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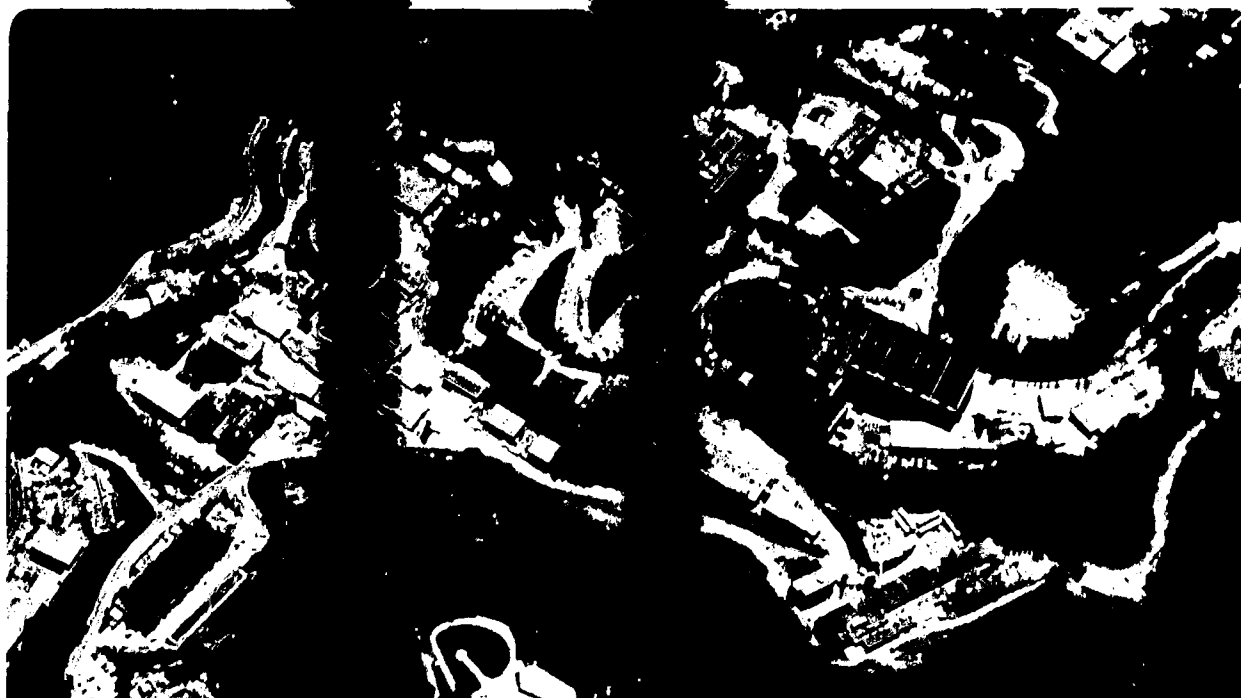
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A SMOOTH TOPOLOGICAL PLUG FOR "QUARK-COLOR" SWITCHING*

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ABSTRACT

"Quark-color" switching is given a smooth topological representation that leaves junction lines uncrossed by charge or momentum arcs. One of the 3 topological colors maintains a distinguished role, but color asymmetry is diminished with respect to an earlier nonsmooth switching proposal. Deficiencies of the earlier proposal are remedied by the new scheme and it is shown that strong-interaction quantum surfaces now never become disconnected.

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I. INTRODUCTION

A recently-proposed dual topological theory of strong interactions¹ describes baryons through a "quark-diquark" structure² where in lowest order only one of the baryon's 3 quarks interacts with mesons. Higher-order topological-expansion components, where more than one baryon quark interacts with mesons, have been associated with a topological structure called a "glitch". This paper proposes to replace the glitch by a simpler topology which remedies various glitch deficiencies.

The theory of Ref. (1) employs a "quantum surface" on which there appear "quark" triangles carrying one of 3 distinct "topological colors" as well as spin, electric charge and flavor. Topological color is a physically-inaccessible quark-permutation degree of freedom that becomes erased through the topological expansion--which sums over permutations in constructing physical amplitudes from topological amplitudes. An elementary-baryon disk may appear on the quantum surface as any one of 6 distinct permutations of 3 quark triangles surrounding a core triangle, each quark carrying a definite flavor and spin; an elementary baryonium disk similarly may appear as any one of 4 permutations of two quarks and two antiquarks surrounding a pair of core triangles. Amplitude products representing S-matrix unitarity require that any baryon or baryonium quark-triangle permutation be joinable ("pluggable") to any other permutation representing the same elementary particle. Plugs between different permutations have been called "switches". Switches involve topological-color exchange between quarks, each color being separately conserved but

movable from one quark to another. In the theory of Ref. (1) one distinct topological color--designated #1--plays an exceptional role to be explained below; #1 quarks interact with mesons.

