirical observations, but it is extraordinarily difficult to make sense of the picture of the world that it delivers. "

Hawking-Mlodinov[18] say that predictions of quantum theory "match the vew of reality we all develop as we experience the world around us. But individual atoms and molecules operate in a manner profoundly different from that of our everyday experience".

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13 Ib. (p.39).
14 Ib. (p.48).
15 Ib. (p.65).
16 Ib. (p.114).
17 Ib. (p.334).
18 Stephen HAWKING and Leonard MLODINOV, *The Grand Design* 2011 (p.87).

From the words above, two facts are inferred to be taken for granted: one is the mathematical formalism, on which there is no disagreement among theoretical physicists, since it is empirically proven that the calculus works, and the other is the interpretation of the formalism, that has led to various hypotheses and models, for it is in the objectual structure underlying equations where disputes arise.

Another historically current parallelism between the causal gap between consciousness and physical laws and between classical physics and metaphysics (here the authors refer to the cosmological derivations and assumptions of the string theory) is illustrated as follows by Mlodinov-Hawking:

"It seems that we are in a critical point in the history of science, in which we must change our conception of the aims and what makes a physical theory acceptable. It seems that the values of key parameters and even the shape of the apparent laws of nature are not required by any physical or logical principle"[19].

It can be easily asserted that two events that occurred in the course of two decades have marked a fundamental turning point in physics, assaying its fundamental characteristics, and its new name.

The first occurred on December 14th of 1900, when Max Planck presented to the German Physical Society the demonstration that energy neither grows nor decreases in a continuous way, but by multiples of a discrete amount or quanta, today known as Planck's constant, notated as *h*, equivalent to 6.6262 x 10-34 joules per second.

Max Planck solved in this way the mystery of the so called "ultraviolet catastrophe”, which is the range of radiation that, according to the physical theory at the time, a black body subject to elevated temperatures should have achieved but in fact did not achieve, remaining in x-rays or in gamma rays. Below these values energy exchanges could not occur, as the Planck scale is the shortest measure of space and the shortest moment of time.

A few years later Niels Bohr solved another "mystery", this time concerning the structure of the atom, mystery that Scaruffi describes as follows:

"The electrons spin about the nucleus and only some orbits are allowed. Again, nature seemes to restrain the existence between orbits"[20].

The second fact is that Louis de Broglie in 1923, as Einstein did with light, hypothesized that waves and particles are two aspects of the same phenomenon, to which values as energy, mass, frequency and wavelength could be simultaneously adscribed.

The equations that calculate the behavior of these parameters have been developed by Heisenberg in 1925 and by Schrödinger in 1926.

Through matrix type equations, the former would formulate the principle of uncertainty or indeterminacy, which allows us to simultaneously measure certain values, such as position and the momentum of a particle.

Hawking-Mlodinov describes this as follows:

"According to the uncertainty principle, for example, if you multiply the uncertainty in the position of a particle by the uncertainty in its momentum (its mass times velocity) the result can never be

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[19] Ib. (p.164).

[20] Piero SCARUFFI, *La nuova fisica: l’asimmetria omnipresente* 2003 (p.9).

small than a certain fixed quantity called Planck's constant."(...) The more precisely you measure speed, the less precisely you can measure position, and vice versa. For instance, if you halve the uncertainty in position, you have to double the uncertainty in velocity"[21].

Taking a practical example: "If we measure the position of an electron to a precision corresponding to roughly the size of an atom, the uncertainty principle dictates that we cannot know the electron's speed more precisely than about plus or minus 1.000 kilometers per second, which is not very precise at all"[22].

The consequence in our ability to obtain information is that we can not predict with certainty the results of the physical processes since they are not determined. However, at these (subatomic) levels what the laws of nature determine with great precision are the probabilities of events.

The Heisenberg uncertainty principle rises as a crucial principle in quantum mechanics as it reveals and anchors its probabilistic appearance at a deep level of the theory and proclaims that indeterminacy can not be eliminated from the theory.

The other equation, the Schrödinger equation, describes the statistical behavior of the particles. In its simplest formulation not dependent on time parameter, by Born: $H\psi = E\psi$, where the symbol ψ represents the wave function of the particle, H an operator and E the energy level .

The solutions of the Schrödinger equation are "waves"[23] and thanks to them scientists have been able to obtain specific wave functions to describe particles or photons.

This would lead to the quantum theory to reveal two of its essential characteristics: probability and superposition[24].

Therefore, when we deal with quantum systems (an electron is one), each of them associated to a wave function ψ, we are no longer dealing with determined systems. A particle can be described only in terms of probability, and this description is operated by ψ, so that the probability of finding a particle at a particular position is proportional to the square of the amplitude of the wave function ($|\psi|^2$) in that position .

The second essential feature that the Schrödinger equation evinces is the principle of superposition of waves.

This property explains the phenomenon of interference that occurs in the double-slit experiment, first performed by Thomas Young in the early nineteenth century and which showed experimentally the wave nature of particles (in the case of Young they were photons) once they have been fired on a background screen or from a source and after having passed through another screen with two slits. The result reveals an interference pattern with light and dark stripes, characteristic of waves. The light bands on the screen identify the areas where the waves interfere with each other, so that in some cases both values must be added, when they coincide with its "peaks" and with the light bands, in other cases they coincide with their "valleys" and with the dark bands and therefore they must be subtracted. In one case the interference is constructive and in the other destructive.

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21 Stephen HAWKING and Leonard MLODINOV, *The Grand Design* 2011 (p.91).

22 Ib.(p.92)

23 Amir ACZEL, *Entanglement: the greatest mystery in physics* 2002(p.64).

24 Ib.

In the twentieth century the experiment would yield more surprises since the same defraction pattern would occur when the shot was performed with a single photon. This fact would yield two consequences: the photon was interfering with itself and it passed through both slits. The photon state was therefore in a superposition state with itself.

On the other hand, since the discovery of the photoelectric effect and its interpretation by Einstein, it has followed that photons behave both like waves and as particles. In the 50s of the twentieth century it has been discovered that this behavior also existed in electrons, later also known in neutrons (70s) and in the 80s also in atoms[25]. Naturally this behavior of nature caused a great shock in the scientific community and it is one of the fundamental phenomena that the new physics presented, such that Feynman said of it that it "contains all the mystery of quantum mechanics"[26].

The superposition property indicates that the system is in a state that is a mixture of states, precisely due to the overlap, such is the quantum state of the system, that coincides with the state vector or wave function.

This particular quality is at the basis of the paradox of "Schrödinger's cat". But for an accurate solution, more quantum acrobatics are needed, "the second part of the story" as Chalmers identifies the measurement postulate, also known as the collapse of the wave function or "projection postulate"[27].

The measurement postulate tells us that when we make a measurement, the state or the wave function collapses in another state, more defined, or pure state. This means that if we measure the position of a particle or its spin, the state will collapse in any of the possible values of these observables, while we are unable to know in advance in which of them. This value, called *eigenvalue*, gives us information about the position, the time, or whether the spin is up or down, depending on the properties of the particle.

Both the Schrödinger equation and the measurement postulate are, on the whole, a powerful tool for the prediction of the evolution of a system, as well as of the probabilities that the states collapsed by the measure would yield.

However, problems arise when we question about how it is possible that the calculus works and about what happens in parallel in the "objective world" in order for the predictions to be so precise[28].

These questions will lead us also to possible responses and interpretations of quantum mechanics.

IV. INTERPRETATIONS OF QUANTUM MECHANICS. THE PILOT-WAVE OF DAVID BOHM.

A. J. Diéguez[29] presents the seven interpretations of the meaning of ψ by Landé, reduced to five:

[25]Amir ACZEL, *Entanglement: the greatest mystery in physics* (p.21).

[26]Stephen HAWKING and Leonard MLODINOV, *The Gran Design*, 2011 (p.85).

[27]David Chalmers, *The Conscious Mind* 1996 (p.337).

[28]Ib. (P.338).

[29]Antonio J. DIÉGUEZ, Realismo y teoría cuántica 1996 (p.4).

–ψ represents something real, a physical field or objective properties. Among its defenders we find Einstein, de Broglie, Schrödinger, Bohm, Bell and Penrose.

–ψ does not represent anything real, but it is reduced to a mathematical calculation tool of measurements. It is the Copenhagen interpretation adopted by Bohr.

–ψ represents our state of knowledge of the system. We find it also in the Copenhagen interpretation assumed by Born and by Bohm, Heisenberg and in part by Schrödinger.

