Chapter 18
Is the Source of Awareness Present in the Quantum Vacuum?

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18.1 Introduction

The phenomenon of awareness is common to all animate species. It is also at the core of cognition in any sentient being we consider capable of possessing consciousness. Consciousness is the very window through which we perceive reality and reflect upon the emotions and feelings that colour our lives. It is the vehicle, as well, through which we acquire that cherished knowledge of the physical world, which is embodied in science. Because it is both an *instrument* of perception and a *perceived entity* itself, consciousness is qualitatively very different from anything else we know. We might say awareness is aware of itself and, as such, could be a fundamental element of the universe. Can we then dismiss it as just an emergent property of matter or a mere epiphenomenon arising out of computational processes in our brain?

An abundant number of very eminent scientists have considered consciousness to be indeed fundamental. None other than the godfather of quantum theory, Max Planck (1931: 199) declared, "I regard consciousness as fundamental. I regard matter as derivative from consciousness". The quantum pioneer Erwin Schrödinger (1964) is more explicit in emphasizing that "Consciousness cannot be accounted for in physical terms. For consciousness is absolutely fundamental. It cannot be accounted for in terms of anything else". Schrödinger also found the potential existence of a cosmic awareness and its probable close relationship to our awareness very compelling. He forcefully pointed out the universal nature of consciousness of all human beings in asserting "... inconceivable as it seems to ordinary reason, you—and all other conscious beings as such—are all in all" (Schrödinger 1964: 21). The celebrated neurologist Karl Pribram believes that our individual conscious experience partakes of a larger consciousness.

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The conscious human mind's uncanny ability to understand the laws of nature has presented many legendary scientists with a mystery. Einstein expressed it lucidly when he said, "The most incomprehensible fact about nature is that it is comprehensible". Distinguished mathematician Sir Roger Penrose is bemused by the fact that the universe has developed in obedience to the laws that our consciousness seems designed to grasp. Nobel Laureate Eugene Wigner (1960) referred to the double miracle of the existence of the laws of nature and the human mind's capacity to divine them. Scientists have recently warmed up to what is known as the anthropic principle that would provide a means for bridging these two miracles. A corollary of this principle suggests that the conditions were such at the moment of the inception of our universe as to presage the eventual emergence of intelligent beings like ourselves.

At its beginning, the entire universe was much smaller than an atom and, therefore, subject to the laws of quantum physics. Accordingly, our universe could have begun in many possible ways. If the anthropic principle is factored in, the evolution of conscious beings would be a necessary condition for the beginning of our universe. One of the thoughtful scientists of our time, John Wheeler (1996), is even more emphatic. Based upon his extensive studies of quantum phenomena, he concluded that "In this sense it is incontrovertible that the observer is a participator in genesis". The eminent physicist Freeman Dyson (1979) also finds that "the universe in some sense must have known that we were coming". In other words, the potentiality of consciousness has been present in our universe from the beginning.

In spite of the keen interest and efforts of so many illustrious scientists, the study of the origin and the nature of existence of consciousness is still a scientific work in progress, looking for a breakthrough. Considerable advances have been made recently, particularly through neuroscience, in understanding how consciousness operates in terms of physical activity in the brain. We can see which areas of the brain "light up" when we explore a math problem and which light up when we see a pretty face. These studies tend to regard consciousness to be a result of neural correlates. But the so-called hard problem (Chalmers 1996) of consciousness stems from the fact that we have no clue as to how these physical brain functions give rise to a subjective conscious *experience*.

Physicist Henry Stapp contends that it would be difficult if not impossible "to provide a rational explanation how a physically described brain could produce something so completely unlike itself as a mental event". He insists that "the more rational science based approach to this problem should be based upon the empirically validated quantum mechanical conceptions that naturally incorporates mind, rather than upon the invalidated classical approximation that, as a matter of principle, leaves mind out".

