Philosophy Study, ISSN 2159-5313
October 2012, Vol. 2, No. 10, 689-703

A Conceptual Framework for Consciousness Based on a Deep Understanding of Matter

Joachim Keppler
DIWISS

One of the main challenges in consciousness research is widely known as the hard problem of consciousness. In order to tackle this problem, I utilize an approach from theoretical physics, called stochastic electrodynamics (SED), which goes one step beyond quantum theory and sheds new light on the reality behind matter. According to this approach, matter is a resonant oscillator that is orchestrated by an all-pervasive stochastic radiation field, called zero-point field (ZPF). The properties of matter are not intrinsic but acquired by dynamic interaction with the ZPF, which in turn picks up information about the material system as soon as an ordered state, i.e., a stable attractor, is reached. I point out that these principles apply also to macroscopic biological systems. From this perspective, long-range correlations in the brain, such as neural gamma synchrony, can be interpreted in terms of order phenomena induced and stabilized by the ZPF, suggesting that every attractor in the brain goes along with an information state in the ZPF. In order to build the bridge to consciousness, I employ additional input from Eastern philosophy. From a comparison between SED and Eastern philosophy I draw the conclusion that the ZPF is an appropriate candidate for the substrate of consciousness, implying that information states in the ZPF are associated with conscious states. On this basis I develop a conceptual framework for consciousness that is fully consistent with physics, neurophysiology, and Eastern philosophy. I argue that this conceptual framework has many interesting features and opens a door to a theory of consciousness. Particularly, it solves the problem of how matter and consciousness communicate in a causally closed functional chain, it gives a physical grounding to existing approaches regarding the connection between consciousness and information, and it gives clear direction to future models and experiments.

Keywords: consciousness, hard problem, quantum physics, stochastic electrodynamics, zero-point field, double-aspect principle, psychophysical laws, qualia

1. Introduction

One of the main challenges in consciousness research is widely known as the hard problem of consciousness (Chalmers 1995; 1996). The core of the hard problem amounts to the question of how a physical system such as the human brain gives rise to conscious experience. In our standard world view this problem appears truly hard because we assume that matter *produces* consciousness. From this perspective, it is difficult to understand how a material system, however complex it may be organized, brings about phenomenal qualities. After all, we describe the structure and the dynamics of matter on the basis of physical equations that cover the

---

Joachim Keppler, Ph.D. in physics, member of the Science Consult Network, Department of Physics, DIWISS, Germany; main research fields: Foundation for a Theory of Consciousness, Interface between Mind and Matter, Quantum Aspects of Life.

quantitative aspects of the outer world, but definitely lack the qualitative aspects that characterize our inner world. I hold the view that the inner world we experience is the essence of our existence, which I do not question. With this in mind, the challenge is to find an integrated approach for the understanding of the outer world (physics) and the inner world (consciousness) as well as their interdependence.

How can such an approach look like? On closer inspection, the hard problem turns out to be tightly linked to the western way of thinking that adheres to the idea of a matter-dominated universe. This mindset proves extremely obstructive not only to the progress in consciousness research, but also to the deeper understanding of the physical world. In fact, there are currently many open questions in various areas of science, particularly in physics and most obviously in quantum physics, which are of fundamental nature and cannot be resolved as long as we stick to our conventional way of thinking. A new mindset, a paradigm shift, is required.

In this paper I take the view that a solution to the hard problem is linked to unraveling the mysteries of quantum physics. This implies that quantum physics and consciousness have a common basis, so that a deeper understanding of the quantum world sheds new light on the nature of consciousness. I argue that this is indeed the most promising way to tackle the problem. My reasoning is based on a theoretical approach called stochastic electrodynamics (SED), which aims at deriving quantum physics from first principles, thus providing a look behind the scenes of matter and showing how physics can be reconciled with consciousness.

I would like to point out that this approach differs significantly from the prevailing approaches that try to establish a connection between quantum physics and consciousness. Most of these attempts (Beck and Eccles 1992; Stapp 1993; Hameroff and Penrose 1996) relate consciousness to quantum state reductions in the brain and attribute the mysteries of consciousness to the poorly understood transition from potentiality to reality, without providing a convincing explanation for the nature of consciousness. In contrast, the SED-based approach goes one step beyond quantum physics, thus being able to overcome the restrictions of the quantum framework and offering the possibility to get to the heart of the problem. Instead of purely *describing* quantum systems, as the established formalism of quantum mechanics and quantum field theory does, SED helps to understand the underlying principles in nature that cause quantum behavior. This means that SED is capable of *explaining* the origin of quantum phenomena such as the stability of matter, entanglement, and non-locality. And it is exactly the discovery of the reality behind matter that opens a door to a theory of consciousness.

However, even though it makes a substantial contribution, the physical framework of SED cannot be the only mainstay of a science of consciousness. Like other physical theories, SED is a representative of the Western approach of science that has always concentrated on analyzing and exploring the outer world. As such, SED alone cannot tell us anything about consciousness. Hence, in order to get valuable clues regarding the inner world, we need additional input from a discipline that has studied the nature of consciousness as objectively as possible. Here, I would like to categorize this discipline with the term *Eastern philosophy*. Even though aspects of Eastern philosophy are also found in Western philosophy, the Eastern approach differs from the Western approach in that statements about consciousness do not originate from metaphysical speculations, but rather from meditative experience. Accordingly, Western science and Eastern philosophy are complementary, with each of these approaches generating findings the other is not able to produce. That is why the core statements of Eastern philosophy do make an important contribution to a science of consciousness.

This article is organized as follows. Section 2 starts with a brief overview of SED. Here I argue that SED goes along with a new mindset and is a promising way to tackle many fundamental problems of physics. In Section 3 we take a closer look behind the scenes of matter from an SED point of view. Section 4 deals with the connection between neurophysiology and SED. I argue that the core principles that hold true for relatively simple physical systems can be transferred to complex biological systems. In Section 5 I compare the findings of SED with the wisdom of Eastern philosophy. On the one hand, this comparison corroborates the SED approach and the underlying philosophy of matter. On the other hand, it provides new insight into the relationship between mind and matter. Section 6 is then devoted to the formulation of a conclusive conceptual framework for consciousness. In Section 7 I finally discuss the main implications of this conceptual framework and I also give an outline of the strategy required to push the framework forward to a full theory of consciousness.