–ψ represents a set of experimentally actualized potentialities. Accepted by Heisenberg.

–ψ describes the behavior of a set of systems, not just one. It would be a statistical interpretation assumed by Einstein, Popper, Landé and Ballantine.

David Chalmers also reduces to five the interpretations[30] of quantum theory:

Option 1. It takes the quantum formalism literally: the system collapses when measured by the intervention of the observer. This is the orthodox or standard interpretation of quantum mechanics.

According to Chalmers, it is counterintuitive.

Option 2. This option supports the existence of many overlapping microscopic superpositions whose interactions can produce a relatively defined macroscopic state. Due to some complex mathematical properties, we may infer that the effective collapse would result from certain microscopic uncertainties. Thus, the probabilistic collapse would be replaced by a statistical process of a complex emerging system.

In this line,Gell -Mann and Hartle 1990 argue.

Chalmers suggests that these calculations have been unsuccessful and require further development. Nor do they explain why just one of the elements of the macroscopic state is actualized.

The author suggests combining it with Option 5, which is the option that he opts to support.

Option 3. It proposes the inhibition of the quantum mechanical calculus of possible correlations with the real world, opting to adhere exclusively to its functionality, given that the calculus is effective.

This stance is taken by Bohr's version of the Copenhagen interpretation.

This interpretation emphasizes the "classic" nature of measuring instruments, suggesting that only classical or macroscopic objects have an objective state. In this way, questions about the "real" state of the objects described by the superposition of states are prohibited.

However, Chalmers believes that Bohr 's writings not always are clear and easy to interpret.

Option 4. Chalmers clusters in this option the interpretations that purport to ignore the measurement problem and the collapse of the wave function assuming that a basic physic state is a wave function governed by the Schrödinger equation, to which new principles are needed to de added for the state to becomes discrete.

The interpretation of Ghirardi, Rimini and Weber (GRW) 1986, assumes that breakdowns can occur spontaneously at a microscopic level at each moment, with a very low probability to occur, but when it happens it usually leads to a collapse of the state of a macroscopic system, due to the inseparability of the two states, "micro " and " macro". In turn, any macroscopic state at any time can be made up of a greater number of particles generally in a relatively discrete state.

[30]David Chalmers, *The Conscious Mind* 1996 (Chapter 10).

Another alternative to avoid the collapse is to refuse that the basic level of reality is superposed. This theory would thus need at this basic level hidden variables that could be able to explain the macroscopic or discrete state. This is the reason to consider the theory incomplete.
This is the line of David Bohm, which, due to its interest, I will treat in the following section, attending the particular interpretation of Davide Fiscaletti 2007.
According to Chalmers[31], GRW interpretation as well as Bohm's suffer from excessful complexity.
Option 5. In this interpretation, Schrödinger equation suffices, the collapse being unnecessary.
It is considered by Chalmers the cornerstone of quantum mechanics. The other theories always add something more to the equation, in order to explain the discrete state of the world, but the simplest interpretation is the one which assumes the equation as a complete description of the physical state of the world at any level, by means of the evolution of the wave function.
This is the 1957 interpretation of Everett by Chalmers in the version that he assumes and that we will see further along.

IV.1 Bohm's pilot-wave model

David Bohm 1952 developed an interpretation of quantum mechanics known as the theory of the "pilot-wave" that, contrary to the principle of randomness and causality, generated by the measurement, provides a causal description of atomic processes.
Based on the wave-particle duality, this model suggests that the wave "guides" the particle into the regions of its itinerary where the wave function is more intense[32].
The particle is subject to Newton's classical force laws as well as to a form of energy called quantum potential.
The wave function, without forgetting that we are dealing with mathematical mechanisms, acts as a pilot-wave that "guides" the particle through the action of the quantum potential. Therefore, in the theory of Bohm, the particle momentum does not manifest itself causally or at random, but driven by a "hidden field" (quantum potential) able to determine its trajectory. This potential is not subject to the laws of classical electromagnetic fields, whose action is relative to intensity and distance, but acts as a pure "form" or route.
Fiscaletti[33] proposes the metaphor of a boat powered by a motor (Newtonian function) but guided by a radar (quantum potential).
It is the quantum potential that actually determines the non-locality of microscopic processes and the instantaneity in communication of subatomic particles, as if it were a hidden reality level that guides and connects particles in a superposed or coherent state.
Thus, distant particles even at thousands light-years can communicate to each other.
In the 70s, Bohm proposed a distinction between foreground and background, or explicate or

[31] Ib. (p. 345-346).
[32] Note: the author should probably refer to states where the probability is greater.
[33] Davide FISCALETTI, La non separabilitá quantistica si dimostra come a livello fondamentale della realtá, lo spazio fisico abbia un carattere a-temporale 2007.

implicate order, as two levels of the description of physical systems; the former equivalent to the description or standard formalism of quantum physics of how the world appears to us once it has been measured, that is a fragmented world, and the second level, a hidden level, characterized by non-locality and non-separateness.

An exploration of physical reality, according to Bohm, requires distinguishing the "folded" aspects of its hidden, fundamental levels, from the "unfolded" levels, that correspond to what we see, as a manifestation of the former.

A similar distinction is expressed by Hawking-Mlodinov, in their treatment of dimensions of the space arising from the string theory, where the extra dimensions would be "curled" into an "internal space, as opposed to the three dimensional space that we experience in everyday life[34].

The exact shape of this internal space would determine the values of physical constants as the electron charge or the particle interactions and therefore determine the apparent physical laws that we observe in our world.[35]

To transmit his view of the world, Bohm uses the hologram (a 3D laser photography) metaphor[36], that has the property that each of its parts contains all the information of the whole.

Fiscaletti extracts various scenarios from the wave-particle dualistic model of Bohm:

- At the implicate or fundamental level of physical reality all subatomic particles are infinitely linked by the waves associated to each of them. As we will see, Henry Stapp criticized this proposal because it leads to a regression *ad infinitum*.
- These waves are not visible, and therefore we experience the objects of the world as separate.
- Associating the waves and connecting all of them together in an intricate network permits to give a causal and an intuitive explanation of the origin of the signals that are responsible of all the interactions, which facilitates their unified treatment.
- For this reason it could easily occur that in the implicate order the interaction between two particles is transmitted by a wave which is a combination of the two waves associated with the interacting particles.
- This hypothesis would occur in the interactions of the four forces.
- Applying the wave-particle duality to general relativity, where gravity unfolds itself as a modification of spacetime geometry, it could well be that a mediating entity caused that modification and therefore transmitted gravity, and that that entity were the wave associated to the particles.
- This perspective that Fiscaletti proposes is based on the philosophy of Bohm and discovers a new description of the physical world to which we should add the following proposal also made by the author as a possible explanation of quantum nonlocality.

Because our perception of the world does not allow us to establish that time is a real physical entity, since we can only perceive irreversible material changes both physical and biological or chemical of the physical space or matter, we can assert that the fundamental level of reality is an "a-temporal"

[34]Stephen HAWKING and Leonard MLODINOV, *The Grand Design*, 2011 (p.149).

[35] Ib (p. 151.) (Note: refers to the four forces: gravity, electromagnetism, strong nuclear and weak nuclear).

[36] Davide FISCALETTI Ib.

space. This "timeless" space, therefore devoid of speed, would explain the instantaneous communication of the particles and their entanglement.

The quantum potential would therefore be the "state" of the space at the level of interactions or subatomic processes.

According to Stapp,[37] Bohm's mistake consists in having unnecessarily complicated the theory; if mind had been included in the process, the theory would have been simplified. Stapp also considers that his views about implicate or explicate order lacks mathematical rigor.

Bohm 1986 and 1990[38] tried to involve consciousness in the theory, associating it to an infinite tower of pilot-waves, each of them piloting in turn the one below. However, this model loses itself *ad infinitum*. Another problem for Stapp is that the corresponding ontology of this model, that is deterministic rather than built on free options both of the agents as of nature as we see further, it is only possible in a world in which relativistic particles are neither created nor annihilated[39]. In this world, in the absence of collapse, reality would be "undifferentiated" and therefore constituted by indistinguishable objects.

V. QUANTUM MECHANICS AND CONSCIOUSNESS.

V.1.Henry Stapp: consciousness as a dimension of reality.

