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On the Universal Mechanism Underlying Conscious Systems and the Foundations for a Theory of Consciousness

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Abstract

In this article, I present a novel approach to the scientific understanding of consciousness. It is based on the hypothesis that the full range of phenomenal qualities is built into the frequency spectrum of a ubiquitous background field and proceeds on the assumption that conscious systems employ a universal mechanism by means of which they are able to extract phenomenal nuances selectively from this field. I set forth that in the form of the zero-point field (ZPF) physics can offer a promising candidate that is qualified for playing the dual role as both the carrier of energy and consciousness. The appropriate mechanism, which rests upon the principle of dynamical coupling of ZPF modes, is a unique feature of quantum systems, suggesting that the dividing line between conscious and non-conscious systems is defined by the differentiation between quantum systems and classical systems. The presence of this mechanism in the brain is supported by the neurophysiological body of evidence, leading to a consistent explanation of the dynamical properties of the neural correlates of consciousness. Building on these findings, I lay the foundations for the conceptually coherent integration of consciousness into the physical worldview, derive an indicator for the quantity of consciousness of a given system, and outline the further steps toward a theory of consciousness.

Keywords

Conscious Systems, Theory of Consciousness, Universal Mechanism, Quantum Physics, Zero-Point Field (ZPF)

1. Introduction

The essence of our existence is inseparably connected with our consciousness that manifests itself in a huge variety of phenomenal qualities: the sweet juicy taste of a fresh strawberry, the fragrance of a rose, a moment of happiness while viewing a colorful sunset, the emotional fireworks set off upon achieving a new personal best. Such accounts express the subjective, experiential character of conscious states, also called qualia, the scientific explanation of which cannot be simply reduced to the physical properties of the associated brain states. The resulting explanatory gap is often referred to as the hard problem of consciousness (Chalmers, 1995, 1996).

The bridging of this gap and the scientific understanding of phenomenal awareness should lie in the domain of a theory of consciousness. Such a theory is ultimately expected to be seamlessly integrated into the physical worldview and to correctly predict the states of consciousness that are associated with the physical states of any given system. Expressed differently, in order for a theoretical approach to be classified as a full-fledged theory of consciousness, it must meet the requirement of being able to assign a state of consciousness to any physical state. It is fair to assume that this very ambitious goal can be accomplished only after a longer process of theory building. Nevertheless, any approach that is geared toward the development of a theory should right from the beginning be able to tell us what types of systems are conscious, what distinguishes conscious systems from non-conscious systems, and under what conditions a given system can have conscious experiences. In addition to this, it would also be desirable to have an indicator that measures the quantity of consciousness of a given system.

How do we get to a theory of consciousness? The common strategy in the natural sciences is to examine systems in detail, take data, find regularities, unveil universal principles, and build a solid theoretical structure on top of these principles. Usually, in this process the alternation of hypothesizing and experimental verification proves effective, particularly in view of the fact that new hypotheses entail new experimental paradigms and new data. It should be noted that not before the truly fundamental and universal principles are uncovered we are in a position to understand causal relationships and make valid predictions about the properties of the systems under study.

The strategy for the development of a theory of consciousness should follow the same rules, with the only difference that first-person data and third-person data have to be taken into account. The starting point is the thorough investigation of appropriate systems that are undeniably associated with conscious states. Such systems are our brains and with regard to their functioning there is already an enormous amount of data and insight available. The next step consists in the extraction of regularities from the neurophysiological body of evidence that point to the principles searched for. In this respect, many efforts have been made. However, none of the existing approaches has thus far exposed the truly universal and fundamental principles behind conscious systems. This indicates the necessity for the formulation of new hypotheses accompanied by the development of new experimental paradigms.

Particularly against the background of the mature theories we have in physics, it seems inconceivable that a fundamental theory of consciousness can be formulated at a high level of complexity, such as the level of neural networks. In search of a fundamental theory of consciousness, it is therefore essential to resort to the most basic level of physics. Only at that level will we be able to identify principles behind conscious systems that are on a par with the fundamental principles behind matter. And only at that level will we be able to establish a direct connection to the fundamental interactions and force fields that form the foundations of physics. Such a connection is an indispensable prerequisite for the integration of consciousness into a causally closed and complete scientific description of our world (Keppler, 2012, 2013).

With the above remarks in mind, let us now discuss a novel approach to the scientific understanding of consciousness. As will become obvious, it is advisable to partition the discussion into several guiding research questions that are dealt with successively. At the beginning, I want to address the relationship between brain and consciousness with the intention to scrutinize different directions of thought and identify the most promising approach to tackle the problem of consciousness, which leads to my hypothesis concerning the substrate of consciousness and, as a consequence thereof, to a precise specification of the medium phenomenal qualities are based on. This step is stringently required in order to integrate consciousness into the physical worldview and lay the foundations for a solid theoretical framework. Building on this hypothesis, we are able to get to the bottom of the mechanism behind conscious systems and processes. The mechanism I propose is qualified for the truly fundamental and universal principle on the basis of which conscious systems acquire their phenomenal qualities. Thereafter, we take a look at the neurophysiological body of evidence, suggesting that conscious processes in the brain actually bear on the proposed mechanism. Finally, I derive an indicator for the quantity of consciousness of a given system, outline the further steps toward a theory of consciousness, and expand on a testable prediction.

2. Relationship between Brain and Consciousness

How are conscious states related to brain states? In order to avoid a premature restriction of the search space for a theory of consciousness, it is advisable to treat this question as open and unbiased as possible. Bearing this in mind, I want to discuss three approaches that are conceivable and worth considering from a scientific point of view. Approaches other than these three, such as forms of substance dualism, may still be interesting from a philosophical perspective. However, they do not have a reasonable chance of success to fit seamlessly into the physical worldview. In this sense, this section is not intended for an all-encompassing discussion of the mind-body problem. Rather, the following considerations pursue the goal of identifying the most promising direction of thought for the development of a scientifically sound understanding of consciousness.