By a conceptual framework I mean a point of view that copes with all the findings of Western science and at the same time also agrees with the fundamental discoveries of Eastern philosophy, which has a long tradition in exploring the nature of the mind. Against this background, the framework presented here is a novel synthesis of Western and Eastern insights with the goal to prepare a solid scientific grounding for the growing field of consciousness research. It includes the main ingredients but not all the details of a full theory. In this sense, the framework is designed to be a guide for further advancements and a foundation for a future theory of consciousness.

2. Overview of Stochastic Electrodynamics (SED)

Even though physics has proven extremely successful in understanding the fundamental forces of the universe and describing the structure and dynamics of material systems, a lot of open questions do exist, many of which are directly connected to our conception of matter. These reach from the origin of mass and inertia in classical mechanics to the strange and counter-intuitive behavior of particles at small distances through to the characteristics of huge aggregations of matter on cosmological scales.

Most notably, quantum theory plays a central role in this context. Nobody doubts that the description of the world in terms of quantum field theory is excellent. It has never failed to give the right answer. Nevertheless, the theory remains unsatisfactory as long as its mysteries have not been cleared up and a real understanding of what is going on in the quantum world is missing. In the last decades the awareness has grown that the fundamental questions of quantum physics all boil down to our incomplete understanding of the vacuum, meaning that first of all a theory of the vacuum is required from which we derive a consistent theory of matter. Following this train of thought, the structure of the vacuum should be regarded as the primary reality from which matter emerges as the secondary reality.

A physical theory that follows this philosophy is stochastic electrodynamics (SED), which was established in the 1960s and 1970s by Marshall (1963; 1965) and Boyer (1969; 1975). Since then, SED has been continuously advanced by a small circle of physicists. After a phase of stagnation, new ideas and concepts were formed and the field regained momentum in recent years. Important progress was achieved by De la Peña and Cetto (1994; 1996; 2001; 2006) who enhanced the theoretical framework and consolidated the foundations of SED, by Cavalleri and collaborators (2010) who introduced SED with spin, as well as by Cole and Zou (2003; 2004a; 2004b) who performed numerical simulations of nonlinear systems. In addition to these works there is also a very interesting SED-based approach to inertia and gravity, elaborated by Rueda and Haisch (Haisch et al. 1994; Rueda and Haisch 1998a; 1998b; 2005). Through the latest advancements many of the initial problems of SED could be resolved so that the physics community perceives this theory with its intuitive and appealing features as a promising candidate for the tackling of fundamental questions in physics. However, I would like to point out that the formalism of SED is still at the development stage, which means that particularly the practical calculation methods must be improved in order to test the viability of the approach not only on simple systems but also on a wide range of more complex systems and phenomena.

SED is based on the conception that the vacuum is filled with a real, all-pervasive stochastic radiation field, called zero-point field (ZPF), which can be pictured as an infinite sea of light and an ocean of pure energy. In order to allow for a unique mathematical specification of the ZPF, several symmetries are imposed on the field equations, namely homogeneity, isotropy, Lorentz invariance, and scale invariance, leading to a sum of plane electromagnetic waves with random phase and a characteristic power spectrum.

In agreement with conventional quantum field theory, the vacuum of SED is filled with permanent activity. However, there are significant differences. Quantum field theory regards this activity as virtual fluctuations that are an unavoidable by-product of the theory. In contrast, SED attributes the vacuum activity to a real, persistent background field that is the starting point and the core ingredient of the theory, making the vacuum in reality a plenum. These differences manifest themselves also in the creation principles underlying the two theories. According to the mindset of quantum field theory, creation amounts to selective population of the void, while according to SED all physical phenomena come into existence through a filtering process involving the ZPF, i.e., creation can be regarded as selective restriction of the ZPF. It is exactly this mindset inherent in SED that constitutes the paradigm shift required for a deeper understanding of mind and matter.

3. Looking behind the Scenes of Matter from an SED Point of View

In preparation of the subsequent considerations related to consciousness, I restrict myself to the most important facets of SED that essentially deal with the interaction between the ZPF and matter.

In the first step, we have a look at the impacts of the ZPF on matter. As explicated in the last section, SED regards matter as immersed in an all-pervasive stochastic background field with which it interacts permanently and unavoidably, thus acquiring a stochastic motion. This motion can be studied for various systems. As an example we take a closer look at the hydrogen atom, which is composed of a proton and an electron. In classical physics this system is unstable and collapses within a tiny fraction of a second due to the fact that the orbiting electron emits radiation and loses energy. However, within SED the situation changes significantly since the electron is no longer surrounded by a void. Rather, the electron is now able to perform a dynamic interaction with the background field, which results in an exchange of energy between the material system and the ZPF. Indeed, it can be shown analytically and numerically (Cole and Zou 2003; 2004a; 2004b; De la Peña and Cetto 2006, 356-57; Cavalleri et al. 2010, 112-14) that there are certain dynamic situations in which the average power absorbed by the atomic electron compensates its average radiated power. These situations are characterized by quantization conditions and correspond exactly to the stationary states predicted by quantum theory, i.e., the stability of matter goes necessarily hand in hand with the quantum behavior of matter and both are a consequence of the interaction with the ZPF.

A closer look behind the scenes of matter from an SED point of view reveals that not only the stability of matter but also its spatial structure and three-dimensional conformation are governed by the ZPF. Hence, SED is able to provide a clearer and more intuitive understanding of structure formation, in such a way that a quantum mechanical orbital, which reflects the probability density of finding an electron in a specific region around the nucleus, is associated with a stable attractor of the stochastic interaction process between the electron and the ZPF (Rodriguez 2012). In other words, every stationary state of matter is characterized by an individual dance pattern that comes into being under direction of the ZPF. External stimuli, such as the presence of a magnetic field, can cause transitions between different attractors, i.e., an external stimulus or a perturbation can prompt the system to follow a new dance pattern.

