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Spontaneous potentiality as formative cause of thermo-quantum consciousness

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Abstract

A macro-quantum model is developed to describe spontaneous processes in terms of computable equations. The resultant macro-quantum wave equation (Schrödinger-type equation) is solved via a Madelung transformation to yield a complex-valued solution whose real part gives the macro-quantum potential energy. We show that the mechanism responsible for spontaneous phase differences is a pilot-wave force attributed to the internal thermo-quantum energy. Its functionality contributes to the phase synchrony in the emergence of 'long-range order' occurring by means of the actualized phase differences of the spontaneous processes. Macroscopic pilot-wave theory is used to describe how informational patterns carry 'meaning' via a 'consciousness code' arising from thermo-quantum fluctuations. The resultant negentropic entanglement of the actualized phase differences according to panexperientialism acts as a 'conscious pilot' that provides stability through a pilot-wave guided negentropic action emerging from macro-quantum potential energy. In view of the above, the thermo-quantum consciousness is a process based on Aristotelian doctrine of causes. The material cause as uncertainty in the brain expressed through the wave function, naturally leads to pilot-wave guided negentropic action as the efficient cause of conscious recall that actualizes spontaneous potentiality as its formative cause, with inner experiences as the final cause. It is the final cause that is expressed in memory after consciousness and their interrelationship with uncertainty in the brain, that forms a relational holon.

Keywords

Pilot-wave theory; wave function; quantum fluids; macro-quantum potential energy; de Broglie thermodynamics; negentropy principle of information; thermo-quantum effect; panexperientialism; relational holon; Aristotelian doctrine of causes; uncertainty in the brain

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1. Introduction

Eccles [1] proposed that quantum processes may be important in understanding the subtler characteristics of brain function as an entry point for mental causation. The subtlety of the mind was further explored in relation to consciousness and quantum indeterminism [2–4]. The search for cytoskeletal consciousness was investigated extensively by Hameroff [5]. If microtubules are the site for quantum effects, and clearly hepatic microtubules play no role in consciousness, then why should microtubules have this role in neurons? An answer might be that microtubules are the only cytoplasmic components that oscillate in the THz frequency range [6]. A further link is by way of a 'conscious pilot' that itself may reflect upon a finer-scale process extending within neuronal interiors originating from non-polar hydrophobic regions where London force dipoles oscillate coherently [7–9]. This of course differs from the neuroscience of consciousness where consciousness is believed to involve firing dynamics of action potentials in neural networks [10] or embodied spatial cognition through the minimization of the energy-difference between model prediction and data [11] or coherent energy transfer [12].

However, all the above attempts at explaining consciousness have been unable to bridge the explanatory gap [13]. Accordingly, subjectivity is phenomenal from where experiences arise in the sense of Chalmers [14], and objectivity is physical and non-experiential. Based on the existence of intrinsic 'potential' information as information theoretic entropy, we can close the gap between subjective, phenomenal experience and its physical manifestation in terms of negentropy [15]. The idea behind negentropy is to 'inform meaning' or 'forming of meaning' attributed to intrinsic 'potential' information which is subjective [16]. We use this intrinsic 'potential' information to explain spontaneous processes in holonomic brain theory [17], yet it is not a physical real phenomenon, but exists only in our description therefore it is 'poesies' [18]. How to relate such information theoretic entropy with real phenomena? Considering information (theoretic) entropy to be subjective that supervenes over and above the physical processes like for example, thermal entropy then the negentropy principle of information [15, 19] gives a clear interrelationship between the two entropies and hence a possible way

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to span the bridge across the explanatory gap.

Aristotelian doctrine of causes is needed because consciousness does not affect the physical world and so there cannot be a clear interrelationship between the subjective (experiential) and physical (non-experiential) properties. The problem with nominalism is that it only recognizes the final causality such as inner experiences [14]. Therefore, the essence of our working model is based on Aristotelian doctrine of causes as interpreted by Heidegger [18]. We propose that macroscopic quantum level description provides a novel physical attribution to 'long-range' coherence in biological systems [20] where synchrony has been invoked as a solution to the phenomenal binding problem as well as a precedence for unitary binding of consciousness [21] resulting in a unified conscious field [22]. The model proposes that brain-based consciousness is not distinctively based on quantum effects (cf. [23]), but instead relies on nonlocal neocortical energy processing based on holonomic brain theory [17]. The nonlocality of both conscious recall and memory signifies the consciousness process as a holon in terms of the end of consciousness and the beginning of memory via uncertainty in the brain [24]. The 'conscious pilot' embodied in the activity of subneuronal structures of nonsynaptic spines form a holoscope. Specifically, below chemistry via an approach that was based on the de Broglie thermodynamics [25].

2. Origins of Thermo-Quantum Effects

It is well known that the crossover between quantum and classical regime requires the 'quantum' temperature to be equivalent to body temperature under equilibrium conditions. We define the quantum temperature in Kelvin [26]:

$$T* = \frac{\hbar \mathrm{f}}{\mathrm{k_B}} = 4.8 \text{ x } 10^{-8}\mathrm{f} \tag{1}$$

where $\hbar = 6.6 \times 10^{-34}$Js (Planck constant), $\mathrm{k_B} = 1.38 \times 10^{-23}$J/K (Boltzmann constant). If the human body temperature is 310K we need frequency (f) of dipole oscillations in the THz range (or higher) for quantum processing in the brain [27]; otherwise neural processes are thermal not quantum. It is known that the Schrödinger equation may be derived from a hydrodynamic model in which diffusion of an ensemble of particles without spin represent the 'quantum-like' state [28]. We call this approach 'thermo-quantum diffusion' or 'quantum thermo-hydrodynamics' (cf. [29, 30]). It is based on energy processing and information flow [31] and relies on macro-quantum states in biological processing [32]. Therefore, our approach can be precisely defined to be 'thermo-quantum' effects in quantum fluids [26].

Consciousness co-exists with cognition and it cannot function causally in the production of physical behavior according to 'biological naturalism' [22]. What this means is thermo-quantum consciousness has no causal power and cannot be interacting with polarized regions capable of transmutation of thermo-quantum fluctuations to normal-level neural signaling [33]. Where in neurons do nonpolarized / apolar regions exist? One possibility is by way of dipole-bound electrons in nonpolar hydrophobic regions of molecular proteins where energy processing can take place. Neuronal branchlets, especially thin axons, favour electrical isolation from synaptic inputs. The lower limit on the axon diameter is 0.08–0.1μm [34]. Such very thin neuronal branchlets resemble 'nanotubes' and are inoperable for communication based on action potential propagation due to channel noise effects. Faisal & Laughlin [35] hypothesized such nanotube-like branchlets may be purposely designed for presynaptic information processing carrying specific sensory and pain transmission associated with subjective processes (e.g., 'feelings'). Similar sized structures are spines, approximately 0.09μm in diameter in the larger pyramidal neurons of the neocortex [36]. Particularly, nonsynaptic spines with clearly absent synaptic-head like filopodia, that emanate from such fine distal branchlets (see Fig. 1). Although the percentage of nonsynaptic spines is 3.4% of the total number of spines [37], thousands of spines are present in a typical cortical interneuron. Cytoskeletal structures like microtubules grow out of lamellar bodies, which are in the main dendrite adjacent to the gap junctions in spines [38, 39], while the main shaft contains cytoplasmic proteins that bind to actin-filaments [40].

The 'pilot-wave' guided negentropic action hypothesized to be responsible in the maintenance of 'long-range order' associated with phase differences of dipole-bound electron oscillations. The oscillating dipoles that correspond to the oscillating electromagnetic field are not the same in the physical sense to the dipole-bound electron oscillations through a macroscopic pilot-wave theory. Although they are both based on quantum state of the brain that depends on a property called macroscopic quantum coherence**,** which needs to be maintained for around a few milliseconds. According to Tegmark [41], this property does not to hold for more than about 10^{-13}s. Hagen *et al*. [42] have advanced reasons why this number should be of the order of a few milliseconds, but this is a very big difference to explain away and serious doubts remain about whether macroscopic quantum coherent states can exist in the brain [32]. The resolution comes from the stability that emulates the quantum-like dynamical states in the brain. It is the spontaneous phase differences of dipolar-bound electron oscillations that govern 'long-range order' (i.e., high degree of coherence), leading to stability and unitary binding of consciousness.

However, supply of energy is unnecessary for coherence in phase differences to arise spontaneously, but rather it will be shown that it is the potentiality (and not the kinetic energy), through the macro-quantum potential energy that triggers coherence in phase differences of dipole-bound electron oscillations. It is conceivable that the term 'thermo-quantum consciousness' could be acted upon by 'long-range order' in the integrated phase-differences manifested by pilot waves through thermo-quantum energy processing. Moreover, the magnetic component of the endogenous electromagnetic field is too small to induce nuclear spin effects under the Born-Oppenheimer approximation. Therefore spin entanglement between molecules seems very unlikely to occur since thermal fluctuations would essentially eliminate such tiny quantum effects. In view of the above, we postulate a new model that posits not spin entanglement, but an internal thermo-quantum energy that invokes the negentropy principle of information defined as 'negentropic entanglement' to be responsible for actualized phase differences of the dipole-bound electron oscillations. They arise spontaneously from the macro-quantum potential energy (and not kinetic energy) that may provide the necessary support for unitary binding of consciousness.

3. A Macroscopic Pilot-Wave Theory Underlying Phase Differences

Is it possible to formulate a macroscopic pilot-wave theory and apply it to brain functioning? The idea is to extend de Broglie-Bohm

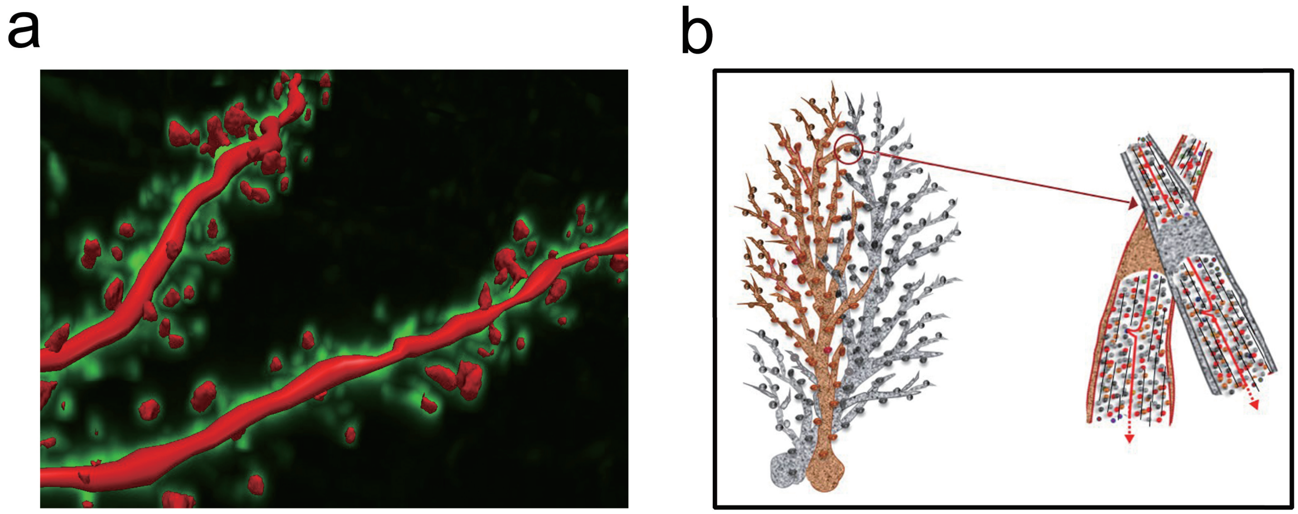

Fig. 1. (a) is a micrograph of two dendrites studded with nonsynaptic dendritic spines in neocortex (from MBF Biosciences labs). The key criteria for nonsynaptic is the absence of a postsynaptic density. Thus, the term 'nonsynaptic' does not exclude electrical synapses (i.e. gap-junctions). (b) is a schematic diagram of two neuronal branchlets juxtaposed with a cross-section of two gap-junctionally connected spine shafts containing molecular proteins (not to size) bound to actin filaments (black lines). Changes in relations among an ensemble of phase differences is caused by the internal thermo-quantum energy acting as a 'pilot wave' (red arrow) in the proteinaceous hydrophobic pockets (not to scale).

wave mechanics to explain macro-quantum phenomena. To do so we analyse the general structure of Bohmian-type models based on ontological formalism of quantum theory [43–45] combined with a holonomic formalism [17]. Such combined formalism is based not on quantum indeterminacy, but through the wave equation that thermo-quantum effects are implicated because of a 'hidden variable' known as the macro-quantum potential energy or neural quantum potential [46]. The pilot-wave force guides thermo-quantum fluctuations of dipole-bound electron oscillations through their phase differences where the changes in relation to an ensemble of actualized phase differences, which is referred to as 'binding'.

