Generalizing "Charge without Charge" to Obtain Classical Analogs of Short-Range Interactions

Mark F. Sharlow

ABSTRACT

Several decades ago, Wheeler and Misner presented a model of electric charge ("charge without charge") based on the topological trapping of electric field lines in wormholes. In this paper, which does not argue for or against the "charge without charge" concept, I describe some generalizations of this model which might serve as topological analogs of color charges and electroweak charges.

Cautionary note to the reader

As the reader probably already knows, there has been a great deal of scientifically unsupported speculation about wormholes and related topics, both on the Internet and in the popular literature. In writing this paper, I do not mean to fuel this kind of speculation. I mean only to present the much more conservative idea summarized in the paper's abstract. Judging by the experimental evidence available today, there currently is no evidence that the topological models presented in this paper are directly relevant to particle physics. Like any classical analogs of quantum phenomena, these models may nevertheless be physically or mathematically interesting. Those who are interested in the scientific precedents for the ideas presented here are welcome to examine the references cited in the paper.

1. Introduction

Several decades ago, John A. Wheeler [1955] proposed a physical model for electric charge that portrayed charge as the result of the topological trapping of electric field lines in wormholes. Wheeler and Charles W. Misner later championed this model ([Misner & Wheeler, 1957]; [Wheeler, 1957]; [Wheeler, 1962]; [Wheeler, 1968]; [Misner et al., 1973]) and described it as "charge without charge" [Misner & Wheeler, 1957]. One aspect of this model was the suggestion that the charges on elementary particles might arise from the presence of short-lived wormholes throughout space at the Planck scale, $\sim 10^{-35}$ m ([Wheeler, 1957]; [Wheeler, 1968]; [Misner et al., 1973]). The "charge without charge" concept became the object of much discussion and research; in the 1980s, a generalization to Kaluza-Klein theory was proposed [Kalinowski and Kunstatter, 1984]. The idea of "charge without charge" is less popular today, partly because of certain conceptual difficulties (see [Sharlow, 2004b] for a summary) and partly because of the great popularity of string theory, in which the idea plays no part. Nevertheless, "charge without charge" continues to be the subject of discussion and speculation. At very least, "charge without charge" can be thought of as an interesting classical analog of real electric charge -- regardless of what one thinks of its relationship to the actual charges of particles.[1]

In this paper, I will not argue for or against the concept of "charge without charge." Instead, I will explore some ways in which this concept might be extended to provide topological analogs of charges besides electric charge -- specifically, the color charge of QCD and the charge that appears in the Weinberg-Salam theory of electroweak interactions. This endeavor is of interest regardless of whether one takes "charge without charge" seriously; at very least, one can think of the generalized models given here as classical analogs of microscopic physical phenomena. Such classical analogs sometimes turn out to be instructive.

I wish to warn the reader that what I am doing here is highly speculative in some respects. To make the generalized models work, I will have to make some physically plausible assumptions about the behavior of wormholes. Given the present state of our knowledge of wormholes (none yet detected!), such assumptions undeniably are speculative.

2. Wormhole Mouths with Multiple Throats

The key to the models presented here is the concept of a wormhole mouth that has *multiple throats*. Figure 1 illustrates such a wormhole mouth. Intuitively, we might think of this object as the result of letting two wormhole mouths fall into a third wormhole mouth without collapse of the throats, so that we end up with a mouth that leads into three throats. A topologist might prefer to think of this object as the result of a cut-and-paste operation involving the splicing of three handles on to a 3-space in such a way that one end from each handle is spliced into the same place.