From these findings one can derive a universal mechanism of structure formation. Starting from the free ZPF, which contains infinite energy and potential, material systems build up hierarchically through selective restriction of the infinite potential, i.e., through selective filtering of the ZPF. On each hierarchical level new properties emerge that do not exist on the lower levels. In order to reach and maintain stability, the components of matter must be driven with characteristic resonance frequencies that are filtered out of the ZPF spectrum. Stable systems arise whenever the dynamic interaction between the ZPF and the components of the system fulfills a balance condition. Hence, stable structures can also be viewed as stable resonance patterns or stable attractors. Interestingly, every balance condition is associated with a quantization rule, i.e., quantum behavior results from the interaction process between matter and the ZPF (De la Peña and Cetto 2001, 1703-04; 2006, 356).

Given this universal mechanism of structure formation, it is quite obvious that there is no clear separation between the microcosm and the macrocosm, i.e., quantum behavior should not be restricted to the lowest hierarchical levels of matter. Rather, it is to be expected that under appropriate conditions quantum phenomena arise in many macroscopic systems, particularly in biological systems. This is how selective filtering of the ZPF gives rise to diversity and complexity in the universe, with the self-similarity of nature being due to the scale-invariance of the ZPF.

So far, we have dealt with the impacts of the ZPF on matter. In the second step, we now have a look at the impacts of matter on the ZPF. This is very important because it must be considered that matter and ZPF exert a mutual influence, i.e., not only the ZPF affects the dynamics of matter, but the latter also affects the dynamics of the ZPF. From the study of simple nonlinear systems (De la Peña and Cetto 2001; 2006) one can learn that the ZPF is modified as soon as the system reaches a stable attractor. The free field with the initially random phase adapts itself to the new situation in such a way that the relevant frequency components involved in the maintenance of the equilibrium become highly correlated (De la Peña and Cetto 2001, 1711). In other words, the formation of a stable attractor results in a de-randomization of the local ZPF. This amounts to imprinting an information state on the ZPF. Different attractors are associated with different ZPF configurations and, hence, different information states.

This paragraph compresses the findings of SED elucidated in this section. Accordingly, matter can be viewed as a resonant stochastic oscillator driven by the ZPF. There is a permanent flow of energy between matter and the ZPF. As soon as a system reaches a stationary state, i.e., falls into a stable attractor, quantum behavior sets in. Each attractor is associated with an information state in the ZPF. All the parts of a stationary system are connected and coupled through the ZPF. This is the reason why such systems exhibit collective cooperation and long-range coherence, even on macroscopic scales. This behavior appears to be nonlocal to an external observer since the vacuum field remains unobserved (De la Peña and Cetto 2001, 1720).

Hence, the key insight from SED is that the peculiar features of quantum physics can be traced back to stable resonances between matter and an all-pervasive stochastic radiation field. According to this approach, the properties of matter are not intrinsic but acquired by dynamic interaction with the ZPF, which in turn picks up information about the material system. In summary, the ZPF orchestrates matter and matter generates information states in the ZPF.

4. Connection between Neurophysiology and SED

After having discussed the core principles of matter on the basis of relatively simple physical systems, I want to address the much more complex systems we find in biology. In the last section I already foreshadowed that in those systems the same principles should apply, so that quantum phenomena are to be expected under appropriate conditions. To this end, we have a closer look at the body of evidence resulting from the analysis of neural activity patterns.

First of all, one can observe long-range coherence in the brain, which means that the activity of distant brain regions is highly correlated. Particularly, synchronized activity in the gamma frequency band, ranging from 25 to 100 Hz, is strongly associated with perceptual awareness and consciousness (Crick and Koch 1990; Engel et al. 1999; Engel and Singer 2001; Melloni et al. 2007). It was found that gamma synchrony shows up not only during attention to an external stimulus, but also during meditation (Lutz et al. 2004) and REM sleep (Llinás and Ribary 1993; Montgomery et al. 2008). In order to understand gamma synchrony, deterministic neural network models have been studied, which generate autocoherent gamma oscillations as an emergent network property. However, such models can be ruled out because the analysis of real data reveals that the brain behaves like a resonant stochastic oscillator (Burns et al. 2010). This means that the brain activity cannot be understood on the basis of a deterministic model. Rather, any realistic model must incorporate a stochastic driving force.

Furthermore, it turns out that the dynamics of the brain is scale-free (Linkenkaer-Hansen et al. 2001; Freeman 2004a; 2004b), meaning that the activity patterns of the system are governed by a universal mechanism. In this context, the works of Walter Freeman are of major importance, showing that every conditioned stimulus is associated with a specific activity pattern that can be regarded as an attractor in an adaptive attractor landscape (Freeman 1991; 2005). Vast collections of neurons shift abruptly and simultaneously between different attractors, indicating that an instantaneous communication must occur in the system.

For a physicist all these pieces of evidence clearly suggest that the brain behaves like a macroscopic quantum system. This view is also taken by Freeman and Vitiello who interpret the nonlinear brain dynamics as a macroscopic manifestation of underlying many-body field dynamics (Freeman and Vitiello 2006). They argue that the patterns detected in the brain resemble those of quantum many-body systems, so that many-body quantum field theory is the appropriate tool to study brain dynamics and the only way to understand pattern formation and phase transitions in the brain. From this perspective, the brain is a complex system that operates near a critical point of a phase transition. In the unordered phase the brain displays irregular dynamics. However, an external stimulus above a certain threshold can vary the system parameters appropriately and induce a spontaneous transition to the ordered phase that is characterized by scale-free activity patterns, long-range correlations, particularly gamma synchrony, and spatiotemporal attractors.

In order to understand the causal mechanism of the phase transitions taking place in the brain, several approaches have been pursued. At this point I would like to be brief and confine myself to the essentials. It can be stated that most probably the microtubules play a central role. They can be viewed as arrays of coupled dipole oscillators and ordered water molecules and have been studied utilizing models that are based on the formalism of quantum field theory (Jibu et al. 1994; Mavromatos et al. 2002). Depending on the external parameters, the system of microtubules is assumed to work in two different phases. The models suggest that the ordered phase, which correlates with consciousness, is mediated by coherent modes in the system of microtubules. These modes trigger the generation of synchronous gamma waves (Jibu et al. 1994, 207; Hameroff 2006, 409-10), resulting in the formation of stable attractors. A better understanding of this process, which includes all the levels of microscopic and macroscopic organization, is definitely required, with special attention to the conditions under which gamma synchrony and stable attractors are possible. Nevertheless, from the existing quantum field theoretical models one can draw the conclusion that the whole process is initiated and stabilized by the electromagnetic vacuum fluctuations. According to the explications in Section 2, this is equivalent to saying that the process is driven by the ZPF.