All the foregoing features we here maintain. However Ref. (1) assigns to any switch involving color #1 a topological representation qualitatively different from that for switches not involving color #1; the term "glitch" was invoked to describe a color #1 switch because the plug was not smooth in the topological embellishments representing momentum and electric charge. The present note describes an alternative color #1 switch which is smooth and which diminishes the distinction between the 3 colors. Other aspects of the new proposal will be discussed.

II. GLITCH vs. DIQUARK TWIST

Appendix B of Ref. (1) describes the original proposal for color-switch plugs. Were we here immediately to present the alternative glitchless scheme, the reader might wonder why the glitch was proposed in the first place. So we begin by a brief review which sets the stage for the new smooth color-switch plugs.

Motivation for the glitch arose from even-permutation plugs, such as shown in Fig.1(b) together with an identity plug (no switch) presented for comparison in Fig.1(a). Figure 1 reproduces part of Fig. 42 of Ref. (1) and adds thereto color numbers 1, 2, 3 according to the rule of Fig. 27 from Ref. 1: The quark triangle whose edge carries the end of the baryon momentum arc is colored #1, while colors #2 and #3 follow around the baryon perimeter in the cyclic order given by the orientation of the quark triangles. Each quark triangle intersects exactly one (smooth) sheet of the transverse "classical" surface which carries the Landau (momentum) graph as well as charge arcs, and at "zero entropy" each separate sheet has a distinct topological color. There is a unique zero-entropy sheet colored #1 which carries all core-charge arcs and the full Landau graph. Figure 2 shows the classical-surface boundary ("belt") portion that intersects the baryon disks of Fig. 1(b). Here the dot locates the end of the core charge arc, which in singling out a sheet of the classical surface plays the same role as the cross of Fig. 1. For reasons later to emerge we shall henceforth in this paper use the core-charge arc location to define color #1.

The "in" and "out" baryon disks of Fig. 1(b) and 2 differ by a cyclic color permutation, and it originally seemed natural to accomplish the plug by a rigid 120° rotation of the "in" disk with respect to the "out" disk--matching flavors smoothly but mismatching the crosses in Fig. 1 and thus generating a discontinuity in the baryon momentum arc as well as in the core-charge arc. In order to reconnect these arcs in the new classical surface resulting from the baryon plug, it was necessary to introduce a "glitch"--causing the baryon momentum arc and the core charge arc to cross from one sheet of the classical surface to another, traversing a junction line where three smooth pieces of classical surface meet.

In contrast the odd-permutation plug of Fig. 3, which interchanges colors #2 and #3,^{*} is accomplished in Ref. (1) without a glitch. A plug is made of the core triangle together with the #1 quark triangle so that momentum and charge arcs are continuous, and then the #2, 3 quark triangles are "cross-plugged" so as to match flavor orientations. The corresponding two sheets of the classical surface are thereby united along their #2, 3 belt portions, with a "twist" that increases genus (a Möbius band is created). In Ref.(1) a pair of #2, 3 quarks attached to the same core triangle was called a "diquark" and the plug of Fig. 3 was called a "diquark twist".

Reference (1) proposed that the remaining permutations--exchange of color #1 with #2 or color #1 with #3, should correspond to a glitch followed by a diquark twist or vice versa. It was implied that the

order of these latter two operations is immaterial, but in fact the resulting topology depends on the order--an unnoticed symptom of inadequacy in the original proposal.

* This 2-3 permutation may arise in baryonium as well as in baryon plugs.

III. THE UNIFORMLY-SMOOTH COLOR-SWITCH PLUG

The new proposal follows the original diquark-twist idea and thereby achieves uniform smoothness, regardless of which colors are exchanged. The core triangle is plugged, so as to match the ends of both charge and momentum arcs, and the quark triangles are plugged so as to match flavors. Any odd permutation increases classical-surface genus by one unit--just as for the diquark twist, while any even permutation increases the genus by two units. All switch plugs are manifestly unique and junction lines remain uncrossed by either charge or momentum arcs.