The wave function (ψ)is a complex function, which has a state of reality used to describe the passage of potentiality to actualization based on its averaged statistical characteristics. It is not the wave function of quantum mechanics that guides individual particles, but it guides an ensemble of dipole-bound electron density distributions with respect to their phase differences.

Macroscopic pilot-wave theory posits the fundamental property of all physical processes undergoing actualized differences stemming from the antagonistic nature of macro-quantum potential energy. The actualized differences are phase differences of dipole-bound electron oscillations are guided by the macro-quantum potential energy through 'long-range' correlations of phase differences. This is known as the pilot-wave guiding principle, which classical transportation of information occurs via nonlocal cortical processing [17]. Such macro-quantum nonlocality is different to the microscopic 'spooky-action-at-a-distance' [47]. However, the question is whether quantum nonlocality based on de Broglie-Bohm formalism can be applied to biology remains speculative (but see [48]).

In this study, the wave function (ψ) describes the instantaneous state of dipole-bound electron density distribution determined from the solution of the macro-quantum wave equation [17, 46]:

$$i\gamma\frac{\partial\psi}{\partial t}=-\frac{\gamma^2}{2}\nabla^2\psi+U\psi \tag{2}$$

This is like the Schrödinger equation that can be found by substituting the Madelung transformation: $\psi=\sqrt{\rho(x,t)}\,e^{iS}$ into the macro-quantum wave equation, upon separating the imaginary and real parts. The imaginary part is the continuity equation of the dipole-bound electron density distribution, while the real part describes the phase differences of the dipole-bound electron oscillations, expressed by the Hamilton-Jacobi equation [46]:

$$\frac{\partial S}{\partial t}+\frac{\gamma}{2}(\nabla S)^2+U+Q=0 \tag{3}$$

where $S=\frac{i}{2}\log\frac{\psi^*}{\psi}$ is the phase function that describes the phase differences in oscillation of the dipole-bound electron fluid in units of time (t), ψ^* is the complex conjugate of the function and ∇ is the gradient (in one-dimension $\equiv\frac{\partial}{\partial x}$). The constant $\gamma=\nu/\nabla S$ is a positive constant relating the de Broglie guiding equation, in terms of the velocity driven ensemble of phase differences (ν) to the gradient of the phase function(∇S):

$$\nabla S=i\left(\frac{1}{\sqrt{\psi^*}}\frac{\partial\sqrt{\psi^*}}{\partial x}-\frac{1}{\sqrt{\psi}}\frac{\partial\sqrt{\psi}}{\partial x}\right). \tag{4}$$

The phase function whose dynamical evolution is under the action of two 'potentials': (i) the classical potential energy function U(x,t) and (ii) the macro-quantum potential energy:

$$Q(x,t)=-\frac{1}{2}\gamma\frac{\nabla^2\sqrt{\rho(x,t)}}{\sqrt{\rho(x,t)}} \tag{5}$$

where ρ(x, t) is the dipole-bound electron density distribution in Debye layer, x is the spatial distance along the Debye layer and ∇^2 is the Laplacian (in one-dimension $\equiv\frac{\partial^2}{\partial x^2}$). The macro-quantum potential like the quantum potential [49] is an emergent potential that is not given in the Hamilton-Jacobi equation until the solution of the macro-quantum wave equation is found via the Born rule linking the amplitude of the wave function to the dipole-bound electron density distribution $\rho(\mathrm{x,t}) = |\psi|^2$ and which results in the following expression for the macro-quantum potential energy:

$$Q(x,t) = -\frac{1}{2}\gamma(\sqrt{\frac{\psi^*}{\psi}}\frac{\partial^2\sqrt{\psi}}{\partial x^2} + \frac{2}{\sqrt{\psi\psi^*}}\frac{\partial\sqrt{\psi^*}}{\partial x}\frac{\partial\sqrt{\psi}}{\partial x} + \sqrt{\frac{\psi}{\psi^*}}\frac{\partial^2\sqrt{\psi^*}}{\partial x^2}) \quad (6)$$

If we introduce the classical potential energy (U≠0), then the solution of the macro-quantum wave equation is can be shown via a perturbation method:

$$\psi(x,t) \approx \psi_0 + \int_0^x \int_0^t \psi_0(x-\xi, t-s)\, U(\xi, s)\, ds d\xi + \int_0^x \int_0^t \left(\int_0^y \int_0^r \psi_0(y-\eta, r-\beta) U(\eta,\beta) d\beta d\eta \right) drdy \quad (7)$$

where $\psi_0(x,t)$satisfies the macro-quantum wave equation:

$$i\gamma\frac{\partial\psi_0}{\partial t} = -\frac{\gamma^2}{2}\nabla^2\psi_0 \quad (8)$$

This equation ignores the effects of the classical potential energy U=0 and considers solely the quantum effects of the dipole-bound electron oscillations.

The separation of variables method gives a solution of the reduced macro-quantum wave equation along spatial region of length L (dimensionless) subject to Dirichlet boundary conditions [17]:

$$\psi_0(x,t) = (\frac{1}{L})\sum\nolimits_{n=1}^{\infty} c_n e^{-\frac{2}{\gamma}i(\frac{\gamma^2}{L^2}\pi^2 n^2 t - \frac{\gamma}{L}\pi x)} \quad (9)$$

where c_n are Fourier coefficients independent of time and the dipole-bound electron density distribution along the Debye layer is $\rho(x,t) = |\psi_0|^2$. The density distribution, which is a measure of the intensity of the wave function between points $x = 0$ and $x = L$ is given by:

$$\int \rho dx = \int |\psi|^2 dx = \int \psi\psi * dx. \quad (10)$$

The intensity of the wave function is a measure of dipole-bound electron oscillations with synchronous phase differences carried by Q in a 'nonlocal' manner to bring about macroscopic coherent state in the phase.

4. Phase Coherence in the Absence of Classical Potential Energy Function $U(x,t) = 0$

Synchrony refers to a consistent phase relationship among dipole-bound electron oscillations generally referred to as phase coherence, but not necessarily in-phase, i.e., with zero phase difference between them. The phase function $S_0 = \frac{i}{2}\log\frac{\psi_0^*}{\psi_0}$ is shown for $L = 1$, $\gamma = 1.0$, $x = 0.1$ (see Fig. 2a), $L = 0.1$, $\gamma = 0.01$, $x = 0.01$ (see Fig. 2b)and $L = 1.5$, $\gamma = 2$, $x = 0.5$ (see Fig. 2c).The real component represents the domain averaged dipole-bound electron density oscillations and the imaginary part represents the fluctuation from this mean. The real component amplitude varies between $-\pi/2$ and $\pi/2$. It is shown to be periodic approximately every 0.32-time unit and the imaginary component is almost zero. Therefore, the phase function is coherent. Phase coherence (resonance) of the real component of the phase function (S) is present as waveforms for different L, γ, and x values has a constant phase difference and the same frequency, and the same waveform.

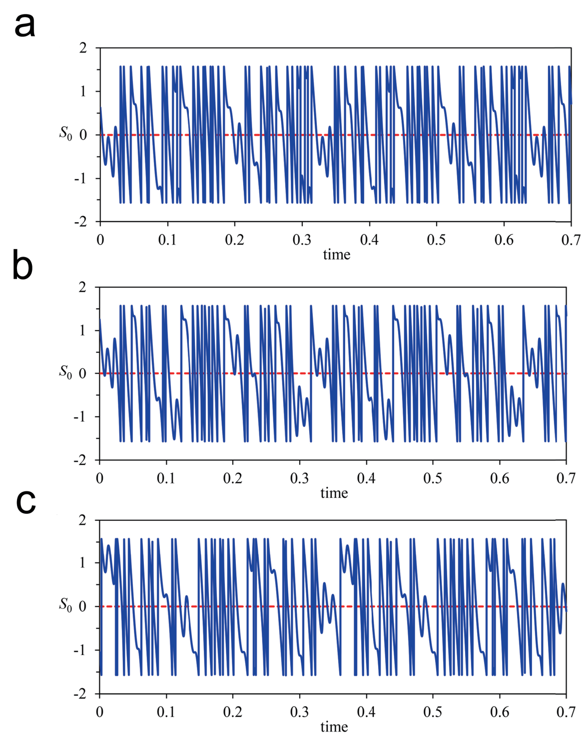

Fig. 2. *Phase function (S_0)versus time (t) for L=1, $\gamma = 1.0$, x=0.1(Fig. 2a), L=0.1, $\gamma = 0.02$, x=0.01 (Fig. 2b) and L=1.5, $\gamma = 2$, x=0.5 (Fig. 2c). The phase synchrony of the dipole-bound electron oscillations is only in the real component of the phase function. Its amplitude varies between –π/2 and +π/2 showing coherence on phase (resonance). The imaginary component of the phase function remains close to zero. Real component is shown as a continuous line (blue) and imaginary component is shown as a dashed line (red).*

5. Phase Non-Coherence in the Presence of Classical Static Potential Energy $U(x,t) = 1$

If we introduce the simple case of a static classical potential energy with a unitary value (U=1) then the solution of the macro-quantum wave equation is readily found, viz.

$$\psi(x,t) = \psi_0 e^{-\frac{i}{\gamma}t} \quad (11)$$

The phase function(S) is shown for $L = 1$, $\gamma = 1.0$, $x = 0.01$ (see **Fig 3a**), $L = 0.1$, $\gamma = 0.01$, $x = 0.01$ (see Fig. 3b) and $L = 1.5$, $x = 0.5, \gamma = 1.0$ (see Fig. 3c). As indicated in Fig. 3 the real component amplitude is bounded by $-\frac{\pi}{2}$ and $+\frac{\pi}{2}$. The imaginary component is almost zero. The waveform of the real component is chaotic (non-periodic) and therefore non-coherent.