These findings can be translated into the framework of SED, amounting to the following statements. The brain is a resonant stochastic oscillator driven by the ZPF. Quantum behavior emerges as soon as the brain reaches a stationary state, i.e., as soon as the activity of the brain falls into a stable attractor. As we already know from Section 3, each attractor is associated with an information state in the ZPF. Accordingly, the neural activity of the brain modifies the local ZPF and the modified ZPF in turn influences the brain.

5. Comparison between Physics and Eastern Philosophy

In the previous two sections I demonstrated that the theoretical framework of SED is very helpful to get a clearer picture of matter and to understand the structuring principles in the universe. Moreover, I established a connection between neurophysiology and SED in the sense that there are several plausible reasons to trace the complex activity patterns in the brain back to exactly those principles that control the dynamics of simple physical systems.

Sure enough, these insights are very illuminating, but they do not immediately enable us to grasp the nature of the mind. As already mentioned in Section 1, we need additional input in order to discover the relationship between mind and matter. That is why we turn toward Eastern philosophy whose sages have a long tradition in studying consciousness during periods of undisturbed meditation. As a matter of fact, there is no western branch of study that investigated our inner world as intensely and systematically as Eastern philosophy. Here I cannot give a full account of the wisdom gathered over the centuries. Rather, I would like to refer to books which give an excellent summary of this wisdom (Govinda 1969; Ricard and Thuan 2004) and confine myself to a comparison between physics on the one hand and Eastern philosophy on the other hand (see Table 1). The statements in the left column of this table describe the modern understanding of the physical universe including matter as seen from the perspective of SED, while the statements in the right column describe the central discoveries of Eastern philosophy, expressed in the words of Buddhism. It is important to note that the statements of Eastern philosophy cannot be derived logically from the statements of SED since they emanate from a complementary knowledge acquisition process. However, the findings of Eastern philosophy can be compared to the insights gained from SED and interpreted in the light of SED.

Notably, the comparison first of all corroborates the SED-based approach and the underlying philosophy of matter. In particular, the findings of SED agree perfectly with the foundations of the Buddhist world view, namely emptiness and interdependence, meaning that the properties of matter are not intrinsic but, via the ZPF, acquired by dynamic interaction with the rest of the world.

The second conclusion one can draw concerns the relationship between mind and matter. The core message of Eastern philosophy is that there is an implicit unity of primordial energy and primordial consciousness, i.e., mind and matter are based on the same substrate. The comparison suggests that the ZPF is an appropriate candidate for this substrate and that modifications of the local ZPF in terms of information states can be interpreted as conscious states. This opens a door to a conceptual framework for consciousness.

Table 1

Comparison between Physics and Eastern Philosophy

Physics (SED)	Eastern Philosophy (Buddhism)
The universe is based on an all-pervasive radiation field (ZPF) exhibiting infinite energy and potential.	Prana is the principle of movement, the all-powerful, all-pervasive rhythm of the universe.[1]
All properties of matter are acquired by dynamic interaction with the ZPF, i.e., all physical phenomena result from selective restriction of the ZPF.	Nothing exists on its own. The properties of matter are not intrinsic (emptiness), but appear only in conjunction with the rest of the world (interdependence).[2]
The ZPF shapes matter and matter shapes the ZPF. This interplay gives rise to information states in the ZPF.	Consciousness shapes matter and matter shapes consciousness. The fundamental level of consciousness and the world of phenomena are linked by interdependence.[2]
All forces of the universe are mediated by the ZPF, i.e., local modifications, distortions, and asymmetries of the ZPF result in forces.	All forces of the universe, like those of the human mind, from the highest consciousness to the depths of the subconscious, are modifications of Prana.[1]

Note: A one to one comparison between the insights gained from SED (left) and the central discoveries of Eastern philosophy (right) shows a perfect match as far as the understanding of the physical world is concerned. Beyond that, one can also draw the conclusion that mind and matter are based on the same substrate and that the ZPF is an appropriate candidate for this substrate. The statements of SED are a summary of the explanations given in the Sections 2 and 3, the statements of Buddhism are extracted from (Govinda 1969)[1] and (Ricard and Thuan 2004)[2].

6. Conceptual Framework for Consciousness

In the following, I present the cornerstones of a conceptual framework for consciousness. As noted in Section 1, this conceptual framework is designed to be in accordance with all the scientific findings of physics and neurophysiology, explicated in Sections 2 to 4, and at the same time with the discoveries of Eastern philosophy, summarized in Section 5. The framework is formulated in terms of three main principles.

Principle 1: Consciousness is a fundamental property of the universe.

According to Eastern philosophy, mind and matter are composed of the same primordial energy, i.e., there is an implicit unity of primordial energy and primordial consciousness. Hence, consciousness is not produced by matter. Rather, matter and consciousness have a common basis.

Principle 2: The ZPF is the substrate of consciousness.

According to SED, primordial energy is represented by the ZPF. All phenomena spring forth from this field through selective restriction and a dynamic flow of interactions. Since, as laid down in hypothesis 1, primordial energy and primordial consciousness are based on the same substrate, the ZPF is an appropriate candidate for the substrate of consciousness.

Principle 3: Our individual consciousness is the result of a dynamic interaction process that causes the realization of information states in the ZPF.

The neural activity of the brain modifies the ZPF, which is the substrate of consciousness. Whenever the activity of the brain falls into a stable attractor, there is an information state in the ZPF that is associated with a conscious state. The modified ZPF, i.e., our consciousness, also influences the brain, so that there is a permanent information transfer between the brain and the ZPF. These interrelationships are depicted in fig. 1.

