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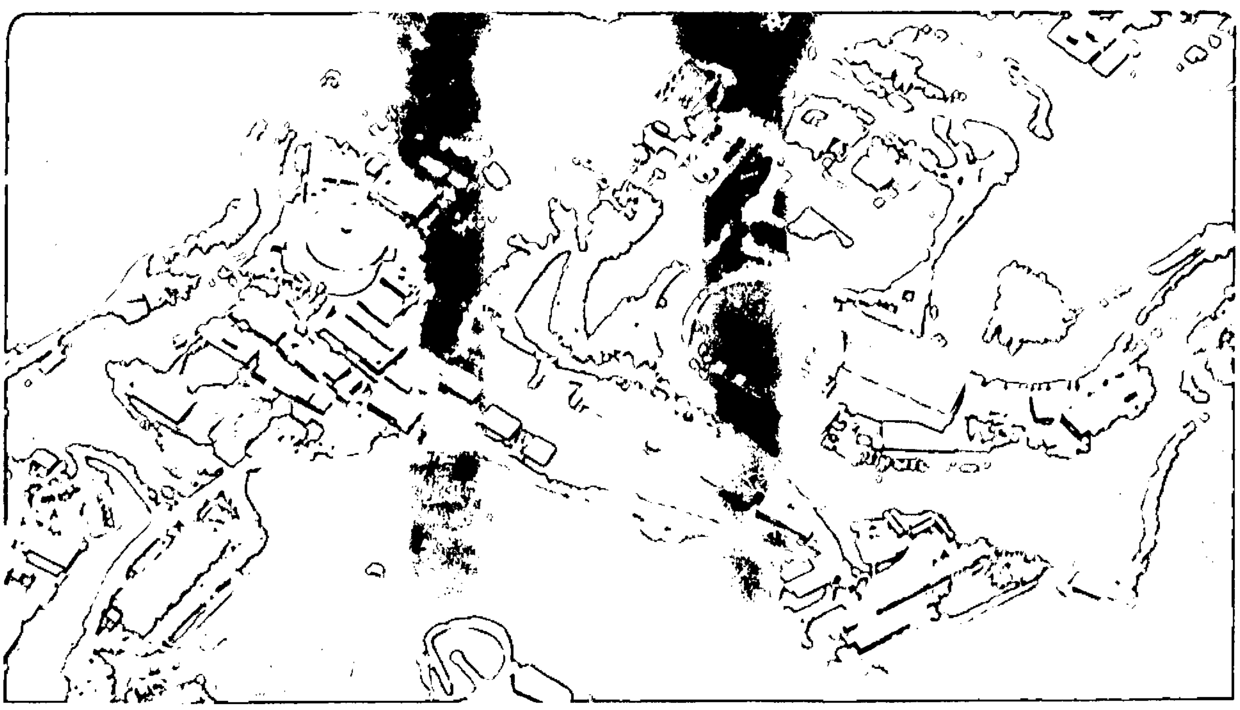

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ABSTRACT

It is shown how the topological bootstrap generates electroweak as well as strong interactions from the requirement of a consistent S matrix. The responsible topological object, unavoidable but heretofore unappreciated, is the "naked cylinder"--whose ground state corresponds to the Higgs scalar boson.

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Topological particle theory[1,2] has by now explained the most essential features of hadrons and strong interactions through the notion of an S-matrix expansion based on topological complexity or "entropy". There are 3 entropy indices g_1, g_2, g_3 which characterize each topology γ appearing in the infinite topological expansion