The first approach builds upon the notion that the brain *generates* consciousness. This position has been represented by very influential personages and is expressed by the hypothesis that consciousness arises as an emergent property of the activity patterns originating from a large collection of interacting neurons (Popper, 1978; Crick, 1994;

Libet, 2004). It is an immediate consequence of this position that the "conscious mental cannot exist without the brain processes that give rise to it" (Libet, 2004). Until today, this is the prevailing point of view among the scientists, particularly among the neuroscientists (Singer, 2015). However, on closer inspection this approach is confronted with considerable problems. If qualia truly emerge from physical processes, this act of creation must be somehow explicable by means of a reasonable mechanism and intelligible laws of nature. But in this respect, no plausible solution is in sight. While all emergent phenomena known in physics can be explained on the basis of weak emergence, the emergence of consciousness from originally non-conscious system components requires strong or brute emergence, which may be logically not impossible but would be completely mysterious. To put it straight, "brute emergence is by definition a miracle every time it occurs" and "a miracle is by definition a violation of a law of nature" (Strawson, 2006). This indicates that the notion of the brain as the generator of consciousness leads to a dead end and suggests that the breakthrough in consciousness research necessitates a departure from this path.

The second approach pursues the idea that the brain *assembles* higher states of consciousness from a great number of elementary building blocks of consciousness. This perspective is grounded on the hypothesis that consciousness is fundamental, ubiquitous, and matter-inherent, which is compatible with the common definition of panpsychism as "the view that the basic physical constituents of the universe have mental properties" (Nagel, 1979). Unquestionably, panpsychism is an interesting path for addressing the mind-body problem. But again, the devil is in the details as we immediately encounter the question of how our rich spectrum of unified macro experiences emerges from a limited spectrum of micro experiences, also known as the combination problem (Seager, 1995, 2010; Goff, 2009; Chalmers, 2013). A concise description is given in (Seager, 2010: p. 170): "The difficulty is that if we assign some sort of extremely primitive or simple consciousness to the elementary features of the physical world we then need to explain how the *complex* conscious states we are introspectively familiar with arise. This seems to be a form of emergence and then the problem is that if panpsychism itself requires a mechanism of emergence then why not take the theoretically more economical route of letting consciousness emerge directly from the physical basis itself rather than from a mental basis."

Hence, the main challenge of this approach is the identification of a plausible aggregation mechanism that is able to explain how complex conscious states emerge from the primitive mental states ascribed to the fundamental entities of the world. Again, a solution is logically not impossible. But whichever way we look at it, there is no tangible mechanism in sight on the basis of which the aggregation of primitive conscious states into complex forms of consciousness is supposed to work.

On closer examination, the combination problem is tightly related to the concept of intrinsic mental properties of matter, indicating that in order to take a decisive step forward this concept should be called into question. On the other hand, however, it is reasonable to preserve the eminently plausible notion of the fundamental nature of consciousness. As a consequence, we should direct our attention to a hitherto hardly considered route that accepts consciousness as a fundamental but not matter-inherent property of the universe. This line of thought is perfectly consistent with the worldview of Eastern philosophy, according to which "consciousness is a primary phenomenon" and "things have no intrinsic reality" (Ricard & Thuan, 2004).

This leads to the third approach, according to which the brain *extracts* the variety of phenomenal nuances from a ubiquitous sea of consciousness. The underlying hypothesis can be formulated such that the functioning of the brain is postulated to rely on a universal filtering mechanism (Keppler, 2013). Correspondingly, the brain should be neither thought of as a generator nor an assembler of conscious states, but rather as a highly specialized *filter* of consciousness.

The main idea behind this approach is depicted in **Figure 1**, where I assume the existence of an all-pervasive background field of consciousness that is in permanent interaction with matter. Accordingly, there is also a continuous interaction between the brain and this background field, which I refer to as the *substrate of consciousness*. A conjectured characteristic of the interaction mechanism is the formation of ordered states in the inherently disordered background field, which is brought about by a selective filtering of the substrate. I hypothesize that such ordered states go along with conscious states. On the supposition that the substrate covers all the shades of phenomenal awareness, i.e., the full spectrum of phenomenal qualities, the mechanism outlined above renders it possible for the brain to cause an enormous variety of conscious states. From this perspective, our brains act as filters that extract nuances of conscious awareness selectively from the universal color palette of consciousness that is built into the ubiquitous background field.

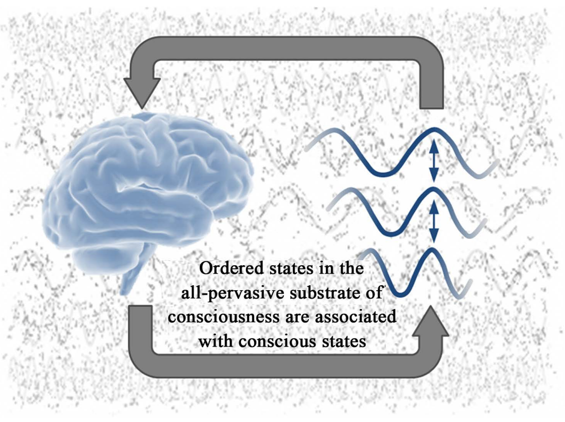

Figure 1. The brain is viewed as a highly specialized filter of consciousness. This approach is based on the hypothesis that the whole range of phenomenal qualities is built into the frequency spectrum of a ubiquitous background field of consciousness. Proceeding on this assumption, the principle of dynamical coupling of selected frequencies is ideally suited to extract a huge variety of phenomenal nuances from the available phenomenal color palette and to conflate shades of phenomenal awareness into unified moments of consciousness. Accordingly, it is postulated that the functioning of the brain relies on a universal mechanism that generates ordered states in an all-pervasive substrate of consciousness.

This is a very elegant approach. However, it raises three core issues, namely the question regarding the nature of the substrate of consciousness, the question of how the interaction mechanism works in detail as well as the question as to whether there is evidence that conscious processes in the brain are really based on such a mechanism. In the subsequent sections, I want to address these questions one after the other, elaborate on the explanatory power of this novel approach, and lay the foundations for the further development of this approach toward a theory.