The argumentative strength of Stapp's theory 2011 rests on the following assumptions:

- The radical substitution of classical physics by quantum physics[40]
- The intervention of consciousness in quantum measurement processes
- Causality of consciousness on the physical processes

Regarding the quantum formalism Stapp assumes the orthodox Copenhagen interpretation, based on the postulate of measurement in the interpretation of von Neumann.

V.1.1 The two physics: two descriptions

According to Stapp, the difference between the two, is that the former is based on variables exclusively relating to physical facts mathematically expressible, while the latter incorporates psychophysical variables, the mental aspect, consisting in the stream of consciousness of the observer, which is translated into an increase of factual knowledge of the reality, without which no physical theory could even exist.

"Hence the foundation of usable science[41] lies ultimately in the mental world of human knowledge."

This aspect is not incorporated just as an ontological aspect, but the importance of it is that it comes

[37] Henry STAPP, *Mindful Universe* 2011((p.62-63).
[38] Ib.
[39] Ib.
[40]Note: since Dirac it is already accepted by theorists that classical physics is a particular case of quantum physics.
[41]Ib. (p.153).

with a unique property, causally independent and related to the discrete state of what we call reality, of what appears or is manifested. This is the orthodox view of quantum mechanics that Stapp assumes.

In this view free will, understood in the context of the theory we are considering at, as an undetermined choice, causally independent, incorporates into causally predictable physical processes, but without interfering with the way in which they are deterministically caused.

The feature that Max Planck discovered in 1900 declares the existence in nature of a "discreet" element "which is not naturally accommodated by continuous dynamics of classical mechanics". So describes it Stapp, quoting James[42] metaphor that "our knowledge "of natural phenomena at certain fundamental levels of matter grows" by buds or drops of perception".

This is precisely the conceptual change from one to another way of description of physical phenomena, and it relates primarily to the epistemological perspective of the description.

Stapp raises the question in this way.

Quantum theory developed a "classic" formalism for the equations to calculate the motion of atoms and subatomic particles, which is the Schrödinger equation, defined "classic" because the physical state that it states for the universe at each moment, fixes the state of the universe completely for future times. So it states the evolution of the universe as expected by the initial conditions.

The problem arises from the following approach: even assuming that at any instant of time the physical state of the universe is consistent with my experience in the present moment, such a state at any finite time later, as established by the Schrödinger equation, can never correspond to any possible experience of the class that corresponds to the flow of my conscious experiences[43].

Similarly, the human brain evolutionary states will not match to any possible experience. The brain state is identical to a state that is a mixture of a huge collection of possible experiences and not just identical to an experience of the kind of experiences that can be lived in the flow of our consciousness.

The solution that the "founders" of quantum mechanics, according to Stapp, were forced to assume, was to incorporate the "reality" of knowledge and the "acquisition" of knowledge to the descriptions of the theory.

This interpretation thus assumes this double perspective in the description of the phenomena that it handles, both ontological and epistemological, and consciousness reappears in science with a particular function.

Wigner describes it in this way:

"When the province of physical theory was extended to encompass microscopic phenomena through the creation of quantum mechanics, the concept of consciousness came to the fore again: it was not possible to formulate the laws of quantum mechanics without reference to consciousness"[44].

The mechanism that will facilitate the increase of knowledge, could be a phenomenon also assumed by the mathematical formalism of quantum theory called Quantum Zeno, which I will discuss in

[42]Ib (p. 154).
[43]Ib (p. 155).
[44]Ib. (p. 175).

section V.1.5.

This incorporation of human mind, ontologically and epistemologically, into the theory, requires the coexistence at the macroscopic level of a cohabitation or correlation with brain neural activity, but we cannot ignore the fact that the macroscopic level is "operated" or "acted" by microscopic quantum dynamics. As a result, the mixed state should occur also in the neural correlate of the state, also "continuous", of possible experiences.

For the classical description of physics and in general of neuroscience, as they opt for physicalism, our thoughts evolve in correspondence to our brain "state", assuming that they are two descriptions or denotations of the same reality. However, under the laws of quantum mechanics, as Stapp emphasizes, physical description would barely match the mental, violating in consequence the identity theory.

Even if Stapp does not mention the objection that also Kripke posed to the materialistic theory of mind-body identity, he leads a different line of discussion and saved the fact that the theory identity of mind and body alone deserves itself an enquiry, I reproduce the objection that Kripke 1971[45] performed to identity as a correspondence relation, that Stapp criticizes:

"If X = Y, then X and Y share all properties, including modal properties. If X is a pain and Y the corresponding brain state, then *being a pain* is an essential property of X and *being a brain state* is an essential property of Y. If the correspondence relation is, in fact, identity, then it must be *necessary* of Y that it corresponds to a pain and necessary of X that it corresponds to a brain state, indeed to this particular brain state Y. Both assertions *seem* false; it *seems* clearly possible that X should have existed without the corresponding brain state, or that the brain state should have existed without being felt as pain. Identity theorists cannot, contrary to their almost universal present practice, accept these intuitions; they must deny them and explain them away. This is none too easy a thing to do".

For both authors, these entities, the mental and its physical correlate, are rigidly designated and have essential properties, but Stapp argues for a causal relationship, with no room for the explanatory gap.

To achieve the match between both states or descriptions, according to the new physics, the "continuous" evolution governed by the Schrödinger equation must be abruptly interrupted by the acquisition of knowledge or the experience of the observer. Each subjective experience occurs in conjunction with a "jump" of the state of the brain (that was before in a “mixed” state and therefore called "quantum jump" by the "founders") during the experience[46]. The remaining brain states or possibilities incompatible with such experience are removed from that state and hence also from the state of the universe "physically" described, being this action" psychophysic".

For Stapp, the explanatory gap only makes sense in the classical description of physics and not in the orthodox interpretation of quantum physics, because there is a causal entanglement of the structure of our conscious experience flows, described in psychological terms and the representation of the physical world described in mathematical language.

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[45]Saul KRIPKE, *Identity and Necessity* New York 1971 (note 17 p.162).

[46]Henry STAPP, *Mindful Universe* 2011 (p.156).

Based upon this assumption, the classical concepts of neurobiology are logically inadequate and therefore false since, unlike what happens in quantum mechanics, they exclude our conscious thoughts.

Stapp repeats *ad nauseam* that classical physics, lasting for two centuries, emerged from the observation of the movement of the planets and other celestial macroscopic objects. This universe has been mapped into "miniature" versions of physical universes at a smaller-scale. Newtonian objects are described by the eminent physicist as "solid, massy, hard, impenetrable movable particles" (Newton 1704)[47], that interacted with each other through contact, as if they were billiard balls. And this would have lasted more if that action at a distance called gravity would have never appeared.

In the early twentieth century another entity revolutionized that universe: the observer. This entity also had a seminal importance in special relativity, but there, it was not conceived in the same way as in orthodox quantum physics by Stapp.

The "founders" presented their theory as a set of laws on how to make predictions of experimental responses that the human observer would experience in performing determinate actions. So far, there would be no difference from classical mechanics, if only because it makes predictions of the evolution of a system, given a time, a location and a velocity of each particle as well as its energy or field information. Here, the observers and their actions are part of the continuous evolution of the pre-determined system, while their stream of consciousness is empirically irrelevant or redundant in the system, a by-product, a correlation or a counterpart.

Under the new physics, however, the world "physically" described is not constituted by bits of matter but by "trends" or discrete "potentialities" for the events to occur. These events are actualized and when this occurs in a measurement process, it does "by buds "or" drops "of perception, as we saw before.

Each event is psychologically described and results in an "increase of knowledge". It is also physically described as an action that performs an abrupt change in the potentialities mathematically described.

This change is described by the measurement postulate.

V.1.2 The measurement postulate.

Wigner introduced the term "orthodox" to describe the formulation of the quantum theory of von Neumann[48].

Henry Stapp, in turn, includes in the term the Copenhagen formulation.

However, from the ontological point of view, according to Stapp, the term "orthodox" refers to the description of von Neumann, Tomonaga and Schwinger, that we will see briefly when we will treat the Whiteheadian ontology. This description covers the entire quantum universe described in

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[47]Ib (p.6).

[48]Ib. (p.55).

physical terms and contains both descriptions of the so-called Process 2 and the occurrence of the interventions of Process 1.

This is the form of the current theory, supported by the empirical experimental facts.

The only difficulty, and Stapp recognizes this, is to check whether macroscopic physical systems also interact with the environment as quantum-agent, in other words, if the state reductions occur in these systems. Because of this difficulty, theorists have designed alternative hypotheses or (non-orthodox) theories, as the theories of Bohm or Everett.