It is evident that the pilot-wave guiding principle based on the macro-quantum potential energy is annihilated in the presence of classical potential energy due to the absence of synchrony. This indicates that the phase differences underlying 'long-range order' are subtle and exist only in the absence of classical potential energy. The macro-quantum potential energy having a relatively high magnitude of the amplitude in its real component is negligible in the imaginary component. The results indicate that asynchronous waveforms are associated with the phase oscillations of the wave function. It is evident that the real component is causally affected by the presence of classical potential energy because the phase differences of the dipole-

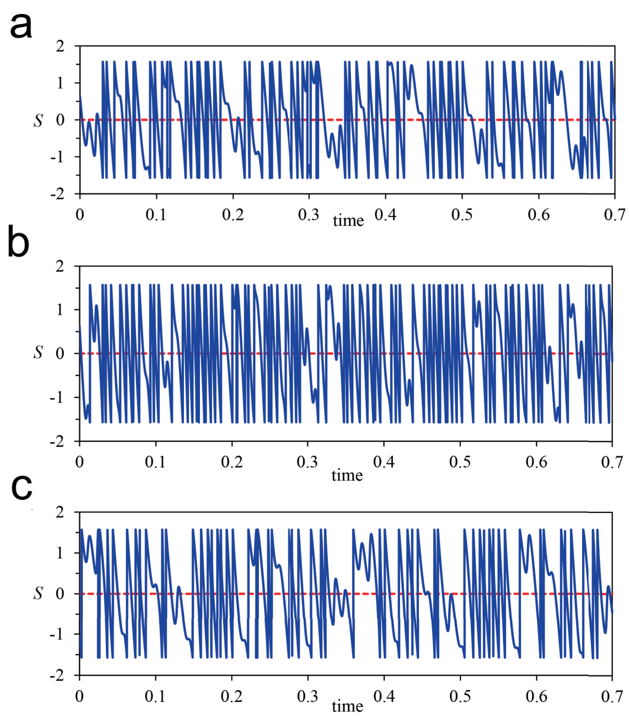

Fig. 3. *Phase function (S)versus time (t) for L=1, $\gamma = 1.0$, x=0.1(Fig. 3a), L=0.1, $\gamma = 0.01$, x=0.01 (Fig. 3b) and L=1.5, $\gamma = 2$, x=0.5 (Fig. 3c) in the presence of classical potential energy U=1. The phase differences of the dipole-bound electron oscillations are asynchronous as evident from the real component of the phase function. Its amplitude varies between $-\pi/2$ and $+\pi/2$ showing non-coherence. The imaginary component of the phase function remains close to zero. Real component is shown as a continuous line (blue) and imaginary component is shown as a dashed line (red).*

bound electron oscillations illustrated in Fig. 3 show non-coherence for the real component of the wave function.

6. The Macro-Quantum Potential as Thermo-Quantum Internal Energy

It is essential to regard the quantum potential energy, as internal energy since the quantum potential has no external energy source [50]. There have been numerous physical descriptions of the quantum potential from: spin related internal motion [51]; energy due to the oscillating electromagnetic field (virtual photon) coupled with moving charged particle [52]; to geometrodynamics [53]. However, we define the macro-quantum potential energy to be thermo-quantum internal energy, representing the macroscopic aggregated effect of the microscopic random thermo-quantum fluctuations (cf. [30]). The origin of thermo-quantum fluctuations is movement of macro-quantum potential energy rather than kinetic energy which is due to the large fluctuations in the energy of the electrons introduced in the Heisenberg uncertainty principle to emerge from the constant jiggling of neighboring dipole-bound electrons in a non-zero temperature (Kelvin) at small length scale (L) where the thermal de Broglie wavelength is greater than the typical length scale.

The results in Fig. 4– 5 show that the real components for Q and Q_o are both temporally positive and negative in amplitude. This signifies how the internal energy is to be redistributed between the kinetic energy (negative values) and potential energy (positive values). Thermo-quantum internal energy is a somewhat strange concept, however here we simply note that in the same sense that under the de Broglie guiding equation, the imaginary component of the thermo-quantum internal energy carries informational content. In other words, given change from the average phase differences is relatively insignificant because the imaginary component for both Q and Q_o is quite small, where the minuscule size of the imaginary component indicates a unique informational pattern that reflects on the movement of the phase differences from their average values. The waveform resembles a characteristic pattern that may have an informational content that is reflected in the movement of the phase coherence. In a similar way to the physical meaning of the quantum potential in the ontological interpretation of quantum mechanics, is that of an emergent potential that informs atomic particles in a way, so it acts as also an information channel through a context-dependent energy redistribution [43, 54, 55].

7. A Pilot-Wave Force Driving the Wave Function

Invoking Bohm's ideas, we show that a nonlocal force that does not fade with distance. The pilot-wave force $F_\psi$can be written as $\partial M/\partial t$ where the mechanical momentum M is given by M$= -i\gamma\int_{-\infty}^{\infty}\psi^*\frac{\partial\psi}{\partial x}dx$ assuming $\psi(\pm\infty, t) = 0$, viz

$$F_\psi = i\,\gamma\int_{-\infty}^{\infty}\left[\frac{\partial\psi}{\partial x}\left(\frac{i\gamma}{2}\frac{\partial^2\psi^*}{\partial x^2} - \frac{i}{\gamma}U\psi^*\right) - \frac{\partial\psi^*}{\partial x}\left(\frac{i\gamma}{2}\frac{\partial^2\psi}{\partial x^2} - \frac{i}{\gamma}U\psi\right)\right]dx \tag{12}$$

where the above expression yields the expectation of the pilot-wave force driving the wave function for a specified classical potential energy and macro-quantum potential energy.

As indicated in Fig. 6 the imaginary component of the temporal variation of the pilot-wave force has a waveform that is coherent (periodic and non-chaotic) and it is the same when driving the reduced wave function. The zero-real values of F_ψ can be estimated from the expectation value of the driving force $-\nabla U$ (Ehrenfest theorem, see [56]) and in our example $U = 1$ so $U' = 0$. This result obeys classical mechanics, but the fact that the imaginary component of F_ψ is nonzero comes about from the thermo-quantum effect of the macro-quantum potential energy. In other words, the macro-quantum potential energy exerts a force that does not fall off with distance (Fig. 6b). Therefore, the macro-quantum potential energy acts nonlocally through the imaginary component of the wave function where a small magnitude of Q can produce a large effect in the pilot-wave force F_ψ. This result is interesting because a large change in the form of the wave function as indicated by F_ψ is produced from a very small effect through Q. In other words, since the real component is zero, this indicates no change to the average phase difference of the dipole-bound electron oscillations, but a large imaginary component signifies the fluctuation from this average that generates phase differences over long distances.

This pilot-wave force driving the wave function is not the mean-field approximation of the pilot-wave force. Since the pilot-wave exerts a force through the imaginary component of the wave function, while the real component is zero. This suggests that the pilot-wave exerts a negligible force not responsible for the 'long-range order'. Perhaps, it is the force determined directly by the macro-quantum

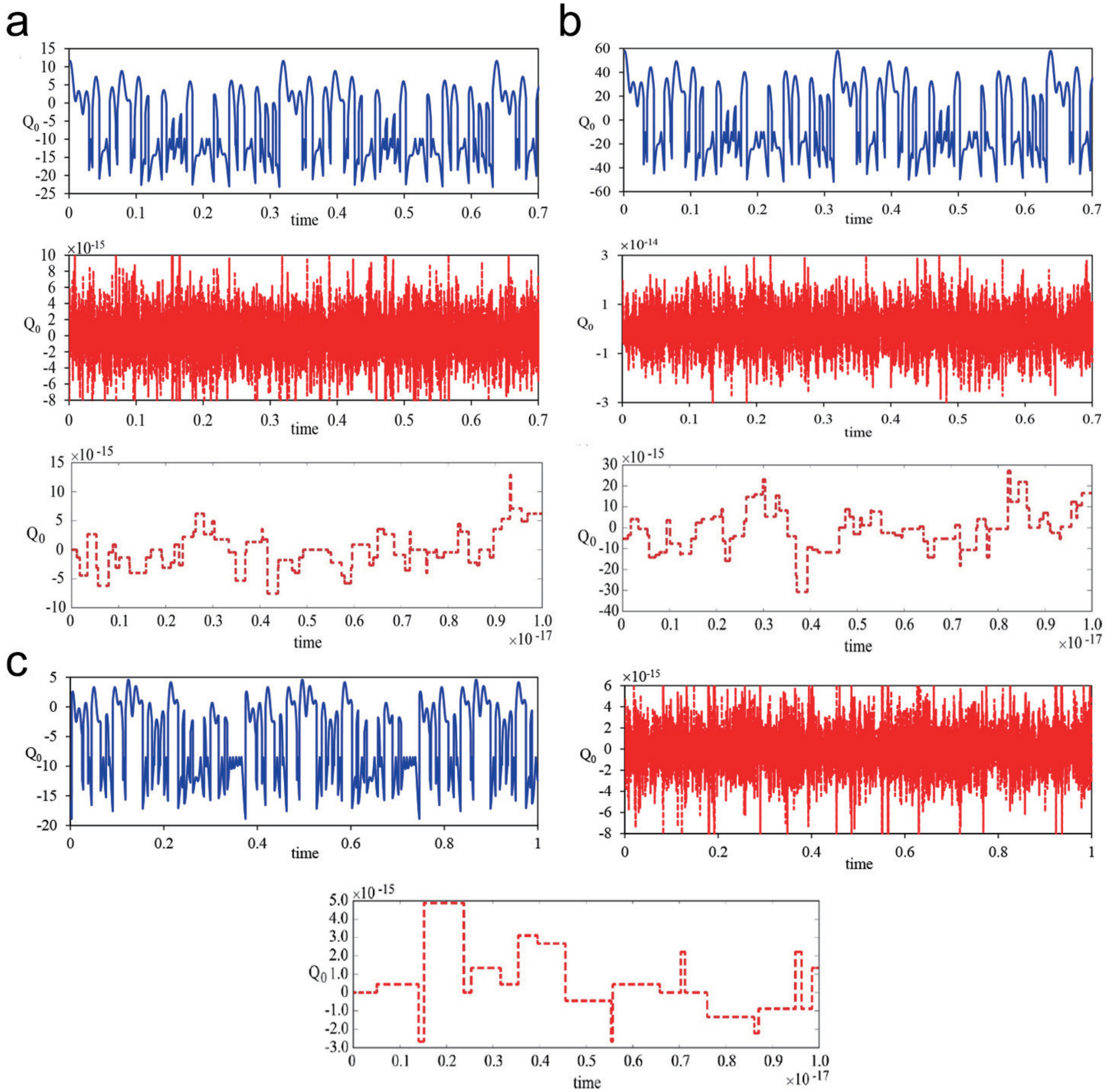

Fig. 4. *The reduced macro-quantum potential energy* (Q_0) *for (a) L=1, x=0.1,* $\gamma = 1.0$ *(b) L=0.1, x=0.01,* $\gamma = 0.01$*. and (c) L=1.49, x=0.5,* $\gamma = 1.9$*. The real component is periodic and therefore coherent. The imaginary part is shown to fluctuate about zero and when 'zoomed-in' in time produces a unique informational pattern. Real component is shown as a continuous line (blue) and imaginary component is shown as a dashed line(red).*

potential energy through its canonical momentum $F_Q = -\nabla Q$. In the de Broglie-Bohm pilot wave theory, concepts like momentum, and energy are ill-defined since the motion is ruled by Bohmian mechanics and not by Newtonian mechanics [57]. An ensemble of the pilot-wave force reflects $-\nabla Q$ as the force determined by Q in which the internal thermo-quantum energy guides the actualization of the phase differences (cf. [55, 58]).