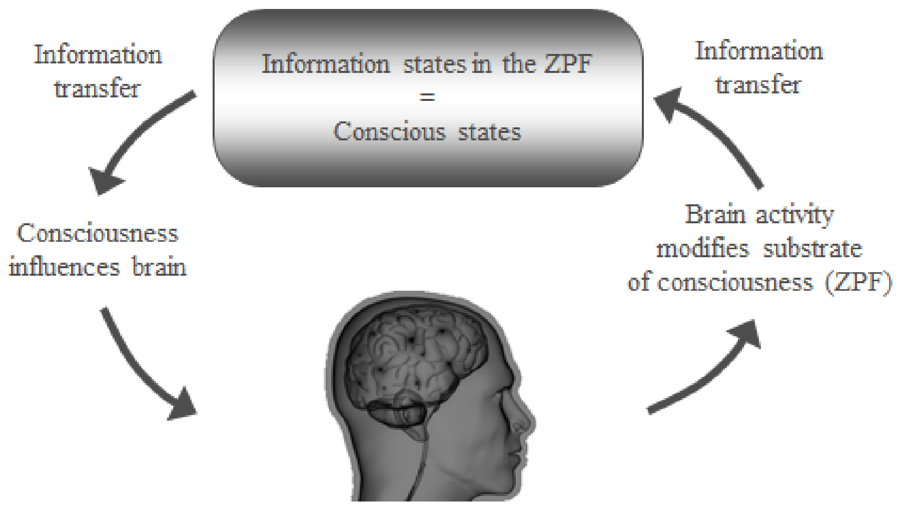

Fig. 1. Dynamic Interaction Process between the ZPF and the Brain.

Note: The ZPF is the carrier of primordial consciousness. The neural activity of the brain causes information states in the ZPF that produce the stream of our individual consciousness.

From the above principles and explanations I deduce a few more implications that can also be understood as guidelines for a theory of consciousness. These implications are summarized in fig. 2.

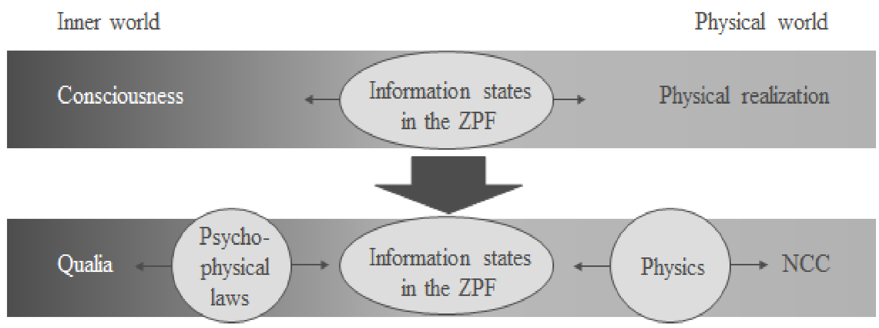

Fig. 2. Relationship between the Inner World and the Physical World.

Note: The physical world and our inner world are two different manifestations of information states in the ZPF. While the external world is governed by the laws of physics, psychophysical laws are required to describe the relationship between information states in the ZPF and our world of qualia.

Fig. 2 shows that the physical and phenomenal properties turn out to be two different aspects of a single world. This is in line with the double-aspect principle of information (Chalmers 1995, 216-17; 1996, 284-87). In the context of the SED-based approach presented here, this means that particular information states in the ZPF, if not all, are associated with a physical realization and a conscious experience. In other words, the internal aspects of such ZPF information states are phenomenal, i.e., a conscious moment is a ZPF information state experienced from inside. The external aspects of such information states are physical and manifest themselves as the neural correlates of consciousness (NCC).

Hence, a key characteristic and important quality of this conceptual framework is the notion of an *information state in the ZPF*, also called *ZPF information state*, which is the central link between a physical manifestation in the outer world and a psychological state in our inner world. The relationship between information states in the ZPF and NCC is completely determined by the laws of physics, while the connection between information states in the ZPF and our spectrum of qualia is specified by psychophysical laws. However, these psychophysical laws have nothing to do with extensions to the existing laws of physics. Rather, they can be regarded as mapping rules between ZPF information states and qualia, describing where a given information state in the ZPF is located in qualia space. I will return to this in the subsequent discussion.

7. Discussion

The conceptual framework for consciousness set forth in this paper exhibits a number of very interesting features, which I would like to summarize and discuss in this section.

7.1. Consciousness and Matter

As explained in Section 3, the theoretical framework of SED and the notion of the ZPF make a substantial contribution toward elevating our understanding of matter to a higher level. This is due to the fact that SED goes one step beyond quantum physics and enables us not only to describe quantum systems, but also to grasp the underlying principles in nature that cause quantum behavior. As a result, many of the mysteries attached to the quantum world can be unraveled in that the stability as well as all the properties of matter can be traced back to a permanent interaction between matter and the ZPF. This shows us how all structures in the universe, from the microcosm to the macrocosm, build up hierarchically through selective filtering of the ZPF.

Taken to its logical end, this also indicates that the elementary particles, which constitute the first hierarchical level of matter, must emerge as stable or transient patterns from the ZPF. In order to understand this dynamical creation of elementary particles out of the ZPF, the theoretical framework of SED, which is currently confined to electrodynamics, must be extended to the weak and strong interaction. This remains an ambitious goal for the future.

Looking at higher levels of complexity, it is quite obvious that the universal mechanism of structure formation must apply also to living matter, indicating that biological systems can be fully understood only on the basis of the electromagnetic vacuum fields, as addressed by SED and described by the formalism of quantum electrodynamics. In this respect, good progress has been made in the last years (Del Giudice et al. 2005).

As expounded in Section 5, the understanding of matter suggested by SED is in perfect agreement with the wisdom of Eastern philosophy, which helps us to gain deeper insight into the nature of consciousness. The crucial point is that according to Eastern philosophy matter and consciousness are based on one and the same substrate, leading us to the conceptual framework described in Section 6. The significant advantage of this conceptual framework is the idea of one fundamental substrate. On the one hand, this substrate is the origin of all physical phenomena and the source of the enormous diversity of external manifestations. On the other hand, this substrate is also the basis of our inner world with its rich spectrum of qualia and subjective experience. Hence, consciousness is deeply rooted in the foundation of the universe. This approach answers fundamental questions and solves the problem of how matter and consciousness communicate in a causally closed functional chain, as explained in Section 6.

