Title

A TOPOLOGICAL THEORY OF ELECTRIC CHARGE

Permalink

https://escholarship.org/uc/item/5n53v9v2

Authors

Chew, G.F.
McMurray, F.R.
Poenaru, V.

Publication Date

1980-09-01

LBL-11431 c. 2
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

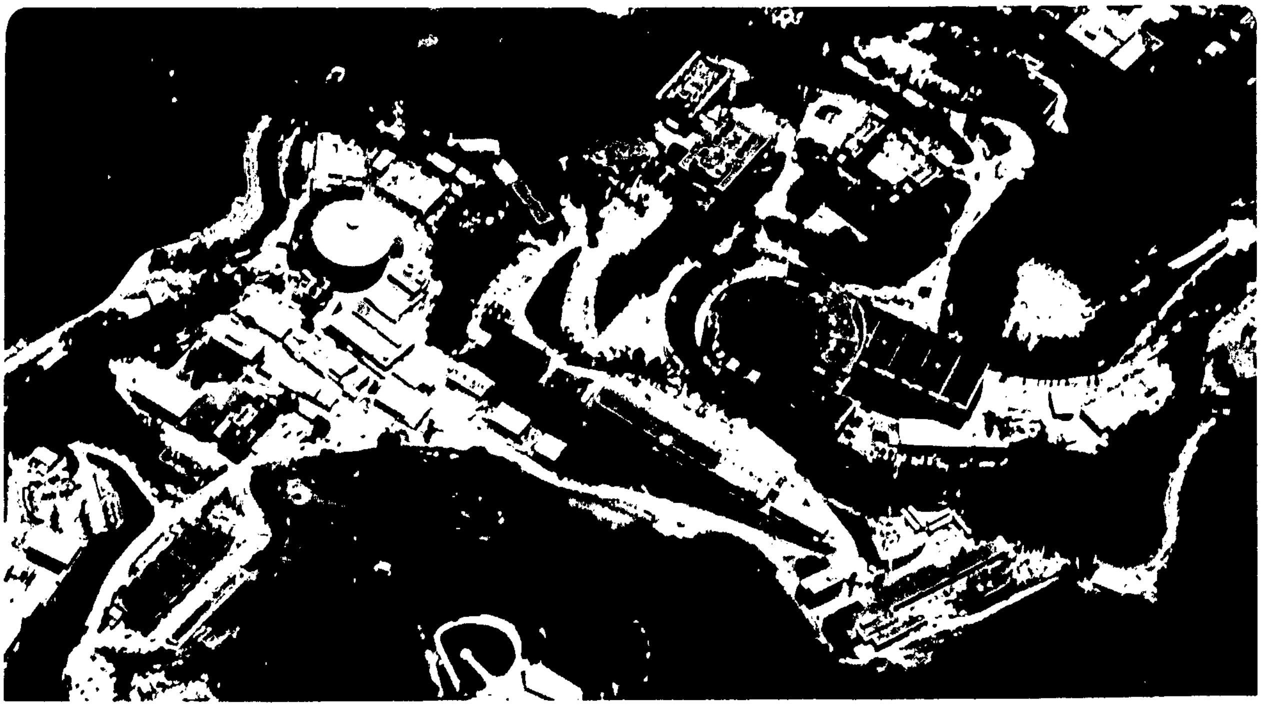
Physics, Computer Science & Mathematics Division

Submitted to Physical Review Letters

A TOPOLOGICAL THEORY OF ELECTRIC CHARGE

G.F. Chew, J. Finkelstein, R. McMurray, and V. Poénaru

September 1980



Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

DISCLAIMER

September 1980 LBL-11431

A TOPOLOGICAL THEORY
OF ELECTRIC CHARGE

G. F. Chew

Lawrence Berkeley Laboratory
and
Department of Physics
University of California
Berkeley, California 94720

J. Finkelstein*

Department of Physics
San Jose State University
San Jose, California 95192

R. McMurray

Department of Physics
University of California
Berkeley, California 94720

V. Poénaru

Départment de Mathématique
Université de Paris-Sud, 91405, Orsay, France

ABSTRACT

A recently-proposed topological theory of strong interactions is extended to electromagnetism. The values of the electric charges of both hadrons and leptons emerge naturally.