8. Spontaneous Emergence of Macro-Quantum Potential Energy

The recent work of Guevara-Erra *et al*. [59] asserts that awake states reflect consciousness and greater information is present due to large information (theoretic) entropy values, suggesting consciousness could be the optimization of information processing. This type of evidence is flawed as it ignores the negentropy principle of information [19]. This principle claims that decrease in information (theoretic) entropy increases the thermal entropy. Therefore, with this

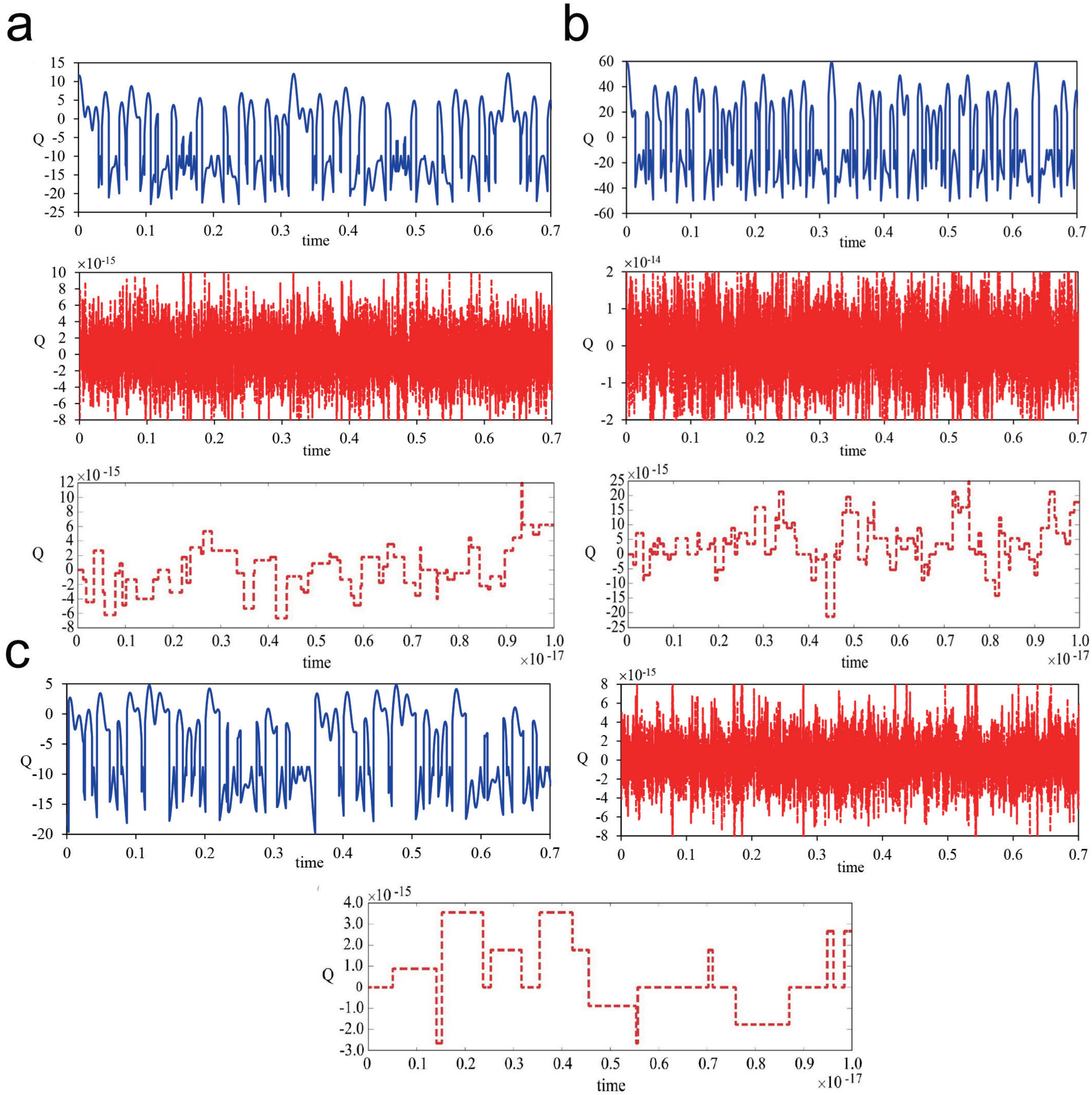

Fig. 5. *The macro-quantum potential energy* (Q) *for (a) L=1,* $x = 0.1.\gamma = 1.0$ *(b) L=0.1, x=0.01,* $\gamma = 0.01$. *and (c) L=1.5, x=0.5,* $\gamma = 2$. *The real component is chaotic (non-periodic) and therefore non-coherent. The imaginary part is shown to fluctuate about zero and when 'zoomed-in' in time clearly reveals a unique informational pattern. Real component is shown as a continuous line (blue) and imaginary component is shown as a dashed line (red).*

principle, information is not just a quantitative description of the causal relations between measured events (subjective) but has a physical reality in thermal entropy, which is an objective property of the brain. We assert that spontaneous potentiality as governed by negentropy principle of information allows to bridge the explanatory gap [13] between subjective 'phenomenal' experience and physical properties, and therefore a formative cause of consciousness in the brain.

The macro-quantum potential, $\mathrm{Q(x,t)} = -\frac{1}{2}\gamma\frac{\nabla^2\sqrt{\rho(\mathrm{x,t})}}{\sqrt{\rho(\mathrm{x,t})}}$ like the quantum potential, is also an emergent potential but it conveys 'meaning' in an 'information channel' as a quantum 'corrector' of the kinetic energy and potential energy [54]. The kinetic energy is $\frac{\gamma}{2}(\nabla \mathrm{S})^2$ and from the Hamilton-Jacobi equation the total energy is $-\frac{\partial \mathrm{S}}{\partial \mathrm{t}}$. Based on the expression for the conservation of energy in the quantum case is [47]:

$$\begin{aligned} &\textit{Kinetic energy} + \textit{Classical Potential energy} \\ &+ \textit{Quantum Potential energy} = \textit{Total energy} \end{aligned} \tag{13}$$

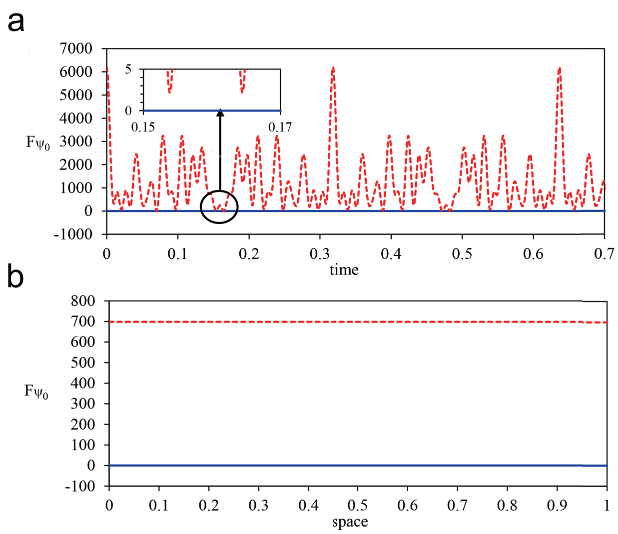

Fig. 6. *(a) Temporal variation in the pilot-wave force driving the wave function* (ψ) *for L=1, x=0.1,* $\gamma = 1.0$ *and (b) spatial variation showing the pilot-wave force driving the wave function* (ψ) *for L=1,* $\gamma = 1.0$*, t=0.1, The imaginary component in (b) is relatively large depending on the instant in time the measurement is taken, while the real component is zero. The imaginary component is never zero while the real component is zero. The latter signifies that* F_ψ *is not a Bohmian force. Real component is shown as a continuous line (blue) and imaginary component is shown as a dashed line (red).*

While in the thermo-quantum case a more appropriate formulation of the energy balance is via free-energy [60]:

$$Free\ energy = Internal\ energy\ (Q) - Entropy\ (S_Q) \times Temperature\ (T) \qquad (14)$$

Thermal entropy S_Q is not the quantum entropy at temperature T, which is known as the von Neumann entropy for T→ 0, S_Q→ 0; internal energy (Q) is separated in scale from the macroscopic ordered energy associated with an ensemble of dipole-bound electron fluid. This refers to the microscopic scale energy on the sub-atomic scale of quasi-free electrons undergoing thermo-quantum fluctuations based on quantum statistical mechanics with an emphasis on dynamical processes in quasi-equilibrium conditions [60]. When free-energy is positive the process will proceed spontaneously in the reverse direction to increase potentiality (not kinetic energy) through the macro-quantum potential energy, to provide a negentropic action that triggers the opportunity for unitary binding of consciousness. This negentropic action is not equivalent to the action caused by entropic forces in non-equilibrium conditions of open systems [61]. The quasi-equilibrium thermodynamics of the spontaneous processes are 'isolated' systems at one hierarchical level, but are 'quasi-closed' systems in the sense there is unidirectional exchanges with the environment of matter, energy, and information across hierarchical levels (cf. [62]).

With Born's rule and application of chain and product rules, the thermodynamic origin of the macro-quantum potential energy becomes (cf. [63]):

$$Q(x,t) = -\frac{1}{4}\gamma\left[\frac{\nabla^2\rho}{\rho} - \frac{1}{2}\frac{(\nabla\rho)^2}{\rho^2}\right] \qquad (15)$$

and together with $\frac{\nabla\rho}{\rho} = \nabla(\log\rho)$ the macro-quantum potential energy reduces to

$$Q(x,t) = -\frac{\gamma}{8}\left[\nabla(\log\rho)^2\right] - \frac{\gamma}{4}\left[\nabla^2(\log\rho)\right] \qquad (16)$$

However, in the context of thermodynamic effects, Q is proportional to Fisher information (theoretic) entropy (measure of the uncertainty of data in an 'information channel') and the pilot-wave force can be explicitly determined from the gradient of the local Boltzmann thermal entropy (cf., [64]). Therefore, the macro-quantum potential energy in the context of thermo-quantum fluctuations produces a negentropic action that can be explicitly represented through the gradient of the local Boltzmann thermal entropy, which is not a mechanical action but the action of S. The dissipative coupling between quantum subsystem and a thermal bath at temperature T via a mixed quantum-classical dynamical system differs in the approach we advocate, which is a classical system with thermo-quantum effects [65].