3. Substrate of Consciousness

As already pointed out, it should be expected that a deep understanding of consciousness is closely connected with a deep understanding of matter. In the last decades the awareness has grown among physicists that the notion of the vacuum plays a key role in this context. As a result, the materialistic worldview has been replaced by a modern perspective that acknowledges the structure of the vacuum as the primary reality from which the properties of matter emerge as the secondary reality (Wilczek, 2008).

A physical theory that underpins this philosophy is stochastic electrodynamics (SED), the foundations of which were laid in the 1960s and 1970s with the goal of eliminating the explanatory gaps of quantum theory (Marshall, 1963, 1965; Boyer, 1969, 1975). Since then, the framework of SED has been continuously advanced and methodologically refined (De la Peña & Cetto, 1994, 1995, 1996, 2001, 2006; De la Peña, Valdés-Hernández, & Cetto, 2009; Cetto, De la Peña & Valdés-Hernández, 2012; De la Peña, Cetto, & Valdés-Hernández, 2015). Through these developments a sound conceptual basis could be established, now enabling the derivation of the formalism of quantum mechanics and quantum electrodynamics (QED) from SED. The enormous achievement of SED is that it provides novel insight into the nature of quantum systems, thereby unveiling the origin of quantum phenomena and disclosing the fundamental principles underlying matter. Since all physical phenomena on the length scale of biological systems are dominated by the electromagnetic interaction, it can be assumed that SED constitutes the appropriate framework for the understanding of these systems.

In this context, I would like to emphasize that SED does not replace QED, nor does it improve the predictions of QED. The dynamics of quantum systems is correctly *described* by QED. The additional feature and advantage of SED is the capability of *explaining* the physical mechanisms that account for the quantum behavior of matter. In this sense, SED opens up new perspectives that otherwise remain concealed behind the formalism of QED. In particular, as we will see below, completely new perspectives are opened up for consciousness research.

SED is based on the conception that the vacuum is imbued with permanent activity, represented by a real, all-pervasive stochastic radiation field, called zero-point field (ZPF), which can be interpreted as an ocean of light. The field equations obey several symmetries, namely homogeneity, isotropy, Lorentz invariance as well as scale invariance, leading to a sum of plane electromagnetic waves with a unique power spectrum

(De la Peña & Cetto, 1994, 1995). Due to its inherent completeness and stochastic nature, the undisturbed ZPF comprises the full spectrum of frequency components, which are entirely uncorrelated among each other. In this sense, the free ZPF is a maximally disordered field (De la Peña, Valdés-Hernández, & Cetto, 2009).

These characteristics convey the idea of the ZPF as an omnipresent background field and formative agent behind the scenes that holds the potential for the huge variety of material manifestations. This is examined and substantiated in the subsequent section where we take a closer look at the interaction mechanism between matter and the radiative background. The main findings imply that the ZPF shapes and orchestrates matter and, in turn, is itself shaped and modified in this process. Moreover, it becomes apparent that the constituents of matter have no intrinsic properties. Rather, they *acquire* their stability and their physical properties, such as energy levels and spin, in the course of their dynamic interaction with the background (De la Peña & Cetto, 1995, 2001; De la Peña, Valdés-Hernández, & Cetto, 2009). This property acquisition process is based on the unique features of the ZPF and the interaction mechanism that acts like a filter on the energy field.

Given the above explanations, SED commends itself as a promising approach for the integration of consciousness into a coherent theoretical framework, making the ZPF an obvious candidate for the substrate of consciousness. The significant advantage of this approach is the notion of one fundamental field that is not only the carrier of energy, but also the carrier of consciousness. This opens up the perspective that by means of one and the same mechanism particular systems acquire not only their physical properties, but also their phenomenal qualities, which perfectly satisfies the law of parsimony. In other words, any system that makes use of the mentioned universal mechanism filters its individual stream of consciousness out of the ubiquitous sea of consciousness.

According to this approach, the ZPF constitutes the basis for an absolute background of consciousness. The justification for such a background is best put into words by Arthur Eddington (1928: p. 259): "The physical atom is, like everything else in physics, a schedule of pointer readings. The schedule is, we agree, attached to some unknown background. … It seems rather silly to prefer to attach it to something of a so-called 'concrete' nature inconsistent with thought, and then to wonder where the thought comes from. We have dismissed all preconceptions as to the background of our pointer readings, and for the most part we can discover nothing as to its nature. But in one case —namely, for the pointer readings of my own brain—I have an insight which is not limited to the evidence of the pointer readings. That insight shows that they are attached to a background of consciousness."

In summary, I posit that SED is the appropriate foundation for the scientific understanding of mental phenomena and I hypothesize that *the ZPF is the substrate of consciousness*. From this point of view, there is actually no aggregation problem of how complex states of consciousness emerge from the combination of primitive states of consciousness. Rather, all the shades of phenomenal consciousness are already inherent in the full frequency spectrum of the ZPF. As a result, it is the dynamic variability of a given system that determines the accessible frequency components and, hence, the range of phenomenal qualities that can be transiently acquired from the ubiquitous carrier of consciousness. However, this does not imply that every material system is conscious. Instead, only systems that make use of a specific mechanism can produce conscious states. In this way, the approach is able to draw a dividing line between conscious and non-conscious systems.

4. Mechanism Underlying Conscious Systems

Let us now study the interaction between matter and ZPF in more detail. To this end, we return to the essence of SED, according to which the electrically charged constituents of every physical system interact permanently and unavoidably with the initially uncorrelated frequency components of the ZPF, thus acquiring a stochastic motion and behaving as stochastic oscillators. As long as the coupling strength between the charged constituents and the relevant frequency components prevails over disturbing forces such as thermal noise, the energy exchange between the constituents and the ZPF can reach equilibrium where the average power absorbed by the system compensates exactly the average radiated power. These balance situations are characterized by quantization conditions and correspond to the stationary states predicted by quantum theory (De la Peña & Cetto, 1995, 2001, 2006). Hence, any dynamical system in equilibrium with the ZPF displays quantum behavior. Upon reaching equilibrium, such a system falls into an attractor (De la Peña & Cetto, 1995), as shown in **Figure 2(a)**. Expressed

