Brief Reports

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Electrospin and broken SU(2) symmetry

G. F. Chew
Lawrence Berkeley Laboratory, Berkeley, California 94720
and Department of Physics, University of California, Berkeley, California 94720

J. Finkelstein*
Department of Physics, San Jose State University, San Jose, California 95192
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We identify within topological particle theory a broken SU(2) "electrospin" symmetry and enumerate a related collection of exact and approximate conservation laws. One component of electrospin, equal to $Q-\frac{1}{2}(B-L)$, is always conserved. The connection of electrospin with strong and weak isospin is discussed.

In this paper we discuss SU(2) symmetry within topological particle theory.[1] We identify within this theory a broken SU(2) symmetry, which we call "electrospin," and discuss its connection with both strong and weak isospin. We will point out that one component of electrospin has value equal to $Q-\frac{1}{2}(B-L)$, and so is exactly conserved.

By generalizing Harari-Rosner dual diagrams,[2] topological particle theory[3,4] associates each elementary particle with a collection of ends of oriented lines: The "quark lines" of dual diagrams are here called "fermion lines," and a meson contains the ends of two fermion lines, a baryon the ends of three, and a baryonium the ends of four. There are also "junction lines" of which a baryon has one and baryonium two. An elementary electroweak boson has a pair of fermion-line ends[5] (of opposite orientation, just like a meson) and an elementary lepton has a single fermion-line end together with a single junction-line end, of the same orientation.[6]

These lines can be considered to carry the spin (S), baryon number (B), and lepton number (L) of the particles, as shown in the following table.

(a) Quantum numbers carried by fermion and junction lines:

	S	B	L
Fermion line F^+	$\frac{1}{2}$	$\frac{1}{4}$	$-\frac{1}{4}$
Junction line J^+	0	$-\frac{1}{4}$	$-\frac{3}{4}$

(b) Elementary particles:

Hadrons		Nonhadrons	
Meson	F^+,F^-	Electroweak boson	F^+,F^-
Baryon	$F^+,F^+F^+J^-$	Lepton	F^-,J^-
Baryonium	$F^+F^+J^-,F^-F^-J^+$	H particle	J^+,J^-

Here F and J refer to fermion and junction line, respectively, and $\pm$ denotes the two possible orientations (+ is head of arrow, − is tail). The H particle is a neutral scalar whose status is uncertain.

In this paper we must also pay attention to another kind of line: Each end of a fermion or junction line is accompanied by the end of this third category of line which in the past has been called "charge arc" because of its control of particle electric-charge content.[7] The present paper identifies a broken SU(2) symmetry that motivates the recent Ref. 5 renaming of charge arcs as "electrospin lines."

Each electrospin line connects the head of a fermion or junction line to the tail of a fermion or junction line. In accord with Ref. 5, we characterize the orientation of an electrospin line as c ("charged") if it *agrees* with the orientation of the fermion or junction lines at its ends (agreement at one end ensures agreement at the other). The fermion- or junction-line end then can be said to transport +1 unit of electric charge in the direction of the line orientation.[7] If the electrospin orientation *disagrees* with that of the fermion or junction lines near its ends, these line ends are electrically neutral—designated n. Any fermion-line end can be either charged (c) or neutral (n).[5] Elementary particles, being "built" from the ends of fermion and junction lines, carry a quantity of electric charge which for an outgoing particle is equal to N^c, where N^c is the total number of outgoing charged lines minus the total ingoing number. N^c is an absolutely conserved quantum number that labels *physical* particles as well as elementary particles.

In all strong-interaction (purely hadronic) topologies and in topologies that represent interaction *among* nonhadrons, electrospin lines with one end belonging to a fermion line invariably have the other end also fermionic, and one recognizes a $c \leftrightarrow n$ fermion symmetry: Each fermion electrospin line may be independently reversed in orientation without affecting the amplitude. Such a discrete symmetry, which correlates two oppositely oriented ends of fermion lines, was shown by Paton and Chan[8] to imply a continuous SU(2) symmetry in a Hilbert space where the *bra* vectors are direct products of $\{^c_n\}$ vectors attached, each, to the head of a fermion arrow, while *ket* vectors similarly are built from fermion tails. The set of 3 SU(2) generators we describe as electrospin and denote by

$$\vec{E}=(E_1,E_2,E_3) \ , \tag{1}$$

where E_3 is diagonal in the topological basis, with eigenvalues

$$E_3=\tfrac{1}{2}(N_f^c-N_f^n) \ , \tag{2}$$

if $N_f^{c,n}$ is the total number of outgoing (c,n) fermion lines building the particle minus the ingoing number.

The electrospin orientation of a nonhadronic junction line (both ends) is always n,[6] while that of a hadron junction line is always c^3 (see table). Because the electrospin orientation of a junction line cannot be reversed, full SU(2) (fermionic) symmetry depends on no fermion lines having electroconnection to junction lines. But with *any* electroconnections the quantity (2) remains conserved,[9] corresponding to unbreakable symmetry with respect to rotations about the 3 axis in electrospin space.

It is possible (see table above), because fermion-line ends effectively carry conserved topological quantum numbers in addition to N^c,[10] to break E into "quark," lepton, and electroweak-boson components,

$$\vec{E}=\vec{E}^q+\vec{E}^l+\vec{E}^b \ , \tag{3}$$

and, further, to decompose $\vec{E}^q$ and $\vec{E}^l$ according to generation G:

$$\vec{E}^{q,l}=\sum \vec{E}_G^{q,l} \ . \tag{4}$$

For topologies where all lines (external and internal) belong to elementary hadrons, junction lines have no electroconnection to fermion lines and the electrospins E_G^q are separately conserved, corresponding to separate $SU(2)_G^q$ symmetry groups.

Such purely hadronic topologies are further characterized by generation symmetry, which when combined with $(c \leftrightarrow n)$ symmetry gives rise to an $SU(N_f)$ symmetry, where N_f (number of flavors) $=2\times$ number of generations. For *physical* hadrons there is breaking of generation symmetry, and the *topological* index G need not correspond to the "physical-quark" generation index (up-down, charmed-strange, etc). One may therefore not identify "strong isospin" with an individual $SU(2)_G^q$, although the dimensionality of the respective Hilbert spaces is the same. Whether physical and topological quark generations are connected by a "Cabibbo rotation" is presently unknown.

For topologies in which all lines belong to elementary leptons and electroweak bosons, each fermion line may be classified as being either left or right handed; and for these topologies we have separate $SU(2)_L$ and $SU(2)_R$ symmetry groups. When restricted to these particles, this $SU(2)_L$ coincides with the standard-model "weak isospin."[11]

The full electrospin E is conserved for any topology that lacks electrocoupling between junction lines and fermion lines. The third component of total electrospin is always conserved and thereby attaches to physical as well as to elementary particles. For any particle, formula (2) above together with Ref. 10 (or table above) yields

$$E_3=Q-\tfrac{1}{2}(B-L) \ , \tag{5}$$

where Q, B, and L are, respectively, electric charge, baryon number, and lepton number.

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*Participating guest at Lawrence Berkeley Laboratory.

[1]This paper simplifies the exposition and expands the content of Report No. LBL-14225, 1982 (unpublished).

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