The difficulty of the measurement problem consists essentially on how to link the physical or mathematically described aspects of quantum theory to human experience.

According to the orthodox quantum theory, the observer affects the state.

The state reduction through which a mixed state, including in that of the brain, passes into the state of conscious experience, is triggered by what von Neumann calles Process 1, which selects from the set of evolutionary potentialities of the state of the system, called Process 2, a determinate way to separate or partition this state into a collection of components, each of which corresponds to a determinate experience.

The form of that "intervention" is not determined, as it is in Process 2, by a dynamic and definable "continuum" but by another class of input[49].

The choice that takes place in this "intervention" seems influenced by a kind of conscious evaluation: when I choose to look at the system, the system is modified.

Process 2 corresponds to the mechanically controlled and orderly evolution that occurs between Process 1 interventions.

In Process 2 the state of the wave function evolves spreading throughout the universe as the Schrödinger equation establishes, in a deterministic and probabilistic way.

But, as already stated, if the world behave macroscopically as the equation suggests, it would result in a "nebulous" wave. For this reason it is necessary to include Process 1, as expressed by von Neumann.

There is another line of discussion in which von Neumann, in *Mathematische Grundlagen der Quantenmechanik* 1932[50] addresses the connection between knowledge and physical processes by means of a version of Leo Szilard thought experiment, based on the second law of thermodynamics, which states that the entropy of a system tends to increase forward in time. Slizard takes in turn this experiment by a similar experiment, by Maxwell, known as "Maxwell's demon" that Slizard replaces by a mechanism capable to operate the selection[51].

The aim of these experiments is to argue that the intellectual process of knowing something and the consequent action based on such knowledge is closely related to the probability of entropy of the

[49]Ib. (p. 32).

[50]Ib. (p.168).

[51]Note: This experiment is known as the "Maxwell's demon", a thought experiment devised by the Scottish physicist in 1867 in which he imagines a demon strategically located near two adjacent containers, separated by a wall in which there is a gate, initially closed. One of them contains particles of two types: one get heated at a faster speed than the other. The demon, being so close to the gate, is able to distinguish each type of particles and opens the gate only to warm those that get heated faster. Thereby he achieves to separate any kind of particle in each container, hence violating the second law of thermodynamics that states that in an isolated system entropy increases with time.

physical system in question.
Von Neumann proposed that the modification in the knowledge given in Process 1 is quantitatively related to the probability associated with the entropy, so that, on one hand, the entropy of the system is not modified under the action of the Process 2 and secondly, it never decreases by an event operated by Process 1, since part of the components or energy of the system are transformed in information. Regarding Process 2 the result will be the same as in any classical system and Process 1 will give a definite answer, being specified as a probability associated with each possible answer and not as an answer itself. This response results in an increase of knowledge.
This is a "quantum version" of the second law of thermodynamics where the ratio of the increase of entropy is determined by the number and nature of the objectively actual events of Process 1.

V.1.3 The epistemologically perspective.

The historian Hendry 1984, in *The Creation of Quantum Mechanics and the Bohr-Pauli Dialogue*[52], explains how the founders (Bohr, Heisenberg, Pauli, Dirac and Born), in the 1927 Solvay Conference, found a solution to the difficulty of rational understanding of the data that atomic phenomena were showing. This solution was called the Copenhagen interpretation, due to the central role of the Dane Niels Bohr. The key cahracteristics of the solution according to Dirac[53] are its restriction of the theory to our knowledge of the system as well as its lack of ontological content. Thus, as Hendry argues, in this interpretation, the wave function represents our knowledge of the system, and the reduced wave packets represent our more accurate knowledge, after the measurement.
The human mind thus enters into the structure of the basic physical theory, as we have already seen. Stapp[54] excerpts the following reflection by Heisenberg 1958:
"The conception of the objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior".
In this initial interpretation of physics, instruments were treated as extensions of our bodies. It was not important whether the measuring instrument was mechanic or human, which left open some ambiguity about the process.
It was von Neumann who incorporated the entire universe, including therefore our own brain, as a physically described world, as well as the actions operated by the stream of consciousness of the experimenter while acting directly on it.
To this interpretation of von Neumann of the orthodox theory, it should be added the contribution of Heisenberg, which Stapp considers from the “technical”[55] point of view the principal founder of quantum theory, for it was precisely Heisenberg who realized that the quantities called numbers

[52]Ib. (p.12).
[53]Ib. (p. 13).
[54]Ib. (p.11).
[55]Ib. (p. 19).

used by classical physics should be treated as 'actions' and that the order in which they act is important[56]: it is not the same to multiply 13 by 3 as to multiply 3 by 13. Although they give the same numerical result, the action that they represent is not the same and this is important for a system. This resulted in the uncertainty principle of the German physicist that we treated in the chapter of the "new physics".

In classical physics, values such as position or energy are both an attribute of the system state and an 'observable', therefore a quantity that can be measured by an observer at any given time. Possible values of a system will be a 'phase space' in which there are all the potential 'states' of the particle.

A phase space is the set of possibilities of observables at any given time. For example, given a system like a pendulum in motion, it will have a position and speed at any instant of time, and this forecast is deterministic, given certain initial conditions. If instead the pendulum were quantum, we could not determine its position or its speed but a 'cloud of points' in which either of them could be when we make the measurement.

In quantum theory every possible measurement will be associated to a number of different experiential outcomes that constitute the 'cloud of points' or 'numbers cloud', being those numbers complex.

The theory provides specific rules that compute the probabilities for each of the various possible outcomes of the experiments of each of the measurements (position, energy, etc.), however measurements are not governed by any rules, since they are a result of our free choice.

The properties of matter are represented in terms of properties mathematically described related to space-time points, but its essential nature is made up of 'potentialities' of occurrences of psychophysics events[57].

These events occur at the interface between the two aspects of nature and von Neumann has shown us the laws that regulate this interface or interaction[58].

Stapp translates these facts on the philosophical level as the replacement of elements of 'being' by elements of 'doing', from the world of material substance to the world of actions and potentialities, both resulting in a increased of knowledge[59].

There is a further fact that Stapp introduces in the theory, of great importance in order to produce the acquisition of knowledge that is the Quantum Zeno[60] effect, at which we will dwell on (see Section V.1.5).

V.1.4 The ontological perspective. Whiteheadian Ontology.

Although the founders pointed out a lack of ontological content in the theory of quantum systems behavior, Stapp believes that conscious experiences are ontological realities rather than just bits of

[56]Ib.
[57]Ib. (p.181).
[58]Ib. (p.182).
[59]Ib. (p. 20).
[60]Note: The name is inspired by the paradox of Zeno's arrow.

knowledge[61] and proposes Whitehead's ontology, based on the Whiteheadian conception of the natural processes of nature as a whole, as a model for such behavior, although he is aware of the danger of falling into the anthropocentrism due to the inclusion of the observer in the ontology. He presents the Whiteheadian ontology as a variant inspired by Tomonaga and Schwinger, taking into account also Heisenberg and von Neumann, due to the fact that their relativistic proposal, in Stapp's view, is very close to the key ideas of Whitehead, who in turn tries to reconcile the mechanics of the 20s of the twentieth century with classical philosophy.

The core of Whitehead processes and quantum processes is constituted by the emergence of the "discrete" from the "continuous". The graphical representation of the evolution of the process consists of a circular wave that travels from the center to the ends and that reaches by chance the detectors barrier, firing only one of them. It can be assumed that it occurs with the measurement, since Stapp does not mention it.

The space of possibilities is reduced to a set of discrete subsets.

Why does this change occur? We know that the answer of orthodox quantum theory is that it is the experimenter who decides, the experimenter, who is in turn a set of possibilities that are updating at any moment.

Von Neumann named this fact 'intervention' or Process1. Heisenberg and Bohr, called it "a choice o the part of the experimenter"[62]. Stapp calls it "process zero", and this process would select the "partition" specified by the process described "in physical terms" by Process 1.

What Stapp actually says is that the process of measurement or von Neumann's Process 1 is split into two processes: that that the experimenter chooses (free choice process) at will and that that nature 'decides ', randomly, offering any of the possible options.

The first process is beyond any calculation or algorithm and therefore outside of any "physically described" language. In other words, the partition does not derive from "physically describable" aspects of the world acting exclusively on their own. The discrete cannot be created by the continuum, and the intervention of Process 1 is necessary.