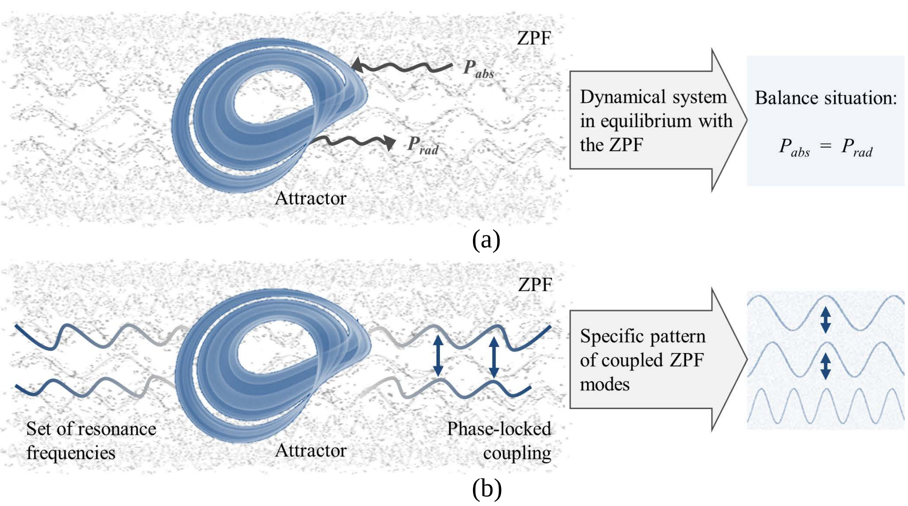

Figure 2. Quantum systems are orchestrated by the ZPF. (a) According to SED, the electrically charged constituents of every physical system interact permanently with the ZPF, thus behaving as stochastic oscillators. Under appropriate conditions, the stability of a system is created dynamically as soon as the average power absorbed by the system (P_{abs}) compensates exactly the average radiated power (P_{rad}). Upon reaching equilibrium, a system falls into an attractor (as depicted symbolically) and enters the quantum regime; (b) The presence of matter affects the ZPF in such a way that the resonance frequencies involved in the maintenance of the equilibrium become highly correlated. As a consequence, the formation of an attractor is accompanied by a specific pattern of phase-locked ZPF modes.

differently, every stationary quantum state is characterized by an individual dance pattern that is orchestrated by the ZPF. It is a main feature of quantum systems that appropriate external stimuli can cause transitions between different attractors and, hence, can prompt a system to follow a new dance pattern.

Owing to the close interrelationship between matter and ZPF, the presence of matter also affects the dynamics of the ZPF. For nonlinear systems in equilibrium, the interplay between the charged constituents and the relevant ZPF modes, for which the system exhibits a strong resonant behavior, causes a modification of the originally disordered background field. As soon as a stable attractor is reached, these frequency components are involved in the maintenance of the equilibrium and become highly correlated (De la Peña & Cetto, 2001, 2006), resulting in a partial organization of the local field (De la Peña, Valdés-Hernández, & Cetto, 2009). In other words, as illustrated and summarized in **Figure 2(b)**, the initially chaotic ZPF adapts itself to the balance situation in such a manner that the relevant modes, which can be regarded as a specific set of resonance frequencies, undergo a phase-locked coupling. In this way, all the constituents of the system are effectively coupled through the ZPF (De la Peña & Cetto, 2001), giving rise to collective cooperation and long-range coherence. Hence, the key insight from SED is that quantum phenomena are emergent phenomena that can be traced back to the resonant interaction between the constituents and the ZPF. In line with this, the properties of a quantum system are not intrinsic properties, but dynamically acquired properties that can be attributed to the system over the lifetime of an attractor.

There are two ways of looking at this fundamental mechanism underlying quantum systems. On the one hand, the patterns of phase-locked ZPF modes can be interpreted as information states in an information space, in the following referred to as *ZPF information states*. This means that the formation of an attractor imprints an information state on the ZPF, with the information content depending on the dynamical properties of the attractor. Each quantum system distinguishes itself by its specific set of resonance frequencies and the respective pattern of coupled ZPF modes. As a consequence, different attractors go along with different ZPF information states.

On the other hand, the mechanism explained above can be viewed as a particular type of extraction or filtering in such a way that quantum systems function as resonant stochastic oscillators that filter their sets of resonance frequencies selectively out of the full ZPF spectrum. This selective interaction results in the phase locking of the system-specific ZPF modes, with all the other modes remaining unaffected. Thus, in a metaphorical sense, the formation of an attractor corresponds to a chord played on the keyboard of the zero-point field.

Following the hypothesis that the ZPF is the substrate of consciousness, it is natural to assume that the fundamental mechanism underlying conscious systems is identical to the mechanism behind quantum systems. Under this assumption, the presented mechanism has the potential to provide such systems with the ability to acquire not only their physical properties, but also their phenomenal qualities. More precisely, the principle of dynamical and flexible coupling of sets of ZPF modes is ideally suited to filter a huge variety of phenomenal nuances out of the full phenomenal color palette represented by the ZPF and to conflate shades of phenomenal awareness into unified moments of consciousness. On the basis of this unique feature and the strong argument in favor of a universal principle, I posit that *the mechanism underlying conscious systems is due to the partial organization of the local ZPF* and that *every ZPF information state is associated with a conscious state*. This hypothesis reflects the dual role of the ZPF as the carrier of both energy and consciousness and expresses that every ordered state in the ZPF goes hand in hand with a conscious state, or in other words, a pattern of phase-locked ZPF modes determines both the physical and the phenomenal properties of a quantum system (Keppler, 2013).

According to this approach, the dividing line between conscious and non-conscious systems is defined by the differentiation between quantum systems and classical systems. While the constituents of quantum systems are dynamically coupled via the ZPF, the dynamics of classical systems is completely independent of the ZPF, thus leaving the background field unaffected and having no means of generating ordered states in the substrate of consciousness.

