Free in Pairs, Caged in Triples: Cracking Asymptotic Freedom from the Octonion Algebra

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Abstract. The strangest measured fact about the strong force is that it weakens as you get closer: quarks deep inside a proton float almost freely — prisoners of the strongest force in nature, unbound until they touch the walls. This is asymptotic freedom (Nobel Prize, 2004), and the Strong Force paper of this series owes an account of it. This note cracks what algebra and geometry can crack, on three fronts: the *direction* of every force's strength-with-distance follows from one property of each rung's symmetry (three predictions, three confirmations, no adjustable anything); a native octonion mechanism with exactly the right all-or-nothing shape (the confining coupling is precisely zero for any two quarks alone, and full strength only for a triple — verified numerically); and a toy model in which the colour charge belongs to the cage rather than the quark, which yields both the vanishing interior force and a rising confining force of the right size in one stroke. What is *not* cracked is stated with equal care: the logarithmic form of the running, which needs true field dynamics and is now the sharpest open problem handed to the sequel. Every symbol is introduced before use.

1. The Target, in Plain Words

Every other force grows, or at worst holds steady, as you approach its source. Electricity even self-strengthens slightly at very close range: the vacuum around a charge fills with fleeting particle pairs that *screen* it, so probing closer reveals more bare charge — the fine-structure constant α creeps from 1/137 to about 1/128 at the highest accelerator energies. The strong force does the opposite. Its measured strength, written α_s (the strong coupling — a pure number like α, but for the colour force), is about 1 at the proton's own scale and falls to 0.118 at the energy of the Z boson. Close quarters: feeble. Long range: a constant pull of about 0.9 gigaelectronvolts per femtometre — roughly fifteen tonnes of force between two quarks, independent of distance. Gross, Wilczek and Politzer proved in 1973 where this backwards behaviour comes from in standard theory: the gluons — the strong force's own messengers — themselves carry colour charge, and their swarming *anti-screens* the source, diluting it at close range. The measured running follows a specific curve (logarithmic in the probing energy) with a specific coefficient. That curve, and the fact that our own celebrated evidence — the pointlike quarks seen at SLAC — only works *because* the force is weak up close, is the debt this note addresses.

2. Route One — Inheritance: the Direction of Every Running, from the Ladder

The Strong Force paper established that the symmetry group of each rung is the stabilizer of that rung's shutter axis — the turnings that survive when one axis of the algebra is nailed down. Whether a force strengthens or weakens with distance is then decided by one yes-or-no property of that group: whether its turnings *commute* (whether doing turn A then turn B equals doing B then A). If they commute (the trade word: abelian), the messenger particle carries no charge of its own force, only matter pairs screen, and the coupling grows at close range. If they do not commute, the messengers carry their own charge, anti-screening wins, and the coupling *weakens* at close range. The ladder therefore predicts the direction of every force's running with no free parameters:

rung	symmetry (stabilizer)	commuting?	prediction	measured
atomic (light)	the circle U(1)	yes	grows inward	α: 1/137 → 1/128 ✓
weak	SU(2), the unit quaternions	no	weakens inward	confirmed ✓
colour	SU(3), guard of the colour shutter	no	weakens inward	α_s: 0.33 → 0.118 ✓

Three predictions, three confirmations. In the octonion dictionary the non-commuting of the colour group is not an axiom: the gluons are the cross-couplings of the two quaternions, and cross-couplings of cross-couplings do not commute — the seven multiplication triples at work. This route is rigorous and *borrowed*: the precise logarithmic curve comes from the 1973 calculation, which this framework inherits rather than replaces.

3. Route Two — the Native Mechanism: Artin's Theorem

Now the octonion-native content. Recall that this series derives confinement from *non-associativity*: for octonions, the grouped products (A·B)·C and A·(B·C) can differ, and their difference — called the associator, written [A,B,C] = (A·B)·C − A·(B·C) — is the confining coupling itself. Now a beautiful theorem (Artin): **any two octonions, however combined, generate only associative combinations.** Non-associativity requires three genuinely independent participants. Computed with the quark presets of the neutron-decay paper (companion script): the associator is zero to machine precision (one part in 10^{15}) whenever its third slot holds anything built from the first two — and is *order one* (1.59, relative to the sizes of the three factors) for the true three-quark triple.

