

Hypothesis

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Hypothesis

The Quantum Blueprint Formalism: An Informational Extension of Dissipative Quantum Field Theory in Living Systems

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Abstract

We propose a generalization of the dissipative quantum field theory (DQFT) as developed by Celeghini, Rasetti, and Vitiello to describe the dynamic informational feedback underlying biological coherence. The new framework, termed the Quantum Blueprint Formalism (QBF), builds on the fact that in DQFT the conjugate field $\psi^\dagger$ is an active dynamical partner of ψ , representing the time-reversed degrees of freedom that co-generate dissipation, irreversibility, and the selection of inequivalent vacuum states. Rather than functioning as a mere repository of past interactions, $\psi^\dagger$ participates continuously in the system's coherent evolution through SU(1,1) Bogoliubov mixing. QBF extends this structure by allowing the ψ - $\psi^\dagger$ coupling to become explicitly state-dependent, thereby endowing the conjugate field with an informational role that reflects and influences the system's ongoing coherence pattern. Correlation parameters $\Theta = \{\theta_k\}$ quantify the instantaneous coherence relations between the two sectors and evolve in time according to a nonlinear stochastic differential equation derived from the dissipative field dynamics. This extended formalism provides quantitative links between informational coherence and physiological observables such as heart rate variability (HRV), EEG phase synchronization, water-domain ordering, and ultraweak photon emission. It thereby establishes a bridge between dissipative quantum physics, information theory, and experimental biophysics, offering a consistent mathematical and empirical basis for understanding life as an informationally guided, self-organizing process in which ψ and $\psi^\dagger$ jointly sustain and regenerate coherence.

Keywords: dissipative quantum field theory; thermo field dynamics; doubled Hilbert space; conjugate field dynamics; ψ - $\psi^\dagger$ coupling; SU(1,1) symmetry; informational field; coherence dynamics; biological coherence; quantum biophysics; correlation parameters Θ ; coherence restoration; non-equilibrium systems; informational attractor; Blueprint Coherence Index; long-range order in living systems; ultraweak photon emission; HRV coherence; EEG synchronization; quantum-informed physiology; self-organizing biological systems; informational feedback

1. Introduction

Biological systems maintain long-range order far from thermodynamic equilibrium, continuously exchanging energy and information with their environment. Classical thermodynamics cannot account for such persistent coherence (Prigogine & Stengers, 1984). To address this, Celeghini, Rasetti, and Vitiello (1992) formulated a dissipative quantum field theory (DQFT) based on Thermo Field Dynamics (TFD) (Umezawa, 1967), in which the Hilbert space is doubled to include both the system (ψ) and its conjugate ($\psi^\dagger$), representing the time-reversed dynamical partner required for dissipation.

In this framework, coherence arises from spontaneous symmetry breaking and the condensation of Nambu–Goldstone modes, producing macroscopic quantum domains that underlie perception, memory, and self-organization (Freeman & Vitiello, 2006). While the tilde field $\psi^\dagger$ in DQFT encodes

the environmental and historical degrees of freedom necessary for irreversibility and memory, it does not explicitly implement *informational feedback* into the system's evolution.

The Quantum Blueprint Formalism (QBF) extends this idea by assigning $\tilde{\psi}$ an explicit informational role that elaborates—and does not contradict—the active function already present in dissipative quantum field theory (DQFT). In the original DQFT of Celeghini, Rasetti, and Vitiello, the conjugate field $\tilde{\psi}$ is not a passive repository of dissipated modes but an active dynamical partner of ψ . Their $SU(1,1)$ -mediated coupling is governed by the Bogoliubov parameters θ_k , which encode the degree of mixing between the two sectors and thereby regulate memory formation, irreversibility, and long-range coherence. In other words, the feedback between system and tilde-system is already mediated by θ_k in DQFT, where these parameters label distinct inequivalent vacua and determine the strength of ψ - $\tilde{\psi}$ entanglement.

