Quantum Phenomena and Classical Limits

Expanded Depth Series: Paper 13

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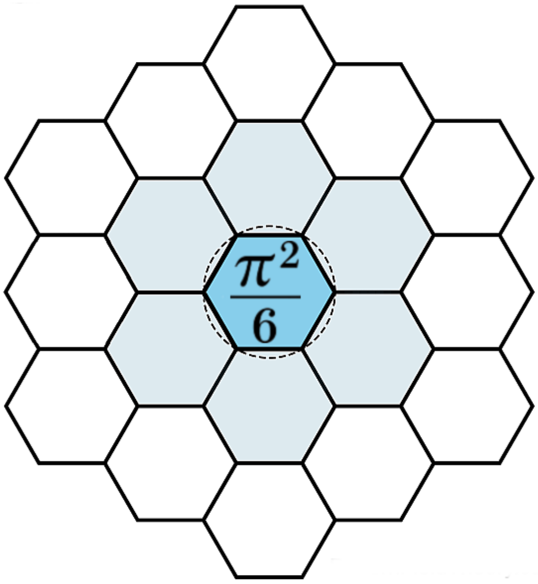

Abstract

This paper reconstructs canonical quantum phenomena within Pattern Field Theory (PFT) as consequences of discrete constraint geometry on the Allen Orbital Lattice (AOL) under Phase Alignment Lock (PAL). The central claim is that "quantumness" does not require fundamental particles, trajectories, or intrinsic randomness; it arises from (i) discrete admissible reconfiguration paths, (ii) PAL-gated projection into effective embeddings, and (iii) coarse-grained descriptions that compress combinatorial structure into continuum amplitudes.

We provide equation-anchored correspondences to the Schrödinger formalism and to core structural features of quantum field theory (QFT): superposition as path-set coexistence, interference as phase-structured path aggregation, measurement as apparatus-coupled constraint injection, commutators as non-commuting reconfiguration operators, and the classical limit as phase concentration under decohering constraint environments. The result is a reviewer-legible bridge: PFT reproduces the predictive architecture of quantum theory while replacing ontological primitives (particles/fields) with constraint-first structure on the AOL.

1 Orientation and Dependencies

Paper 11 defined fields and forces as emergent, coarse-grained summaries of constraint accessibility. Paper 12 constructed metric notions as emergent descriptions of constraint geometry under scale and depth change.

This paper addresses the remaining gap: how the characteristic mathematical objects of quantum mechanics (Hilbert states, complex amplitudes, unitary time evolution) and of QFT (fields, creation/annihilation operators, propagators) arise as effective descriptions of PAL-constrained AOL reconfiguration.

Throughout, the foundational level contains:

- no fundamental particles,
- no continuous trajectories,
- no fundamental continuum spacetime,
- no primitive probability field.

Quantum structure emerges as the minimal mathematics required to summarize large path-ensembles of discrete PAL-admissible reconfigurations.

2 Foundational Objects and Notation

2.1 Lattice configurations and projection

Let Ω denote the space of discrete AOL configurations at a fixed depth resolution. A configuration $\omega \in \Omega$ is an assignment of local coherence identities (coherons/coheromes) and adjacency relations consistent with earlier papers.

Let Π denote an embedding/projection map from lattice configuration space to an effective description space $\mathcal{E}$ (which may be represented as $\mathbb{R}^d$ with an emergent metric, per Paper 12):

$$\Pi : \Omega \to \mathcal{E}.$$

The map Π is not assumed to be smooth or globally defined. It exists operationally where PAL constraints allow stable projection.

2.2 PAL admissibility

PAL is treated as a constraint predicate that selects permissible transitions:

$$\mathrm{PAL}(\omega \to \omega') \in \{0, 1\}.$$

Define the directed admissibility relation

$$\omega \rightsquigarrow \omega' \quad \Longleftrightarrow \quad \mathrm{PAL}(\omega \to \omega') = 1.$$

A discrete path of length n is a sequence

$$\gamma = (\omega_0, \omega_1, \ldots, \omega_n) \quad \text{with} \quad \omega_k \rightsquigarrow \omega_{k+1}.$$

Let $\Gamma(\omega_a \to \omega_b)$ denote the set of admissible paths from ω_a to ω_b.

2.3 Complex weighting as phase-structured counting

PFT does not assume intrinsic stochasticity. Nevertheless, any external description must summarize extremely large path sets. The correct compression tool is a complex measure because it can represent both constructive and destructive aggregation over alternatives.