---

*Participating guest at Lawrence Berkeley Laboratory

A topological theory of strong interactions has been proposed.[1] This Letter outlines an extension to electromagnetism, details being presented in Ref. [2]. The extended theory continues to employ a topological expansion of S-matrix connected parts, each expansion component corresponding to a quantum-classical surface pair $\Sigma = (\Sigma_Q , \Sigma_C)$ generated by unitarity from certain leading components of minimal complexity. Although the leading electromagnetic components (denoted below by $\Sigma = \Sigma^{0,EM}$) are inadequate to describe most experimental hadronic observables--higher components being in principle computable but at present uncomputed--they provide a representation of electric charge. We shall show how all observed charges of leptons and hadrons emerge.

The theory described in Ref. [1] distinguishes quark from antiquark by the (interior) orientation of Σ_Q triangles, while orientations of the two peripheral edges of a peripheral triangle distinguish 4 flavor generations. Further, because each Σ_Q triangle constitutes part of the boundary of Σ_C, we may associate to each triangle a direction, either <u>into</u> or <u>out of</u> Σ_C. Since, as we show below, this orientation will control electric charge we call it the <u>charge direction</u>. For peripheral triangles the two-fold choice of charge direction is in addition to the 4 peripheral-edge orientation possibilities, so the theory contains a total of 8 quark (and 8 antiquark) flavors.

Since mated Σ_Q triangles carry matching flavors, a triangle whose charge direction is "in" is mated with one whose charge direction is "out." We thus associate with each mated triangle pair a directed "charge arc" lying in Σ_C and connecting the "in" triangle to the "out" triangle; the charge arc direction represents the charge directions of the Σ_Q triangles. All triangles, core as well as peripheral, have attached charge arcs, but we shall see below that core-charge orientation is determined by the interior orientation of the core triangle. (Core triangles are unflavored.)

Figure 1(a) shows a zero-entropy (strong-interaction) Σ_C^o for a 3-meson connected part. In this figure dashed lines represent Landau arcs and dotted lines Harari-Rosner (HR) arcs, while wavy lines represent the charge arcs. Because meson quantum discs contain no core triangles, all the Σ_Q triangles connected by the charge arcs of Fig. 1(a) are peripheral (i.e. they are quarks); this fact is signaled by the presence along each charge arc of an HR arc whose orientation distinguishes quark from antiquark. HR arcs carry spin in the theory of Ref. [1] and do not connect core triangles. For describing the quark aspects of strong interactions one could omit peripheral-triangle charge arcs and represent each charge direction by a 2-valued index on an HR arc. However, charge arcs are indispensable to our representation of electromagnetism.

We propose that an external photon be represented, not by a Σ_Q disc like a lepton or a hadron, but by a disconnected sphere, covered by two triangles with oppositely-oriented interiors but lacking edge orientations and unconnected by any HR arcs. The vector character of the photon is represented through the patchwise orientation of the classical surface, as described in Appendix B of Ref. [2]. The absence of photon HR arcs reflects the absence of photon flavor as well as the difference from hadrons and leptons in the representation of photon spin. The two photon triangles furnish end points, as we shall see, for a pair of oppositely-directed charge arcs. Let us designate by $\Sigma^{0,EM}$ a minimum-complexity

Σ belonging to a single-photon connected part. $\Sigma_Q^{0,EM}$ consists of two disconnected spheres, one containing the photon and the other either a hadron collection or a lepton pair. Suppose that the photon couples to 3 mesons; then $\Sigma_C^{0,EM}$ might look like Fig. 1(b) where the boundary consists of two disconnected belt components. The lune near the center is the belt component encircling the photon sphere. This figure displays the Landau arcs, including that of the photon, and the (quark) HR arcs, but we have not yet drawn in the charge arcs. The special location of the photon boundary suggests its interaction with the quark pair in the same region; we now explain how this interaction involves the charge arc in that region.