QBF builds on this foundation by interpreting the correlation parameters $\Theta = \{\theta_k\}$ not only as markers of vacuum structure but as informational coherence amplitudes that dynamically encode the system's evolving resonance with its own history of ordered states. In this generalized framework, the ψ - $\tilde{\psi}$ coupling becomes explicitly state-dependent, and $\tilde{\psi}$ functions as an informational attractor that reorganizes the physical system through correlation-sensitive feedback. The dynamics of $\Theta(t)$ thus quantify the organism's capacity to restore order following perturbation, translating the inherent feedback structure of DQFT into a biologically and informationally meaningful form.

2. Mathematical Structure of the Quantum Blueprint Formalism

2.1. The Doubled Hilbert Space

In thermo-field dynamics (TFD), the state of an open quantum system is expressed as

$$|\Psi\rangle = |\psi\rangle \otimes |\tilde{\psi}\rangle$$

where $|\tilde{\psi}\rangle$ represents the time-reversed copy required to describe dissipation.

The evolution is generated not by introducing an additional dissipative operator, but by the non-Hermitian structure of the doubled Hamiltonian:

$$H_{\text{total}} = H - \tilde{H}$$

where $\tilde{H}$ is obtained from H by tilde conjugation and encodes the environmental (time-reversed) degrees of freedom.

Irreversibility and energy flow arise from the Bogoliubov transformations that mix ψ and $\tilde{\psi}$, while DQFT ensures energy balance via

$$\langle\psi|H|\psi\rangle = \langle\tilde{\psi}|\tilde{H}|\tilde{\psi}\rangle.$$

In QBF, dissipation remains entirely contained in the doubled $(\psi, \tilde{\psi})$ structure, but the coupling between the two sectors becomes state-dependent. This is expressed by allowing the mixing parameters (or the transformation generator) to depend on instantaneous correlations between ψ and $\tilde{\psi}$:

$$H_{\text{total}} = H - \tilde{H} \text{ (with state-dependent } \psi\text{-}\tilde{\psi} \text{ coupling)}.$$

Instead of adding an operator $\Gamma(\psi, \tilde{\psi})$, QBF modifies the correlation-dependent mixing between the two sectors, so that informational feedback and coherence restoration arise dynamically from the structure of the doubled Hilbert space.

2.2. Ordered Vacua and Correlation Parameters

In both DQFT and QBF, ordered vacua $|0(\Theta)\rangle$ are parameterized by Bogoliubov transformations:

$$a_k(\theta_k)|0(\Theta)\rangle = 0 = \tilde{a}_k(\theta_k)|0(\Theta)\rangle$$

The modal occupation number is

$$N_k = \langle 0(\Theta) | a_k^\dagger a_k | 0(\Theta) \rangle = \sinh^2(\theta_k).$$

The overlap between vacua defines the correlation function

$$C(\Theta, \Theta') = \langle 0(\Theta') | 0(\Theta) \rangle = \prod_k [1 / \cosh(\theta_k - \theta'_k)].$$

In QBF, a reference configuration Θ_{ref} denotes the attractor state toward which the system tends when its ψ - $\tilde{\psi}$ correlations are maximally coherent. Deviations $\Delta\theta_k = \theta_k - \theta_{k,\text{ref}}$ quantify departures from this coherence state and therefore measure informational disorder.

2.3. Dynamical Evolution of Correlation Parameters

The time evolution of $\Theta(t)$ follows a dissipative-stochastic equation derived from the non-Hermitian Hamiltonian:

$$d\theta_k/dt = -\kappa_k(\theta_k - \theta_{k,\text{ref}}) + g_k h(t) + \sum_j \mu_{kj} F(\theta_k, \theta_j) + \eta_k(t)$$

where:

- κ_k is the intrinsic relaxation rate of mode k ;
- $g_k h(t)$ describes external perturbations (e.g., electromagnetic or thermal fields);
- $\mu_{kj} F(\theta_k, \theta_j)$ accounts for cross-mode coupling between correlated domains;
- $\eta_k(t)$ represents stochastic noise from environmental or quantum sources.