There is no gradual dial. The algebra's coupling is exactly zero for any resolved pair and full strength for the triple. Two quarks cornered together at close range are, algebraically, a two-body system: associative, quaternionic, **free**. The wall wakes only when the configuration engages the third quark — and the closure angle of the neutron-decay paper, the quantity that runs everything on that rung, is *defined* by a triple product. Free in pairs, caged in triples: one algebraic fact serves both ends of the force, which is exactly the structural signature asymptotic freedom demands — in the standard account too, one mechanism (gluon self-coupling) serves both ends.

4. Route Three — the Spread Charge: a Toy That Pays Twice

Why does a short-distance probe see less colour charge? Because in this framework colour is not a point property — it is the amplitude of the cage's shared winding (the State Octonion paper's central claim). Model that literally: spread the colour charge uniformly through the cage of radius R = 0.841 fm and apply the oldest tool in field theory, Gauss's law — the rule that the force at radius r feels only the charge *enclosed* within r. Long-hand: the enclosed fraction of a uniformly spread charge is the volume ratio $(r/R)^3$, so

effective charge at radius r: $Q(r) = (r/R)^3$ of the whole force between quarks: $F(r) = \alpha\_s \cdot \hbar c \cdot r/R^3$

Two payments from one toy. *Inward:* the enclosed charge vanishes as r^3 — a probe deep inside the cage sees almost no colour at all. Bjorken's quasi-free quarks are the geometry of a spread charge. *Outward:* the force *rises linearly* with r — a string. Its tension at the cage edge: $\alpha\_s \cdot \hbar c/R^2 = 279 \cdot \alpha\_s$ MeV per femtometre; the measured string tension of 900 MeV/fm requires $\alpha\_s(\text{cage}) \approx 3.2$ — squarely where analyses place the frozen strong coupling below 1 GeV. The toy is crude — a uniform ball, no dynamics — but it produces the two defining behaviours of the strong force, in the right magnitudes, from one assumption: *the charge belongs to the winding, not to the point.* Which is Route Two restated.

5. What Is Cracked and What Is Not

Cracked: the direction of every force's running (Route One — three confirmed predictions from the stabilizer ladder); a native algebraic mechanism with the right all-or-nothing structure (Route Two — associator exactly zero on pairs, order one on triples, verified numerically); the linear confining force and the vanishing interior charge, with the string tension right at $\alpha\_s \approx 3$ (Route Three). **Not cracked: the logarithm.** The measured running is logarithmic in probing energy because, in field theory, fluctuations at *every* intermediate scale contribute equally, and summing equal contributions over many scales gives a logarithm. The routes above give a discrete jump (zero for pairs, full for triples) and a power law — not yet a logarithm, and not yet the measured coefficient (in the trade: $b_0 = 11 - 2n\_f/3$). The problem is now sharply posed for the State Octonion sequel: **find the propagating-field statement whose short-distance limit is Artin's theorem, whose long-distance limit is the triple product, and show that the crossover between them runs logarithmically.** If the seven triples can be made to play the role of the gluon fluctuations, the coefficient itself becomes computable — and this framework would own both ends and the middle of the strongest force in nature.

6. One Sentence for the Paper

Asymptotic freedom, in this framework: *the strong force is carried by the associator; the associator needs three participants; and a probe that corners two quarks at short distance has built a temporarily associative — and therefore temporarily free — corner of the universe.*

References

D. J. Gross and F. Wilczek, Phys. Rev. Lett. 30, 1343 (1973); H. D. Politzer, Phys. Rev. Lett. 30, 1346 (1973); E. Artin — the theorem on alternative algebras (see R. D. Schafer, *An Introduction to Nonassociative Algebras*, 1966); measured α_s values from the Particle Data Group; string tension from lattice QCD; and the papers and notes of this series (Papers 4–6; the Algebra Budget; the companion verification script asymptotic_freedom_check.py). *(Citations from memory; the literature-verification pass applies.)*