Title
TOPOLOGICAL COMPOSITENESS OF QUARKS, LEPTONS AND ELECTROWEAK BOSONS

Author
Chew, G.F.

Publication Date
1982

LBL-13988
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

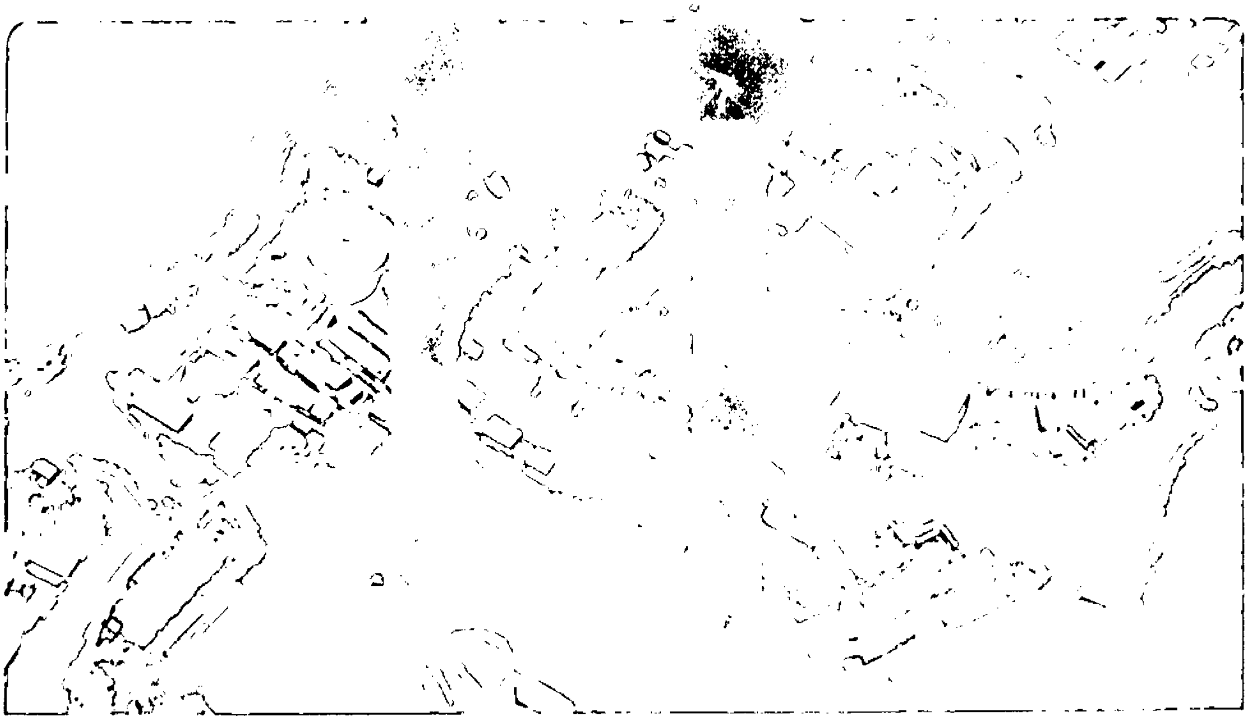
Physics, Computer Science & Mathematics Division

Submitted for Publication

TOPOLOGICAL COMPOSITENESS OF QUARKS, LEPTONS AND ELECTROWEAK BOSONS

G.F. Chew, J. Finkelstein, B. Nicolescu,
and V. Poenaru

January 1982



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

DISCLAIMER

TOPOLOGICAL COMPOSITENESS OF QUARKS, LEPTONS AND ELECTROWEAK BOSONS

G.F. CHEW[†]

Lawrence Berkeley Laboratory and Department of Physics,
University of California, Berkeley, California 94720, U.S.A.

J. FINKELSTEIN[+]

Department of Physics, San Jose State University, San
Jose, California 95192, U.S.A.

B. NICOLESCU

Division de Physique Théorique[*], Institut de Physique Nucléaire,
91406 Orsay Cedex and L.P.T.P.E., Université Pierre
et Marie Curie, Paris, France

and

V. POENARU

Département de Mathématique, Université de Paris-Sud,
91405 Orsay Cedex, France

IPNO/TH 82-4

- January 1982 -

LBL-13988

[+]Participating guest at Lawrence Berkeley Laboratory

[*]Laboratoire associé au C.N.R.S.