7.2. Consciousness and Information

As far as the connection between consciousness and information is concerned, the SED-based framework for consciousness is able to specify and particularize existing approaches, notably the double-aspect principle of information (Chalmers 1995; 1996) and the integrated information theory (Tononi 2004; 2008).

I would like to start with David Chalmers' approach. He holds the view that the double-aspect principle of information is a “candidate for a *basic principle* that might form the cornerstone of a fundamental theory of consciousness” (1995, 212). Moreover, he explains:

> Where there is information, there are *information states* embedded in an *information space*.… This leads to a natural hypothesis: that information (or at least some information) has two basic aspects, a physical aspect and a phenomenal aspect. Of course, the double-aspect principle is … underdetermined, leaving a number of key questions unanswered. An obvious question is whether *all* information has a phenomenal aspect. One possibility is that we need a further constraint on the fundamental theory, indicating just what *sort* of information has a phenomenal aspect. The other possibility is that there is no such constraint. (1995, 216-17)

The conceptual framework presented in Section 6 gives an answer to this question in such a way that it does impose a constraint on the sort of information that is associated with consciousness. According to this framework, only ZPF information states have phenomenal aspects. This is based on the hypothesis that the ZPF is the carrier of primordial consciousness, i.e., it requires modifications of the primary substrate of consciousness in order to produce conscious states. As explained, ZPF information states are generated whenever nonlinear systems interact dynamically with the ZPF and reach stable attractors. This is characteristic for all nonlinear quantum systems. The functionality of our brains rests exactly on this mechanism, bringing about our streams of consciousness.

In summary, this means that all microscopic and macroscopic quantum systems may be conscious, with simple systems having only a very simple and rudimentary form of consciousness, while complex systems give rise to a much wider range of conscious states and phenomenal qualities.

These ideas are closely related to the integrated information theory, which claims that “… the *quantity* of consciousness generated by a complex of elements is determined by the amount of integrated information it generates above and beyond its parts …,” while “… the *quality* of consciousness is determined by the set of all the informational relationships its mechanisms generate. That is, *how* integrated information is generated within a complex determines not only the amount of consciousness it has, but also what kind of consciousness” (Tononi 2008, 224).

The strong point of the SED-based framework is that it provides such a universal mechanism for information integration, namely the interaction between the ZPF and the elements of the system, thus being able to link Giulio Tononi’s theoretical approach to real physics. In other words, SED can answer how a system integrates information and, hence, provides an opportunity to determine the quantity and quality of consciousness of a given system. I will come back to this point in Section 7.5.

7.3. Consciousness and Memory

Experimental evidence suggests that memory is associated with consciousness. Accordingly, models have been proposed that deal with the relationship between conscious events and several forms of memory, not only working memory (Crick and Koch 1990, 269-72; Baars and Franklin 2003), but also transient episodic memory and various types of long-term memory, such as procedural and autobiographic memory (Franklin et al. 2005).

The SED-based conceptual framework presented here also gives a clear indication of a connection between memory and consciousness. In its present form, the framework cannot make detailed statements as to how the different types of memory exactly work, but it can shed light on the fundamental mechanisms of memory storage and retrieval. According to the principles described in Section 6, the key to these processes is the functioning of the brain as a system that generates information states in the ZPF. It seems natural to associate these information states not only with conscious states, but also with memory states. Hence, the upward process in fig. 1, in which the neural activity of the brain modifies the ZPF, corresponds to writing information into the personal memory, while the downward process in fig. 1 corresponds to information retrieval from the personal memory. It is to be expected that this closed loop is also the basis for learning, i.e., in the upward process the brain shapes consciousness, in the downward process consciousness shapes the structure of the brain by modifying the connections of the neural network.

This model implies that our memories are not stored in the physical brain, but rather in the ZPF. As a consequence, the SED-based approach provides a new perspective on experiments that study the characteristics of consciousness and memory in patients with brain damage or brain anomalies. Moreover, it is suggested that our conscious minds and our memories are potentially persistent after the physical death. Sure enough, such aspects are highly interesting. However, I will not further discuss them in this article.

In summary, the brain should not be regarded as a complex memory device, as most people think. Rather, it works as a highly adaptive read/write head that on the one hand imprints information states on the ZPF and on the other hand extracts information states from the ZPF.

7.4. Ground State of Consciousness

Central to the SED-based approach is the concept of ZPF information states. In Section 6 I argued that the external aspects of these information states are physical, while the internal aspects of these states are phenomenal, i.e., a conscious moment is a ZPF information state experienced from inside. As expounded, such information states arise from the free ZPF through a dynamic interaction process, a kind of filtering process, which results in a de-randomization of the ZPF. This happens whenever the activity of a nonlinear system, particularly the brain, falls into a stable attractor.

An interesting question concerns the state of consciousness that corresponds to the free ZPF. According to Section 5, this state can be equated with primordial consciousness and may be called the ground state of consciousness. It should be present when the filtering process of the brain is phased down, i.e., when the disturbing influences of neural information processing are switched off and the activity of the mind is calmed. Indeed, the experiential reports of Eastern philosophy indicate that this state is accessible through the practice of meditation. It is characterized as a “state of perfect symmetry” that “is imbued with the qualities of bliss, luminosity, and nonconceptuality” (Wallace 2006, 116-17).

Such a characterization of the ground state of consciousness corroborates the view that all the nuances of our sensations and emotions are selectively filtered out of this state. Hence, the ground state is a very important reference state for a theory of consciousness. I will return to this point in the next section.

7.5. Toward a Theory of Consciousness

The conceptual framework presented in this paper includes only the main ingredients but not all the details of a full theory. In order to develop a theory, we need models as well as experiments that are inspired by the principles incorporated in these models. In this respect, I fully agree with Tononi who argues that “… the nature of the problems posed by a science of consciousness requires a combination of experiment and theory: one could say that theories without experiments are lame, but experiments without theories are blind” (2008, 232). In this spirit, I would like to conclude with an outline of a strategy that aims at giving direction to future models and experiments. A central element of the strategy, which becomes obvious by taking a look at fig. 2, is to separate the journey from the physical world (NCC) to the inner world (qualia) into two steps.

