Chronoscalar Field Theory XVII: Color, Confinement, and the Strong Interaction

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December 2025

Abstract

In Chronoscalar Field Theory the only fundamental field is the chronoscalar condensate $T(x^\mu)$ with a permanent cosmological gradient ∇T created by a single Machian event. Papers XIV–XVI showed that gravity, inertia, electromagnetism, and quantum entanglement geometry all emerge from the gradient structure of T and its transverse fluctuations.

In this seventeenth paper we extend the construction to the strong interaction. We show that non-abelian color gauge symmetry is not fundamental but arises from the *frame degeneracy* of transverse directions in the T-orthogonal bundle. A local choice of three orthonormal transverse basis vectors defines an internal "color frame", and local rotations of this frame generate an emergent SU(3) gauge field. The gluon field A^a_μ appears as the connection associated with parallel transport of this color frame, and the field strength $F^a_{\mu\nu}$ is the chronoscalar curvature of the transverse bundle.

Confinement follows from the energy cost of twisting ∇T over macroscopic distances: color flux tubes are quantised strands of transverse-bundle curvature whose energy grows linearly with separation. Baryons and mesons correspond to color-neutral topological composites of these strands. No fundamental Yang–Mills action is assumed; the entire QCD sector emerges from the same parent chronoscalar action already used for gravity and electromagnetism.

1 Introduction: From U(1) to SU(3) in a Single-Field Universe

Paper XVI established that classical electromagnetism and its gauge redundancy arise from the geometry of the chronoscalar field:

- The electric field is the longitudinal projection of transverse fluctuations of T along the Gabriel Corridor direction (parallel to ∇T).
- The magnetic field is the orthogonal, rotational component in the plane perpendicular to ∇T.
- The vector potential A_μ is a derived quantity: it is the effective connection that keeps track of how the transverse plane twists along spacetime trajectories.

- Gauge transformations $A_\mu \to A_\mu + \partial_\mu \Lambda$ come from the freedom to add pure-gradient deformations of T that do not change the physical transverse field.

Thus the abelian $U(1)$ gauge "symmetry" of electromagnetism is not a fundamental internal symmetry but an emergent redundancy of our description: many different choices of δT and transverse frame yield the same physical electric and magnetic fields.

The strong interaction requires more:

- Three color charges (red, green, blue) carried by quarks;
- Eight gluons mediating a non-abelian SU(3) gauge field;
- Confinement at large distances and asymptotic freedom at high energies;
- A mass gap and color-neutral hadrons as physical states.

The question addressed in this paper is:

Can all of this structure arise from the same chronoscalar condensate $T(x^\mu)$, with no additional fundamental fields?

We answer in the affirmative by showing that:

1. The two-dimensional plane orthogonal to ∇T is naturally extended to a three-dimensional *internal* transverse bundle once baryonic cores form.
2. Local choices of orthonormal basis in this internal transverse bundle define a color frame, and local rotations of this frame form an SU(3) gauge group.
3. The gluon field A_μ^a is the connection that compensates for changes in the color frame along spacetime curves.
4. The non-abelian field strength $F_{\mu\nu}^a$ is the curvature of this connection—the chronoscalar analogue of Riemann curvature but in the internal color bundle.
5. Confinement is a global statement about the impossibility of separating color flux lines without introducing macroscopically large distortions of the chronoscalar gradient.

In this way, *both* electromagnetism (Paper XVI) and the strong interaction (this paper) emerge from the same geometric origin: the structure of directions transverse to ∇T in a Universe whose only fundamental field is the chronoscalar condensate.

2 Transverse Bundles and the Color Frame

Let n_μ denote the unit vector along the chronoscalar gradient:

$$n_\mu \equiv \frac{\nabla_\mu T}{|\nabla T|}, \qquad n_\mu n^\mu = 1. \tag{1}$$

The local spacetime can be decomposed into components parallel and orthogonal to n_μ via the projector

$$P_{\mu\nu} = g_{\mu\nu} - n_\mu n_\nu. \tag{2}$$

In the purely electromagnetic case, this two-dimensional subspace orthogonal to n_μ was sufficient: the electric field lives along n_μ and the magnetic field lives in the orthogonal plane.

Once baryonic cores form, however, the chronoscalar condensate near each core acquires additional structure. The Planck-scale cores are discrete, localized sources of ∇T (Paper III and XIV). In their vicinity, the transverse subspace splits into an *internal* three-dimensional bundle that carries the degeneracy associated with how different cores share and twist the gradient lines.

We formalize this by introducing a set of three orthonormal internal basis vectors

$$v^{\beta,c}(x), \qquad c = 1, 2, 3, \tag{3}$$

such that:

$$n_\mu v^{\mu,c} = 0, \qquad v^{\mu,c} v_{\mu,d} = \delta^{cd}. \tag{4}$$

At each spacetime point, the set $\{v^{\beta,c}\}$ defines a *color frame*: three independent transverse directions in which the chronoscalar condensate can fluctuate around a given baryonic core.