The new switch plug creates bridges between sheets which at zero entropy start out with distinct colors, and a simple device allows these switch bridges to be marked unambiguously in a manner that localizes each bridge between a definite pair of adjacent Landau-graph vertices. As will be described in a separate paper, the switch-bridge marking device plays a natural role in representing chirality and electroweak interactions, so we expect it to be a permanent embellishment for topological bootstrap theory. Immediately-interesting consequences are: (a) With identifiable bridges that localize color switches, each portion of the classical surface carries a well-defined topological color to all orders of the topological expansion. (b) Duality transformations (contractions) cannot move a Landau vertex past any switch.

The embellishment in question recognizes that, at zero entropy, sheets colored #2 or #3 have so far carried no Landau (momentum) arcs although each such sheet has exactly one charge arc belonging to one

mated pair of quark (quantum) triangles. The proposed embellishment adds to each color #2, 3 sheet one line (parallel to the quark charge arc) with ends on the triangle edges shared by quark and core triangles. The location of this new line, that is to say, is similar to that of a baryon or baryonium momentum line on sheet #1. To increase the similarity, we further put a trivial vertex on the new line to correspond to the vertex on the #1 line, thus dividing it into two arcs. One may think of each of the two added arcs on a zero-entropy sheet colored #2 or #3 as being an exact copy of some momentum arc colored #1. Meson momentum arcs (always colored #1) are not duplicated in colors #2, 3, but each baryon momentum arc has two copies and each baryonium momentum arc has four copies.

"Momentum-copy" arcs reduce although they do not remove distinction between the 3 topological colors. Every quark triangle now has an attached momentum arc^{*} as well as a charge arc--as shown in Fig. 4(a). Quark color is defined to be that of the classical-surface sheet touching the quark triangle. Every core triangle has 3 attached momentum arcs, as shown in Fig. 4(b). One sees that the definition of color now requires the location of the core charge arc; momentum-arc location is no longer adequate.

The rules for building general strong-interaction topologies from zero entropy ensure there will always be a single connected complete (momentum arcs for all external particles) Landau graph colored #1, embedded in a single (smooth) sheet of the classical

* There is, however, no "quark momentum" in topological bootstrap theory. The "momentum arc" of a quark with color #2, 3 is a copy of a baryon or baryonium momentum arc.

surface. A switch involving color #1 and color #2 builds a bridge between corresponding sheets and this bridge is traversed by a #2 copy-momentum arc so as to have a point of tangency with the #1 momentum arc belonging to the plugged particle. See Fig. 5. The point of tangency can be displaced across the bridge, so a precise statement of color integrity attaches color to Landau graphs, not to sheets of the classical surface. Switch bridges, however, are marked by tangency points between differently-colored Landau graphs. A cut through the point of tangency breaks the bridge and produces separately-colored sheets. Note how the corresponding #1 and #2 trivial vertices in Fig. 5 indicate that the bridge is "twisted".

A diquark twist exchanging colors #2, 3 produces a local topological structure similar to that of Fig. 5, but we need to consider separately the even-permutation baryon plug which originally was represented by a glitch. The new smooth plug generates two twisted bridges, as shown in Fig. 6.

In strong-interaction topologies the #2, 3 copy-momentum graphs contain only trivial vertices, with the #1 graph housing all non-trivial vertices, but in a separate paper we propose cubic electroweak vertices colored #2, 3. It is then not possible to speak of a "complete" thickened Landau graph housed in the classical surface. For strong interactions, however, the #1 Landau graph contains all the momentum-flow information and the #1 sheet, isolated by cutting through switch bridges as well as junction lines, may be regarded as the #1 Landau-graph thickening. At the same time any smooth sheet of the classical surface, including switch bridges, houses the thickening of a connected collection of tangent colored momentum graphs.

IV. DISCUSSION

Already mentioned has been one deficiency of the originally-proposed switch plugs: a topological ambiguity for any odd permutation involving color #1. This defect has now been removed. A second deficiency was failure of the diquark-twist topology to provide a reason preventing the twist from being slid past an adjacent Landau vertex. Embellishment with copy-momentum arcs has remedied the latter defect by placing on the Landau graph a tangency point for any color switch.

A notational device introduced through Figs. 27, 28, 29 of Ref. (1) becomes even more natural in the new scheme: It is possible to embellish the thickened #1 Landau graph with flavor-carrying "quark lines" whose position relative to the associated momentum arc corresponds to topological color. Switches thereby are represented by exchange of quark-line positions. It should be remembered that quark charge arcs on the classical surface never cross momentum arcs or each other. Quark lines embellishing a thickened Landau graph, even though constituting a complete topological record, should not be confused with quark charge arcs on the classical surface.

