Constitutive Mechanics of the Vacuum

Companion Paper X

The Strong Interaction: Topological Locking and Constitutive Admissibility of Defects

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Abstract

The strong interaction binds quarks into hadrons and enforces confinement, yet resists intuitive mechanical explanation. In this companion paper, we reinterpret the strong interaction within the Constitutive Vacuum (CV) framework. We show that strong phenomena arise from **topological admissibility constraints** in a highly stiff elastic vacuum medium. This work assumes the constitutive vacuum ontology and mode separation developed in Constitutive Mechanics of the Vacuum III, particularly the distinction between shear-supported transverse dynamics and bulk-modulus-dominated longitudinal constraints. Quarks correspond to incomplete defect segments that are mechanically inadmissible in isolation. Hadrons are closed, admissible composite defects that minimize global strain energy. Confinement is therefore not the result of a force that grows with separation, but a consequence of constitutive locking: isolated sub-defects cannot exist as stable configurations of the medium. Gluons are identified as internal stress-redistribution modes within composite defects rather than as freely propagating particles. This interpretation preserves all observed strong-interaction phenomenology while restoring a purely mechanical ontology.

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1. Introduction

1.1 The Confinement Problem

The defining feature of the strong interaction is confinement: quarks are never observed in isolation. In conventional quantum chromodynamics (QCD), confinement is described via non-Abelian gauge fields and a rising potential at large separation.

While mathematically consistent, this description leaves unanswered the physical question:

Why are isolated quarks mechanically forbidden?

Within the CV framework, this question is addressed by defect mechanics rather than force mediation.

1.2 Scope and Claims

This paper advances the following limited claims:

- Strong interaction phenomena arise from **topological admissibility**
- Quarks are **partial defects**, not particles in free space
- Confinement is a **global constitutive constraint**
- No long-range force or signal is involved

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2. Defects in a High-Stiffness Medium

2.1 Topological Closure

In elastic media, only defects that satisfy global closure conditions are stable. Examples include:

- Closed dislocation loops
- Frank loops
- Disclination rings

Open-ended defect segments produce divergent strain fields and are mechanically forbidden.

2.2 Application to Subnuclear Defects

Within the CV framework:

- **Quarks** correspond to incomplete or open defect segments
- **Hadrons** correspond to closed composite defect structures

- **Confinement** reflects the impossibility of isolating open segments

This is not a dynamic binding process, but a **static admissibility condition**.

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3. Energy Scaling and Apparent Confinement

3.1 Strain Energy of Open Defects

The elastic strain energy Eassociated with an open defect segment grows with separation length L:

$$E(L) \propto \int_0^L \sigma^2 (r)\, dr \to \infty$$

As separation increases, the energy cost diverges.

3.2 No Restoring Force Required

Because isolated configurations are inadmissible, no restoring force is required to "pull quarks back together." Instead:

- The medium cannot support the configuration
- Any attempted separation results in defect reclosure or reconfiguration
- New closed defects (hadrons) form instead

This explains quark–antiquark pair production during high-energy collisions.

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4. Color as Topological Bookkeeping

4.1 Interpretation of Color Charge

Color charge is not a physical charge. It is a **label identifying how partial defects combine to achieve closure**.

Within this interpretation:

- Three "colors" correspond to three closure-compatible orientations
- Color neutrality reflects complete topological closure

- Color conservation enforces admissibility rules

4.2 SU(3) as a Diagnostic Symmetry

The SU(3) gauge structure of QCD encodes these admissibility constraints algebraically. It remains a valid mathematical description, but its physical content is topological rather than force-mediated.

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5. Gluons as Internal Stress Modes

5.1 No Free Gluons

Gluons are not free particles propagating through space. They are **internal stress redistribution modes** confined within composite defects.

They:

- Rebalance strain internally
- Mediate reconfiguration during interactions
- Cannot exist independently of hadrons

5.2 High-Energy Scattering

At high energies, localized regions of the defect may temporarily decouple, producing the appearance of asymptotic freedom. This reflects **local dominance of strain over topology**, not absence of constraint.

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6. Relation to Nuclear Binding

Nuclear forces between hadrons arise from **overlapping defect strain fields**, not residual color forces. This explains:

- Short-range nuclear attraction
- Saturation of nuclear forces
- Absence of long-range strong interaction

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7. Relation to the Standard Model

Standard Model Concept	Constitutive Interpretation
Strong force	Topological admissibility
Confinement	Inadmissible open defects
Color charge	Closure bookkeeping
Gluons	Internal stress modes
Asymptotic freedom	Local strain dominance

This reinterpretation preserves all observed strong-interaction behavior.

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8. Limitations and Non-Claims

This paper does **not** claim:

- Elimination of QCD formalism
- Calculation of hadron masses
- Replacement of lattice QCD
- Direct experimental distinction at present

It provides a **mechanical ontology** underlying existing theory.

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9. Discussion

Once matter is treated as a topological defect embedded in a highly stiff elastic medium, the strong interaction ceases to be mysterious. Confinement is no longer a dynamical puzzle, but a structural necessity. The apparent complexity of strong interactions reflects the richness of defect topology, not fundamental force proliferation.

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10. Conclusion

The strong interaction emerges naturally from topological admissibility constraints in a structured vacuum medium. Quarks are incomplete defects that cannot exist in isolation, while hadrons are closed, mechanically admissible configurations. Confinement requires no force, no signaling, and no special dynamics—it is enforced by the medium itself. This completes the mechanical reinterpretation of all fundamental interactions within the Constitutive Vacuum framework.

References

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