[†]This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

This manuscript was printed from originals provided by the authors.

Abstract

Topological Particle Theory yields a unified particle description in terms of two topological constituents, which we call the I-triangle and the Y-triangle. Each triangle is a charge doublet ; the I-triangle has spin $\frac{1}{2}$ while the Y-triangle has spin 0. Leptons are $\bar{I}\bar{Y}$; electroweak vector bosons are $I\bar{I}$; hadrons are $I\bar{I}$ (mesons), $III\bar{Y}$ (baryons), or $II\bar{Y}Y\bar{I}\bar{I}$ (baryoniums). An as-yet-undiscovered singlet neutral electroweak scalar boson is predicted, corresponding to $Y\bar{Y}$.

Topological Particle Theory involves a quantum-classical pair of intersecting surfaces [1] : the "classical" surface describes space-time aspects of particle interactions while the "quantum" surface is the source of internal quantum numbers.

The closed quantum surface Σ_Q divides into oriented triangles which intersect the classical surface Σ_C either in the "I" pattern of fig.1(a) or the "Y" pattern of fig.1(b). Since Σ_Q also divides into elementary-particle connected areas, it is possible to describe each elementary particle as "built" from I- and Y- triangles. An individual triangle does not carry energy-momentum and cannot alone be interpreted as an elementary particle, but individual triangles do carry charge, spin, chirality and generation index and their orientation distinguishes "antitriangle" from triangle. The idea of triangular constituents within elementary particles is then relevant to all particle properties except energy-momentum. We here supplement earlier proposals for the triangular structure of elementary hadrons and leptons with an electroweak-boson proposal. The resulting constituent picture groups hadrons and electroweak particles into a remarkably simple unified pattern --a "Topological Grand Unification" (TGU). In fig.2 we show how TGU particles are constructed from I- and Y-triangle constituents hadrons are $I\bar{I}$, $II I\bar{Y}$ or $II\bar{Y}Y\bar{I}\bar{I}$; leptons are $\bar{I}\bar{Y}$; electroweak vector bosons are $I\bar{I}$ and (Higgs?) scalars are $Y\bar{Y}$.

Refs.[2] and [3] explain how each triangle is a charge doublet inasmuch as exactly one end of an oriented charge arc ends inside each triangle ; the relative orientation of charge-arc and triangle allows each triangle to be labelled as charged (I_{ch},Y_{ch}) or neutral (I_{neut},Y_{neut}). Charge defined as in ref.[3] is conserved on any (closed) Σ_Q when the total number of antitriangles equals the total number of triangles. Necessarily accompanying a conserved charge is thus a second conserved quantum number $N = N_I + N_Y$ -- the number of triangles minus the number of antitriangles (see table I). Baryon number B and lepton number L are identifiable as linear combinations of N_I and N_Y :

$$B \equiv \frac{1}{4}(N_I - N_Y)$$

$$L \equiv -\frac{1}{4}(N_I + 3N_Y) \quad ,$$

so $N = 2(B-L)$. For those components of the topological expansion where every triangle is mated in the sense of ref.[1] (see also below) to a triangle of opposite orientation, the quantities N_I and N_Y are individually conserved. B and L are then separately good quantum numbers.

Within hadron areas Y triangles are always charged [3], while within electroweak particle areas they are always neutral [4]. I-triangles may carry either charge value in any particle area where they appear.

The boundary (belt) of Σ_C, which is embedded in Σ_Q, divides into connected pieces belonging to separate particles and the belt always passes from one particle area to another at a vertex of the Σ_Q triangulation [1] . It follows from fig.1 that the edges of Y-triangles never lie along the boundary of a particle area (for this reason Y-triangles have heretofore been called "core triangles"). Because the generation index resides on this boundary [1,4] , Y triangles are flavorless --flavor being defined as the combination of generation index with electric charge. An I-triangle, as described in refs.[1] and [4], may be "peripheral"--sharing its two edges uncut by the belt with another I-triangle ; if so the I-triangle carries a generation index through the orientation of these two edges. Peripheral I-triangles within hadrons have been previously called "topological quarks". As do all triangles they carry integral electric charge, so standard fractionally-charged quarks do not appear as elementary constituents in our theory.