Reference (1) introduced an orientable thickened Landau graph, but as an entity generally separate from the classical surface and with arbitrariness in its definition. In the new scheme the Landau-graph thickening is housed in the classical surface. One consequence is an unambiguous cylinder topology for all lowest-order baryonium \rightarrow meson transitions, with or without switches and regardless of switch type. A corresponding statement in Ref. (1) depended on having arbitrarily chosen an orientable thickening.

Another attractive feature of the new proposal is its guarantee that strong-interaction quantum surfaces remain permanently connected, no matter how great their complexity. Such is not the case when glitches are allowed. Permanent strong-interaction connectivity follows from the fact that every #1 quark triangle and every core triangle at zero entropy touch two special points on the quantum sphere--vertices appropriately called "north and south poles". Whenever these triangles are plugged under the new rules, north pole will identify with north pole and south pole with south pole. (North and south poles become mutually identified in certain topologies.) Even if quantum-surface components become otherwise disconnected, they must continue to touch at the poles, because every elementary-hadron disk contains core triangles and/or #1 quark triangles.

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1. G. F. Chew and V. Poénaru, Lawrence Berkeley Laboratory preprint 11433, to be published in Zeit. f. Physik.
2. The quark-diquark structure also occurs in the theory of H. P. Stapp, LBL-11770, Berkeley (1981).

FIGURE CAPTIONS

1. Even-permutation baryon plugs: (a) the identity (b) A cyclic quark permutation.
2. Belt attachment for the baryon disks of Figure 1b.
3. An odd-permutation baryon plug that exchanges colors #2 and #3.
4. (a) Quark Triangle with end of momentum arc.
(b) Core triangle with 3 colored momentum-arc ends.
5. Bridge for a #1, 2 color switch.
6. Double bridge for a cyclic color permutation.