$$M_{fi} = \sum_{\gamma} M^{\gamma}_{fi} \qquad (1)$$

of an S-matrix connected part M_{fi}. Each γ corresponds to a pair of intersecting surfaces (Σ_Q, Σ_C); the entropy of γ resides in the "classical" surface Σ_C--which embeds momentum (Feynman-Landau) and charge (Finkelstein) graphs and whose boundary constitutes a third graph (Harari-Rosner) that carries spin.[3] The index g_1 is the genus of Σ_C, measuring the number of handles and Möbius bands.[4] The index g_2 is equal to $b - 1 + g_1$ where b is the number of boundary components, while the index g_3 counts the number of "topological gluons"--chiral patch boundary lines on Σ_C that are not momentum lines.[3] Zero-entropy topological components have $g_1 = g_2 = g_3 = 0$, and strong interactions have been defined as those components reachable through successive connected sums of zero-entropy components. This approach has explained the origin of all observed strong-interaction quantum numbers and symmetries[1,2] and also the observed values of hadron coupling constants.[5,6] (For a recent review see Ref. (7). The notation $g_{1,2,3}$ conforms to this review rather than to Ref. (1).) An obvious question is why there should be anything in nature beyond strong interactions. In this letter we explain how the requirement of a consistent S matrix demands additional low-level topological components with properties close to observed electroweak interactions.

The indices f and i in Eq. (1) refer to final and initial channels of "elementary particles"--each belonging to a characteristic triangulated area of the quantum surface Σ_Q. A product of connected parts, $M'_{fn} \otimes M''_{ni}$, meaning for which is required by S-matrix unitarity, corresponds to a "connected sum" of surface pairs, $\gamma' \# \gamma'' = \gamma$, where a "plug" indentifies outgoing-particle Σ_Q areas of γ'' with ingoing-particle areas of γ'.[1] The dynamical equations of topological particle theory are Landau-Cutkosky discontinuity formulas[8] for the M^{γ}_{fi} that arise from unitarity, in conjunction with the topological expansion. Schematically each Landau singularity is described by a Cutkosky formula

$$\mathrm{disc}_n M^{\gamma}_{fi} = \sum_{\gamma' \# \gamma'' = \gamma} M^{\gamma'}_{fn} \otimes M^{\gamma''}_{ni} \qquad (2)$$

where the number of terms is finite. Implicit in this formula is the assumption that <u>all</u> real singularities of any M^{γ}_{fi} correspond to intermediate elementary particles (within the f, i space)--<u>that belong to triangulated areas of Σ_Q</u>.

A definite and finite set of such particles, belonging to Σ_Q disks, has been established from the consistency demands of Formula (2) for zero entropy,[1] recognizing that zero entropy for γ requires zero entropy for <u>both</u> γ' and γ''. Here it is necessary to appreciate why the term "entropy" (rather than "complexity") is being used. Both g_1 and g_3 enjoy a "strong-entropy" property in any connected sum:

$$g_{1,3} \geqslant g'_{1,3} + g''_{1,3} \qquad (3)$$

while g_2 satisfies a "weak entropy" property[1]

$$g_2 \geqslant \max(g'_2, g''_2) \qquad (4)$$

Thus zero entropy can only be built from itself; elementary hadrons are determinable from nonlinear but self-contained zero-entropy discontinuity formulas. The question addressed in this letter is whether Formula (2) can be used to build systematically all <u>other</u> components of the S-matrix topological expansion, starting from zero entropy and elementary hadrons. In other words, is the Hilbert space of hadronic Σ_Q disks sufficient for a consistent universe?

For components with g_1 or g_3 not equal to zero, there is no problem. The equations generating such components are <u>linear</u> because the strong-entropy property (3) prevents γ' and γ'' from both being equal to γ in a connected sum. The poles of such amplitudes must already be present in amplitudes of lower entropy; the <u>infinite</u> entropy sum (1) may generate new poles without inconsistency. It turns out however that, because g_2 satisfies only the weak entropy property (2), there is exactly one (finite) entropy level above zero entropy that can reproduce itself. This is the level $g_1 = g_3 = 0$, $g_2 = 1$; we shall refer to this exceptional topology as the "naked cylinder".[9]

Because naked cylindrical components of the topological expansion satisfy <u>nonlinear</u> equations (as do zero-entropy components), it is possible that they contain real poles <u>in addition to</u> those of zero entropy. If so, an inconsistency arises in the program of developing a complete S matrix through Eq. (2) on the basis of zero-entropy hadron disks.