The spatial spread of the internal energy (Q) is both negative and positive, although a positive approximations of Q is $\frac{\gamma^2}{8}(\nabla[\log(\rho)])^2$ [30] and define the Boltzmann thermal entropy [54] as a log function $S_Q = -\frac{1}{2}\log(\rho)$ and Q becomes a negentropically defined macro-quantum potential energy:

$$Q(x,t) = -\frac{\gamma}{2}\left[\nabla(S_Q)^2\right] + \frac{\gamma}{2}\nabla^2 S_Q \qquad (17)$$

Here the first-term on the RHS is viewed as the macro-quantum 'corrector' of kinetic energy term and the second-term on the RHS influences the potential energy term U. The kinetic energy becomes $\frac{\gamma}{2}(\nabla S)^2 - \frac{\gamma}{2}[\nabla(S_Q)^2]$ and the classical potential energy becomes $U + \frac{\gamma}{2}\nabla^2 S_Q$. This implies that the kinetic energy of the dipole-bound electron oscillations contains a negentropic term $\frac{\gamma}{2}[\nabla(S_Q)^2]$ that relates to intrinsic 'potential' information. In other words, the macro-quantum potential energy informs 'meaning' via the quantum wave function by negentropic action. The reference to 'meaning' is due to the $\nabla^2 S_Q$ term influencing the classical potential energy. The concealed motion of the Q [66] is associated with the kinetic energy perturbed by the term $\nabla(S_Q)^2$. The negentropic term is shown in Fig. 7. It clearly exists at almost the same negative value range for both real and imaginary components as expected for the average values (real) against the movement of the phase differences from their average values (imaginary). In other words, the negentropic entanglement is independent of the amplitude of the macro-quantum potential energy as the internal thermo-quantum potential (Q) where the real component is an order of magnitude greater than the imaginary component.

The negentropic action can be explicitly represented by the gradient of the local Boltzmann thermal entropy ∇S_Q, which is shown in Fig. 8. Therefore, the negentropic entanglement through the negentropic action governs the phase synchrony which contributes equally to the average values (real component) and against the movement of the phase differences from their average values (imaginary component). This negentropic action can only be seen at the pico-scale, which is the macro-quantum level and so is not detectable by dielectric scanning microscopy. Furthermore, since the free-energy is positive, 'long-range order' in the phase differences arise spontaneously in the reverse direction through potentiality. This is a significant outcome because it can be extrapolated to the 'conscious-pilot' scenario where consciousness is spontaneous emerging from its own potentiality.

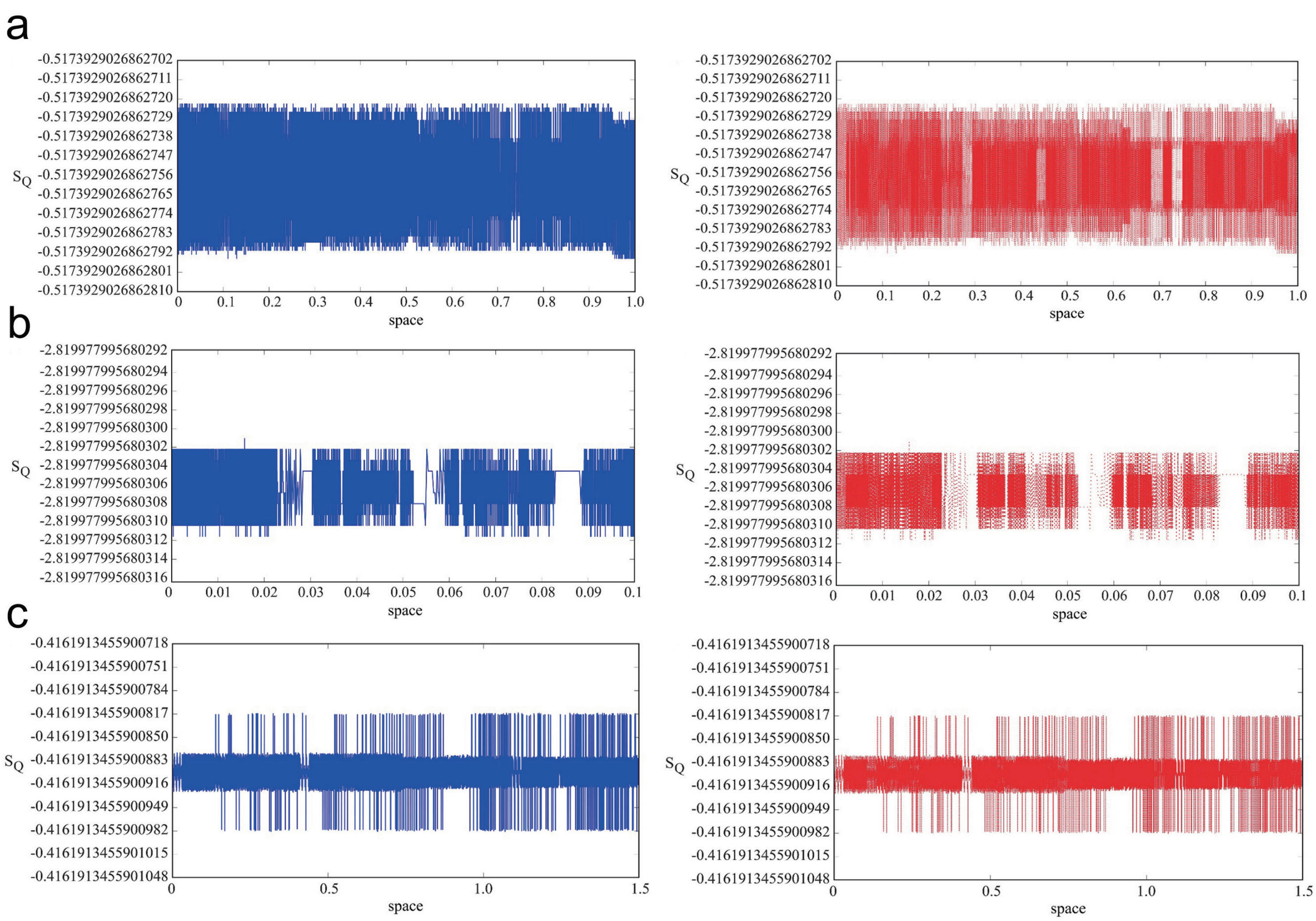

Fig. 7. *The negative entropy based on local Boltzmann thermal entropy (S_Q) which is directly related to negative entropy (negentropy) via the macro-quantum potential (Q) for (a) L=1, $\gamma = 1.0$, $t = 0.1$ (b) L=0.1, $\gamma = 0.01, t = 0.01$ and (c) $L = 1.5$, $\gamma = 2, t = 0.5$. The effect of the classical potential energy $U = 1$ has same negentropy as in the absence of classic potential energy $U = 0$. The variation in entropy is observed at the 13th significant figure with real component shown in blue and the imaginary component shown in red.*

The internal or intrinsic ('potential') information is observer-independent, although 'meaning' is ascribed to the negentropic action (or flow of energy that results in a pilot-wave guided negentropic force) causing negentropic entanglement, which is dependent on the measurement. Results reveal a minuscule internal thermo-quantum energy acting on the negentropic action that informs 'meaning' through patterns of intrinsic 'potential' information. In view of the negentropy principle of information, this negentropic action that is so minuscule is a 'conscious pilot' because information (theoretic) entropy is a subjective measurement. The 'conscious pilot' consists of intrinsic 'potential' informational patterns (see Fig. 9). This spontaneous potentiality points to how information entropy (subjectivity) is guided by the negentropy principle of information to reveal a 'consciousness code' from an increase in the Boltzmann thermal entropy∇S_Q. The 'consciousness code' is therefore an informational pattern caused by negentropic action actualizing spontaneous potentiality. There is almost an infinite unique variation of these patterns. The 'consciousness code' can be deciphered but not predicted as it remains both chaotic and spontaneous.

The amplitude of the negentropic action depends on the length scale L. The smaller the length scale L the greater is the amplitude of energy flow that results in a pilot-wave guided negentropic action. It can be seen in Fig. 10 that the amplitude is greatest when $\mathrm{L} = 10^{-9}$ compared with $\mathrm{L} = 10^{-7}$ (cf.Fig. 9). We can conclude that the effects in the movement of the averaged phase differences, including the movement of the fluctuation from the averages are greater for smaller length scale L, while at a spatially larger-scale the negentropic action results in a significantly reduced amplitude.

9. Discussion

Our hypothesis is that consciousness is a spontaneous process encompassing potentiality. The results indicate that static classical potential energy can disrupt the synchrony of phase differences of dipole-bound electron oscillations. We emphasize that unitary binding of consciousness can only be formed by spontaneous potentiality across the brain, especially the neocortex, while the midbrain reticulum could be the initiation zone of consciousness in the brain. The 'long-range order' occurs in the actualized phase differences of dipole-bound electron oscillations. If consciousness emerged from the spontaneity of its potentiality, then it is noncomputational. Indeed, due to spontaneity associated with potentiality, consciousness cannot be expressed in terms of global firing of spikes in neurons, which means that consciousness is not neurocentric in the sense that

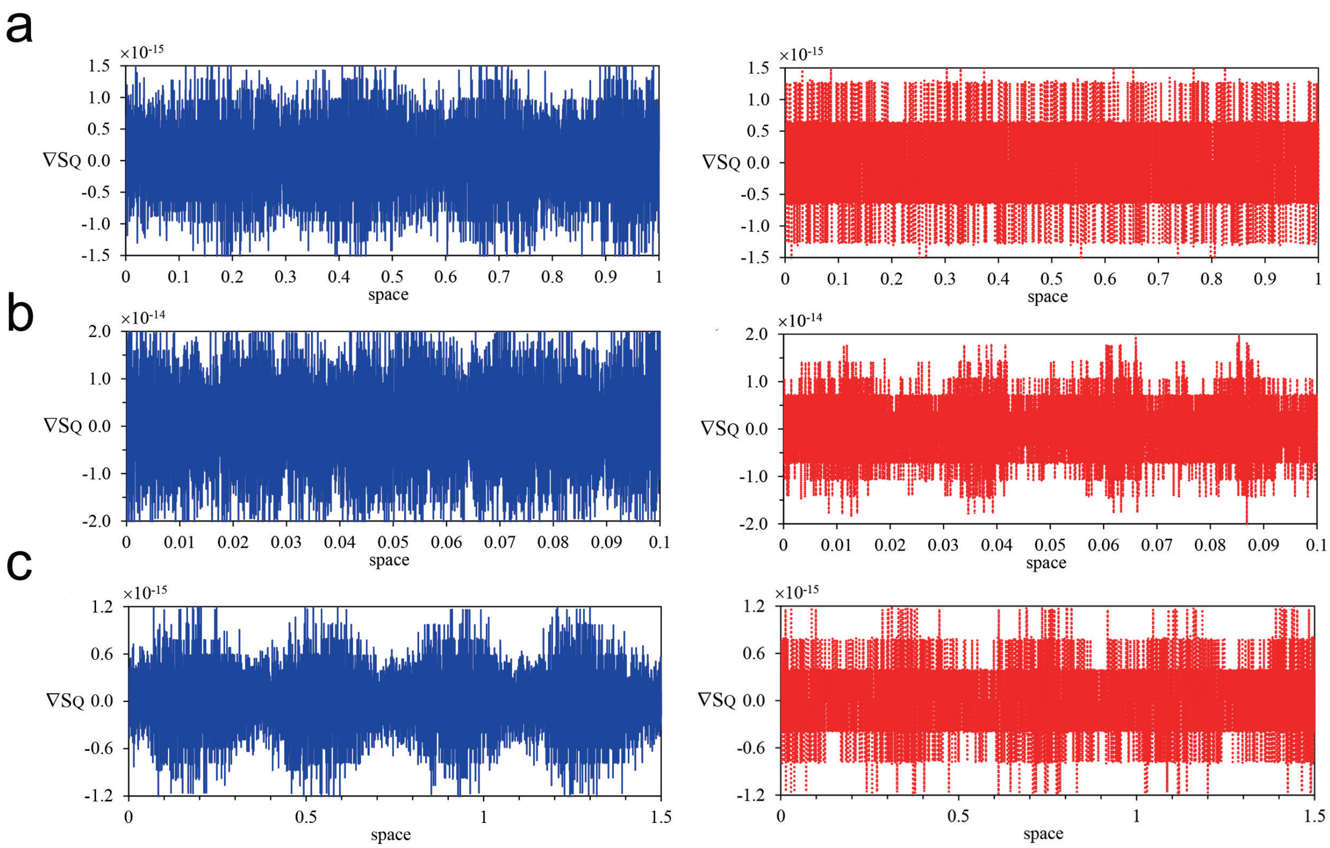

Fig. 8. *The gradient of the negative entropy based on local Boltzmann thermal entropy (S_Q) which is directly related to negative entropy (negentropy) via the macro-quantum potential (Q) for (a) L=1, $\gamma = 1.0$, t=0.1 (b) L=0.1, $\gamma = 0.01$, $t = 0.01$ and (c) L=1.5, $\gamma = 2$, t=0.5. The effect of the classical potential energy U=1 has same negentropy as in the absence of classic potential energy U=0. Real component shown in blue and imaginary component shown in red.*

it is based on computation along or across the neuronal membrane.