The ends of energy-momentum (Feynman-Landau) graphs on Σ_C uniformly lie on an intersection of the belt with an edge of the Σ_Q

triangulation and never inside triangles [4,5]. Figs.2(a,b,c) locate momentum-arc ends for each of the elementary-hadron disks of ref.[1]; fig.2(f) does the same for the lepton area of ref.[4]. It is evidently not possible to attribute momentum to an individual triangle. In this sense I or Y triangles are permanently "confined".

What about the spin content of I- and Y-triangles ? According to ref.[6], chirality resides in the (local)orientation of Σ_C areas not adjacent to a junction line but adjacent to a peripheral I triangle. Peripheral I-triangles inherit from the adjacent Σ_C area a corresponding chirality and carry spin 1/2 as well as flavor. Because Y-triangles touch junction lines [1] and are always adjacent to nonoriented Σ_C areas [6], they carry no spin. The spin content of both hadrons and leptons resides in their I-triangles, which are all peripheral (see figs.2(a,b,c,d)): mesons appear as spin S = 0,1 $I\bar{I}$ states, baryonium as S = 0,1,2 $II\bar{Y}Y\bar{I}\bar{I}$ states, baryons as S = 1/2, 3/2 $III\bar{Y}$ states, and leptons as S = 1/2 $\bar{I}\bar{Y}$ states.

What about nonperipheral I-triangles ? The Σ_C topology of electroweak currents implies that such a triangle, even though flavorless, has fermion (spin-1/2) content via its belt-intersected vertex [7]. In other words N_I is fermion number. Chirality, however, is an attribute restricted to peripheral I-triangles.

The quantum numbers associated with I and Y constituents are summarized in table II.*

---

*One might be puzzled by the absence of QCD color. Recall, however, that I and Y triangles are permanently "confined" by their lack of energy-momentum. In fact, as explained in ref.[1], a "topological color" is implied for topological quarks by the location of the momentum-arc end in figs.2(a,b,c).

Ref.[4] describes in detail a lepton area built from one $\bar{I}$-triangle and one $\bar{Y}$-triangle. The $\bar{I}\bar{Y}$ surface, shown in fig.2(f), is a Möbius band with perimeter composed of the two $\bar{I}$-triangle edges not cut by the belt. Because a closed (perimeter-less) area need carry no flavor, it is natural that <u>closed</u> 2-triangle areas should represent electroweak bosons, belt continuity allowing both $I\bar{I}$ and $Y\bar{Y}$ possibilities. Ref.[2] proposed to represent a vector boson through a <u>sphere</u> covered by $I\bar{I}$ triangles, but the absence of flavor here is not compelling. (It may be recalled that strong-interaction topologies of nonzero entropy include spherical quantum areas for flavor-carrying self-conjugate mesons such as ρ_0, ω, φ.) Flavor content is precluded for electroweak vector bosons if I and $\bar{I}$ triangles fail to be adjacent along edges uncut by the belt. Maintenance of the mating rule [1] that each triangle on Σ_Q share all 3 of its vertices with exactly one other triangle then leads to the vector-boson edge identifications ee and ff of fig.2(d), with the sense given by the arrows. This closed surface is globally nonorientable, namely it is a Klein bottle. Justification for vector-boson association with fig.2(d) requires attention to locally-oriented Σ_C chiral areas. The essentials of the ref.[2] chirality picture survive even though the chiral topology of refs.[1] and [2] has subsequently been amended [6]. The entire content of ref.[3] is compatible with a Klein-bottle vector boson.

Given the lepton and vector-boson topologies of figs. 2(f) and 2(d), it is natural to expect the $Y\bar{Y}$ closed surface of fig. 2(e) also to belong to an elementary particle. This particle would be a neutral scalar; since it might be identified with the Higgs boson which appears in gauge theories, we will call it the H particle. Electroweak Y-triangles are then uniformly Möbius bands while strong-interaction Y triangles are uniformly disks. I-triangles are disks in both hadrons and leptons but Möbius bands in vector bosons.

The triangle structure presented here yields the quartet of vector bosons employed in standard Weinberg-Salam electroweak theory [8], as well as the singlet H. With I- and Y-triangles as building units the Weinberg-Salam pattern does not appear arbitrary. We furthermore achieve (see fig.2) a unified pattern for the three types of hadron and for the three types of electroweak particles. Parallelism between baryons and leptons and between mesons and electroweak vector bosons has been noted long ago without appeal to combinatorial topology, although not in such a precise sense as achieved here. The TGU parallel structure for baryoniums and the H boson is a totally new idea.