Stapp proposes the following operating schema to propose a design of the "modified" Whiteheadian world, as he calls it, incorporating the theories of Tomonaga and Schwinger:

- On the basis of the key ideas of Whitehead, space-time aspects of the process of creation of reality/knowledge of reality, are formed.
- Afterwards, the ontological structure conceived by the relativistic quantum field theory of Tomonaga and Schwinger is described, and with these elements consistently ordered, the space-time quantum process is designed.
- The next step is to perform a comparison of the two descriptions to define their identity and hence to propose a unified and non-anthropic ontology.

Stapp is aware that the proposed ontology is not exhaustive, but it will certainly prevent the panpsychist drift.

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[61]Ib. (p.106).

[62]Ib. (p.89).

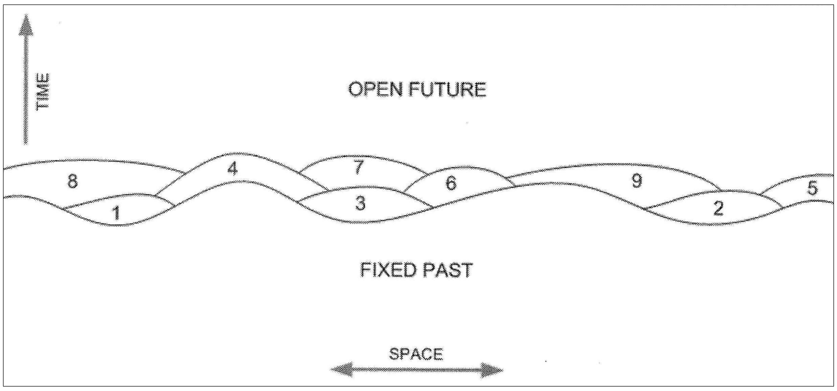

Figure 1[63]

In the graphic, a different number is assigned to each piece or region of the space-time with common boundaries, and they form altogether a surface above the line of the past and below the line of the future.

The pieces are the entities that Whitehead called "actual entities"[64] and that correspond to the "buds or drops of perception" described by James, through which we acquire the knowledge of the world.

They are "discrete" entities that "make real", in words of Whitehead in *Process and Reality*[65], “what was previously merely potential”.

This space-time, which represents the growing process of the past, is contrasted by Stapp with the corresponding idea of non-relativistic quantum physics (NRQT), consisting of an overview of the theory that violates the principle of special relativity, which states that no force and object can travel faster than the speed of light. To this theory, each quantum event or reduction (Whiteheadian buds) occurs, however, in a determined "now", but in the whole space.

Stapp represents this structure of the space-time in another diagram (Figure 2) where events are represented as a set of parallel lines numbered from the past into the future or "interventions" associated with each jump to a new quantum state ψ (t).

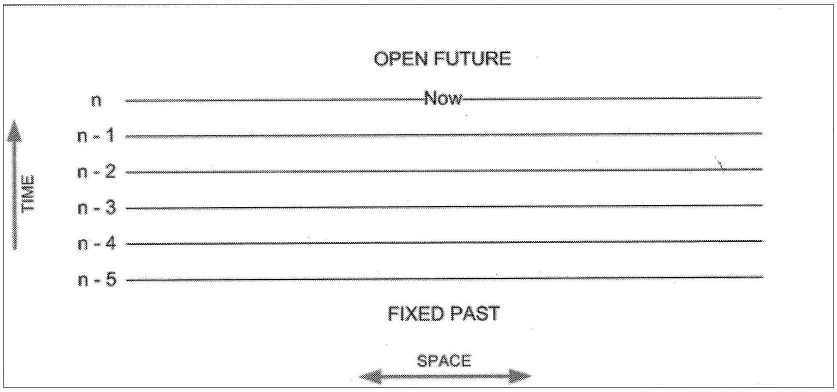

Figure 2[66]

[63]Ib.Note: This figure corresponds to figure 13.1 of the book (p.92).
[64]Ib. (p.90).
[65]Ib. (p.91).
[66]Ib.Note: this figure corresponds to figure 13.2 of the book (p.93).

Each line corresponds to a continuous spatiotemporal surface made of points. Being continuous, no speed limit is accepted, according to special relativity.
This non-relativistic space-time structure is replaced by relativistic quantum field theory, as developed by Tomonaga and Schwinger 's relativistic, wich a similar structure to that of Whitehead and Stapp shown in Figure 1.
Stapp thus purports to show that with these structures or separate pieces of the space-time the principle of special relativity is preserved and our information of the system and therefore of reality increases, since the transition from a 'potentiality' to an 'actuality' occurs during the act of observation. Each space or portion of activity represents an "actual occasion".
This ontology is accommodated by Stapp in his work. Being described both physically and psychologically, it is not anthropocentric since an "actual occasion" is an event whose mental output is conceived as an 'addition' to the human stream of conscious events, being the physical described output the actualized neural correlate of the neural output[67].
Stapp is aware that this ontology is not "implied" in the current empirical data rather than at an outlined level, but he maintains however, that it may be considered as a rationally based proposal to take into account all along the research results.

V.1.5 The Quantum Zeno effect.

The correspondence that, on Stapp's account, occurs in our brain as a quantum system, between the completion of actions and quantum potentialities and the highly organized neural states, occurs due to a causal process.
He calls "templates for action" a macroscopic brain state that, if sustained in time, allows certain action to occur, as it leads in the case of actions based on trial and error, to make choices between 'yes' and 'no', equivalent in turn to von Neumann's Process 1.
If we choose the answer 'yes' and we keep it during a certain time, it will result in the success or the achievement of the intentionality.
Behind this process there is a mental effort that, if maintained, would be equivalent to successive measurements of the state and would result in a greater ability of the agent and therefore in an advantage over his or her competitors. Using the descriptive terms of Stapp, 'realities' 'mentally' described shall take effect on the brain 'physically' described realities.
This effect is called Quantum Zeno effect[68], mathematically described by quantum mechanics.
This effect is considered by Stapp as able to explain the result of the placebo effect experiments, conducted by Price et al. 2007[69], in the respect of certain patients suffering from irritable bowel syndrome, where a high percentage of them experienced a remission of the symptoms. The fact was monitored by fMRI, in which they observed the neural correlates during the remission of symptoms, coincident with the attention that the patients were paying to the Instructor words

[67]Ib. (p.97).
[68]Note: metaphorical name given by physicists Sudarshan and Misra 1977 inspired by the paradox of Zeno's arrow.
[69]Ib. (p.147).

indicating in turn how the remission of the pain would take place.
In Figure 3 we see represented the evolutionary state of a brain quantum system whose macroscopic physical structure is composed by microelements as ions and atoms whose behavior is of microscopic dynamics.

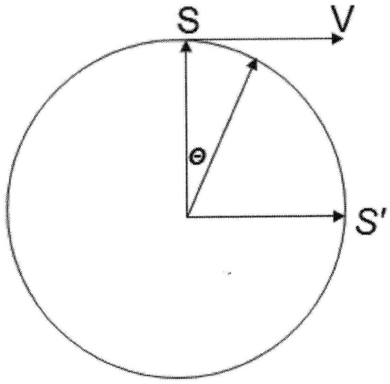

Figure 3[70]

In this case, the pattern of neural activity would be equivalent to a pointer or a measuring instrument of whatever system, and it will represent the abrupt physical event sequences that would be the neural correlates of mental event sequences.
According to the Schrödinger equation, the state of a system, in this case the brain, will be evolving as any other pointer and will consist in a combination (mixed state) of many components of the kind of experiences that we humans usually have.
As we have seen, the founders resolved this situation, that did not allow to actualize a concrete experience, incorporating the observer (Stapp does not distinguish between a conscious or an unconscious observer since the phenomenon takes place in both conscious and unconscious acts) to the theory.
Thus, a physical system that acts as an observer is able to do measurements. Each of them extracts a quantum state 'S' of the 'pointer' that is being observed[71].
This state 'S' corresponds to a possible experience of the observer.
As soon as the observer chooses that state 'S', nature, under the laws of quantum physics, immediately responds with a 'reduction' of the wave packet, or quantum collapse. This reduction is represented by a 'quantum jump' of the actual quantum state to a selected state 'S' to another state 'S''.
The probability that the state shown in Figure 3 as angle θ would jump to the experientially realizable selected state, 'S', has assigned a calculable value (expressed in probabilities). In figure 3, V indicates the pointer’s speed.
In other words, if the observer chooses to perform the measurement, which will cause the pointer (state or wave function) to jump to the state 'S' and if nature "decides" to respond to the

[70]Ib. Note: it corresponds to figure 17.1 (p.150 of the book).
[71]Ib. (p.149).

measurement, the vector will effectively jump to 'S '. It may also jump to ‘S ’’, but with a lower probability in the case of Figure 3, as the arrow or pointer is closer to ‘S’ than to ‘S’’.