Syncytial effects between neuronal branchlets can carry 'pilot waves' through gap junctions, which are present at a higher density on most distal neuronal branchlets in the mammalian cortex [67]. The extrapolation to intraneuronal 'long-range order' would require a many-body wave equation, analogous to the many-body Schrödinger equation, resulting in many-body Hamilton-Jacobi equation with multiple wave functions, each corresponding to different spines on cortical interneuron branchlets coupled through gap-junctions. Whether 'long-range order' is achievable through sites connected by gap-junctions [38, 39] remains to be fully explored.

What seems to come out of Bohm's ontological interpretation of quantum mechanics is quantum nonlocality or 'spooky-action-at-a-distance' [44, 45], but according to Tegmark [41] there can be no 'spooky-action-at-a-distance' in 'warm' brains. Hiley [47] has defined nonlocality as the occurrence when the wave function is entangled through a common quantum potential. In other words, if we assume the wave function is in a non-entangled state:

$$\psi(x_1, x_2, t) = \psi_A(x_1, t)\psi_B(x_2, t) \tag{18}$$

and

$$Q(x_1, x_2, t) = Q_A(x_1, t)\left(= \frac{-\gamma}{2}\frac{(\nabla_1^2\sqrt{\rho(x_1, t)}}{\sqrt{\rho(x_1, t)}}\right) + Q_A(x_2, t)\left(= \frac{-\gamma}{2}\frac{(\nabla_2^2\sqrt{\rho(x_2, t)}}{\sqrt{\rho(x_2, t)}}\right) \tag{19}$$

Results in two wave functions that are entangled through a common macro-quantum potentials then we have by Madelung transformation: $\psi(x_1, x_2, t) = \sqrt{\rho(x_1, x_2, t)}e^{iS(x_1, x_2, t)}$, viz

$$\psi(x_1 x_{,2}, t) = \frac{1}{2}\left[\psi_A(x_1, t)\psi_B(x_2, t) - \psi_B(x_1, t)\psi_A(x_2, t)\right] \tag{20}$$

and

$$Q(x_1, x_2, t) = \frac{-\gamma}{2}\left[\frac{(\nabla_1^2 + \nabla_2^2)\sqrt{\rho(x_1, x_2, t)}}{\sqrt{\rho(x_1, x_2, t)}}\right] \tag{21}$$

The meaning of negentropically entangled spines conjures for example, that the two wave functions corresponding to different nonsynaptic spines, where the macro-quantum potential energy finds passage across gap junctions. This biological quantum nonlocality would be another way for negentropic entanglement if a correlation between negative entropy through the pilot-wave guiding principle is taken instead. It is further proposed that pilot-waves inform 'meaning' through negative entropy [68].

It is suggested that 'qualia' as the content of consciousness can be influenced by negentropic entanglement. This influence is a pattern of intrinsic 'potential' information and the 'meaning' of a subjective observer extracting the pattern or sequence, corresponds to a 'consciousness code,' ready to convey an intimate connection to cognition and then through memory to become a conscious experience. It can be said that a unique 'consciousness code' is a gateway to conscious cognition [69]. The 'consciousness code' is a pathway for

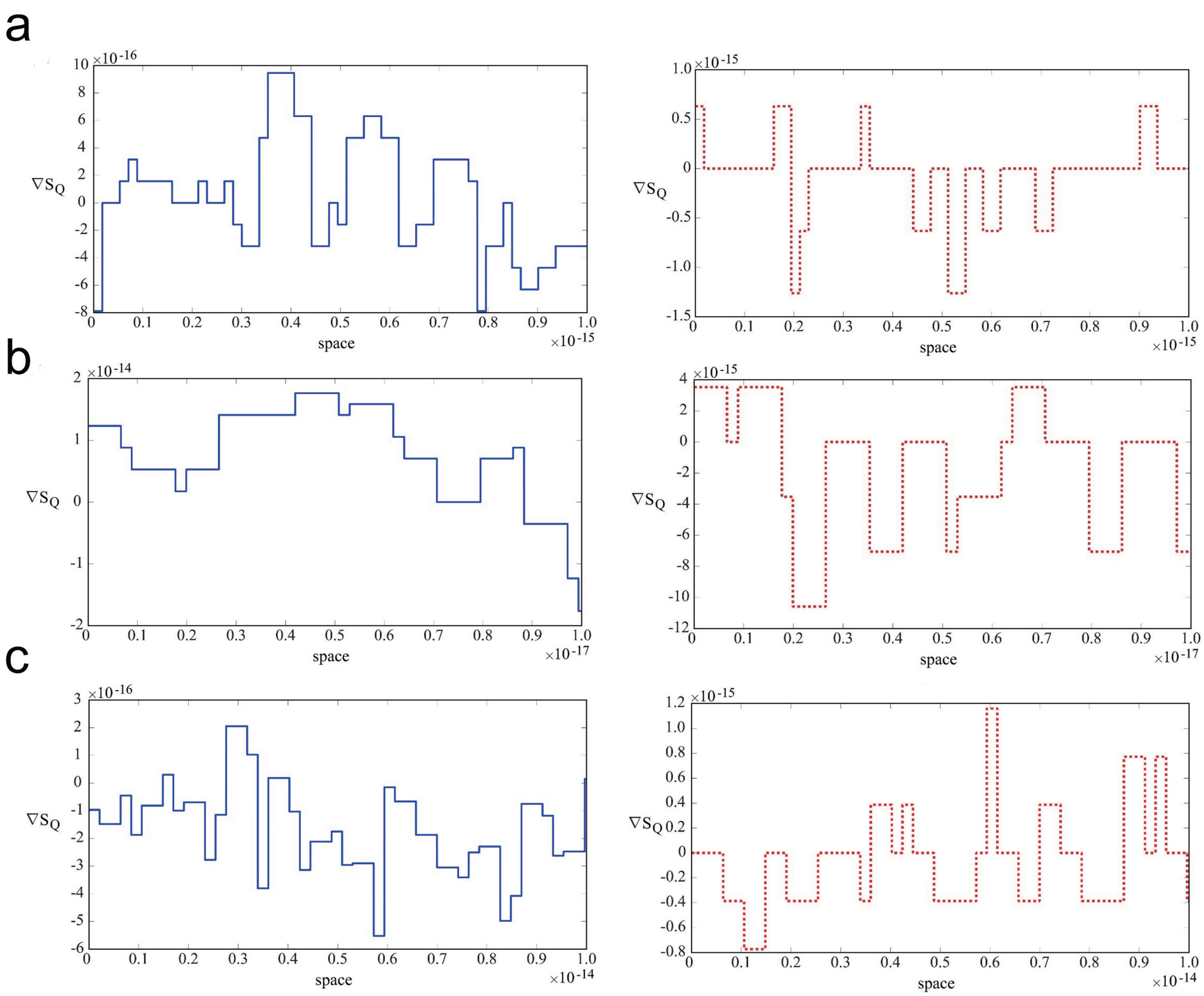

Fig. 9. *A blown-up version for the component of Fig. 8 presented with a clearly indicated zigzagging wave exerted by the macro-quantum potential energy, which is an internal energy or intrinsic 'potential' informational pattern. Each pattern is chaotic suggesting that each information pattern that carries 'meaning' informs conscious cognition in a unique way. (a) L=1, $\gamma = 1.0$, t=0.1 (b) L=0.1, $\gamma = 0.01, t = 0.01$ and (c) L=1.5, $\gamma = 2$, t=0.5.* Real component shown in blue and imaginary component shown in red.

example through language. However, there is no conscious cognition without recognition, so conscious recall arises instead of memory and only in the presence of 'uncertainty' where memory is reconsolidated [24]. This is also the final cause of consciousness. Thus, memory must be a way of compensating for the partial information (entropy). This compensatory mechanism is broadly defined as "uncertainty"[1] [24]. In other words, consciousness and memory formation must be intimately linked [70, 71]. In memory after consciousness, requires the end of consciousness and the beginning of memory, suggest an illusion [72]. The sequence of pre-consciousness and post-consciousness is not an illusion when memory is nonlocal [73].

The standard or orthodox approach to quantum mechanics is known as the Copenhagen interpretation [71]. This approach focuses on an 'observer' collapsing the wave function. Our approach is analogous to Bohm's realist ontological interpretation of quantum mechanics [43]. There is no observer but 'hidden variable' – the quantum potential, and it arises naturally from Schrödinger's equation (see [56] for an introduction to quantum mechanics). We have extrapolated Bohm's quantum potential to the macroscopic scale as the 'macro-quantum potential'. Consequently, we can develop a mixed quantum-classical dynamical system for two independent modes of operation which are intimately linked: thermo-quantum consciousness and cognition. They are independent physical processes that coalesce in the context of the absence of emergence. The phenomenal 'feel' of conscious cognition is based on thermodynamic transfer of intrinsic conformation actualized as a 'consciousness code' arising through negentropy principle of information. Higher up conscious cognition dominates, and the unitary binding of consciousness disseminates which means consciousness cannot function causally in the actualization of physical behavior, i.e., consciousness has no causal powers [22]. However, there must be unitary binding of consciousness across the neocortex for conscious cognition to emerge by way of 'sensing' consciousness. Phase synchrony of dipole-bound electron oscillations form a macroscopic coherent state that gives stability

[1] One can also think of 'uncertainty' as arising from its response to intrinsic/internal 'potential' information.

