Structural Regime Resolution in Quantum Criticality and Superconductivity

Structural Regime Resolution Series — Paper III

James Johan Sebastian Allen
`PatternFieldTheory.com`

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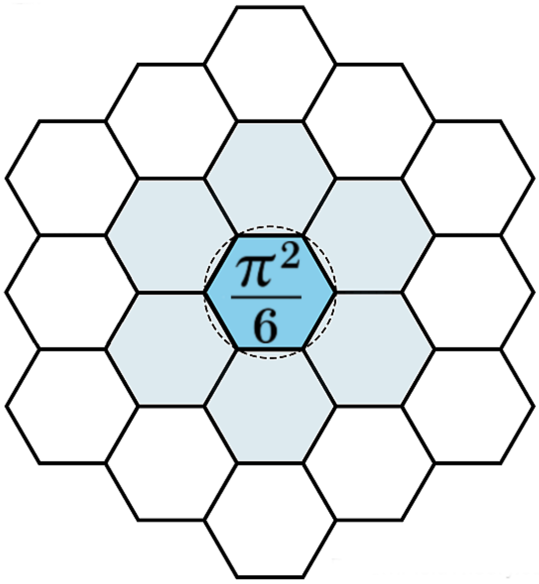

Abstract

This paper applies Structural Regime Resolution (SRR) to quantum critical phenomena and superconducting phase transitions. The central claim is that many "sharp" quantum phase boundaries and critical points are low-SRR collapses of extended volumetric constraint transition zones. At high SRR, quantum criticality, pseudogap regimes, strange metals, vortex liquids, and fluctuation-dominated phases appear as distributed regions of constraint frustration, excitation, and partial reconfiguration. Superconductivity is reframed in Pattern Field Theory (PFT) as PAL-stabilized coheron ordering emerging from a volumetric constraint-resolution process rather than a surface-like phase boundary. SRR unifies classical phase transitions, quantum phase transitions, and high-T_c phenomenology under a single structural description.

Quantum Phase Structure under Structural Regime Resolution

Scope and Aim

Paper I defined Structural Regime Resolution (SRR). Paper II applied it to plasma dominion boundaries. This paper applies SRR to:

- quantum phase transitions (QPTs),
- quantum critical points and critical fans,
- superconducting transitions (classical and high-T_c),
- pseudogap and strange-metal regimes.

The goal is to show that many "points", "lines", and "sharp boundaries" in phase diagrams are low-SRR artifacts of volumetric constraint transition zones.

Quantum Phase Transitions as Constraint Transitions

Definition 1 (Quantum phase transition (PFT))**.** *A quantum phase transition is a zero-temperature constraint reconfiguration driven by quantum fluctuations when two ordering regimes cannot be simultaneously satisfied.*

In PFT terms:

- the driver is constraint incompatibility,
- the stress is stored as frustration,
- the manifestation is quantum excitation,
- the outcome is reconfiguration of ordering.

SRR and the Meaning of a "Quantum Critical Point"

In conventional treatments, a quantum critical point (QCP) is represented as a point in parameter space.

Under SRR:

- **High SRR:** the "point" is a volumetric region where correlation length $\xi \to \infty$ and the entire system is a single constraint transition zone.
- **Low SRR:** the region collapses to a point or line in the phase diagram.

Proposition 1 (SRR at criticality)**.** *When $\xi \gg L$ (system size), SRR must be high: the entire system becomes a single frustration volume and boundary descriptions lose meaning.*

Quantum Critical Fans as Volumetric Transition Zones

The “quantum critical fan” observed above QCPs is interpreted in PFT as:

- a finite-temperature cross-section of a volumetric constraint transition zone,
- dominated by persistent excitation and partial ordering failure,
- not a separate “phase” but an unresolved transition region.

Low SRR collapses this entire volume into a narrow region around a line in the phase diagram.

Superconductivity as PAL-Stabilized Constraint Resolution

In Pattern Field Theory, superconductivity is described as:

- coheron ordering stabilized by Phase Alignment Lock (PAL),
- emerging from a constraint-frustrated normal state,
- through a volumetric reorganization of ordering.

5.1 SRR view of the superconducting transition

- **High SRR:** a finite transition region with fluctuating pairing, vortex matter, partial coherence, and excitation.
- **Low SRR:** a sharp T_c line separating “normal” and “superconducting” states.

High-T_c Cuprates and the Pseudogap

The pseudogap regime in cuprates is a canonical example of high-SRR physics:

- partial ordering,
- persistent frustration between competing constraints,
- distributed excitation,
- incomplete PAL locking.

In SRR terms:

- the pseudogap is not a separate phase,
- it is a volumetric unresolved constraint region preceding full PAL stabilization.

Strange Metals and Non-Fermi Liquids

Strange metals and non-Fermi-liquid regimes correspond to:

- failure of any single ordering constraint to dominate,
- persistent volumetric excitation,
- absence of a stable low-SRR description.

They are high-SRR manifestations of unresolved constraint competition.

Vortex Matter and Type-II Superconductors

In type-II superconductors:

- vortex liquids, glasses, and lattices represent internal structure of the transition zone,
- low SRR collapses all of this into a simple “mixed phase” or boundary description.

This is directly analogous to layered heliopause structure in Paper II.

SRR and Luttinger Theorem Violations

Apparent violations of Luttinger’s theorem in pseudogap and strange-metal regimes indicate:

- breakdown of low-SRR quasiparticle volume counting,
- persistence of high-SRR volumetric constraint structure,
- in PFT: unresolved coheron ordering across the AOL.

Canonical Statement

Remark 1 (Quantum SRR statement)**.** *In Pattern Field Theory, quantum critical points, sharp phase boundaries, and abrupt superconducting transitions are low-SRR projections of volumetric constraint transition zones governed by frustration, excitation, and PAL-mediated reconfiguration.*

Consequences

- No quantum phase boundary is fundamentally sharp.
- Criticality is a volumetric state, not a point.
- Pseudogaps and strange metals are not anomalies but expected high-SRR regimes.
- Superconductivity emerges from volumetric ordering, not boundary crossing.

Conclusion

Structural Regime Resolution provides a unified structural interpretation of quantum criticality and superconductivity. It explains the ubiquity of extended fluctuation regimes, the failure of sharp phase descriptions near criticality, and the layered internal structure of superconducting transitions. Paper IV will extend SRR to quanta-scale regimes, where even single-particle "boundaries" dissolve into volumetric constraint zones.

Glossary

Structural Regime Resolution (SRR) Resolution level controlling whether transitions are represented as volumes or boundaries.

Quantum phase transition Zero-temperature constraint reconfiguration driven by quantum fluctuations.

Quantum critical point Low-SRR projection of a volumetric constraint transition.

Pseudogap High-SRR regime of partial ordering and persistent frustration preceding full PAL locking.

Strange metal High-SRR regime of persistent excitation without stable quasiparticle description.

PAL Phase Alignment Lock, coherence stabilization mechanism in PFT.

Coheron Fundamental excitation/order carrier in PFT.

Document Timestamp and Provenance

This document is part of Pattern Field Theory (PFT) and the Allen Orbital Lattice (AOL). It applies Structural Regime Resolution (SRR) to quantum criticality and superconductivity, serving as Paper III in the Structural Regime Resolution Series.