In consequence, at least as long as there is no indication of any plausible additional exclusion principle, I hypothesize that *every quantum system is a conscious system*, with the dynamic variability of a system determining the accessible spectrum of conscious states. This variability is characterized by the complexity of the attractor landscape, which defines both the degree of consciousness and the diversity of conscious experiences of a system. While simple systems can be expected to have a very rudimentary, limited, and monotonous form of consciousness, we may assume that complex systems are endowed with a broad range of multifaceted conscious experiences. In this sense, evolution has not invented consciousness in the guise of a mysterious mechanism for creating conscious systems out of non-conscious subsystems. Rather, evolution has brought forth increasingly complex quantum systems that rely on a universal and intelligible mechanism on the basis of which they are able to extract increasingly complex phenomenal qualities from the ubiquitous field of consciousness. At this point, it is important to recall that the properties of a quantum system are not intrinsic properties, but dynamically acquired properties that can be attributed to the system over the lifetime of an attractor.

I would like to mention that in nature there are many classical systems composed of quantum systems, such as a gas consisting of hydrogen molecules. In this case, the individual molecules are microscopic quantum systems, each of which is presumably associated with a primitive and monotonous conscious state. However, while every single molecule is in equilibrium with the ZPF, the entire system of molecules is not dynamically coupled via the background field. Accordingly, there is no conscious level of the system over and above the conscious states of the individual molecules. Only when the system as a whole is orchestrated by the ZPF and displays long-range coherence, a system-wide reorganization of the ZPF can arise. In this case we deal with a macroscopic quantum system, the formation of which is the prerequisite for a higher level of consciousness. A macroscopic quantum system distinguishes itself from a microscopic quantum system by an extended range of ZPF interaction frequencies toward the lower part of the spectrum, opening up the potential for a significant increase in the number of ZPF resonance frequencies and accessible ZPF information states. The body of evidence resulting from the analysis of neural activity patterns suggests that the functioning of the brain is based on exactly this principle.

5. Realization of the Mechanism in the Brain

In the following, we take a closer look at the neurophysiological findings. A common strategy behind the ongoing activities in this field of research, which have been methodologically refined over the years (Aru, Bachmann, Singer, & Melloni, 2012; Singer, 2015), consists in distilling the neural correlates of consciousness (NCC).

Taken together, it can be clearly stated that those proposals on NCC receive the greatest support according to which conscious states are associated with long-range coherence in the brain, particularly with synchronized activity in the beta and gamma frequency band. This relation between long-range synchronization and consciousness has been multiply corroborated on the basis of different experimental paradigms (Crick & Koch, 1990; Desmedt & Tomberg, 1994; Rodriguez, George, Lachaux, Martinerie, Renault, & Varela, 1999; Engel & Singer, 2001; Melloni, Molina, Pena, Torres, Singer, & Rodriguez, 2007; Gaillard, Dehaene, Adam, Clemenceau, Hasboun, Baulac et al., 2009). Moreover, it was found that gamma synchrony shows up not only during conscious awareness of an external stimulus, but also in altered states of consciousness, such as meditation (Lutz, Greischar, Rawlings, Ricard, & Davidson, 2004) and REM sleep (Llinás & Ribary, 1993; Montgomery, Sirota, & Buzsáki, 2008). From this neurophysiological perspective, it is the binding of distributed neurons into functionally coherent assemblies that accounts for the unified nature of conscious experience (Singer, 2015). Going one step further, the experiments suggest that "discrete moments of perceptual experience are implemented by transient gamma-band synchronization of relevant cortical regions, and that disintegration and reintegration of these assemblies is time-locked to ongoing theta oscillations" (Doesburg, Green, McDonald, & Ward, 2009). This means that "theta oscillations could serve to structure the flow of conscious experience, allowing for changes in content every few hundred milliseconds" (Singer, 2015).

These findings are supported and enriched by Walter Freeman's studies in animals, demonstrating that conditioned stimuli are associated with macroscopic patterns of amplitude modulation of a carrier wave in the gamma and beta frequency range, which represent attractors in an attractor landscape (Freeman, 1991, 2005). The results further suggest that these attractors are the NCC, since the corresponding activity patterns are "correlated with the actions and inferred perceptions of the animals" (Freeman, 2007). In this context, it was also discovered that "vast collections of neurons shift abruptly and simultaneously" between different attractors (Freeman, 1991). Accordingly, the brain can be regarded as a complex system that operates near a critical point of a phase transition. While the brain displays spontaneous activity and irregular dynamics in the disordered phase, an appropriate stimulus can transfer it to the ordered phase that exhibits long-range correlations and attractors (Freeman, 2007). These findings clearly indicate that the brain has all the characteristics of a macroscopic quantum system, meaning that classical explanations are inadequate and that the observed macroscopic features like dissipative structures, pattern formation, and phase transitions cannot be understood without recourse to quantum dynamics and the theoretical framework of quantum field theory (Freeman & Vitiello, 2006, 2007).

In addition, a deep analysis of the spontaneous background electrocorticogram revealed that the background activity of the brain is self-regulated noise showing repetitive steep decreases in the analytic power, called null spikes (Freeman, 2009). These events, which occur at theta rates, trigger phase transitions by dissolving coherent assemblies and initiating short periods of disorder. Such a moment of disorder creates the prerequisites for a stimulus to induce a reorganization of the background activity and to prompt the emergence of the subsequent attractor (Freeman, 2004, 2009). These results imply that noise plays a fundamental role in the functioning of the brain, which has been confirmed by investigations of other groups (Kitajo, Doesburg, Yamanaka, Nozaki, Ward, & Yamamoto, 2007; Burns, Xing, Shelley, & Shapley, 2010; Burns, Xing, & Shapley, 2011).

As already pointed out above, this neurophysiological body of evidence suggests that quantum field theory, concretely QED, is the appropriate tool to describe the dynamical properties of the NCC, particularly their enormous coherence length as well as their rapid formation and dissolution. However, in order to understand what happens behind the scenes of the NCC, we have to go one step beyond QED and make use of the framework of SED, which provides a very transparent interpretation of the findings in that it discloses the core principles behind quantum systems and opens up a new perspective on the brain as a stochastic oscillator driven by the ZPF (Keppler, 2013).