We therefore define a complex weight for each admissible step, written as

$$w(\omega \to \omega') = \exp\big(i\,\theta(\omega \to \omega')\big)\,\rho(\omega \to \omega'),$$

where $\rho \geq 0$ is a structural accessibility factor (constraint availability) and θ is an emergent phase functional induced by constraint geometry and depth change.

The weight of a path γ is

$$W[\gamma] = \prod_{k=0}^{n-1} w(\omega_k \to \omega_{k+1}).$$

3 Quantum State as a Coarse-Grained Description

3.1 Effective state vector

Let $\mathcal{H}$ be a Hilbert space used purely as an effective representation space. PFT does not claim $\mathcal{H}$ is fundamental; it is a compression of path-ensembles into amplitudes.

Define an effective amplitude $\psi(e)$ over emergent coordinates $e \in \mathcal{E}$ as the aggregated contribution of all admissible paths projecting into e:

$$\psi(e) \;\propto\; \sum_{\omega:\,\Pi(\omega)=e} \;\; \sum_{\gamma \in \Gamma(\omega_0 \to \omega)} W[\gamma].$$

This expression is schematic: the core point is that ψ is not a "wave of stuff" but a structured sum over admissible reconfiguration paths compressed into the emergent representation.

3.2 Superposition and interference

In PFT, "superposition" means: multiple admissible path families exist simultaneously at the descriptive level because the theory has not injected constraints that would select a single compatible history.

Interference arises because aggregation is complex. For two path families Γ_1, Γ_2 contributing to the same effective endpoint,

$$\psi = \psi_1 + \psi_2, \qquad |\psi|^2 = |\psi_1|^2 + |\psi_2|^2 + 2\Re(\psi_1 \overline{\psi_2}),$$

and the cross term is the observational signature of constraint-structured phase differences between admissible reconfiguration families.

4 Schrödinger Correspondence from Discrete PAL Dynamics

4.1 Discrete update and continuum limit

Assume an ordered reconfiguration parameter t indexing update depth or step count. Let ψ_t denote the effective state after t updates.

Define a linear update operator $U_{\Delta t}$ acting on ψ as the coarse-grained effect of one PAL-admissible update layer:

$$\psi_{t+\Delta t} = U_{\Delta t}\,\psi_t.$$

When coarse graining yields approximate norm preservation, we write

$$U_{\Delta t} \approx \exp\left(-\frac{i}{\hbar}\hat{H}\Delta t\right),$$

which implies the Schrödinger form in the small-step limit:

$$i\hbar\frac{\partial\psi}{\partial t} = \hat{H}\psi.$$

In PFT, $\hat{H}$ is not fundamental energy. It is the generator that encodes how PAL-permitted accessibility and phase weighting change under ordered reconfiguration.

4.2 Canonical kinetic-plus-potential form as a limit

In standard quantum mechanics, for a single effective coordinate x,

$$\hat{H} = -\frac{\hbar^2}{2m}\nabla^2 + V(x).$$

PFT interprets this as a limit of a discrete adjacency operator on AOL regions:

- the Laplacian emerges from nearest-neighbor accessibility on the projected graph,
- m encodes how strongly PAL restricts rapid reconfiguration (inertial rigidity),
- $V(x)$ summarizes constraint bias from boundary conditions and coupling to environment/apparatus.

Thus the Schrödinger equation is recovered as the best continuum summary of a PAL-gated discrete reconfiguration process.

5 Energy as Continuous Constraint Validation

In Pattern Field Theory, energy is not a substance, field, or conserved quantity in the fundamental sense. Energy corresponds to the rate at which Phase Alignment Lock is evaluated to maintain coherent projection of lattice configurations into higher-dimensional embeddings.

Let $\mathcal{P}$ denote a projected coheron configuration. Persistence of $\mathcal{P}$ requires continuous satisfaction of PAL constraints across ordered reconfiguration steps. The energetic cost is proportional to the frequency and complexity of these evaluations.

Motion is therefore not translation through space but sequential admissible re-projection across adjacent lattice regions.