The first term drives the system toward its informational attractor Θ_{ref} , while the coupling matrix μ_{kj} introduces hierarchical coherence across scales.

The global coherence measure is given by the Blueprint Coherence Index (BCI):

$$\text{BCI}(t) = \exp[-\frac{1}{2} \sum_k w_k (\theta_k - \theta_{k,\text{ref}})^2].$$

$\text{BCI} \in [0,1]$ quantifies the instantaneous informational alignment between ψ and $\tilde{\psi}$.

3. Derivation from the Dissipative Lagrangian

Starting from the non-Hermitian Lagrangian density

$$\mathcal{L}_{\text{eff}} = \mathcal{A}(\psi) - \mathcal{A}(\tilde{\psi}) + i \cdot \Phi(\psi, \tilde{\psi}),$$

the Euler-Lagrange equations yield

$$\delta \mathcal{L}_{\text{eff}} / \delta \psi = 0, \quad \delta \mathcal{L}_{\text{eff}} / \delta \tilde{\psi} = 0.$$

If Φ depends on the phase correlation between ψ and $\tilde{\psi}$,

$$\Phi(\psi, \tilde{\psi}) = \sum_k \kappa_k (\theta_k - \theta_{k,\text{ref}})^2 / 2 - \sum_j \mu_{kj} F(\theta_k, \theta_j),$$

then the variational derivative with respect to θ_k leads directly to

$$d\theta_k/dt = -\partial\Phi/\partial\theta_k + \eta_k(t),$$

which recovers the QBF dynamic equation.

Thus, QBF remains variationally consistent with the dissipative Lagrangian formalism and extends it by including an informational potential $\Phi(\psi, \psi^\dagger)$.

4. Constructive Noise and Stochastic Resonance

The stochastic term $\eta_k(t)$ can be expressed as

$$\eta_k(t) = \xi_k \zeta(t)$$

with $\zeta(t)$ representing quantum noise (white or pink) and ξ_k its coupling amplitude. The response of mode k is characterized by its susceptibility

$$\chi_k(\omega) = g_k / [(\omega_k^2 - \omega^2) + i \gamma_k \omega].$$

When the spectral density $S_\eta(\omega)$ overlaps with $|\chi_k(\omega)|^2$, noise enhances coherence — a phenomenon known as stochastic resonance (McDonnell & Ward 2011). This mechanism explains how biological systems can exploit fluctuations to maintain order near criticality.

5. Empirical Correspondence and Testability

The QBF provides quantitative links between theoretical parameters and measurable physiological observables.

Theoretical variable	Empirical observable	Method
$\Delta\theta_k = \theta_k - \theta_{k,ref}$	HRV phase deviation	Fourier and wavelet HRV analysis
BCI(t)	HRV coherence index	0.1 Hz spectral power ratio (Shaffer & Ginsberg 2017)
$\psi^\dagger$ feedback	Ultraweak photon emission (UPE)	Biophoton photomultiplier counts (Popp 1992; Van Wijk 2014)
$\chi_k(\omega)$	EEG phase coherence, dielectric spectroscopy	FFT/PSD methods
$\eta_k(t)$	Controlled noise input or QRNG modulation	Correlation and entropy measures
Θ_{ref} drift	Longitudinal HRV + photonic correlations	Week-to-week BCI trajectory

5.1. HRV and Systemic Coherence

Heart rate variability reflects the organism’s capacity for self-regulation. Within QBF, HRV coherence corresponds to convergence of the low-frequency (~0.1 Hz) oscillatory mode toward its Θ_{ref} . High BCI(t) values correlate with stable 0.1 Hz oscillations (Shaffer & Ginsberg 2017).

5.2. EEG Coherence

EEG phase synchronization represents high-frequency analogues of θ_k dynamics in neural domains. Periods of sustained alpha or gamma synchronization correspond to temporary increases in ψ - $\tilde{\psi}$ alignment.