It can be shown that any naked-cylinder pole will have vacuum quantum numbers (lying on a 0^+, 2^+... "naked pomeron" trajectory) and will be a totally-symmetric singlet in all topological degrees of freedom. Now all models of zero-entropy dynamics, when extended to the naked cylinder, predict the existence of a real 0^+ pole of lower mass than the m_0 shared by the supermultiplet[5,11] of zero-entropy hadrons.[12] The topological expansion based on zero entropy alone is therefore almost certainly inconsistent, although the difficulty is statistically tiny because the disk Hilbert space contains roughly 10^4 elementary hadrons. The S matrix can be almost but not quite unitary if the single exceptional bound state is ignored. To achieve complete unitarity a representation on the quantum surface must be given to the naked-cylinder ground state.

A natural device is a non-disk elementary-particle Σ_Q area together with a cylinder Σ_C to represent couplings of the naked-cylinder pole. The new topology, not reachable from zero entropy, must obey a host of consistency considerations. As partially explained in Ref. (13) a promising non-disk Σ_Q representation of a singlet particle--totally symmetric in all the degrees of freedom of topological supersymmetry--is a 2-triangle $I\bar{I}$ Klein bottle. (A $Y\bar{Y}$ structure is unsuitable because, according to the chirality rules of Ref. (3), it does not couple to mesons.) Now because I triangles are doublets both in charge and in spin, one cannot represent the spinless and electrically-neutral naked-cylinder ground state without introducing companion (non-singlet) elementary particles that carry charge and spin. One must accept charge quartets (decomposable into singlet plus triplet) with spin 0 and 1, but all couplings to hadrons are completely determined by corresponding naked-cylinder couplings. As will be described elsewhere, coupling ratios turn out to be similar to those of SU(2) × U(1); what about the coupling strength?

The same models[10] that predict the naked-cylinder ground-state mass to be less than the supersymmetric hadron mass m_0 also predict a naked-cylinder coupling constant approximately equal to g_0--the supersymmetric elementary-hadron coupling constant.[5] Now it has been shown, from comparison with physical hadron coupling constants[6] as well as from models of zero-entropy dynamics,[14] that $g_0 \approx e$; so we have found that the most straightforward accommodation of the naked-cylinder dilemma leads to topological components beyond strong interactions--characterized by a symmetry similar to SU(2) ×U(1), with a coupling constant close to the observed value of the fine structure constant, and mediated by charge quartets of vector and scalar bosons. Supposing the naked cylinder ground state to have zero mass, a possibility compatible with model estimates, we find ourselves strikingly close to the starting point of the standard Weinberg-Salam theory of electroweak interactions.[15] We expect the equivalent of a Higgs-mechanism to be contained in higher components of the topological expansion, leading by the usual route to 3 massive vector bosons, the massless photon and one residual (Higgs) scalar boson.[16] One might characterize the latter particle as the physical representative of the naked-cylinder ground state.

The topological boostrap explains all parameters so one test will be the value of the Weinberg angle. Before inclusion of higher-order (hadron-loop) corrections that mix elementary photon with elementary Z_0 and give mass to $W^{\pm}$ and Z_0, the topological Weinberg angle is 45°. In a separate paper it will be shown how a 100 GeV mass scale for weak bosons naturally arises from hadron loops, although it is not yet known how difficult it will be to predict

W and Z_0 masses quantitatively or to correct the Weinberg angle. A challenging test will be whether consistency conditions force the 3 vector bosons that acquire mass to choose a single handedness. The ultimate test will be whether (strong-interaction) dynamical models of zero entropy and naked cylinder, as they are improved, converge toward a naked-cylinder coupling constant precisely equal to the observed value of e.

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