The style of presentation here may suggest that the properties of I- and Y-triangles have been chosen so that simple combinations generate observed-particle quantum numbers. In point of fact the relevance of the constituent idea became appreciated well after stabilization of most elements in Topological Particle Theory. In particular, more than a year before recognition of their role as universal constituents the I- and Y-triangles were already part of the theory.

The fact that it is not quantum numerology but the bootstrap principle of self-consistency that leads Topological Particle Theory to describe physical phenomena in terms of universal constituents is not surprising. The constituent idea appeared in reaction to the proliferation of quarks, leptons and associated arbitrary parameters [9]. The essential virtue of the bootstrap principle is its elimination of arbitrariness.

Two positive qualitative features of TGU deserve mention : (1) No exotic states (e.g., spin 3/2 leptons) are predicted ; (2) The too-easy occurences of rare processes, a frequent difficulty of composites models [9], is avoided. For example it is natural for TGU to allow quark-generation mixing without lepton-generation mixing [4] , so processes like $\mu \rightarrow e \gamma$ will be rare if allowed at all. We anticipate that the precise topological definition of constituents, united with general features of the topological expansion, will lead to a rich array of phenomenological predictions.

A word of caution in closing : the triangle constituent viewpoint does not permit immediate transcription into Lagrangian form because triangles, lacking energy-momentum, are not localizable in space-time. A general connection with local field theory remains to be found although Feynman rules for lepton-photon interactions have been generated from Topological Particle Theory [2,7].

Acknowledgments

The nomenclature "I"- and "Y"-triangle has been suggested by Fritjof Capra, who stressed to us the beauty and universality of the 2-triangle picture. The authors also thank Drs. P. Gauron and J. Uschersohn for useful discussions.

This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

References

[1] G.F. Chew and V. Poénaru, Phys. Rev. Lett. 45 (1980) 229 ; Zeit. für Physik C 11 (1981) 59. Note that the Y pattern emerged, in connection with junction lines, only in the second of these two papers.

[2] G.F. Chew, J. Finkelstein, R. Mc Murray and V. Poénaru, Phys. Letters 100B (1981) 53 ; Phys. Rev. D24 (1981) 2287.

[3] G.F. Chew, J. Finkelstein and V. Poénaru, Phys. Rev. D24 (1981) 2764.

[4] G.F. Chew and V. Poénaru, LBL preprint 13842, to be submitted to Zeit. für Physik C.

[5] G.F. Chew and J. Finkelstein, LBL preprint 13322 (1981) ; J. Finkelstein, Zeit. für Physik C (to be published).

[6] G.F. Chew and J. Finkelstein, LBL preprint 13382 (1981), Zeit. für Physik C (to be published).

[7] G.F. Chew, J. Finkelstein and V. Poénaru, LBL preprint 13841, to be submitted to Zeit. für Physik C.

[8] S. Weinberg, Phys. Rev. Lett. 19 (1967) 1264 ; A. Salam, Proc. 8th Nobel Symposium, Stockholm, ed. N. Swartholm (1968).

[9] For recent reviews see e.g., M.E. Peskin, Cornell University preprint CLNS 81/516 (1981) ; M.A.B. Bég, Invited Plenary Talk at the International Conference on High Energy Physics, Lisbon, July 9-15, 1981, Rockefeller University preprint RU 81/B/9 (1981).

	N_I	N_Y	N
Baryon	3	-1	2
Lepton	-1	-1	-2
All other particles in fig.2	0	0	0

Table I : Net triangle content of the particles.

	S	Q	B	L
I_{ch}	1/2	+1	1/4	-1/4
I_{neut}	1/2	0	1/4	-1/4
Y_{ch}	0	+1	-1/4	-3/4
Y_{neut}	0	0	-1/4	-3/4

Table II : Quantum numbers of the universal I and Y constituents.

Figure Captions

Fig.1 The universal constituents :

(a) The I-triangle

(b) The Y-triangle

(the notations are the following : —— triangle edge, --- boundary (belt) of Σ_C , • end of charge arc).