From this point of view, the ZPF acts as a ubiquitous noise source that causes the spontaneous background activity of the brain. An appropriate stimulus induces a phase transition and reorganization of the cortical background activity that culminates in an attractor, the formation and stabilization of which is accompanied by a reorganization of the ZPF. In this stadium, the ZPF is used as communication channel to establish synchronization and convey influence from each part of the coherence domain to every other part. As soon as a stationary equilibrium between the oscillating cell assembly and the ZPF is reached, an information state is imprinted on the ZPF, which originates from the attractor-specific phase locking of ZPF modes. According to the hypotheses and explanations given in the previous sections, such a ZPF information state is expected to be associated with a conscious state. Every theta cycle together with its conscious state is terminated by a null spike that decouples the existing attractor from its driving force, the ZPF. As a consequence, the equilibrium between the involved cell assembly and the ZPF is disrupted, the attractor collapses and the system returns to the disordered phase, thus clearing the way for the emergence of the next attractor. This is how the brain produces an individual stream of consciousness by periodically modifying the ZPF and generating ZPF information states (Keppler, 2013).

We can conclude that SED provides a consistent picture of the observed processes in the brain. The high coherence of the ZPF modes that sustain the stationary states contrasts considerably with the incoherent noise sources characteristic of classical systems, and the unique spectral energy density of the ZPF is essential in ensuring the stability of attractors. What makes these attractors so special is that they are the only activity patterns that can leave fingerprints in the ZPF, the presumed substrate of consciousness. So, coming back to the postulated mechanism underlying conscious systems, there is plenty of evidence that the brain does make use of this mechanism. More precisely, the body of evidence supports the view that conscious processes are those processes where the mechanism is active, while in unconscious processes the mechanism is not active.

What still needs to be accomplished is a detailed understanding of the phase transition that includes all levels of microscopic, mesoscopic, and macroscopic organization. In this connection, it is already becoming apparent from QED calculations that the special properties of water are important for the dynamics existing in living organisms (Del Giudice, De Ninno, Fleischmann, Mengoli, Milani, Talpo, & Vitiello, 2005; Del Giudice, Spinetti, & Tedeschi, 2010) and the formation of dissipative structures (Marchettini, Del Giudice, Voeikov, & Tiezzi, 2010). Interpreted from the viewpoint of SED, these investigations reveal that the interaction between the water molecules and the ZPF gives rise to extended regions exhibiting coherent dynamics, resulting in coherence domains. Particularly in interfacial water, i.e., in water adjacent to hydrophilic surfaces, the attraction between the water molecules and the wall is able to neutralize disruptive thermal effects, thus simulating a low temperature environment, stabilizing coherent dynamics, and supporting the emergence of much more extended coherence domains (Del Giudice, Spinetti, & Tedeschi, 2010; Del Giudice, Tedeschi, Vitiello, & Voeikov, 2013). It is plausible that under such favorable conditions long-range coherence in the brain can arise. The whole orchestration process involves a hierarchy of ZPF modes that reaches from the THz and GHz to the MHz frequency band. At the macroscopic level this orchestration triggers gamma synchrony, which is the observed response of the whole system.

6. Toward a Theory of Consciousness

Looking back at the preceding sections, it can be summarized that the new avenue to the scientific understanding of consciousness turns out to be very promising. The novel approach presented here builds upon the notion that conscious systems employ a universal mechanism of extracting conscious states from a ubiquitous substrate of consciousness. As we have seen, satisfactory answers and illuminating details can be given with regard to the nature of the substrate, the principles behind the interaction mechanism, and the realization of the mechanism in the brain.

These points provide the propounded approach with a significant degree of explanatory power, which becomes particularly apparent in the consistent interpretation of the NCC. In this respect, the unique features of the suggested substrate and mechanism give solid reasons as to *why* the experimentally determined correlates are related to conscious awareness. This opens a door to the desirable transition from correlation to explanation. The crucial insight is that solely synchronized activity patterns in stationary equilibrium with the ZPF enjoy the privilege of generating ZPF information states. As a result, we obtain a clear distinguishing criterion between conscious and unconscious brain processes in such a way that only those processes that culminate in transiently stable attractors are able to exert influence on the substrate of consciousness and, hence, have the potential to exceed the threshold to conscious experience. This also explains why conscious perception is an all-or-none phenomenon, as indicated by experiments (Sekar, Findley, Poeppel, & Llinás, 2013).

These findings suggest that the ideas set forth in this article provide a solid basis for the development of a theory of consciousness. Referring to the introductory remarks, an important intermediate step on the way to such a theory should consist in the specification of a universal indicator for the quantity of consciousness of a given system. In fact, the derivation of such an indicator is straightforward and follows directly from the hypothesized mechanism underlying conscious systems according to which conscious states arise when the initially disordered ZPF is transferred to a partially ordered state. As discussed in the previous sections, this process is due to the phase locking of ZPF modes accompanying the formation of attractors. More precisely, every conscious state of a given system is assumed to be characterized by a specific set of phase-locked ZPF modes, with the rule that more complex and multifaceted phenomenal qualities originate from more complex attractors, which are associated with more complex sets of correlated ZPF modes.

Building on this, I posit that *a natural measure for the quantity of consciousness of a state is the degree of order in the local ZPF compared to the completely disordered field*, or expressed differently, *the information gain of the corresponding ZPF information state compared to the disordered initial state*. The appropriate indicator for this information gain is the Kullback-Leibler divergence D_{KL} (Kullback & Leibler, 1951), which is a strictly positive measure for the difference between two probability distributions. Consequently, the quantity of consciousness of a state, referred to as Q_C^{state}, can be determined by

$$Q_C^{state} = D_{KL} \equiv \int_{-\pi}^{\pi} p(\Delta\varphi_{ZPF}) \log\left(\frac{p(\Delta\varphi_{ZPF})}{q(\Delta\varphi_{ZPF})}\right) \mathrm{d}(\Delta\varphi_{ZPF}), \tag{1}$$

where in our case $p(\Delta\varphi_{ZPF})$ and $q(\Delta\varphi_{ZPF})$ denote the probability distribution of the ordered and the completely disordered ZPF, respectively, with the phase difference $\Delta\varphi_{ZPF}$ between the frequency components of the ZPF ranging from −π to π. As a result, it is reasonable to assess the quantity of consciousness of a given system by taking the maximum quantity of consciousness of all the states this system can produce, which can be expressed by