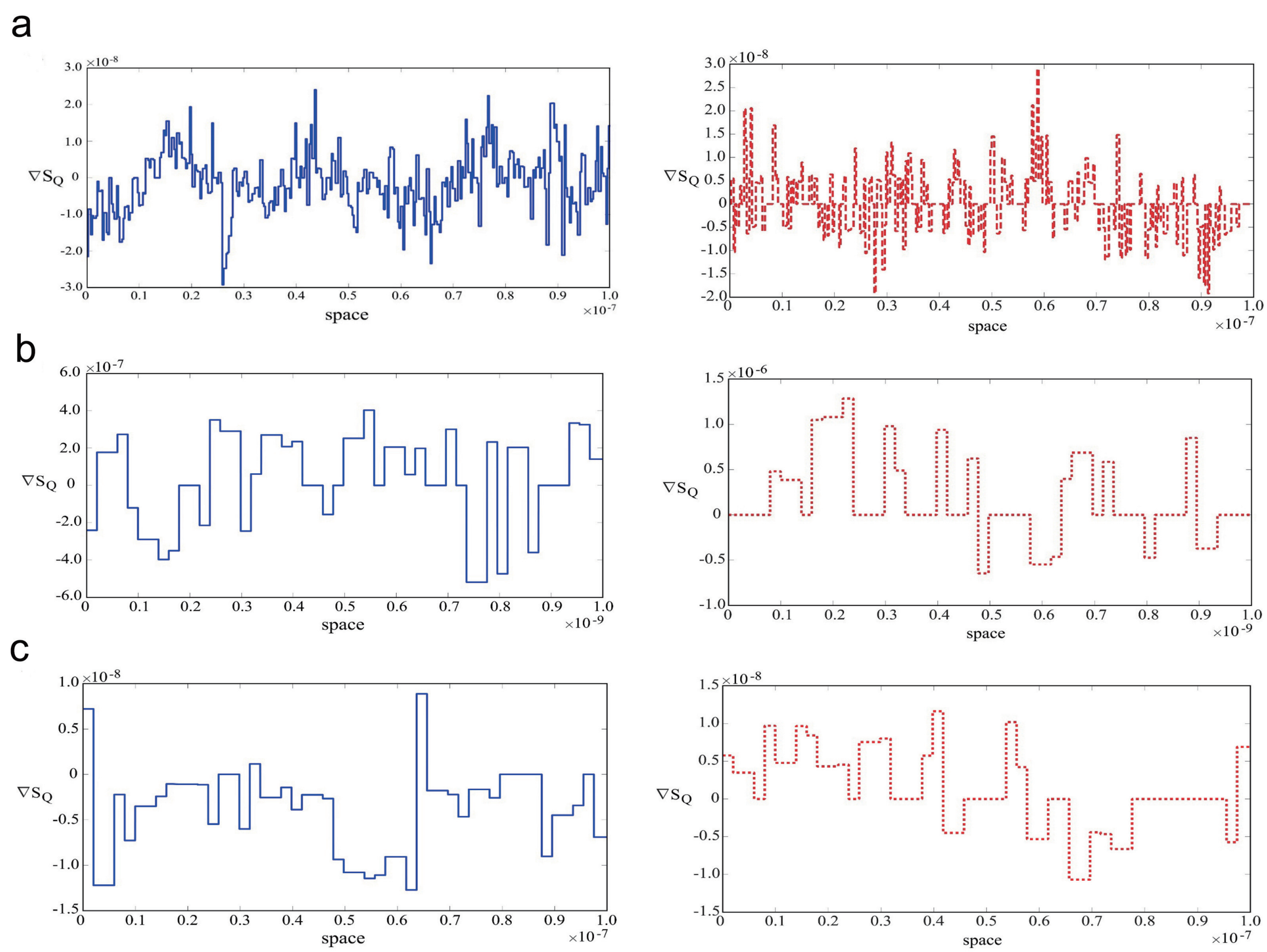

Fig. 10. *Effect of smaller L on the Boltzmann thermal entropy as an internal energy or intrinsic 'potential' informational pattern. Each pattern is chaotic suggesting that each information pattern that carries 'meaning' informs conscious cognition in a unique way. (a) L=10^{-7}, $\gamma = 1.0$, t=0.1 (b) L=10^{-9}, $\gamma = 0.01, t = 0.01$ and (c) L=10^{-7}, $\gamma = 2$, t=0.5.* Real component is shown in blue and imaginary component is shown in red.

for unitary binding of consciousness in terms of the 'consciousness code'.

What the macroscopic pilot-wave theory points to is synchrony of phase differences occurring in the absence of classical potential energy, while reconciliation of the quantum effect resulting from the thermo-quantum fluctuations in the presence of classical potential energy occurs through a pilot-wave force. Furthermore, the pilot-wave force does not have a causal role in generating neuronal synchronization, but instead there is supervenience relation. The highly localized information processing cannot be connected by strict laws with the nonlocal cortical processing governed by the pilot-wave theory. This is not in tune with Searle [22] who refers to consciousness as a biological phenomenon or 'biological naturalism' to explain in naturalistic terms that there is nothing in the brain that supervene upon the physical processes, yet our knowledge is limited in differentiating between two unique physical processes: the local and the nonlocal.

The intrinsic/internal 'potential' information (observer-independent) is discrete and based on the structuring of macro-quantum potential energy that represent a vast range of potential possibilities. The macro-quantum potential energy arises according to 'hidden' thermodynamics of particles and negentropic action arising from the microscopic scale of matter. Moreover, the quantum-like realm is characterized by indeterminism, i.e., non-causal effects [3], this is incongruent to nonreductive physicalism where quantum effects are assumed to impact higher-up hierarchical levels of brain function. According to panexperientialism it is energy transfer described in terms of actualized differences that supervene on material interactions. The notion of emergence of consciousness from matter or panexperiential materialism is advocated here given that the hidden energy is intrinsic to matter [25]. Also given that information in the brain is based on two different processes (i.e., local and nonlocal) it is virtually impossible to conceive integrated information theory, but rather the 'self-actualization' of the organism—the process of conversion of potentiality into actuality in the context of organismic teleofunctionality[2].

The macro-quantum potential energy is an informational channel that carries 'meaning' in highly interconnected macro-quantum systems. Such interconnectedness is possible through temporal coupling of the pilot-wave force driving the wave function, and the time scale of cellular processes, which is 10^{-9} sec and longer. The thermo-quantum energies associated with the 'consciousness code' are capable of being 'sensed' by the quickest cellular processes

[2]Is a reflection of subjectivity in the teleofunctionalist epistemology.

which would fathom self-awareness through conscious cognition. Moreover, negentropic entanglement is more likely to be an 'integrator' of intrinsic 'potential' information that never directly interacts with conscious cognition rather conscious cognition 'feels' the consciousness process through a mean field approximation $F_Q = -\nabla Q$ (forthcoming).

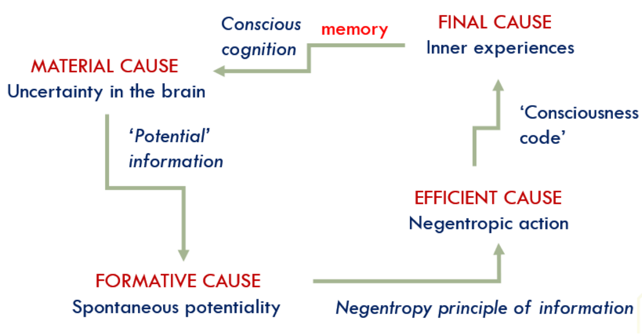

Fig. 11. *Aristotelian fundamental causes as a recursive hierarchy (the relational holon). The causes are integrated so there is no infinite regress associated with first and final cause. Spontaneous potentiality via negentropy principle of information establishes the potential existence as a formal cause in terms of nonlocal contextual potentials (macro-quantum quantum potential energy). Intrinsic 'potential' information transcends both the contextual (potential) and the realized (actual) aspects of the consciousness process. Note the closure of the holon requires acausal relationship with conscious cognition and therefore 'feeling' or 'sensing' is done through a thermodynamically hierarchic transfer of intrinsic information with higher-order cognitive functions, including memory. The direction of each cause is not reversible and closure of the holon at the nexus between consciousness process and its 'feeling' or 'sensing' by conscious cognition is bidirectional, since uncertainty in the brain supervenes on the lower level intrinsic 'potential information', thus excluding the requirement for externalism.*

Spontaneous potentiality as experiential flow of potential energy (and not kinetic energy)as a result of 'pilot-wave' guiding actualized phase differences, which is the mechanism for unitary binding of consciousness and as such a formative cause of consciousness. A direct connection between the collective unconscious and consciousness can be fathomed in embodied cognition. The collective unconscious is like a 'databank' that is completely nonconscious, but may spring into consciousness, by the macro-quantum potential energy as spontaneous potentiality via negentropic action that 'binds' the actualizd phase differences, thus acting as an 'integrator' of intrinsic 'potential' information, which is equivalent to 'uncertainty in the brain', but occurs at a higher level, so its properties supervene on the lower-level properties associated with intrinsic 'potential' information.

The physicality of embodied consciousness remains quantum-like in nature due to its nonlocal character, but this should not be taken as subluminal consciousness. Nonlocality refers to contextual potentials or macro-quantum potential from the thermo-quantum energy processing at the very small scale, just below the molecular level, above the atomic scale. Without the processing of energy, cognition is unable to store information, yet presupposed in and necessary to experience this 'potential' information in the final cause of inner experiences via memory as shown in the holon (Fig. 11). Based on a teleological functionalist epistemology, Aristotelian doctrine of causes becomes: The material cause is the existence of nonlocal causal dynamical relations; formal cause is a contextual potential that realizes a teleofunction; efficient cause is an action realizing (actualizing) a teleofunction; final cause is teleofunctionality [3].

The location of conscious experience or conscious cognition is the feedback from prefrontal cortex to posterior cortical areas, while the nonconscious processing or brain functions are sensory inputs to thalamus to primary visual cortex to prefrontal cortex. Anesthesia disrupts the consciousness in the pathway from the prefrontal cortex to posterior cortical areas [74]. This suggests that the holon gets disrupted between the conscious cognition stage and the 'potential' information stage due to the overwhelming uncertainty in the brain. In other words, anaesthesia increases uncertainty in the brain to a stage where 'potential' information is completely removed, and the consciousness process is no longer capable to continue as spontaneous potentiality.

10. Conclusion

The macro-quantum wave equation was solved to yield the macro-quantum wave function in both the absence of classical potential energy U = 0 and in presence of classical potential energy, for a simple case when U = 1. The presence of macro-quantum potential energy acts as a 'pilot wave' manoeuvring the phase differences, as an integrated negentropic action. Negentropic entanglement 'binds' nonconscious entities to 'potential' conscious entities, temporally, thus acting as an 'integrator' of intrinsic 'potential' information, that convey 'meaning' at the fundamental level. There are distinctive informational patterns that carry 'meaning'. Each 'meaning' is extracted by the subjective observer through self-actualization at the most fundamental level. The internal thermo-quantum energy stabilizes the actualized phase differences without which there would be no 'conscious-pilot'. The 'conscious-pilot' invokes a spontaneous process that functionally cannot be reproduced outside of the brain without an artificial agent that can stabilize and 'bind' the actualized phase differences.

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Conflict of Interest

All authors declare no conflict of interest.

References

[1] Eccles JC (1986) Do mental events cause neural events analogously to the probability fields of quantum mechanics? *Proceedings of the Royal Society* **277(1249)**, 411-428.

[2] Beck F, Eccles JC (1992) Quantum aspects of brain activity and the role of consciousness. *Proceedings of the National Academy of Sciences (USA)* **89**, 11357-11361.

[3] Lewis ER, MacGregor RJ (2006) On indeterminism, chaos, and small number particle systems in the brain. *Journal of Integrative Neuroscience* **5(02)**, 223-247.

[4] Clarke PGH (2014) Neuroscience, quantum indeterminism and the Cartesian soul. *Brain and Cognition* **84(1)**, 109-117.

[3] In the functionally-linked continuum of interconnected intrinsic 'potential' information.

[5] Hameroff SR (1987) *Ultimate Computing: Biomolecular Consciousness and Nanotechnology*. North Holland, Amsterdam.