Fig.2 Particle areas on the quantum surface :

(a) Meson (disk) as $\bar{I}I$ composite

(b) Baryonium (disk) as $II\bar{Y}Y\bar{I}\bar{I}$ composite

(c) Baryon (disk) as $II\bar{Y}I$ composite

(d) Electroweak vector-boson quartet (Klein bottle) as $\bar{I}I$ composites

(e) H scalar (Klein bottle) as $\bar{Y}Y$ composite

(f) Lepton (Möbius band) as $\bar{I}\bar{Y}$ composite

(x denotes end of momentum arc).

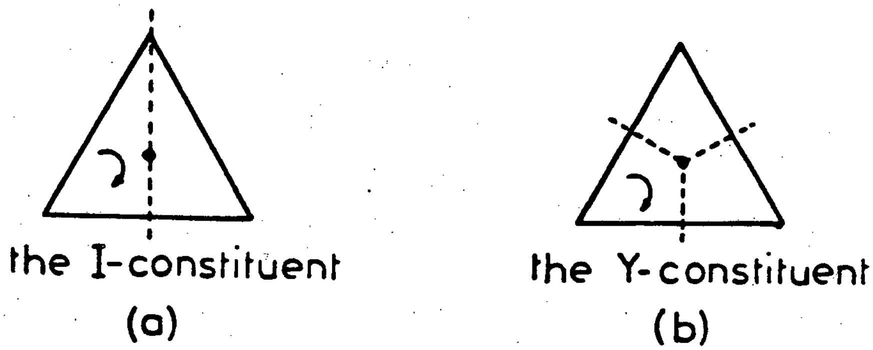

the I-constituent
(a)
the Y-constituent
(b)

Fig. 1

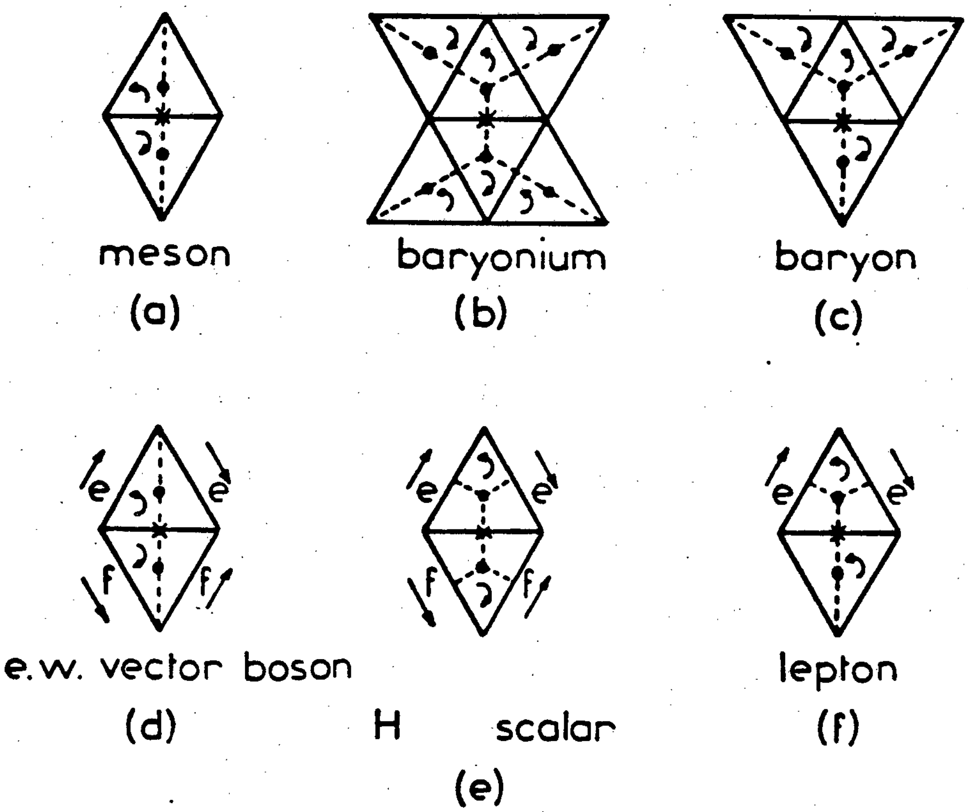

meson
(a)
baryonium
(b)
baryon
(c)
e
e
f
f
e.w. vector boson
(d)
H scalar
(e)
lepton
(f)

Fig. 2

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