A quality akin to awareness indeed seems natural in quantum phenomena. The legendary double-slit experiment using one electron at a time provides a landmark example. After its passage through a double slit, the electron elects a particular outcome from a range of possibilities when landing on a detector screen. The popular explanation for the appearance of the electron on the screen as a particle is that its wave function decoheres by entanglement with the environment, but

this does not tell us why a particular outcome is chosen. Another electron going through the same process can pick out an unpredictable, different outcome. When enough electrons go through the double slit, each one successively picking out its own outcome for landing, a pattern evolves showing the range of possibilities for choice given by Born's rule, as shown in Fig. 18.1. Similar experiments have been performed using photons. The final pattern like Fig. 18.1e appears whether the photons are shot at the double slit all at once or one at a time randomly. This is a striking demonstration of the reality that the final pattern is independent of time spacing of the quantum particle, which would be incomprehensible in terms of classical physics. It strongly suggests there is an immutable underlying entity that is responsible for the ensuing performance.

Thus, a quantum particle, while emerging from the microscopic dimension to our macroscopic domain, acts more like an active agent than inert matter. It would then appear that mind, as manifested by the capacity to make choices, is to some extent inherent in every quantum particle. David Bohm and Basil Hiley (1995: 386) articulate this by their assertion, "It is thus implied that in some sense a rudimentary mind-like quality is present even at the level of particle physics, and that as we go to subtler levels, the mind-like quality becomes stronger and more developed". Freeman Dyson also finds it to be consistent with scientific evidence to think that atoms and humans and a "world-soul" may have minds that differ in degree *but not in kind*.

Consequently, while studies of brain functions are very important for understanding how consciousness works in individual beings, it will be instructive to explore the possibility of a primary cosmic awareness that may be the progenitor of consciousness, a source that evokes awareness in our brain utilizing its unique neural structure. A search for such a universal awareness naturally leads to the ultimate source of everything, which is the quantum vacuum and the quantum field theory (QFT) that deals with it.

18.2 Nature of Reality Portrayed by Quantum Field Theory

QFT has uncovered a fundamental nature of reality, which is radically different from our usual perception. Our customary daily world is very palpable and physical. But QFT asserts this is not the primary reality. The fundamental particles involved at the core of our daily physical reality are only secondary. They are excitations of their respective underlying *abstract* quantum fields, which constitute the primary reality. For example, a physical electron is the excitation of the abstract underlying electron quantum field. This holds for all the fundamental particles, be a boson or a fermion. Thus, QFT substantiates the profoundly counterintuitive departure from our normal perception of reality to reveal that the foundation of our tangible physical world is something totally abstract!

How do we know these abstract quantum fields really exist? Since a quantum system has to be disturbed to observe it, we normally look for their evidence