The goal of the first step consists in getting from NCC to information states in the ZPF. This step has the advantage that the relationship between information states in the ZPF and NCC is completely determined by the laws of physics, with the NCC being the stable attractors the brain activity reaches in connection with conscious states. To the aspects of this step belong the identification of attractors that are related to a selection of representative conscious experiences, the understanding of the attractor dynamics, and the determination of the ZPF information state corresponding to each attractor. Consequently, the experimental setting must be designed such that test persons are brought into reproducible conscious states, the phenomenal qualities (qualia) of which are described on the basis of the first-person accounts. For each of the conscious states the activity patterns of the brain must be analyzed and the specific attractor must be determined. These are the experimental requirements. The understanding of the attractors involves a high degree of physics and means that we have to build ZPF-driven oscillator models of the brain that are sufficiently realistic in order to reproduce the observed attractor dynamics. When such models are in place, we can calculate the modifications of the free ZPF that are associated with the attractors, yielding the sought ZPF information states. It is to be expected that with the help of these models we will also be able to figure out the difference between conscious and unconscious states. My guess is that it requires a certain amount of time to establish a resonance pattern and reach a stable equilibrium. If a stimulus is too short or such that an attractor cannot be reached, there will be no ZPF information state and, hence, no conscious state. This amounts to comparing the equilibration time resulting from the models with the duration of gamma bursts.

The second step concerns the disclosure of the connection between ZPF information states and qualia. In this context, one of the main challenges will be to find an appropriate representation of the information states that enables us to discover regularities. Most likely, a good way of achieving this is to describe ZPF information states in a ZPF information space whose dimensions reflect the main characteristics of ZPF configurations, particularly the spectrum and the richness of the relevant frequency components, the degree of correlation between the frequency components, and the spatial pattern of the correlations. Consequently, every conscious state is associated with a specific attractor and a corresponding ZPF information state, which is characterized by a point or a region in ZPF information space. So, with the experimental setting described above we can pass through a number of conscious states and systematically classify ZPF information space on the basis of the first-person accounts. The classified and in this way calibrated ZPF information space is qualia space.

The classification of ZPF information states will answer essential questions regarding the internal structure of qualia space. It may be hypothesized that the different modalities, such as our visual, auditory, and olfactory experiences, correspond to different subspaces and that there is a similarity principle, in such a way that similar information states correspond to similar phenomenal qualities. These are also central elements of the integrated information theory (Tononi 2008, 227-32). An SED-based theory can verify these hypotheses and put the investigation of qualia space on a sound basis. Moreover, it may also be hypothesized that regularities are found that result in mapping rules between ZPF information states and qualia. These rules describe where a given ZPF information state is located in qualia space. They are tantamount to the psychophysical rules in fig. 2.

While systematically exploring qualia space, we will encounter the ground state of consciousness, which is an important reference state in this space. As mentioned in the previous section, this ground state of consciousness is associated on the one hand with the undisturbed ZPF and on the other hand with the ultimate positive. For the first time, this opens a door to merge the concepts of physics with the wisdom of Eastern philosophy.

Works Cited

Baars, Bernard J., and Stan Franklin. "How Conscious Experience and Working Memory Interact." *Trends in Cognitive Science* 7.4 (2003): 166-72.

Beck, Friedrich, and John C. Eccles. "Quantum Aspects of Brain Activity and the Role of Consciousness." *Proc. Natl. Acad. Sci. USA* 89 (1992): 11357-61.

Boyer, Timothy H. "Derivation of the Blackbody Radiation Spectrum without Quantum Assumptions." *Phys. Rev.* 182.5 (1969): 1374-83.

---. "Random Electrodynamics: The Theory of Classical Electrodynamics with Classical Electromagnetic Zero-Point Radiation." *Phys. Rev. D* 11.4 (1975): 790-808.

Burns, Samuel P., Dajun Xing, Michael J. Shelley, and Robert M. Shapley. "Searching for Autocoherence in the Cortical Network with a Time-Frequency Analysis of the Local Field Potential." *Journal of Neuroscience* 30.11 (2010): 4033-47.

Cavalleri, Giancarlo, Francesco Barbero, Gianfranco Bertazzi, Eros Cesaroni, Ernesto Tonni, Leonardo Bosi, Gianfranco Spavieri, and George T. Gillies. "A Quantitative Assessment of Stochastic Electrodynamics with Spin (SEDS): Physical Principles and Novel Applications." *Front. Phys. China* 5.1 (2010): 107-22.

Chalmers, David J. *The Conscious Mind. In Search of a Fundamental Theory*. New York: Oxford UP, 1996.

---. "Facing Up to the Problem of Consciousness." *Journal of Consciousness Studies* 2.3 (1995): 200-19.

Cole, Daniel C., and Yi Zou. "Quantum Mechanical Ground State of Hydrogen Obtained from Classical Electrodynamics." *Phys. Lett. A* 317 (2003): 14-20.

---. "Simulation Study of Aspects of the Classical Hydrogen Atom Interacting with Electromagnetic Radiation: Circular Orbits." *Journal of Scientific Computing* 20.1 (2004a): 43-68.

---. "Simulation Study of Aspects of the Classical Hydrogen Atom Interacting with Electromagnetic Radiation: Elliptical Orbits." *Journal of Scientific Computing* 20.3 (2004b): 379-404.

Crick, Francis, and Christof Koch. "Towards a Neurobiological Theory of Consciousness." *Seminars in Neurosciences* 2 (1990): 263-75.

De la Peña, L., and A. M. Cetto. "The Foundations of Linear Stochastic Electrodynamics." *Foundations of Physics* 36.3 (2006): 350-68.

---. *The Quantum Dice. An Introduction to Stochastic Electrodynamics*. Dordrecht: Kluwer Acad., 1996.

---. "Quantum Phenomena and the Zeropoint Radiation Field." *Foundations of Physics* 24.6 (1994): 917-48.

---. "Quantum Theory and Linear Stochastic Electrodynamics." *Foundations of Physics* 31.12 (2001): 1703-31.