$$Q_C^{system} = \max_{states\ i} Q_C^i. \tag{2}$$

Realistic estimates for various systems are currently in progress. In order to convey a first impression of the measure of consciousness thus defined, I restrict myself to an example that is illustrated in the **Appendix**. As one can clearly see, the quantity of consciousness of a state increases with the degree of phase locking in the local ZPF. The concomitant information gain in the ZPF, which causes a system to function as a whole, can be interpreted as integrated information, meaning that at this point the presented approach shares commonalities with the integrated information theory (IIT) of consciousness (Tononi, 2004, 2008, 2012; Oizumi, Albantakis, & Tononi, 2014). However, in contrast to IIT, the expression for the quantity of consciousness given here relies on a universal mechanism and a theoretical framework that is on an equal footing with the fundamental theories of physics. Interestingly, in his work Giulio Tononi points out that there are "intriguing parallels between integrated information and quantum notions" (Tononi, 2008) and he notes that "several aspects … of transient attractor dynamics appear well suited to information integration" (Tononi, 2012).

Forging a bridge to the introductory remarks, I would like to complete the discussion with an outline of the essential steps toward a theory of consciousness. These steps can be translated into a strategy that incorporates novel experimental and theoretical approaches. The experimental setup must be designed such that a variety of conscious states are induced in test persons, with the requirement that the individual states should be independent of each other and as reproducible as possible. Each of the conscious states is on the one hand characterized by its phenomenal qualities, described on the basis of the first-person accounts. On the other hand, for each of the conscious states the associated attractor must be analyzed and the corresponding pattern of phase-locked ZPF modes has to be determined. In this way, we can systematically explore qualia space by classifying and calibrating ZPF information space (Keppler, 2012). This strategy is illustrated in **Figure 3**.

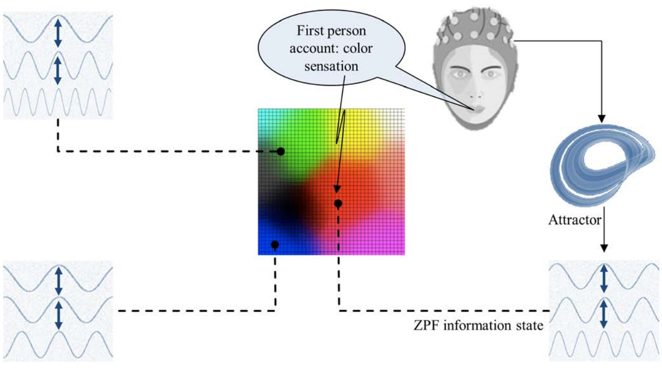

Figure 3. Qualia space can be systematically explored by classifying ZPF information space. This is illustrated using the example of color sensation. A test person is exposed to a variety of visual stimuli, inducing conscious states that are described by the person (shortly afterwards). At the same time, we have to analyze the neural activity patterns, identify the attractors and reconstruct the ZPF information states associated with the induced conscious states. In this way, ZPF information space can be calibrated on the basis of the first-person accounts.

The phenomenal classification of ZPF information states will also shed light on the internal structure of qualia space. It may be hypothesized that conscious experiences originating from different modalities, such as visual and auditory experiences, are located in different ZPF information subspaces and that there is a similarity principle in such a way that similar patterns of phase-locked ZPF modes are associated with similar phenomenal qualities. Such regularities can be expected to result in psychophysical mapping rules between ZPF information states and qualia, describing where a given ZPF information state is located in qualia space. At this stage, the strategic approach will have reached the maturity level of a theory that is able to assign a state of consciousness to any physical state.

The major challenge of the outlined strategy consists in determining patterns of phase-locked ZPF modes, which can in principle be met by two different approaches. The theoretical path involves a high degree of physics and implies that we have to build SED-based simulation 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 undisturbed ZPF caused by the attractors and disclose the ZPF information states searched for. From a present-day perspective, this avenue may have realistic prospects of success in the long run.

In the short term, the experimental path looks more promising. The approach I propose takes advantage of characteristic emissions of coherent photons that are expected concomitant phenomena of transitions from disordered states to ordered macroscopic quantum states (Dicke, 1954), the latter states being presumably associated with conscious states. According to the finding that the generation of conscious states occurs at theta rates (Doesburg, Green, McDonald, & Ward, 2009), I predict a correlation between the photon intensity and the theta rhythm, which should be the first subject of experimental verification and would lead to a direct confirmation of the proposed mechanism. Building on this, a variety of attractors can be included in a more detailed spectroscopic survey with the goal of reconstructing the ZPF information states behind the individual attractors and systematically exploring ZPF information space.

7. Summary and Conclusion

In the preceding sections, we explored a new avenue to the scientific understanding of consciousness. It accepts consciousness as a fundamental but not matter-inherent property of the universe and is based on the hypothesis that the whole range of phenomenal qualities is built into the frequency spectrum of a ubiquitous background field. Proceeding on this assumption, the principle of dynamical coupling of selected frequencies is ideally suited to extract a huge variety of phenomenal nuances from the available phenomenal color palette and to conflate shades of phenomenal awareness into unified moments of consciousness. Following this logic, the functioning of conscious systems is postulated to rely on a universal mechanism that gives rise to ordered states in an all-pervasive substrate of consciousness.

As discussed at length, physics can offer a theoretical framework that provides a promising candidate for the background field as well as a detailed description and explanation of the mechanism. In particular, the unique properties of the ZPF are indicative that this radiation field is able to play the dual role as both the carrier of energy and consciousness. The appropriate mechanism of generating phase-locked ZPF modes is characteristic for quantum systems, opening up the perspective that by means of one and the same universal principle such systems acquire not only their physical properties, but also their phenomenal qualities. In contrast, the dynamics of classical systems is completely independent of the ZPF, thus leaving the background field unaffected and rendering it impossible to generate ordered states in the substrate of consciousness. This suggests that the dividing line between conscious and non-conscious systems is defined by the differentiation between quantum systems and classical systems. A direct consequence thereof is the hypothesis that all quantum systems are conscious systems, with the dynamic variability of a system determining the accessible spectrum of conscious states. It is reasonable to expect that simple quantum systems have a very rudimentary, limited, and monotonous form of consciousness, while complex quantum systems are endowed with a broad range of multifaceted conscious experiences.