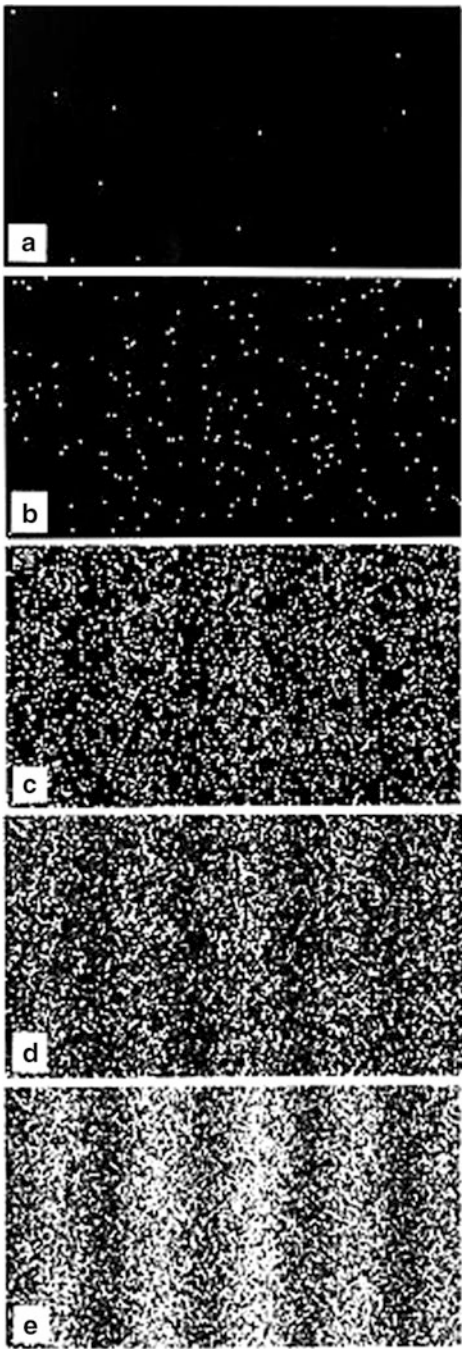

Fig. 18.1 The results of a double-slit experiment performed by Dr. Tanamura using one electron at a time. Images **a** through **e** depict collection of gradually increasing number of electrons on the screen. Numbers of electrons are 10 (**a**), 200 (**b**), 6000 (**c**), 40000 (**d**), 140000 (**e**). Similar results are obtained using a single photon at a time (Source: Wikimedia Commons to Wikipedia: http://en.wikipedia.org/wiki/File:Double-slit_experiment_results_Tanamura_2.jpg)

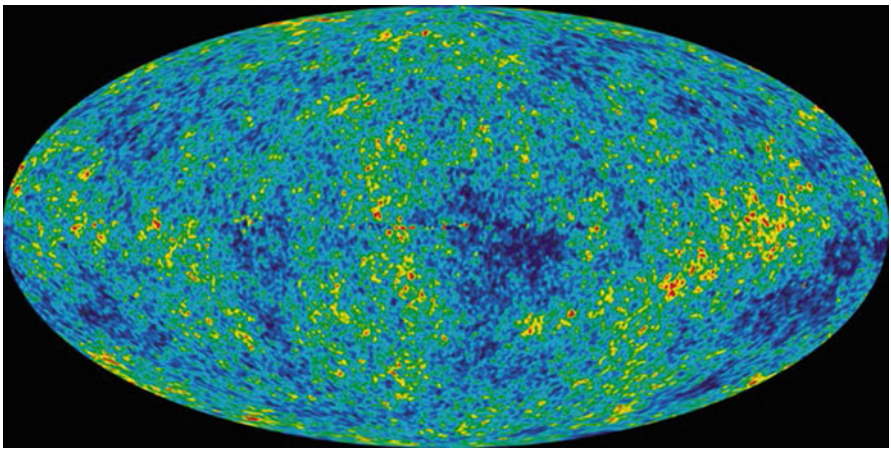

Fig. 18.2 The picture shows the minute temperature inhomogeneities, about 1 part in 100,000, in the cosmic background radiation observed by the WMAP satellite. These inhomogeneities owe their origin to the fluctuations of the quantum field and now believed to provide seeds for forming galaxies, galactic clusters and super clusters

indirectly through their effects such as Casimir effect, Lamb Shift and a host of other phenomena. However, in recent times, a graphic demonstration of their existence seems to have been provided by nature itself in the way of minute temperature inhomogeneities in cosmic microwave background radiation (CMBR) shown in Fig. 18.2. It is now believed that these inhomogeneities in CMBR owe their origin to fluctuations of quantum fields manifesting as wrinkles in spacetime, blown up from their microscopic existence to macroscopic dimensions by a sudden explosive expansion of space in the very early universe, known as inflation. This exceptional depiction is considered to provide compelling evidence of the existence of the abstract quantum fields, in addition to other substantial affirmations of QFT.