Since the photon sphere produces an extra hole in Σ_C, Fig. 1(b) portrays a cylinder, but there is an important difference from a strong-interaction cylinder. Figure 2(a) displays a strong-interaction cylindrical Σ_C with 3 mesons on one boundary and a fourth meson on the other. It looks like Figure 1(b) except for the presence of an extra HR arc and of an extra Landau closed loop, which separates the two belt components. Because of this closed loop, the cylindrical surface of Fig. 2(a) may be regarded as the Landau graph's "thickening." The HR arcs constitute the boundary of the thickened graph. In contrast the bottom HR arc in Fig. 1(b) is not part of the boundary of the Landau graph here (which is a tree). The difference is important because in Fig. 2(a) we can demand consistency between the directions carried by the HR arcs and the orientation of the Landau vertex. This consistency ensures a single coherent HR orientation for any Σ_C generated in connected sums.

Virtual-photon components of the topological expansion are generated by photon-plug connected sums. In the absence of photon HR arcs we may guarantee a coherent orientation for virtual-photon components by assuming that a pair of appropriately-oriented charge arcs always follows the boundary of a thickened photon Landau arc. When a photon is "inserted" into a Σ^0 to form a $\Sigma^{0,EM}$ it may be coupled to any charge arc whose orientation is the same as the (overall) HR orientation. This arc is cut and the two free ends are attached to the appropriate triangles on the photon sphere. Figure 1(c) provides an example, where we have inserted into Fig. 1(b) the charge arcs of Fig. 1(a) and attached the photon to the lower arc, whose orientation is the same as that of the HR arcs. Had this orientation been opposite, attachment of the photon would not have been allowed. In Fig. 1(c) the lower charge arc now lies along the boundary of the thickened Landau graph--including the photon arc.

Thus the orientation of what we have called a charge arc does indeed control the charge. A photon can be coupled to a charge arc if and only if the charge orientation is the same as the HR orientation. In consequence within every flavor doublet one member is electrically neutral and the other is electrically charged. In Fig. 1(a) the quarks whose HR arcs appear at the bottom and at the top left are charged while that at the top right is neutral.

As discussed in Ref. [1] leptons as well as quarks are representable by peripheral triangles; the existence of a neutral member within each lepton doublet is then immediately explained. In conventional theory there is no reason why both members of the doublet should not carry some charge. We also have a neutral member of each quark doublet; while unorthodox, this pattern nevertheless leads to the observed charges for all hadrons, as we now show.

We assume that all charged quarks have the same value for their charge, which we call +1; charged antiquarks then have charge -1. In the convention where all particles are "outgoing," a quark whose charge direction is "out" has charge +1, an antiquark whose charge direction is "in" has charge -1; the other two possibilities correspond to charge zero. A quark flavor doublet (e.g. u,d) has charges (1, 0) while an antiquark doublet has charges (-1, 0). Thus our charge assignments are $\frac{1}{3}$ unit larger than the orthodox assignment for quarks and $-\frac{1}{3}$ unit smaller for antiquarks.

For mesons--built from quark-antiquark pairs--we evidently get the same total charge as by the orthodox rule. For baryons one must consider core as well as peripheral charge arcs. No HR arc being associated with the core, the previously-discussed need to maintain a coherent HR orientation in connected sums requires that core-charge orientation agree with HR orientation even in strong-interaction Σ's. Thus in Fig. 2(b), which shows one sheet of Σ_C for a 2-baryon, 1-meson connected part, the core charge arc at the bottom must be directed to the left, while there is no restriction on the direction of the other two charge arcs.

The core in consequence always carries charge, and since for a baryon the core triangle has an orientation like an antiquark,[1] the baryon core has charge -1 (the antibaryon core has +1). The total baryon charge is the sum of the -1 core charge and its 3 quark charges, which each have $\frac{1}{3}$ unit larger charge than orthodox. The result then agrees with the orthodox rule.

As shown in Ref. [2], it is possible through unitarity products of $\Sigma^{0,EM}$ connected parts to generate amplitudes for arbitrary electromagnetic transitions. However, as emphasized in Ref. [1], any "short-distance" hadronic phenomenon (such as the high-energy R ratio in e^+e^- annihilation) corresponds to very high order within the topological expansion and so is not connected in a simple way to the quark charges discussed here. In contrast the electric charges of both hadrons and leptons have successfully been given a simple topological explanation. Although lepton magnetic moments (to lowest order in the fine-structure constant) are also immediately explained at the $\Sigma^{0,EM}$ level, a quantitative description of hadron magnetic moments requires some higher topological components; preliminary estimates are encouraging.