Once the measurement is done, the vector will rotate to 'S' and the angle θ will progressively increase. If the measurement is repeated ata a later moment, the vector will jump as well from 'S' or to 'S''.

Quantum Zeno effect entails that if Process 1 is repeatedly performed in a short period of time, the spread of the action will be blocked and the state of the brain will be essentially restricted to the response 'S'[72]. In the case of the biological mandate 'fight' or 'attack' it can also be prolonged until response occurs.

Templates for actions is a macroscopic layer (that can cover a large portion of the brain) of neurological activity that, if maintained in time, tends to produce a cerebral activity, which in turn will tend to produce the experienced response[73]. This layer is the neural correlate of the conscious effort made to operate a determinate action.

V.1.6 Author's Conclusions

After more than fifty years of research in quantum theory, Stapp still thinks that the theory is able to reconcile opposite attitudes, pluralism versus monism, idealism and materialism, determinism and free will. His thinking has not changed, but it has been enriched with the research.

He still thinks that in order to obtain a useful scientific theory, the mathematical aspects must be bound to those of our perceptual experience. The mathematical structure of quantum physics is such that the classical materialist physical conceptions of nature does not work, because the founders of quantum theory had to incorporate the conceptualization of potentialities and of the empirical facts corresponding to the reduction, into the mathematical descriptions.

By the 'partition' of the potential state, the theory is linked to human experiences and to rules empirically validated by the theory.

The effect of the reduction occurs throughout the layer of the brain and links the "intented experience" with the experience of the "response" which in turn comes from memories of passed experiences[74].

It is plausible to surmise that these experiences are caused by an increase in the timing *ratio* of actions in Process 1 whose persistence in the neuronal layer may allow intentional action to occur (Quantum Zeno effect).

The effect will consist in keeping the information or 'template for action', as it is called by Stapp, at the macroscopic level.

Quantum theory has the 'technical' ability to explain how the efforts of human consciousness can influence the bodily actions, as it is considered in James assertions[75], which are still up-to-date:

[72]Ib. (p. 76).
[73]Ib. (p.111).
[74]Ib. (p.114).
[75]Ib. (p.115).

"Consciousness seams to be an organ superadded to the other organs, which maintains the animal in its struggle for existence (...) But if it's useful, it must be so through its causal efficaciousness and the automaton theory must succumb o commonsense".
Stapp has defended himself from the danger of anthropocentrism by recourse to Whiteheadian ontology.
Concerning the danger to fall into circularity about when consciousness did emerge, he says that "laws that cause, or allow the physical prerequisites to come into being should not depend on a consciousness that come into being only later"[76].
Such laws should allow, nevertheless, the potentialities to occur and, therefore, the experiences to happen.
The theory of 'observation' here presented, so experimentally 'successful', must be for sure a process aspect of the nature of reality.
The nature of this reality cannot be of the kind of those conceived by classical physics that exclusively consists of objects and fields, with no place neither for the mind nor for consciousness.
Quantum mechanics instead, tells us that even the physical aspects of nature do not fit conceptually to the qualities that classical physics assigns to rocks, since in quantum theory these aspects are mere potentialities of actual events to occur.
A potentiality is more an idea than a material substance and so is treated in the theory, an idea of what can happen. Objective reality is tinted of “idealike” qualities, both at the level of "objective potentialities" as at the level of psychophysical occurrences.
These “idealike” qualities are linked to conscious experiences, albeit they seem to be "carved" into the structure of quantum theory itself as a theory of potentialities.
Such “idealike” aspects of nature are not accidental but features of a natural process that tends to preserve and extend an “acknowledged” order.
This teleology of the order is also found in the last quantum approach to consciousness that we will present.
This last theory is based on a non-Cartesian "quantum interactive dualism", as Stapp himself describes it.

V.2 Other models.

V.2.1 The Everett interpretation (seen by Chalmers).

This interpretation, rather than supporting a causal random choice or one among many possibilities, tries to accept simultaneously all the possibilities in simultaneous actualities, without collapsing into one.
"In other words, the probabilistic nature of quantum mechanics allows the universe unfold in an infinite number of ways”[77].

[76]Ib. (p.135).
[77]Piero SCARUFFI, La nuova física: l’asimmetria omnipresente 2003 (p.21).

If the Schrödinger equation is in fact everything, then the world is superposed at any level even if it does not seem so[78], and the observer perceives an homogeneous flow of changes, a 'discreet' world.
Why? Everett's response, according to Chalmers, is because the overlap also occurs in the mind: the state of the observer's brain is in a superposition of states, one in which the measuring device pointer points up and another state where the pointer is pointing down. Hence, there will be two observers.

This interpretation differs from that of "splitting worlds" attributed to Everett, which contemplates a universe literally divided into two or many multiverses, where in one the pointer points upwards and in the other it points downwards. This interpretation, by Chalmers, somehow revives the measurement problem, for it cannot be known when the partition will occur.

In the first interpretation, which is also the interpretation of Lockwood 1989, no division occurs, but an evolution of the wave function in which the superposed states are constituents of a sole world, where what are divided are the minds of the observers[79], that perceive a "mini-world" as opposed to the sole world or "maxiworld", that is superposed.

We have a state of the world "relative" to the observer and another, "objective" world, which is superposed.

However, the failure of Everett, according to Chalmers[80], is not to analyze the mind-body dichotomy. He assumes that a brain state has different associated experiential subjects, but he does not justify why consciousness perceives only one of these states.

It should be noted that Henry Stapp[81] criticizes Everett's interpretation at a fundamental level because if it were true that the Schrödinger equation alone, including along its route all the interactions with the (macroscopic) environment, suffices to match quantum mathematics to experimental data as a result of the application of this theory, the universe would also have evolved from the big bang exclusively under the influence of the equation, in which case all objects, including our brain, would be in a "amorphous continuum"[82]. Thus, the need to step with the help of the theory of many-minds, where all the parts of our brain would be accompanied by the corresponding experience of the object in question, not being in a single place, but in a continuous aggregation of experiences, one for each location of the object in the vast region of the overall wave function.

Stapp also considers that the many-minds problem is the problem of the measurement[83], but we will see how he proposes and assumes a possible solution to the problem.

This lack of justification enables Chalmers to refocus the dilemma of the relationship between physical processes and experience, of how to discern why the world is superposed and yet we still perceive it "discrete".

Chalmers finally finds an answer in the foundations of a theory of consciousness based, without

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[78]David CHALMERS, *The conscious mind* 1996 (p.347).
[79]Ib. (p.348).
[80]Ib. (p.349).
[81]Henry STAPP, *Mindful Universe* 2011 (p.59).
[82]Ib.
[83] Ib. (p.60).

avoiding dualism, in its explanation from the perspective of an adequate computation[84], where the maximum information of an original physical state P would be superposed to the formalism of the phenomenal physical states of the experience:
"The same information spaces are realized physically and phenomenally"[85], settling hence the double aspect of information as a "physical space" as well as a "formal space".
The structure of the experience is the structure of an information space
phenomenally realized, and the structure of awareness[86] is that of an information space physically realized. A conscious experience would be the realization of an information state[87].
To my knowledge, this suggestive hypothesis, which poses the question to a theory of knowledge, that I mentioned in the first part of this text and that would require further development, could fit into Stapp’s epistemological assumptions.

V.2.2 The Penrose-Hameroff model.