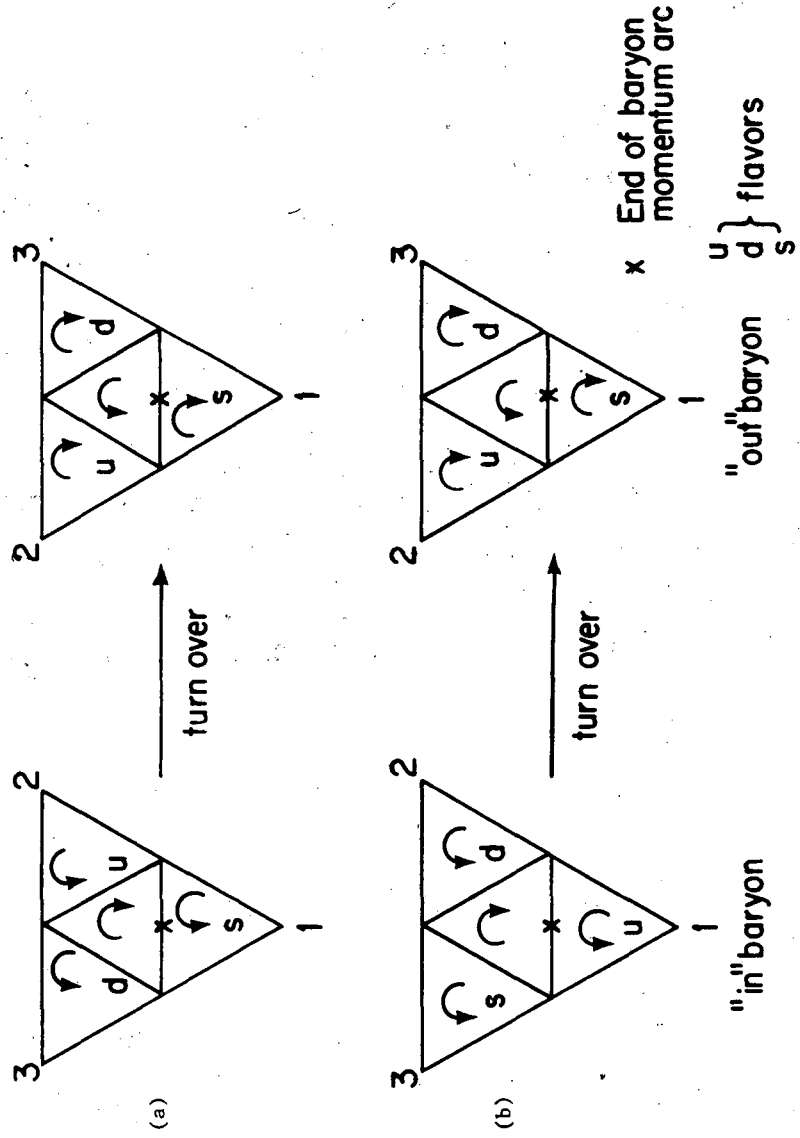


FIG. 1

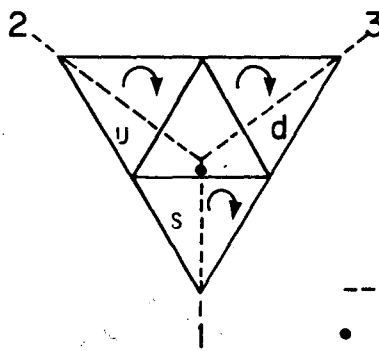
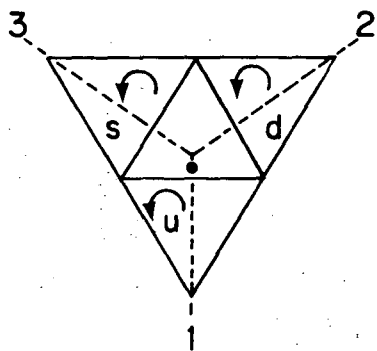
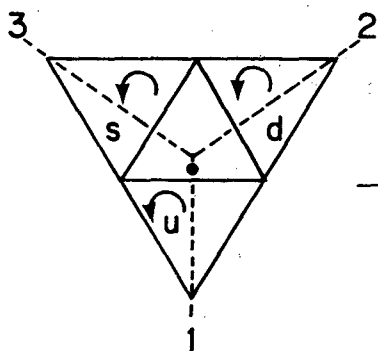


FIG. 2

----- belt
• end of core
charge arc



turn over →

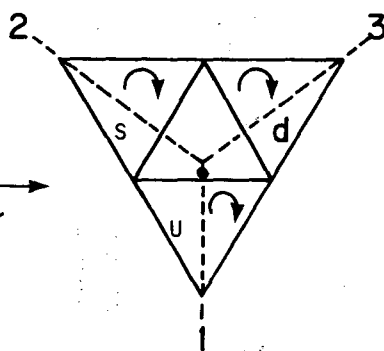


FIG. 3

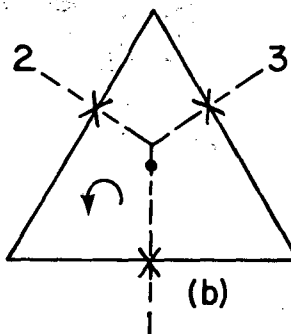
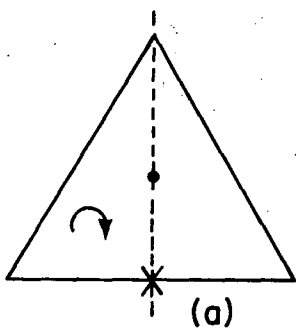
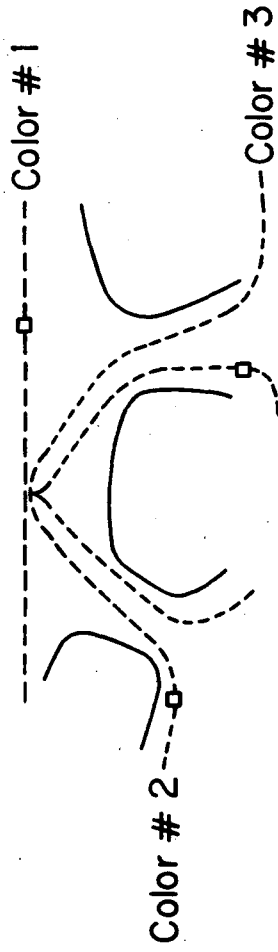
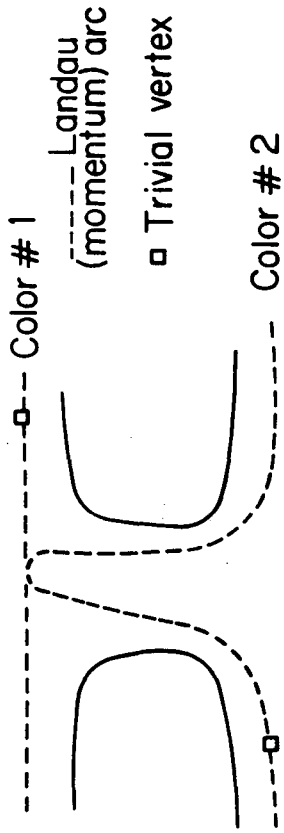


FIG. 4

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FIG. 5

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