By far, the most phenomenal step forward made by QFT is the stunning discovery that the primary source of *everything* in this universe is present in *each element of spacetime*. The quantum fields exist as perturbations of empty space that is otherwise devoid of *anything*, in other words, known as the vacuum. But unlike classical fields, they do not have a particular fixed value, not even zero. According to Heisenberg's uncertainty principle, the quantum fields must always fluctuate. As a result, what was once thought to be desolate empty space is now known as the quantum vacuum, teeming with acts of creation and annihilation of virtual particles by quantum fields and harbouring the source of at least everything physical in each stitch of its fabric throughout this immensely vast universe. In light of this discovery, and the accompanying realization that quantum systems seem to exhibit behaviour akin to awareness, it is incumbent upon us to explore whether or not the source of awareness could also be present in the quantum vacuum.

18.3 Self-Referral of the Immutable Quantum Fields

We know from experimental evidence that the vacuum quantum fields are alive with activity, which has the unique property of being completely spontaneous and unpredictable as to exactly when a particular event will occur cannot be predicted. This is just the slow motion description of events. In actuality, the fields are fluctuating in this manner at mind-boggling speeds with a typical time period of 10^{-24} s or less. In spite of these infinitely dynamic, wild fluctuations, the fields have remained, on an average, *exactly* the same essentially since the beginning of time and throughout the entire universe containing regions, which are too far apart to have any communication even with the speed of light.

While all else in the universe has changed drastically since its beginning, the quantum fields have remained the same across the universe and in each element of spacetime. As seemingly indicated by string theory, when space expands, elements of space actually clone themselves. The cloned elements of space will likely come with their own entire contingent of vacuum fields as well, which would facilitate keeping the value from diminishing during the expansion of space.

According to Narnhofer and Thirring (2012), in quantum field theory, almost everything is entangled. This would be true at least at fundamental dimensions as well as for atomic scales until decoherence by entanglement with the environment takes precedence. As a consequence, the fluctuations of the fields in each element of spacetime are expected to be coherent. Then all the fluctuations of the fields could be coherent throughout the universe by mesoscopic quantum entanglement (Narnhofer and Thirring 2002). *The most intriguing question is what keeps the immutability of the fields intact in each element to begin with*. Does it not suggest the existence of some sort of self-referral scheme that is responsible for maintaining the fidelity of the quantum fields in spite of their frenetic fluctuations, their prodigious dynamism, their spontaneity and unpredictability?

Such a self-referral is an inherent feature of the strongly self-interacting dynamics of the non-Abelian fields. For example, the non-Abelian gluon field strongly responds to its own presence. The electromagnetic fields, at ordinary dimensions, are not known to have significant self-interaction, but the unified electroweak field is non-Abelian. Since the electromagnetic field is an essential component of the electroweak field and their fluctuations are expected to be coherent,[1] the self-interaction of the electroweak field can be imparted to the vacuum fluctuations of the electromagnetic field through quantum entanglement.[2]

The electroweak unification is firmly established theoretically as well as experimentally near 200 Gev, or equivalently, at distances shorter than about 10^{-16} cm. The unification of two such diverse forces has broken the barrier that existed in the mind of the physicists to the unification of all the forces. Most physicists will now agree with physics Nobel Laureate Frank Wilczek (2008) who states, “Nature

[1]Professor Frank Wilczek, private communication by email, 3 July 2011.

[2]Professor Walter Thirring, private communication by email.

seems to be hinting that a unified theory of the fundamental forces is possible". Some promising grand unification theories (GUT) has been constructed that unite the strong and weak nuclear fields with the electromagnetic field.

Observation of neutrino oscillations is considered to provide considerable support to GUTs. Experiments are underway to observe the proton decay that is expected to provide convincing support to such unification. However, the most compelling substantiation comes at this time from the fact that when we extend our laboratory measurements of the strengths of the various forces, they approach parity near Planck's dimensions. According to Frank Wilczek (1999), "From its much inferior strength at accessible energies, gravity ascends to equality with the other interactions at roughly the Planck scale ... Even in the absence of a detailed theory we find here a concrete, semi-quantitative indication that all of the basic forces arise from a common source". In addition to the basic forces, the common source is also envisioned to include unification of bosons and fermions facilitated by the presumed existence of super symmetry.