The model was presented in Tucson (Arizona) in 1994.
It incorporates and combines the knowledge and researches of Roger Penrose and Stuart Hameroff.
Penrose assumes that physical laws can yield actions that are not algorithmic and therefore not simulable, pointing to consciousness as a possible influence.
Out of skepticism concerning the measurement problem- which Stapp considers as a way to include consciousness- Penrose develops the hypothesis of an objective reduction due to quantum gravity, conceiving that gravity could yield the phenomenon of consciousness.
Hameroff, for his part, makes his contribution to the research based on the behavior of microtubules as candidates for the location of consciousness.
Microtubules are tubular structures of eukaryotic cells each being a protein, constituted by proteic subunits called tubulins. They have an outer diameter of approximately 24 nm and an inner diameter of 14 nm. In neurons, microtubules and intermediate filaments extend along axons and dendrites from the cell body to its terminal. Being highly dynamic structures, they are stabilized by a group of proteins known as microtubule-associated proteins (MAP's)[88].
Tubulin shows two different states of electrical polarization that would allow propagation of the complex type signals along microtubules, analogous to a cellular automaton[89].
Together Penrose and Hameroff 1994 conceive the "orchestrated objective reduction" (OR) model, that states that quantum superposition phenomena occur inside the microtubules, where coherent states of quantum computing[90] can be maintained by recourse to the action of gravity. Also inside

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[84]David CHALMERS, *The Conscious Mind* 1996.
[85]Ib. (p.288).
[86]Note: here Chalmers uses the word *awareness.*
[87]Ib. (p.293).
[88]Oscar CASTRO GARCÍA Aspectos biosemióticos de la conciencia: en búsqueda de los signos significativos de la vida y su autoreferencia en la conciencia como principio teleonómico 2006.
[89]Ib.
[90]Ib. Note: according to the author, the concept of *coherent* corresponds to oscillations of the same wavelength, being

the microtubules the self-collapse takes place. This collapse or objective reduction is, according to Penrose, a non computable activity.

A sequence of OR processes, where R is equivalent to von Neumann Process 1, would result in flows of consciousness.

The argument of non-computability of consciousness, assumed by Penrose in *Shadows of the mind* and known as "the new Penrose argument"[91], due to the fact that the author maintained different foundation criteria, considers that contemporary physics does not have elements to provide such a possibility. For this reason physics is incomplete or wrong, hence a new physics needs to be developed.

Penrose defends his argument on the grounds of Gödel's theorem, as Gödel demonstrated that there are mathematical truths that we know both they are true and at the same time unprovable and therefore not computable.

He uses his argument to substantiate the superiority of the human mind over the machine.

For this reason, Penrose appeals to quantum physics and to the measurement postulate, except that he conceives in this case that the collapse happens when the system interacts with the environment, without the need of any observer.

In the Penrose-Hameroff model the criterion is "objective" and precipitates the (objective) reduction of the state function, being the gravitational property of spacetime that will reset its geometry[92].

Grande García explains the OR process as follows, comparing it to that of the standard or orthodox theory:

"An important feature of OR is that non-computable aspects arise only when the quantum system becomes so large that the state suffers a self-collapse, in place of a state of collapse, due to the fact that its growth forces the entanglement with the environment. Due to the random nature of the environment, the action of OR, which is the result of the induced-growth of the entanglement would be indistinguishable from the random SR (subjective reduction), or R processes of standard quantum theory. (..) In standard quantum theory no activity is not computable, and R processes are completely random"[93].

According to Penrose, a threshold of time is needed for the self-collapse to occur, being that time proportional to the magnitude of the overlapped system. Thus, if the system is large it will quickly collapse, if small the superposition shall be maintained.

In the model, consciousness events occur in the range of 25 ms at 40 Hz coherent oscillations, and of 500 ms in the preparatory events of a conscious act.

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ordered and coordinated waves whose upper and lower cusps are interrelated in a way that they can superpose each other. Thus, waves of a coherent field behave the same way, so they can transfer information and string together into a whole cells, tissues and organs (Baines, 1998). This phenomenon refers to circumstances where large numbers of particles can cooperate collectively in a simple quantum state that does not remain entangled with its environment. Such states are spectacularly given in superconductivity phenomena, where the electrical resistance drops to zero, and in superfluidity, where fluid friction or viscosity drops to zero. The particularity of these phenomena is the existence of an energy gap that has to be overcome by the environment in order to perturb this quantum state.

[91] Israel GRANDE GARCÍA, *El modelo cuántico de la conciencia de Penrose y Hameroff: una introducción y evaluación crítica* 2006 (p.22).

[92] Ib.(p.30).

[93] Ib.

However, there are some acknowledged facts, as Grande argues[94], that affect coherence to take place in the brain: if the ambient temperature is very high, an equally high energy of the particles would be needed to alter the consistency and hence yield the collapse. The necessary superconductivity to produce the phenomenon occurs only at very low temperatures, close to absolute zero, not reachable by the brain state.

Nevertheless, Fröhlich, in the 60s, proposed that superconductivity could occur in biological systems, particularly in the membranes of cells.

Penrose and Hameroff, by contrast, proposed microtubules, due to their adequate structural and functional properties, namely to the structure of water inside them, to the field and to the isolation property of microtubules themselves, that would allow to maintain the coherence state.

Thus, microtubules are proposed as quantum computers.

When asked whether the phenomenon of macroscopic coherence occurs in all the brain microtubules or only in some of them[95], Hameroff suggests that it is the quantum tunneling effect that allows the coherence between synaptic clefts, triggered by the synchronized firing of the neurons.

Grande[96] considers that Penrose-Hameroff's theory has however fissures: there are no evidences of correlations between the structure of microtubules and consciousness, being coherence at brain big scale an hypersynchronous activity that can only occur in seizures episodes. On the other hand, the fact that the frequency of 40 Hz is the necessary link for conscious experience to occur, is not the only explanatory fact of consciousness. Finally, there is evidence showing that general anesthesia acts in different parts of the microtubules, and not only consciousness is affected but also speech or thinking activity.

Realizing some criticism regarding the Penrose-Hameroff theory, including that of Max Tegmark, Stapp uses the occasion to revalue[97] von Neumann's description that conceives the brain as a collection of classically described possible states able to survive the decoherence by means of the Quantum Zeno effect. Furthermore, although this argument might seem common to both theories, Stapp's version is also not algorithmic, however this quality in Stapp, as we have seen, is based on the criterion of the "free choice" of the agent.

In any case the Penrose-Hameroff theory points out to what some authors, as Hu[98], call the "narrow problem" of research, aimed at studying the way how a quantum effect as coherence occurs in certain locations or neural substrates delivering a cognitive correlation. However, the "broad problem" which, in my opinion, Stapp chooses to tackle, is the part of the theory that leads to the fundamentals and to the relationships of quantum mechanics with consciousness, preserving an ontological and an epistemological vocation and inflection.

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[94]Ib (p.30).

[95]Ib. (p.49).

[96]Ib. (p. 57).

[97]Henry Stapp *Mindful Universe*. (p.51).

[98]Huping HU & Maoxin WU, *Current Landscape and Future Direction of Theorethical and Experimental Quantum Brain/Mind/Consciousness Research* 2010.

V.2.3 Model of consciousness based on the double solution of the wave function.

This model is extracted from the "unitary" theory of Fantappié 1941, that in the classification made by Vannini[99] is ranged among the models of consciousness based on quantum mechanics, to which a principle of order is adscribed aimed at yielding and organizing the properties of consciousness.
In this theory, special relativity is observed.
According to Vannini, the following models propose the property of order as "consciousness-structurer", based on quantum formalism:
Fantappié 1941
Ricciardi-Umezawa 1967
Frölich 1968
Pribram 1971
Eccles 1986
Marshall 1989
King 1989
Yasue 1995
Vitiello 1995
Flanagan 2003
Pereira 2003
Hu 2005
Baaquie 2005
Hari 2008
Fantappié attempts to synthesize relativistic physics, that provides an essential link between space and time, and quantum physics, in its double aspect corpuscular and undulatory, to show that nature in turn has a double aspect or tendency, both to order and to disorder[100], on the basis of the equation of d'Alembert and its operator, used in wave mechanics, which admits two solutions: the retarded potential solutions, that describe the waves diverging from the source that produced them, and the anticipated potential solutions, that describe the converging waves from a source situated in the future.
The same effect of propagation in time is conceived in the quantum undulatory physics of the Dirac equation and of Klein Gordon's equation.
In 1928 Dirac formulated an equation describing the behavior of electrons in atoms of hydrogen and realized that the equation admitted two types of solutions[101], representative of electrons with positive energy (retarded potentials) and electrons with negative energy (anticipated potentials).
Also the solution of the Klein-Gordon equation can yield mathematically two types of solutions since it depends on a square root of the squared values therein contained.
The practical result of the anticipated potentials solutions are excluded by physicists, as Poincaré[102],