5.3. Water and Dielectric Spectroscopy

Experimental work by Del Giudice and Pollack (2013) suggests that structured water forms coherent domains at infrared frequencies. Dielectric phase measurements reveal dynamic order consistent with correlated θ_k modes.

5.4. Ultraweak Photon Emission (UPE)

Biophotons, as observed by Popp (1992) and Van Wijk (2014), display coherence signatures that reflect $\tilde{\psi}$ feedback. Temporal correlations in photon count distributions could serve as experimental proxies for $\Delta\theta_k$ dynamics.

6. Discussion

6.1. Informational Feedback and Self-Organization

In the dissipative quantum field theory (DQFT) of Ricciardi and Vitiello, the doubled Hilbert space is introduced not as a mathematical convenience but as a structural necessity for describing open quantum systems. The conjugate, or tilde, field $\tilde{\psi}$ does not represent a passive repository of dissipated modes. Rather, $\tilde{\psi}$ is an active dynamical partner that encodes the time-reversed degrees of freedom required for irreversibility, memory formation, and long-range ordering in the system. Through the SU(1,1) Bogoliubov mixing between ψ and $\tilde{\psi}$, the tilde sector participates directly in the selection of inequivalent vacuum states and thereby shapes the system's coherent evolution.

Within this framework, $\tilde{\psi}$ carries contextual and historical information about the accessible vacuum configurations and contributes actively to the system's dynamics. Dissipation in DQFT therefore arises not from an added operator but from the interaction between the two sectors, which jointly determine the temporal arrow and the formation of stable, ordered patterns.

The Quantum Blueprint Formalism (QBF) builds on this foundation by extending the role of the $\tilde{\psi}$ field. While DQFT treats $\tilde{\psi}$ as an indispensable but implicitly defined partner in the dissipative process, QBF interprets the conjugate field as an informationally structured domain whose state reflects the organism's history of coherence and pattern formation. In this view, $\tilde{\psi}$ interacts with ψ through correlation-dependent couplings encoded by the parameters $\Theta(t)$, allowing informational structure to influence the physical evolution of the system.

This generalization preserves the essential features of dissipative quantum dynamics while introducing a mechanism through which informational coherence—rather than energy flow alone—guides the stability, recovery, and adaptation of living matter.

6.2. Connection to Open-System Thermodynamics

The informational feedback implied by QBF is consistent with nonequilibrium thermodynamics and the concept of *dissipative structures* (Prigogine & Stengers 1984). The informational field $\tilde{\psi}$ effectively functions as a low-entropy reservoir that stores correlation information rather than energy. The system therefore minimizes its informational free energy rather than its energetic free energy, a principle reminiscent of Friston's "free-energy principle" in neuroscience, but derived here from first principles in quantum field dynamics. The attractor Θ_{ref} may thus be understood as the instantaneous configuration minimizing the informational free-energy functional

$$F_{\text{info}}(\Theta) = \frac{1}{2} \sum_k \kappa_k (\theta_k - \theta_{k,\text{ref}})^2 - \sum_{kj} \mu_{kj} F(\theta_k, \theta_j).$$

This perspective situates the QBF squarely within the physics of *informational thermodynamics*, where order and meaning emerge as physical invariants of open quantum systems.

6.3. Relation to Quantum Biology

A number of experimental findings in quantum biology resonate with the assumptions of the QBF. Long-range coherence in hydrated biomolecules (Fröhlich 1968), collective dipole oscillations in water (Del Giudice et al. 1988), and coherent energy transfer in photosynthetic complexes all exemplify stable coherence under dissipative conditions. These phenomena suggest that living matter operates close to critical points where small informational perturbations can reorganize macroscopic order. The feedback mechanism $\psi \leftrightarrow \tilde{\psi}$ provides a plausible mathematical foundation for this critical adaptability.

Furthermore, the stochastic-resonance term $\eta_k(t)$ offers a framework for interpreting the beneficial role of biological noise observed in neural, cardiac, and genetic systems (McDonnell & Ward 2011). Instead of disrupting coherence, noise can modulate the effective susceptibility $\chi_k(\omega)$ of coherence modes, enabling adaptive synchronization. The QBF thus integrates coherence, noise, and self-organization into a single dynamical principle.