The non-Abelian self-interaction feature of the fields would be much more pronounced at fundamentally shorter distances, where gradually increasing unification of the fields is expected to occur as represented in Fig. 18.3. The robust self-interacting feature resulting from unification near Planck's dimensions can be imparted to ambient dimensions because of quantum entanglement of the fluctuations in each spacetime element. According to Walter Thirring[3], in general, if B and C represent two strongly bound fundamental particles and A is a test particle, then Bell's inequality tells us that the entanglement of A with the complex of B and C is more than the entanglement of A with B plus that of A with C. Applying this for coherent fluctuations of two strongly self-interacting quantum fields B and C near Planck's dimensions, the entanglement of fluctuations of a quantum field A at ambient dimensions with the complex B and C would be more than the entanglement of A with B plus A with C. In other words, the highly self-interacting dynamics of the expected common source near Planck's dimension being *quantum entangled* with the fluctuations of *all* the quantum fields at ordinary dimensions, the strong self-interaction, can be passed on to conventional dimensions. This appears to be a cogent mechanism for how the immutability of the fields can be ensured for all times in spite of their wild fluctuations.

In light of the possibility that the robust self-referral of the Planck scale can be imparted to ordinary dimensions by the entanglement of quantum fluctuations of all fields in a spacetime element, it is suggestive to seek an explanation of the bizarre behaviour of quantum particles. A fundamental particle like a photon or an electron represents a propagating excited state of their respective underlying quantum fields. Since the propagating states also contain vacuum fluctuations, a fundamental particle would be subjected to vacuum fluctuations along with their attendant self-referral imparted by means of entanglement from the Planck scale, thus making the particle cognizant of its quantum activities. Could this be the

[3]Professor Walter Thirring, private communication by email.

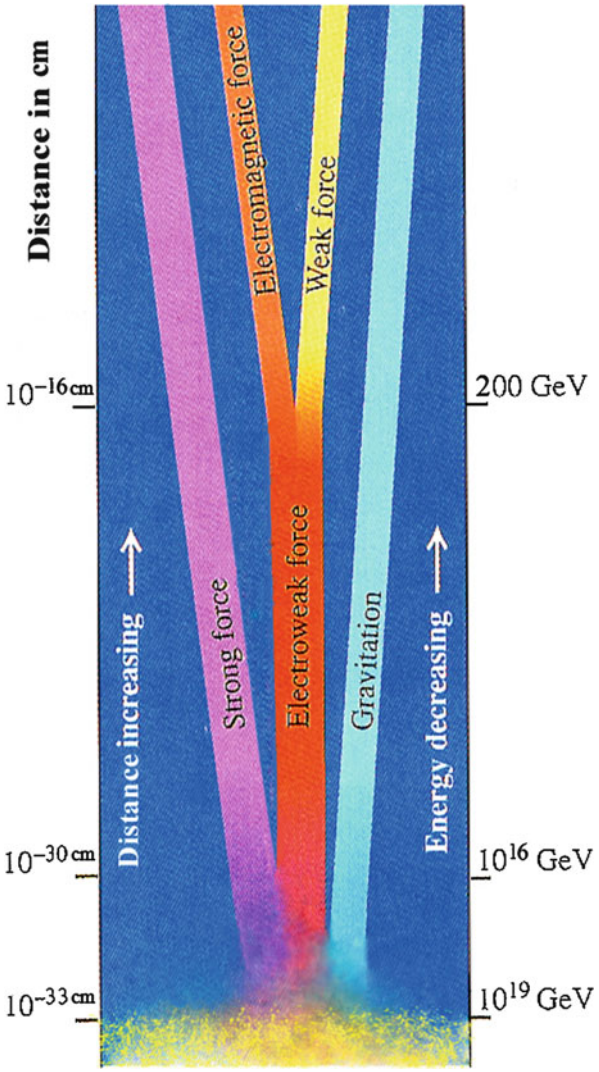

Fig. 18.3 A conceptual diagram showing how the various force fields gradually unite at very high energies, or equivalently, at fundamentally short distances. The super unification of all the force fields as well as the matter fields is presumed to occur near the Planck dimension, aided by super symmetry (Source: Drawing created by the author.)

reason why a quantum particle behaves as an active agent when emerging from the microscopic dimension to land on the screen as shown in the double-slit experiment?