The neurophysiological body of evidence supports the view that the brain has all the characteristics of a macroscopic quantum system and that the principle behind conscious processes rests upon the recurring formation and dissolution of quantum states, all of which are accompanied by patterns of phase-locked ZPF modes. From this perspective, the brain produces an individual stream of phenomenal awareness by periodically modifying the presumed substrate of consciousness. This leads not only to a consistent interpretation of the dynamical properties of the neural correlates of consciousness, but also gives solid reasons as to why the experimentally determined correlates are related to conscious awareness. As a result, we obtain a clear distinguishing criterion between conscious and unconscious brain processes in such a way that only those processes that are able to exert influence on the ZPF have the potential to exceed the threshold to conscious experience.

Building on the hypothesized mechanism underlying conscious systems, it is straightforward to derive an indicator for the quantity of consciousness of a given state. It measures the degree of order in the ZPF compared to the completely disordered field and can be viewed as the first step toward a theory of consciousness, the strategic development of which necessitates the systematic exploration of a variety of conscious states. Each state is on the one hand characterized by its phenomenal qualities, described on the basis of the first-person accounts, and on the other hand by its specific pattern of phase-locked ZPF modes. This opens a door to the phenomenal classification of ZPF information states and the derivation of psychophysical mapping rules. Due to the expectation that transitions between the presumed macroscopic quantum states are accompanied by characteristic photon emissions, the first testable prediction of this approach is a correlation between the photon intensity and the theta rhythm.

In summary, the approach presented in this article meets the standards that are to be imposed on a theoretical framework for consciousness, all the facets of which are aptly described by Thomas Metzinger (1995). To start with, the proposed solution is comprehensive and conceptually coherent, and it manages very well to integrate our current knowledge about mind and matter into a consistent picture. In particular, it preserves the principle of causal closure and it answers the question of how phenomenal awareness can be reconciled with the laws of nature. In doing so, it provides demarcation criteria for the domain of consciousness and sheds light on the conditions under which a given system can have conscious experiences. In this context, it is worth mentioning that these criteria are hardware- and species-independent, making them a suitable basis for the classification of all kinds of organisms. Furthermore, the specified mechanism behind conscious systems offers an explanation for the unity of phenomenal consciousness. And finally, a strategy is suggested on the basis of which the subjective properties of mental states can be interrelated to the objective properties of the underlying physical states, which is an important prerequisite for the development of a theory of consciousness.

What can we expect from a theory of consciousness? If the approach described above proves to be correct, such a theory will be able to answer the question of how consciousness is built into the fabric of the universe. It will also provide answers as to how the physical states of any given system can be mapped onto phenomenal states in qualia space. However, a theory of consciousness will not be able to explain the existence of consciousness, just as little as QED or SED is capable of explaining the existence of energy. In this sense, the source of the all-pervasive ZPF as the carrier of both energy and consciousness may turn out to be the ultimate hidden secret of our cosmos.

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Appendix

In order to express the frequency correlations of a locally ordered ZPF mathematically, a function is used that displays an accumulation of phase differences in the vicinity of $\Delta\varphi_{ZPF} = 0$. An appropriate normalized probability distribution is

$$p\left(\Delta\varphi_{ZPF}\right) = \frac{a}{2\left(1-\mathrm{e}^{-a\pi}\right)}\mathrm{e}^{-a\left|\Delta\varphi_{ZPF}\right|}, \tag{3}$$

where a is a parameter indicating the degree of phase locking. In contrast, the probability distribution of the completely disordered field, which does not exhibit any phase locking, is represented by the normalized uniform distribution

$$q\left(\Delta\varphi_{ZPF}\right) = \frac{1}{2\pi}. \tag{4}$$

Inserting Equation (3) and Equation (4) into Equation (1) and taking the natural logarithm yields

$$Q_C^{state} = \ln\left(\frac{a\pi}{1-\mathrm{e}^{-a\pi}}\right) + \frac{a\pi}{\mathrm{e}^{a\pi}-1} - 1. \tag{5}$$

This function is illustrated in Figure A1.

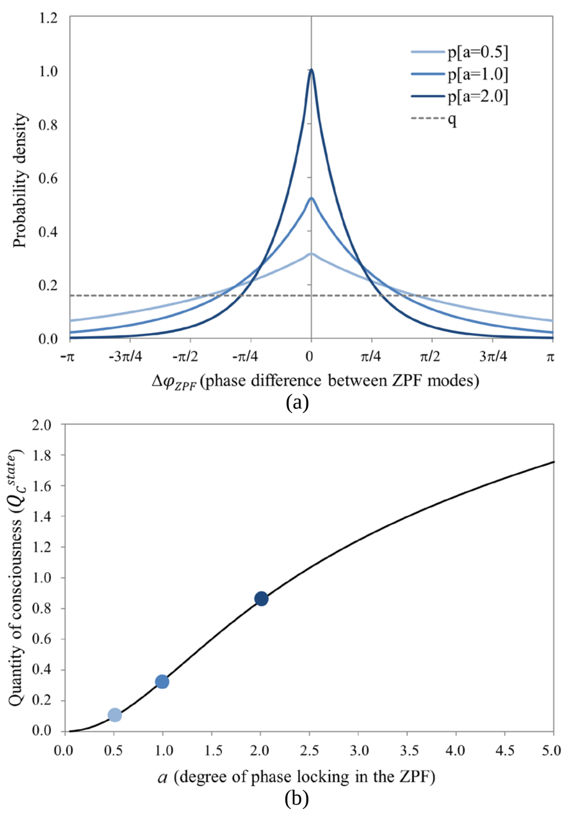

Figure A1. The quantity of consciousness is determined by the degree of order in the ZPF. Part (a) displays Equation (4) as well as Equation (3) for three values of parameter a. Part (b) illustrates Equation (5) together with the marks representing the three values of a. Realistic estimates of a for various systems are currently in progress.