Del Giudice, Emilio, Antonella De Ninno, Martin Fleischmann, Giuliano Mengoli, Marziale Milani, Getullio Talpo, and Giuseppe Vitiello. "Coherent Quantum Electrodynamics in Living Matter." *Electromagnetic Biology and Medicine* 24.3 (2005): 199-210.

Engel, Andreas K., Pascal Fries, Peter König, Michael Brecht, and Wolf Singer. "Temporal Binding, Binocular Rivalry, and Consciousness." *Consciousness and Cognition* 8 (1999): 128-51.

Engel, Andreas K., and Wolf Singer. "Temporal Binding and the Neural Correlates of Sensory Awareness." *Trends Cogn. Sci.* 5 (2001): 16-25.

Franklin, Stan, Bernard J. Baars, Uma Ramamurthy, and Matthew Ventura. "The Role of Consciousness in Memory." *Brains, Minds and Media* 2005.1 (2005): bmm150.

Freeman, Walter J. "Origin, Structure, and Role of Background EEG Activity. Part 1. Analytic Amplitude." *Clin. Neurophysiol.* 115 (2004a): 2077-88.

---. "Origin, Structure, and Role of Background EEG Activity. Part 2. Analytic Phase." *Clin. Neurophysiol.* 115 (2004b): 2089-2107.

---. "Origin, Structure, and Role of Background EEG Activity. Part 3. Neural Frame Classification." *Clin. Neurophysiol.* 116 (2005): 1118-29.

---. "The Physiology of Perception." *Scientific American* 264.2 (1991): 78-85.

Freeman, Walter J., and Giuseppe Vitiello. "Nonlinear Brain Dynamics as Macroscopic Manifestation of Underlying Many-Body Field Dynamics." *Physics of Life Reviews* 3 (2006): 93-118.

Govinda, Lama Anagarika. *Foundations of Tibetan Mysticism*. York Beach: Red Wheel/Weiser, 1969.

Haisch, Bernhard, Alfonso Rueda, and H. E. Puthoff. "Inertia as a Zero-Point Field Lorentz Force." *Phys. Rev. A* 49.2 (1994): 678-94.

Hameroff, Stuart R. “The Entwined Mysteries of Anesthesia and Consciousness.” *Anesthesiology* 105.2 (2006): 400-12.

Hameroff, Stuart R., and Roger Penrose. “Conscious Events as Orchestrated Space-Time Selections.” *Journal of Consciousness Studies* 3.1 (1996): 36-53.

Jibu, Mari, Scott Hagan, Stuart R. Hameroff, Karl H. Pribram, and Kunio Yasue. “Quantum Optical Coherence in Cytoskeletal Microtubules: Implications for Brain Function.” *Biosystems* 32.3 (1994): 195-209.

Linkenkaer-Hansen, Klaus, Vadim V. Nikouline, J. Matias Palva, and Risto J. Ilmoniemi. “Long-Range Temporal Correlations and Scaling Behavior in Human Brain Oscillations.” *Journal of Neuroscience* 21.4 (2001): 1370-77.

Llinás, Rodolfo, and Urs Ribary. “Coherent 40-Hz Oscillation Characterizes Dream State in Humans.” *Proc. Natl. Acad. Sci. USA* 90 (1993): 2078-81.

Lutz, Antoine, Lawrence L. Greischar, Nancy B. Rawlings, Matthieu Ricard, and Richard J. Davidson. “Long-Term Meditators Self-Induce High-Amplitude Gamma Synchrony during Mental Practice.” *Proc. Natl. Acad. Sci. USA* 101 (2004): 16369-73.

Marshall, T. W. “Random Electrodynamics.” *Proc. R. Soc. London A* 276 (1963): 475-91.

---. “Statistical Electrodynamics.” *Proc. Camb. Phil. Soc.* 61 (1965): 537-46.

Mavromatos, Nick E., Andreas Mershin, and Dimitri V. Nanopoulos. “QED-Cavity Model of Microtubules Implies Dissipationless Energy Transfer and Biological Quantum Teleportation.” *Int. J. Mod. Phys. B* 16 (2002): 3623-42.

Melloni, Lucia, Carlos Molina, Marcela Pena, David Torres, Wolf Singer, and Eugenio Rodriguez. “Synchronization of Neural Activity across Cortical Areas Correlates with Conscious Perception.” *Journal of Neuroscience* 27.11 (2007): 2858-65.

Montgomery, Sean M., Anton Sirota, and György Buzsáki. “Theta and Gamma Coordination of Hippocampal Networks during Waking and REM Sleep.” *Journal of Neuroscience* 28.26 (2008): 6731-41.

Ricard, Matthieu, and Trinh X. Thuan. *The Quantum and the Lotus. A Journey to the Frontiers Where Science and Buddhism Meet*. New York: Three Rivers, 2004.

Rodriguez, David. “Orbital Stability and the Quantum Atomic Spectrum from Stochastic Electrodynamics.” 2012. arXiv: 1201.6168v2 (eprint).

Rueda, Alfonso, and Bernhard Haisch. “Contribution to Inertial Mass by Reaction of the Vacuum to Accelerated Motion.” *Found. Phys.* 28 (1998a): 1057-1108.

---. “Gravity and the Quantum Vacuum Inertia Hypothesis.” *Ann. Phys.* 14.8 (2005): 479-98.

---. “Inertia as Reaction of the Vacuum to Accelerated Motion.” *Phys. Lett. A* 240.3 (1998b): 115-26.

Stapp, Henry P. “A Quantum Theory of the Mind-Brain Interface.” Ed. Henry P. Stapp. *Mind, Matter, and Quantum Mechanics.* Berlin: Springer, 1993. 145-72.

Tononi, Giulio. “Consciousness as Integrated Information: A Provisional Manifesto.” *Biol. Bull.* 215 (2008): 216-42.

---. “An Information Integration Theory of Consciousness.” *BMC Neuroscience* 5 (2004): 42.

Wallace, B. Alan. “Vacuum States of Consciousness: A Tibetan Buddhist View.” Ed. D. K. Nauriyal, Michael S. Drummond, and Y. B. Lal. *Buddhist Thought and Applied Psychological Research: Transcending the Boundaries*. London: Routledge, 2006. 112-21.