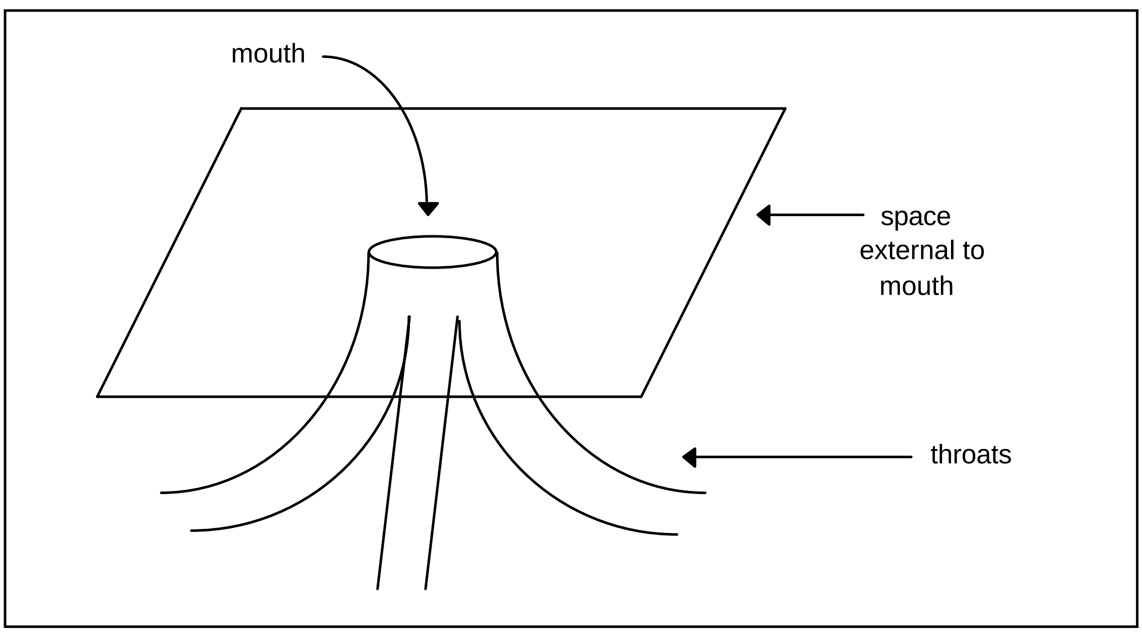

Figure 1. A wormhole mouth with multiple throats.

(*A note on the illustrations in this paper:* Figure 1, like the other illustrations depicting wormholes, is highly schematic. As is customary in drawings of wormholes (see [Misner & Wheeler, 1957]), one space dimension is suppressed, the plane surface around the wormhole mouth represents the space external to the wormhole, and the third dimension in the drawing has no physical significance.)

The issue of the compatibility of this construction with classical general relativity is significant, but not crucial for our present purpose. Some mathematical constructions of wormholes (discussed in [Visser, 1994]) yield wormholes which do not end in black holes. In any case, we do not know enough about quantum gravity to say with confidence which wormhole geometries are stable, especially when dealing with tiny wormholes.

Setting aside the question of the exact geometric structure of these wormholes, we will suppose throughout this paper that there can be wormhole mouths with multiple throats. We will call a mouth with n throats an n-*hole*. If n = 2 or 3, we will call the n-hole a *dihole* or a *trihole* respectively.

Once we have assumed that n-holes are possible, we can ask what kinds of changes an n-hole can undergo. In particular, we can ask whether an n-hole can dissociate into separate wormhole mouths, as shown in the cartoon in Figure 2. (Note that this dissociation process is *not* necessarily an instance of the bifurcation of a black hole, which is impossible in general relativity [Misner et al., 1973].)

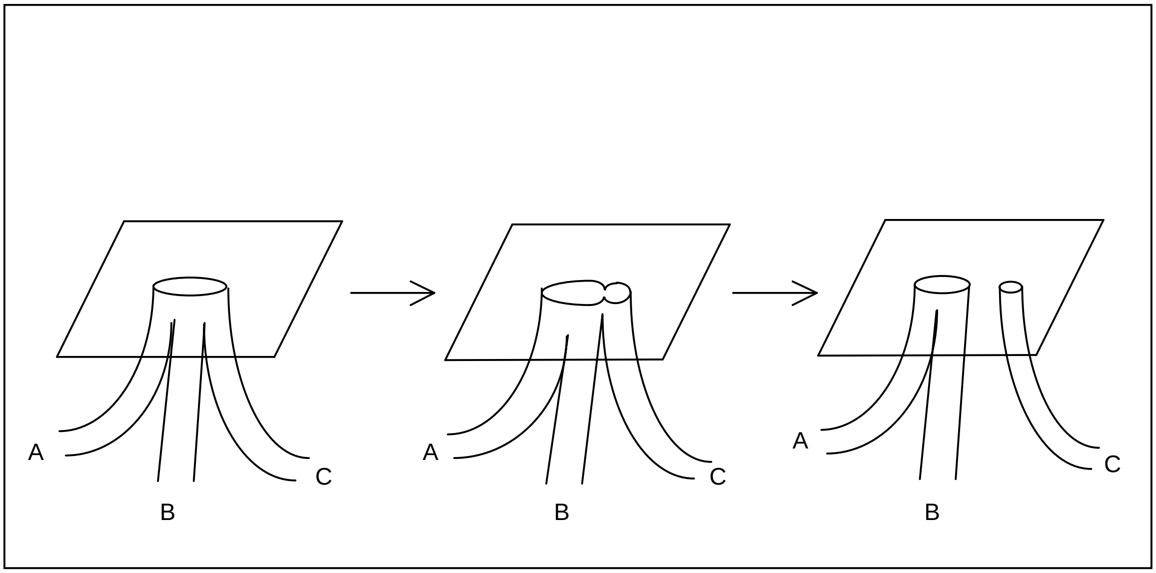

Figure 2. Dissociation of a trihole.