ACKNOWLEDGMENT

This research was supported by the High Energy Physics Division of the U.S. Department of Energy under contract No. W-7405-ENG-48.

One of us (J.F.) wishes to acknowledge the hospitality of Lawrence Berkeley Laboratory.

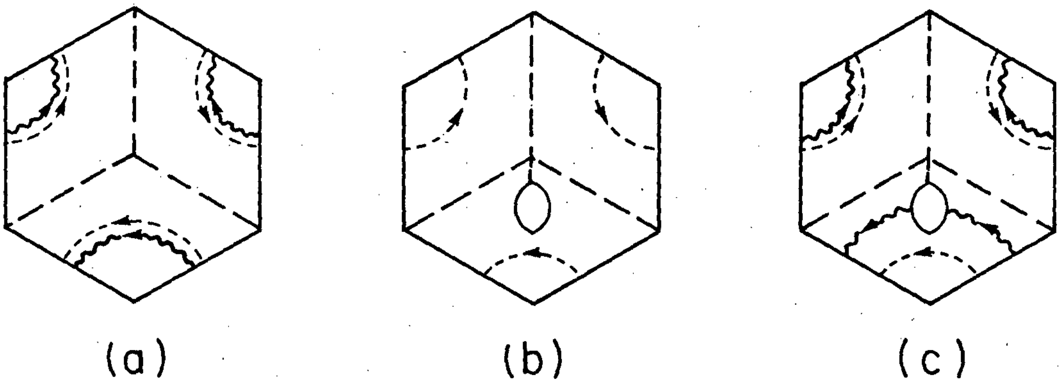
REFERENCES

1. G. F. Chew and V. Poenaru, Phys. Rev. Letts. 45, 229 (1980). Two modifications of the theory, subsequently found desirable, are described in a longer paper by Chew and Poenaru, Lawrence Berkeley Laboratory preprint LBL-11433, to be submitted to Phys. Rev. One of these changes, dealing with baryonic entropy but not affecting zero entropy, can be ignored for the purposes here. The second alteration is in the topological representation of quark-flavor doubling (e.g., up-down). The earlier model associated this doubling with the orientation of the quark triangle's belt-intersected nonperipheral edge. The modified theory does not orient this edge but instead includes the charge orientation described here. For strong interactions the two representations are equivalent.
2. G. F. Chew, J. Finkelstein, R. McMurray and V. Poenaru, Lawrence Berkeley Laboratory preprint LBL-11435, to be submitted to Phys. Rev.

FIGURE CAPTIONS

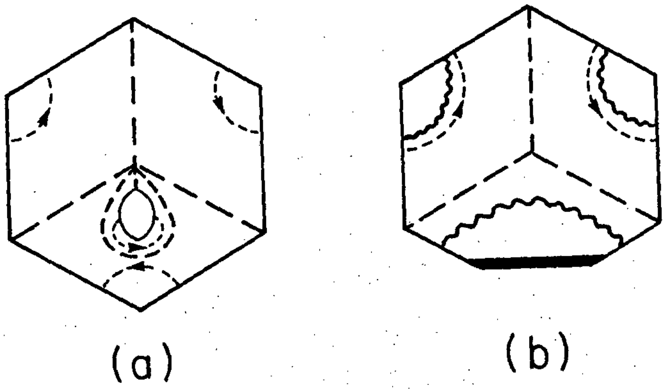
Fig. 1: Minimum-entropy Σ_C for a three-meson connected part (1a) and for a three-meson-plus-photon connected part (1b and 1c).

Fig. 2: Strong-interaction Σ_C for a four-meson cylinder (2a) and a meson-two-baryon connected part (2b). The heavy line at the bottom of Fig. 2b is a junction line where the exhibited sheet joins two other sheets of Σ_C.


(a) (b) (c)

—Figure 1—

XBL 809-1983


(a) (b)

—Figure 2—

XBL 809-1984

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720