Crucially, the choice of this frame is not unique. One may perform local rotations

$$v^{\mu,c}(x) \to R^{cd}(x)\, v^{\mu,d}(x), \qquad R(x) \in \mathrm{SO}(3), \tag{5}$$

without changing n_μ or the underlying distribution of ∇T. When cores are dense and interact via overlapping chronoscalar gradients, the internal symmetry of this frame is promoted from SO(3) to its double cover and complex extension, effectively realizing an SU(3) structure on the bundle of color frames.

In Chronoscalar Field Theory, "color" is therefore:

> The label of a particular direction in the internal transverse bundle of chronoscalar fluctuations orthogonal to ∇T.

Quarks are excitations that carry oriented flux in this bundle. Gluons are fluctuations of the connection that keeps different color frames aligned along spacetime trajectories.

3 Emergent SU(3) Connection and the Origin of Confinement

The chronoscalar condensate possesses a transverse geometry determined by the Hessian of the field,

$$H_{\mu\nu} = \nabla_\mu \nabla_\nu T, \tag{6}$$

whose decomposition into longitudinal and transverse projections is

$$H_{\mu\nu} = n_\mu n_\nu(\Box T) + n_\mu A_\nu + n_\nu A_\mu + H^{(\perp)}_{\mu\nu}, \tag{7}$$

where $n_\mu = \partial_\mu T/|\nabla T|$ and $H^{(\perp)}_{\mu\nu} = P_\mu{}^\alpha P_\nu{}^\beta H_{\alpha\beta}$ is the fully transverse part.

In any region where the background gradient is nonzero, the projector $P_\mu{}^\nu = \delta_\mu{}^\nu - n_\mu n^\nu$ identifies a three-dimensional space orthogonal to ∇T. This transverse space carries the curvature inherited from the Hessian $H^{(\perp)}_{\mu\nu}$ and furnishes an adjoint representation isomorphic to the eight-dimensional algebra $\mathfrak{su}(3)$. This is precisely the mechanism by which the strong interaction emerges.

3.1 Derivation of the SU(3) Gluon Connection

The emergent gluon field G^a_μ (with $a = 1 \dots 8$ for the adjoint representation) must be the connection required to maintain the parallel transport of the color frame $v^{\beta,c}$ in the presence of chronoscalar torsion and curvature. The parallel transport condition in the presence of a non-zero Hessian is given by

$$D_\mu v^{\beta,c} = P_\mu{}^\alpha \nabla_\alpha v^{\beta,c} + G_\mu{}^{cd} v^{\beta,d} = 0. \tag{8}$$

The term $P_\mu{}^\alpha \nabla_\alpha v^{\beta,c}$ represents the change in the transverse frame as we move along μ, projected onto the transverse subspace. This change must be compensated by the gauge connection G_μ. By projecting this equation onto the components of the Hessian (which drives the local chronoscalar rotation), we find that the non-abelian connection naturally emerges as the projection of the chronoscalar curvature onto the internal structure constants $f^a{}_{bc}$:

$$G^a_\mu = f^a{}_{bc} \left(P_\mu{}^\alpha \nabla_\alpha \nabla_\beta T\right) v^{\beta,c}. \tag{9}$$

The expression explicitly shows that the gluon field is a geometric object: the contraction of the Hessian (transverse curvature) with the basis vectors of the internal SU(3) space.

3.2 Chronoscalar Curvature and Non-Abelian Field Strength

The chronoscalar field strength $\mathcal{F}^a_{\mu\nu}$ is the closure failure when attempting to parallel transport a color frame around an infinitesimal loop defined by the coordinates μ and ν. This is the geometric definition of curvature. It is mathematically equivalent to the commutator of two covariant derivatives acting on an arbitrary field ϕ:

$$[D_\mu, D_\nu]\phi^a = -f^a{}_{bc}\mathcal{F}^b_{\mu\nu}\phi^c.$$

The chronoscalar field strength is therefore defined as

$$\mathcal{F}^a_{\mu\nu} = \partial_\mu G^a_\nu - \partial_\nu G^a_\mu + f^a{}_{bc} G^b_\mu G^c_\nu. \tag{10}$$

Thus SU(3) gauge curvature is not fundamental: it is the *rotational curvature of the transverse chronoscalar manifold*, derived from the single scalar field T. This is consistent with the geometric program outlined in CFT XIb and CFT XVI [2, 5].

4 Confinement as a Topological Property of ∇T

Within the high-density environment of hadrons, $|\nabla T|$ becomes extremely large (CFT XIV [4]), and the transverse geometry becomes strongly curved. Quarks correspond to localized topological defects in the scalar field,

$$q(x) = \psi(x)\, e^{i\Theta[T]}, \tag{11}$$

where $\Theta[T]$ is the chronoscalar phase obtained by parallel transport in the transverse space.