[6] Craddock TJA, Kurian P, Preto J, Kamlesh S, Hameroff SR, Klobukowski M, Tuszynski JA (2017) Anesthetic alternations of collective terahertz oscillations in tubulin correlate with clinical potency: implications for anesthetic action and post-operative cognitive dysfunction. *Scientific Reports* **7(1)**: 9877.

[7] Hameroff SR, Watt RC, Borel JD, Carlson G (1982) General anesthetics directly inhibit electron mobility: dipole dispersion theory of anesthetic action. *Physiological Chemistry and Physics* **14(3)**, 183-187.

[8] Hameroff SR (1994) Quantum coherence in microtubules: A neural basis for emergent consciousness. *Journal of Consciousness Studies* **1(1)**, 91-118.

[9] Hameroff SR (2010) The 'conscious pilot' – dendritic synchrony moves through the brain to mediate consciousness. *Journal of Biological Physics* **36(1)**, 71-93.

[10] Buzsáki G (2007) The structure of consciousness. *Nature **446(7133)***, 267.

[11] Rudrauf D, Bennequin D, Granic I, Landini G, Friston K, Williford K (2017) A mathematical model of embodied consciousness. *Journal of Theoretical Biology* **428**, 106-131

[12] Tory Toole J, Kurian P, Craddock TJA (2018) Coherent energy transfer and the potential implications for consciousness. *Journal of Cognitive Science* **19(2)**, 115-124.

[13] Levine J (1983) Materialism and qualia: The explanatory gap. *Pacific Philosophical Quarterly* **64(4)**, 354-361.

[14] Chalmers DJ (1996) *The Conscious Mind: In Search of a Fundamental Theory*. Oxford University Press, New York.

[15] Brillouin L (1962) *Science and Information Theory*. Academic Press, New York.

[16] MacKay DM (1969) *Information Mechanism and Meaning*. MIT Press, Cambr., MA.

[17] Pribram KH (1991) *Brain and Perception: Holonomy and Structure in Figural Processing*. Lawrence Erlbaum, New Jersey.

[18] Heidegger M (1977) *Basic Writings*. Harper Collins, San Francisco.

[19] Brillouin L (1953) The negentropy principle of information. *Journal of Applied Physics* **24(9)**, 1152-1163.

[20] Preto J (2016) Classical investigation of long-range coherence in biological systems. *Chaos: An Interdisciplinary Journal of Nonlinear Science* **26(12)**, 123116-1-13.

[21] Crick F (1995) *Astonishing Hypothesis: The Scientific Search for the Soul*. Scribner, New York.

[22] Searle JR (2007) Biological naturalism. In M. Velmans and S. Schneider, eds *The Blackwell Companion to Consciousness*. Blackwell, Oxford.

[23] Baars BJ, Edelman DB (2012) Consciousness, biology and quantum hypotheses. *Physics of Life Reviews* **9(3)**, 285-294.

[24] Solms M (2017) Consciousness by Surprise. In, R.R.Poznanski, J.A.Tuszynski and T.E. Feinberg (eds) *Biophysics of Consciousness: A Foundational Approach* World Scientific, Singapore.

[25] de Broglie L (1987) Interpretation of quantum mechanics by the double solution theory. *Annales de la Fondation Louis de Broglie* **12(4)**, 1-23.

[26] Sbitnev VI (2016) Quantum consciousness in warm, wet, and noisy brain. *Modern Physics Letters* B**30(28)**, 1650329.

[27] Satyajit S, Ghosh S, Fujita D, Bandyopadhyay A (2014) Live visualizations of single isolated tubulin protein self-assembly via tunneling current: effect of electromagnetic pumping during spontaneous growth of microtubule. *Scientific Reports* **4**, 7303.

[28] Filk T (2012) Quantum-like behavior of classical systems. In Quantum Interactions, Sixth International Symposium, Paris France.

[29] Tsekov R (2011) Quantum diffusion. *Physica Scripta* **83**, 035004.

[30] Heifetz E, Cohen E (2015) Toward a thermo-hydrodynamic like description of Schrödinger equation via the Madelung formulation and Fisher information. *Foundations of Physics* **45(11)**, 1514-1525.

[31] Mahler G (2015) *Quantum Thermodynamics: Energy and Information Flow at the Nanoscale.* CRC Press, Boca Ratom FL.

[32] Salari V, Tuszynski JA, Rahnama M, Bernroider G (2011) Plausibility of quantum coherent states in biological systems. *Journal of Physics: Conference Series* **306(1)**, 012075.

[33] MacGregor RJ (2006) Quantum mechanics and brain uncertainty. *Journal of Integrative Neuroscience* **5(03)**, 373-380.

[34] Faisal AA, White JA, Laughlin SB (2005) Ion-channel noise places limits on the miniaturization of the brain's wiring. *Current Biology* **15(12)**, 1143-1149.

[35] Faisal AA, Laughlin SB (2007) Stochastic simulations on the reliability of action potential propagation in thin axons. *PLoS Computational Biology* **3(5)**: e79.

[36] Arellano JI, Espinosa A, Fairen A, Yuste R, DeFelipe J (2007) Non-synaptic dendritic spines in neocortex. *Neuroscience* **145(2)**, 464-469.

[37] Arellano JI, Benavides-Piccione R, DeFelipe J, Yuste R (2007) Ultrastructure of dendritic spines: correlation between synaptic and spine morphologies. *Frontiers in Neuroscience* **1**, 131-143.

[38] Amitai Y, Gibson JR, Beierlein M, Patrick SL, Ho AM, Conners BW, Golomb D (2002) The spatial dimensions of electrically coupled networks of interneurons in the neocortex. *Journal of Neuroscience* **22(10)**, 4142-4152

[39] Fukuda T (2007) Structural organization of the gap junction network in the cerebral cortex. *The Neuroscientist* **13(3)**, 199-207.

[40] Hotulainen P, Hoogenraad CC (2010) Actin in dendritic spines: connecting dynamics to function. *The Journal of Cell Biology* **189(4)**, 619-629.

[41] Tegmark M (2000) Importance of quantum decoherence in brain processes. *Physical Review E* **61(4)**, 4194-4206.

[42] Hagen S, Hameroff S, Tuszynski JA (2002) Quantum computation in brain microtubules: decoherence and biological feasibility. *Physical Review E* **65(6)**, 061901.

[43] Bohm DJ (1952) A suggested interpretation of the quantum theory in terms of hidden variables. *Physical Review* **85(2)**, 166-193.

[44] Bohm DJ, Hiley BJ, Kaloyerou PN (1987) An ontological basis for the quantum theory. *Physics Reports* **144(6)**, 322-375.

[45] Bohm DJ, Hiley BJ (1993) *The Undivided Universe: An Ontological Interpretation of Quantum Theory*. Routledge. London.

[46] Gould LI (1995) Quantum dynamics and neural dynamics: analogies between the formalisms of Bohm and Pribram. In, J. King and K.H. Pribram (eds.) *Scale in Conscious Experience: Is the Brain Too Important To Be Left to Specialists to Study?* Lawrence Erlbaum, New Jersey.

[47] Hiley BJ (1995) Nonlocality in Microsystems. In, J. King and K.H. Pribram (eds) *Scale in Conscious Experience: Is the Brain Too Important to be Left to the Specialists to Study?* Hillsdale: Lawrence Erlbaum.

[48] Josephson BD, Pallikari-Viras F (1991) Biological utilisation of quantum nonlocality. *Foundations of Physics* **21(2)**, 197-207.

[49] Bohm DJ (1990) A new theory of the relationship of mind and matter. *Philosophical psychology* **3(2-3)**, 271-286.

[50] Hiley BJ (2002) From the Heisenberg picture to Bohm: a new perspective on active information and its relation to Shannon information. InA. Khrennikov (ed.) *Quantum Theory: Reconsideration of Foundations* Växjö University Press, Sweden.

[51] Esposito S (1999) On the role of spin in quantum mechanics. *Foundations of Physics Letters* **12(2)**, 165-177.

[52] Lipovka A (2016) Nature of the quantum potential. *Journal of Applied Mathematics and Physics* **4**, 897-902.

[53] Fiscaletti D (2018) *The Geometry of Quantum Potential: Entropic Information of the Vacuum* World Scientific Publishers, Singapore.

[54] Sbitnev VI (2009) Bohmian trajectories and the path integral paradigm. Complexified Lagrangian mechanics. *International Journal of Bifurcation and Chaos* **19(07)**, 2335-2346.

[55] Dennis G, de Gosson MA, Hiley BJ (2015) Bohm's quantum potential as an internal energy. *Physics Letters A* **379(18-19)**, 1224-1227.

[56] Griffiths DJ (2005) *Introduction to Quantum Mechanics*. Second Edition. Pearson Prentice Hall, NJ.

[57] Passon O (2018) On a common misconception regarding the de Broglie-Bohm theory. *Entropy* **20**, 440.

[58] Heifetz E, Tsekov R, Cohen E, Nussinov Z (2016) On entropy production in the Madelung fluid and the role of Bohm's potential in classical diffusion. *Foundations of Physics* **46(7)**, 815-824.

[59] Guevara Erra R, Mateos DM, Wennberg R, Perez Velazquez JL (2016) Statistical mechanics of consciousness: maximization of information content of network is associated with conscious awareness. *Physical Review E* **94(5)**, 052402.

[60] Tolman RC (1979) *The Principles of Statistical Mechanics* Dover Publication, NY.

[61] Wissner-Gross AD, Freer CE (2013) Causal entropic forces. *Physical Review Letters* **110(16)**, 168702.

[62] Gladyshev GP (2015) Natural selection and thermodynamics of biological evolution. *Natural Science* **7**, 117-126.

[63] Grössing G (2009) On the thermodynamic origin of the quantum potential. *Physica A: Statistical Mechanics and its Applications* **388(6)**, 811-823.

[64] Tsekov R (2012) Bohmian mechanics versus Madelung quantum hydrodynamics. In, V. Popov (ed.) Ananuire de l'Universite de Sofia, Faculte de Physique, Sofia University Press, Sofia.

[65] Wyatt RE (2005) *Quantum Dynamics with Trajectories: Introduction to Quantum Hydrodynamics*. Springer, New York.

[66] Holland P (2015) Quantum potential energy as concealed motion. *Foundations of Physics* **45(2)**, 134-141.

[67] Vervaeke K, Lorincz A, Nusser Z, Angus Silver R (2012) Gap junctions compensate for sublinear dendritic integration in an inhibitory network. *Science* **335**, 1624-1628.

[68] Longo G, Bailly F (2009) Biological organization and negative entropy. *Journal of Biological Systems* **17**, 63-96.

[69] Baars BJ (1998) *A Cognitive Theory of Consciousness*. Cambridge University Press, New York.

[70] Schwartz J, Stapp H, Beuregard M (2005) Quantum physics in neuroscience and psychology: a neurophysical model of min-brain interaction. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* **360(1458)**, 1309-1327.

[71] Stapp HP (2009) *Mind, Matter, and Quantum Mechanics*. Springer, Berlin.

[72] Dennett DC (2017) *From Bacteria to Bach and Back: The Evolution of Minds*. Norton, New York.

[73] Stuart CIJM, Takahashi Y, Umezawa H (1978) On the stability and non-local properties of memory. *Journal of Theoretical Biology* **71(4)**, 605-618.

[74] Mashour GA (2006) Integrating the science of consciousness and anesthesia. *Anesthesia & Analgesia* **103(4)**, 975-982.