[99] Antonella VANNINI, *Modelli quantistici della coscienza* 2008.
[100] Giuseppe e Salvatore ARCIDIACONO, *Sintropia, Entropia, Informazione* 2006 (p.7).
[101] Ib. (p.20).
[102] Ib.

when considered not existent in nature while, in contrast, the former can be reproduced in laboratory.
However, Vannini[103] considers that noticeable physicists have researched and still continue the research based on this conception of time, naming Richard Feynman among them, who designed some diagrams representing the trajectories of electrons that are annihilated in contact with positrons, releasing a big amount of energy.
Yoichiro Nambu 1950, Nobel Prize in Physics 2008, conjectured that what is represented in Feynman diagrams are not annihilations, but a change of the direction of the particle itself from the past to the future or vice versa.
In the same direction of thought we find John Wheeler proposals or Michael Dummett's retrocausality.
Fantappié's theory assumes the above equations as a reference on the basis of an unique ontology of time, a one-time "past-present-future" dimension, and considers that the first class of solutions is applicable to "classic", continuous, wave propagation phenomena, but in discontinuous phenomena such as quantum, where centers of emission and absorption are discontinuous and therefore concentrated in isolated points due to their corpuscular nature[104], the second type of solutions must be applied.
Thus the Italian mathematician concluded that divergent waves correspond to entropic phenomena, while converging to a type of phenomena that he used to call "syntropic"[105].
The former phenomena, that are causative, tend to scattering and are replicable in laboratory; the latter are not causal, tend towards concentration and they are not replicable because, according Fantappié and Arcidiacono[106], the intensity of the converging waves does increasingly concentrate in smaller spaces. However, they consider that in nature there is an exchange of syntropic and entropic phenomena and that it prevents that concentration becomes infinite.
Arcidiacono quotes Teilhard de Chardin's[107] "tangential" and "radial" energies, due to their parallelism with these phenomena, as cause of the progressive process of increasing "complexity" of the matter that, according to him, causes the increasing organization and brain evolution of living beings and therefore a greater awareness capacity. This capability is proposed as the "third infinity" besides the spatial and temporal.
Also by Arcidiacono[108] and *ex* Brillouin, the energy levels of a system are assimilated to the information levels that the system bears. We already saw this hypothesis in von Neumann, so that to lower levels of entropy, larger levels of information correspond.
The development of life is stipulated, in these theories, according to this alternating phenomena.
Fatappié proposes, in fact, as an example of entropic phenomena in living beings, breathing or degenerative processes caused by disease and among syntropic, growth, nutrition or protein synthesis, the latter prevailing in the early stages of life.

[103] Antonella VANNINI, *Modelli quantistici della coscienza* 2008 (p.80).
[104] Giuseppe e Salvatore ARCIDIACONO, *Sintropia, Entropia, Informazione* 2006 (p.18).
[105] Antonella VANNINI, *Un modelllo sintropico della coscienza* 2009 (p.156).
[106] Ib. (p.28).
[107] Ib. (p. 52-54).
[108] Ib. (p.70-72).

Fantappié hypothesizes that as far as living systems are incompatible with the laws of entropy that governs the macrocosm, the basic laws of life must be searched at the microscopic level, where the governing laws are quantum mechanics and where syntropy which enables to create and to order the structures primarily reflected in DNA. He hypothesized that the autonomic nervous system (ANS) locates the structure of living systems intended to supply of syntropy life processes as well as processes of regeneration of the body. This conjeture lead him to surmise that psychophysical parameters of ANS such as heart rate or skin conductance, are somatic markers of anticipation processes, as he considered that the ANS is nourished in turn by energy, formally represented by waves moving in the opposite temporal direction[109].

Another argument used by those who adhere to the converging wave theory based on the Klein Gordon's solution, is that living systems are continuously faced to the choice of taking decisions between causes located in the past and causes located in the future. The success of these elections can not be determined *a priori*.

In Vannini's research, aimed at demonstrating the Fantappié hypothesis that in living beings that operate decisions, this kind of anticipated responses occur, data are collected and obtained from a series of experiments based on statistical techniques performed by Tressoldi et al.[110], of the University of Padova, that could lead to the conclusion that the tested subjects experienced this type of "anticipated response" or " retrocausal effects" of unpredictable sequences of questions. Somatic markers as heart rate and skin conductivity of the subjects were used in the experiment.

The models here presented do not explain consciousness, yet they provide elements of interest that could be taken into consideration in a research that could also take into account biological phenomena and not only physical.

Regarding retrocausality, as Fantappié conceives entropic phenomena, as causal phenomena, and syntropic phenomena as retrocausal. Cuesta[111] contemplates the theoretical plausibility that causal facts can be transmitted backwards in time. In his analysis of the causality in the EPR correlations (this is a thought experiment proposed by Einstein, Podolsky and Rosen in 1935, which shows quantum non-locality and the phenomenon of quantum entanglement between particles, so that, given two particles and performed the measurement of an observable in one of them, we would immediately know the observable of the other and his would violate the theory of relativity) he comes to the conclusion that the effects of causal influences of quantum phenomena can be transmitted backwards in time. While recognizing that this assumption may cause complications or difficulties, he asserts that "for years now that the traditional arguments against backward causation have been refuted" (here he also quotes Dummett) "and, moreover, several causal models of EPR correlations that make use of this possibility are in various stages of development at present".

[109]Antonella VANNINI, *Un modelllo sintropico della coscienza* 2009 (p.157).
[110]Note: The development of the experiment is widely described in caps. 5, 6 of *Un modelllo sintropico della coscienza* 2009.
[111]Mauricio SUÁREZ, *Procesos Causales, Realismo y Mecánica Cuántica* 2007 (p.20).

VI. CONCLUSIONS.

The hypotheses linking quantum physics and consciousness here presented, assume consciousness as a given, without trying to determine its nature.

Taking its existence for granted, they incorporate it into the causal flow of the physical facts, thus in the case of Stapp and by Penrose-Hameroff. This is also true in Noë, although he does not involve quantum mechanics. According to Chalmers, this irreducible stochastic element breaks logical causality.

Quantum mechanics has discovered that the microcosm, at its fundamental level, has different properties than those of the macrocosm, properties lacking grades of definition or of determination of the macrocosm, however raising considerably the predicting values of the behavior of the matter.

Quantum mechanics, interpreted as Stapp does as well as the followers of the orthodox view of the theory, claim that observation allows the properties to be defined.

The Spanish physicist Juan Ignacio Cirac[112] argues that all theories that have tried to refute this assumption, have been refuted in turn by the experiments of quantum mechanics and that quantum superposition is the price we must pay for the postulate to be maintained.

In a short period of time we have passed from a deterministic and continuous universe to a universe that is possible, probable, current and discontinuous.

Stapp, Noë and Fantappié consider consciousness as an evolutionary phenomenon or property, causally related to the properties of order, organization and increasing knowledge and/or information. Chalmers also argues that at a fundamental level, psychophysical states can be explained as information statesor information spaces.

In any case, at a fundamental level, the universe behaves according to the laws of quantum mechanics.

From all the scenarios, perhaps the one that I believe could achieve the grade of "model" in the definition given by Hawking, is Stapp's model, even if it still lacks of the attribute of falsifiability, thus considering it veritable and rationally possible and consistent with the theory whose application shows experimentally that when a particle is observed its nature is changed, we cannot falsify it.

We cannot state why nor when the modification occurs, but that is how nature behaves at least as far as this has been shown, so far, to science.

We are only at the beginning of this puzzling investigation of the properties of matter that have turned upside down our way of interpreting reality.

Stapp, based on von Neumann, raises consciousness at the grade of dimension of reality itself. This "interactive dualism" evokes the descriptive power of Xavier Zubiri when referring to the interaction of human consciousness with reality as "impression of reality", similarly to the actualization described in Whiteheadian ontology.

If this is due to the collapse of our brain state, we cannot yet verify it, as well as we cannot verify neither Quantum Zeno phenomenon by means of its attentional correlate.

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[112]Note: conferences of J.Ignacio Cirac at UIMP (Santander, Spain) august 2011.

Aczel[113] considers that fundamental questions arise about whether macroscopic objects, such as our brain or our body, are in a mixed state or are not, although he says that, presumably, and based on quantum formalism, they are in a mixed state. Nor we do know whether a living being is composed of a set of particles with an associated wave to each of them or wether we should treat it as a single macro-object with a single associated wave function.
We should expect more and more experimental results from the research.
In the meantime, we can only continue to reflect.

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