5.1 Energetic rate functional

Define a PAL-validation count (or cost) per update:

$$C(\omega_t) \;=\; \sum_{(i\to j)\in\mathcal{N}(\omega_t)} c_{ij}(\omega_t)\,\mathbf{1}\{\mathrm{PAL}(i\to j)\},$$

where $\mathcal{N}(\omega_t)$ enumerates local adjacency evaluations and c_{ij} encodes evaluation complexity (depth, basin load, coupling).

Define an effective energy as a rate functional

$$E_{\text{eff}}(t) \;\propto\; \frac{1}{\Delta t}\,\mathbb{E}[C(\omega_t)]\,,$$

where the expectation is taken over the admissible path-ensemble consistent with current constraints.

This definition is not a replacement for Noether energy in a continuum field. It is the PFT primitive that, under coarse-graining and symmetry, yields conserved effective quantities (Paper 7) and the Hamiltonian generator above.

6 Measurement, Apparatus Coupling, and "Collapse"

6.1 Measurement as constraint injection

In PFT, measurement is not a mental act. It is a physical coupling between system and apparatus that injects new PAL constraints, altering the set of admissible paths.

Let $\mathcal{A}$ be an apparatus configuration space and consider the joint configuration $(\omega, \alpha) \in \Omega \times \mathcal{A}$. Coupling introduces a constraint family $\text{PAL}_{\text{joint}}$:

$$(\omega, \alpha) \rightsquigarrow (\omega', \alpha') \quad\iff\quad \text{PAL}_{\text{joint}}(\omega, \alpha \to \omega', \alpha') = 1.$$

The apparatus registers outcomes by entering macroscopically distinct basin regions $\mathcal{B}_k \subset \mathcal{A}$. The effective "outcome" is the basin index k.

6.2 Born rule as stable coarse-grained frequency

PFT does not assume fundamental randomness. The Born rule arises as the stable coarse-grained frequency of basin-attractor entry under typical environmental couplings and initial constraint distributions.

Let $P(k)$ denote the long-run frequency that the apparatus ends in basin $\mathcal{B}_k$. Under wide conditions, the effective amplitude weights produce

$$P(k) \approx \frac{\|\Pi_k \psi\|^2}{\|\psi\|^2},$$

where Π_k is the projector onto the effective subspace corresponding to apparatus basin k.

In this interpretation, "collapse" is not a physical discontinuity. It is a post-selection on basin-registered constraints applied to the path-ensemble.

7 Non-Commutativity and Operator Structure

7.1 Reconfiguration operators

Let $\hat{A}$ and $\hat{B}$ represent two distinct constraint actions (or two distinct measurement couplings) implemented as reconfiguration operators on the effective state:

$$\psi \mapsto \hat{A}\psi, \qquad \psi \mapsto \hat{B}\psi.$$

Non-commutativity

$$[\hat{A}, \hat{B}] = \hat{A}\hat{B} - \hat{B}\hat{A} \neq 0$$

expresses a discrete structural fact: the order in which constraints are injected changes the admissible path set and therefore changes the aggregated amplitude.

This is the PFT origin of Heisenberg-style uncertainty relations: they are coarse-grained summaries of order-sensitive constraint injection, not fundamental limits of "knowledge".

8 Path Integrals as AOL Path Aggregation

8.1 Feynman correspondence

The Feynman kernel

$$K(b, a) = \int \mathcal{D}x \ \exp\left(\frac{i}{\hbar} S[x]\right)$$

is interpreted in PFT as the continuum shadow of discrete AOL path aggregation:

$$K(b, a) \ \sim \sum_{\gamma \in \Gamma(\omega_a \to \omega_b)} W[\gamma].$$

In this correspondence, the action S is not fundamental. It is an emergent functional that reproduces the phase structure induced by PAL-constrained reconfiguration under projection.

When the phase becomes rapidly varying except near stationary points, standard stationary-phase arguments yield the classical limit.

9 Classical Limits from Phase Concentration and Decohering Constraints

9.1 Stationary-phase and effective trajectories

In the limit where phase accumulation is large, the dominant contribution to ψ arises from path families near stationary-phase configurations. This is the structural origin of effective classical trajectories without assuming trajectories at the foundation.

Formally, if S is the emergent action, then dominant paths satisfy

$$\delta S = 0,$$

producing Euler–Lagrange equations as an effective summary.

9.2 Decoherence as constraint environment

Environmental coupling injects constraints that suppress cross terms between macroscopically distinct basin families, yielding effective classical probability distributions. The environment is not "measuring" in the mental sense; it is continuously restricting admissible path families.