An affirmation of this notion may be found in the "quantum potential" propounded and extensively studied by David Bohm and Basil Hiley using noncommutative geometry and other mathematical edifices. They isolated a part of the Schrödinger equation, which they call the quantum potential that is necessary for conservation of energy of both sides of the equation. Most surprisingly, the energy of the quantum potential does not fall off with distance, a discovery that is presumed to have inspired the concept of quantum non-locality. Hiley maintains further that the quantum potential represents an internal energy with "features akin to a

self-organizing potential" indicative of nonseparability as well as participation. Such attributes could originate from the strong self-referral of the vacuum fluctuations conveyed from the Planck scale by quantum entanglement. Also, the internal energy of the quantum potential will remain the same since the values of the quantum fields are same everywhere.

18.4 Source of Universal Awareness

As a consequence of self-interaction, a non-Abelian field responds dynamically to its own presence. This attribute of self-interaction, self-coupling, self-organization or self-referral is also the hallmark of awareness. One could argue that likening awareness to a quantum field responding to its own presence is a bit of a reach. However, the qualitative comparison can be justified if we ponder the fact that physicists really do not know what energy is, much less the far more abstract nature of a quantum field.

When we encounter such a counterintuitive possibility, we sometimes characterize it as incredulous. Eventually, however, we are compelled to yield to a new model, often in spite of our initial disbelief. Such was the case with Newton's theory of gravity, proposing action at a distance without a material connection as well as Einstein's relativity where neither space nor time is absolute. Most of the time, the answer comes by changing the way we think about the question. We might eventually get used to the notion of quantum fields endowed with some form of self-awareness.

At this point it is worth considering a well-argued conjecture advanced by Roger Penrose. Observing the failure of countless attempts over nearly a century to resolve the mystery of the quantum measurement problem, Penrose forcefully argues for the existence of an as yet undiscovered physical process embedded in primary reality that is responsible for the "weird" behaviour of quantum particles. Along with John Wheeler, Penrose also contends that the mysteries of such quantum behaviour and our consciousness are linked. Since quantum properties are part of the fundamental nature of the entire universe, the link would suggest awareness to be an essential aspect of the universe as well. Penrose proposes that our brains have somehow contrived to harness this as yet undiscovered attribute of nature to evoke our own awareness. It would be plausible to consider this unknown attribute to be the awareness aspect that is apparently associated with the quantum fields for keeping their immutability for all times in spite of their fierce fluctuations.

18.5 Complementarity of Existence of Consciousness

Quantum physics has compelled us to accept that two distinct and seemingly contradictory elements of reality can coexist in a complementary way. This represents not merely a paradigm shift in science, but a paradigm shift in thought,

and paves the way for us to consider the possibility that the "immaterial" source of what we call awareness could be inseparably entwined with material reality, as exemplified by the self-referral of the quantum fields, which are also the source of everything physical.

Thus, it is credibly indicative that the source of all things physical as well as the attribute of awareness is present in the quantum vacuum in a complementary fashion throughout the universe. It then follows that this cosmic awareness would be a likely origin of our own consciousness, perhaps through some process like resonance or entanglement occurring in our brains.

Penrose and Stuart Hameroff have given a detailed description of the build-up of some large-scale quantum coherence, acting broadly across considerable regions of the brain. It would be only natural for this quantum coherence of the brain to be in accord with the coherence of the universal quantum fields. The awareness inherent universally with the quantum fields can be harnessed by the brain when an objective reduction takes place in its coherent wave function. Penrose and Hameroff offer a logical scheme whereby the concept that our awareness originates from a cosmic awareness, as envisioned by perceptive scholars like Schrödinger, can be anchored in science.

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