4.1 Topological Justification for the Transverse Bundle Geometry

The confinement argument relies on the assertion that the transverse space is topologically nontrivial, specifically a compact, curved 3-sphere bundle (S^3 bundle). This is a consequence of the field saturation within the core of a color charge (CFT XIV [4]). In regions of ultra-high chronoscalar gradient, the four spacetime dimensions are forced into a preferred temporal direction (n_μ) and a maximal three-dimensional spatial freedom ($P_{\mu\nu}$). The energy density of the chronoscalar field, $\mathcal{E} \propto |\nabla T|^2$, reaches a critical maximum $E_{\max}$ inside the hadron. The manifold defined by $\mathcal{E} = E_{\max}$ must be compact and closed to avoid infinite energy storage, leading to the local geometric structure of a 3-sphere. This compact, curved topology prevents the energy in an isolated color flux line from dissipating at infinity.

A single quark defect enforces a non-integrable phase rotation,

$$\oint d\ell^\mu\, \nabla_\mu \Theta = 2\pi k, \qquad k \in \mathbb{Z}, \tag{12}$$

which defines color charge. However, since the transverse geometry is a compact, curved 3-sphere bundle, the phase accumulated around an isolated quark cannot relax to zero at large distances. Thus an isolated quark would correspond to a nontrivial global defect configuration that the chronoscalar field cannot support.

Confinement follows immediately: only topologically neutral combinations (mesons and baryons) can form finite-energy configurations. There is no need to postulate a confining potential or a special nonperturbative vacuum; confinement is a direct consequence of the curvature and topology of the chronoscalar condensate.

This geometric perspective is formally analogous to the treatment of defects in non-linear sigma models [6], but with the crucial distinction that the target space is not an internal manifold but the *transverse* subspace of spacetime defined by a physically measurable gradient ∇T.

5 The Weak Force: Chirality as Chronoscalar Alignment

The weak interaction arises naturally from the intrinsic chirality of the chronoscalar vacuum. As established in CFT XI and XII [1, 3], left-handed and right-handed fermions couple differently to the chronoscalar field because their spinor phases transform differently with respect to the preferred direction set by ∇T.

Let ψ_L and ψ_R denote the left- and right-handed components of a Dirac field. The chronoscalar coupling takes the form

$$\mathcal{L}_{\text{int}} = q_L\, \bar{\psi}_L \gamma^\mu \psi_L\, \partial_\mu T + q_R\, \bar{\psi}_R \gamma^\mu \psi_R\, \partial_\mu T. \tag{13}$$

In the low-gradient Universe ($|\nabla T| \sim 10^{-14}\,\mathrm{m}^{-1}$), the difference between these couplings is small. However, in the early Universe or within compact objects (CFT XIV), the asymmetry becomes enormous:

$$|q_L - q_R|\, |\nabla T| \gg m_f, \tag{14}$$

for any fermion mass m_f.

Thus the left-handed sector aligns with ∇T while the right-handed sector becomes effectively decoupled. This reproduces the chiral nature of the weak force:

- only ψ_L couples to the emergent weak gauge bosons;
- ψ_R does not participate, matching Standard Model phenomenology;
- sterile neutrinos (purely right-handed) interact only in the high-gradient early Universe (CFT XIV).

5.1 Emergence of SU(2) Isospin Structure

The SU(2) structure of the weak force, with its three gauge bosons W^1, W^2, and Z (or $W^\pm$ and Z^0), emerges from the specific chiral projection of the chronoscalar Hessian, acting in the two-dimensional isospin subspace transverse to ∇T.

We introduce a local isospin basis $\{u^{\beta,1}, u^{\beta,2}\}$ in this plane, orthogonal to n_μ. The three weak bosons $W_\mu^{(i)}$, where $i = 1, 2, 3$, are constructed from the chiral projector $\Pi_\mu{}^\alpha$ acting on the gradient change $\partial_\alpha(\nabla T)$ along the three independent directions defined by the Pauli matrices σ^i (the generators of SU(2)):

$$W_\mu^{(i)} \propto \mathrm{Tr}\left[\sigma^i \cdot \left(\Pi_\mu{}^\alpha \partial_\alpha(\nabla T)\right) \otimes u_\beta^j\right]. \tag{15}$$

Specifically, W_μ^1 and W_μ^2 (which combine to form $W^\pm$) are proportional to the non-diagonal, rotational components of the chiral Hessian projection, while W_μ^3 is proportional to the diagonal component. This geometric definition ensures that the resulting field strength automatically contains the non-abelian self-interaction terms characteristic of SU(2) (CFT XII [3]).

The emergent weak bosons arise from the chiral projection of the chronoscalar Hessian:

$$W_\mu^{(i)} = \Pi_\mu{}^\alpha \partial_\alpha(\nabla T), \tag{16}$$

where $\Pi_\mu^{\ \alpha}$ is the left-handed projector. Parity violation therefore results from the chronoscalar asymmetry, not from a fundamental SU(2) gauge charge.

This completes the unification picture:

$$\begin{aligned} \text{Electromagnetism} &= \text{transverse oscillations of } T, \\ \text{Weak force} &= \text{chiral Hessian projections (SU(2) isospin)}, \\ \text{Strong force} &= \text{topology of the transverse manifold (SU(3) color)}. \end{aligned}$$

References

References

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