This is precisely why macroscopic objects do not exhibit persistent visible superposition in ordinary environments: cross-family interference terms become structurally inaccessible at coarse resolution.

10 QFT Correspondence: Fields, Quanta, and Propagators as Effective Objects

10.1 Effective fields as coarse-grained constraint summaries

In QFT, a field operator $\hat{\phi}(x)$ assigns dynamical degrees of freedom to spacetime points. In PFT, there are no fundamental spacetime points. The effective field is a coarse-grained summary over AOL regions:

$$\phi(e) \;\equiv\; \mathbb{E}\big[F(\omega) \,\big|\, \Pi(\omega) = e\big]\,,$$

where $F(\omega)$ is a lattice-local functional summarizing constraint accessibility, basin load, or coherence density.

Thus the "field" is a statistical descriptor of constraint structure, in direct continuity with Paper 11.

10.2 Creation and annihilation as reconfiguration operators

In QFT, $a_p^\dagger$ and a_p create and annihilate excitations of momentum mode p. In PFT, these correspond to operators that insert/remove stable coheron-coherome excitations within an AOL basin while preserving PAL.

Let $\hat{R}_\lambda^\dagger$ denote an operator that introduces a coherent excitation type λ (a basin-local identity pattern) into a configuration, and $\hat{R}_\lambda$ its reverse, subject to admissibility:

$$\hat{R}_\lambda^\dagger : \Omega \to \Omega, \qquad \hat{R}_\lambda : \Omega \to \Omega, \qquad \mathrm{PAL}(\omega \to \hat{R}_\lambda^\dagger \omega) = 1.$$

The effective QFT ladder operators are the continuum shadows of these discrete operators after projection and mode decomposition.

10.3 Propagators as admissible transfer kernels

The QFT propagator is an amplitude for excitation transfer from a to b:

$$\Delta_F(x-y) = \int \frac{d^4p}{(2\pi)^4} \frac{i}{p^2 - m^2 + i\epsilon} e^{-ip\cdot(x-y)}.$$

In PFT, the corresponding object is a transfer kernel given by AOL path aggregation between projected regions:

$$G(e_b, e_a) \;\sim \sum_{\gamma \in \Gamma(\omega_a \to \omega_b)} W[\gamma].$$

Here m reappears as effective inertial rigidity: a constraint penalty for rapid reconfiguration that suppresses certain path families.

10.4 Renormalization as depth-dependent coarse graining

Renormalization in QFT tracks how effective parameters change with scale. In PFT, this is literal: depth and coarse-graining change the apparent parameters of the emergent description.

Let $\mathcal{G}_\ell$ denote a coarse-graining map at depth/scale ℓ. Then effective couplings $g(\ell)$ are summaries of constraint accessibility at that scale:

$$g(\ell) \;=\; \mathcal{F}(\mathcal{G}_\ell(\Omega), \mathrm{PAL}),$$

and flow equations represent the systematic change in these summaries across depth.

11 Summary of Correspondences and PFT Resolution

The table below summarizes the primary identifications.

Standard quantum/QFT object	PFT interpretation
State $|\psi\rangle$	Coarse-grained path-ensemble amplitude
Superposition	Coexistence of admissible path families
Interference	Phase-structured aggregation over paths
Hamiltonian $\hat{H}$	Generator of PAL-admissible update dynamics
Measurement	Apparatus-coupled constraint injection
Born rule	Stable basin-entry frequencies under typical coupling
Commutator $[\hat{A}, \hat{B}]$	Order-sensitivity of constraint actions
Path integral	Continuum shadow of AOL path summation
Field $\phi(x)$	Coarse-grained constraint accessibility descriptor
Quanta	Stable basin excitations under PAL
Propagator	Admissible transfer kernel between projected regions
Renormalization	Depth/scale-dependent coarse-grain parameter flow

PFT resolves quantum "paradoxes" by removing anthropocentric misattribution and by demoting continuum primitives to effective summaries. The underlying reality is discrete, constraint-first, and PAL-gated. Quantum theory remains correct as an effective calculus for path-ensembles; its conceptual tension arises when its effective objects are mistaken for foundational ontology.

12 Document Timestamp and Provenance

All definitions, constructions, and invariants presented here are foundational and are treated as canonical for subsequent papers addressing coherons, stability, identity recurrence, chemistry, interaction, and experimental interpretation.