6.4. Empirical Perspectives

While fundamentally theoretical, the QBF is testable through observable correlates of informational coherence. Heart-rate-variability coherence (Shaffer & Ginsberg 2017) reflects slow global oscillations (≈ 0.1 Hz) associated with high BCI(t). EEG phase synchronization represents faster local coherence dynamics corresponding to individual θ_k modes. Ultraweak photon emission (Popp 1992; Van Wijk 2014) and dielectric relaxation of water (Pollack 2013) may serve as proxies for $\tilde{\psi}$ feedback processes. Together, these measurements could enable experimental estimation of the parameters κ_k , μ_{kj} , and $\eta_k(t)$ and permit empirical mapping of the system's informational phase trajectory $\Theta(t)$.

Such an integrative approach would transform the study of living coherence from qualitative speculation into quantitative modeling, allowing explicit tests of whether coherence restoration follows the predicted exponential convergence toward Θ_{ref} and whether noise indeed enhances rather than degrades BCI(t).

6.5. Conceptual Implications

By redefining dissipation as a channel for information flow, the QBF reframes life not as a thermodynamic anomaly but as a lawful outcome of open-system physics. The conjugate field $\tilde{\psi}$ becomes the mathematical representation of *context*: the total information of the organism's past interactions that continuously informs its present structure. In this view, coherence, adaptation, and even memory are not separate biological functions but emergent properties of the same informational coupling that underlies all living systems.

7. Conclusion

The Quantum Blueprint Formalism (QBF) extends the dissipative quantum field theory as developed by Celeghini, Rasetti, and Vitiello by introducing an explicit informational feedback mechanism between the physical and conjugate sectors of the doubled Hilbert space. Instead of modifying the Hamiltonian through an additional dissipative operator Γ , dissipation in QBF—consistent with DQFT—is generated entirely through the $SU(1,1)$ Bogoliubov mixing between ψ and $\tilde{\psi}$.

The innovation of QBF does not lie in making the ψ – $\tilde{\psi}$ coupling parameters state-dependent—since in DQFT the Bogoliubov parameters θ_k already evolve with the system's state—but in interpreting these parameters as informational coherence variables that dynamically encode the organism's changing ψ – $\tilde{\psi}$ correlations. On this basis, QBF formulates explicit dynamical equations

for the correlation parameters $\Theta = \{\theta_k\}$, describing how coherence is lost and actively regenerated over time. The introduction of an informational attractor Θ_{ref} transforms the theory from a model primarily concerned with memory preservation into a model of *self-restoring coherence*, in which the system continuously reorganizes itself through informational feedback between the physical and conjugate sectors.

Mathematically, QBF remains consistent with the variational and algebraic structure of dissipative field theory while expanding its descriptive power through the informational potential $\Phi(\psi, \bar{\psi})$ and the Blueprint Coherence Index BCI(t). Physically, it provides a bridge between quantum field dynamics, open-system thermodynamics, and information theory. Biologically, it offers a unifying explanation for coherence phenomena observed across molecular, cellular, and systemic scales.

QBF suggests that living systems operate as *informational oscillators* coupled to their own conjugate fields, continually regenerating order through the feedback of structured information. This insight reframes the classical dichotomy between matter and information: matter appears as the transient projection of an underlying informational process, and life emerges as the perpetual dialogue between the two.

Future research should aim to (1) derive the full QBF equations from a generalized non-Hermitian Lagrangian within the doubled Hilbert-space formalism, (2) identify empirical signatures of ψ - $\bar{\psi}$ coupling through HRV, EEG, dielectric, and photonic measurements, and (3) explore whether the informational potential Φ can be related to entropy production or algorithmic information content. If confirmed, the Quantum Blueprint Formalism may provide the missing physical basis for understanding biological coherence, adaptability, and the continuity between physics, information, and consciousness.

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