We really have no right to make any assumptions about the physical possibility or the energetics of this process, since we know little about the laws governing spacetime geometry at the scale of these objects. However, if we think of wormhole mouths as gravitating objects of some sort, then we can guess that the separation of one mouth from another, as in Figure 2, might require a lot of energy. Here we will enshrine this handwaving argument in a qualitative assumption, which we hope is not too implausible. We will assume that at the energies of present-day particle physics, the process shown in Figure 2 cannot happen.

> *Assumption 1.* At the energies available to present-day experimental particle physics, an n-hole cannot dissociate directly to yield a free single-throated wormhole mouth.

Even with this assumption in effect, there is a possible mechanism by which a single wormhole throat might become detached from an n-hole. This mechanism requires us to assume a well-known idea about spacetime topology in the small: namely, the idea that microscopic wormholes are constantly being created and annihilated throughout space.

This is the well-known idea of "spacetime foam" (see [Wheeler, 1957]; [Wheeler, 1968]; [Misner et al. 1973]; and [Visser, 1994] (who uses the terminology)). If n-holes really are more stable than separate wormhole mouths, as we have assumed, then we would expect the wormholes in spacetime foam to consist mainly of n-holes and not of isolated wormhole mouths. Statistically speaking, diholes should be the most abundant n-holes in the foam, because the formation of a dihole only requires the collision of two mouths. If this guess is correct, then space is filled with a background of transient diholes. (One can think of these diholes as "virtual particles," though they might not be virtual particles in the correct, field theoretic sense.) These diholes may be "open," with the two mouths belonging to different wormhole throats, or "closed," with the two mouths belonging to the same throat. (See Figure 3.)

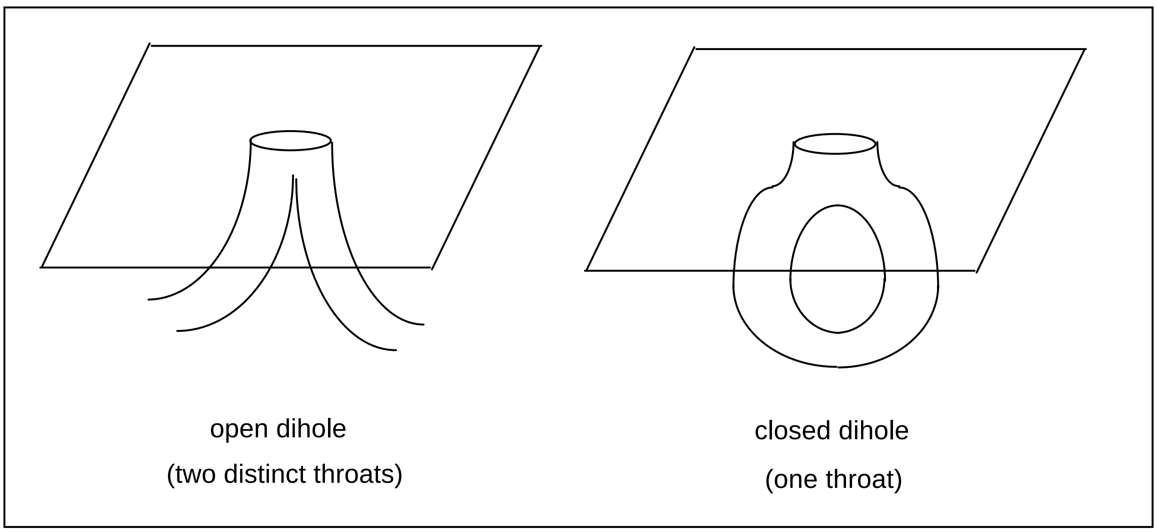

Figure 3. Two kinds of diholes.

The composition of this sea of n-holes depends upon the details of mechanisms of topology change in spacetime. We will not study this mechanism here. However, it has been suggested [Sharlow, 2004a] that topology change may occur mostly through the creation and annihilation of closed diholes. If this is the case, then we would expect the sea of n-holes to consist mostly of closed diholes. This detail will not be important throughout most of this paper, but will come up once later on.

If we assume that space contains a sea of diholes, then the process shown in Figure 4 would be plausible: a trihole exchanges a single throat with a dihole, resulting in a new final trihole and dihole. Note that in Figure 4, the final trihole ends up with a set of throats *different* from the ones in the initial trihole -- and likewise for the initial and final diholes. This difference could have significant consequences: for example, if one of the wormholes in the trihole is charged (as per "charge without charge"), then this charge might end up in the dihole, resulting in a kind of charge exchange between n-holes.

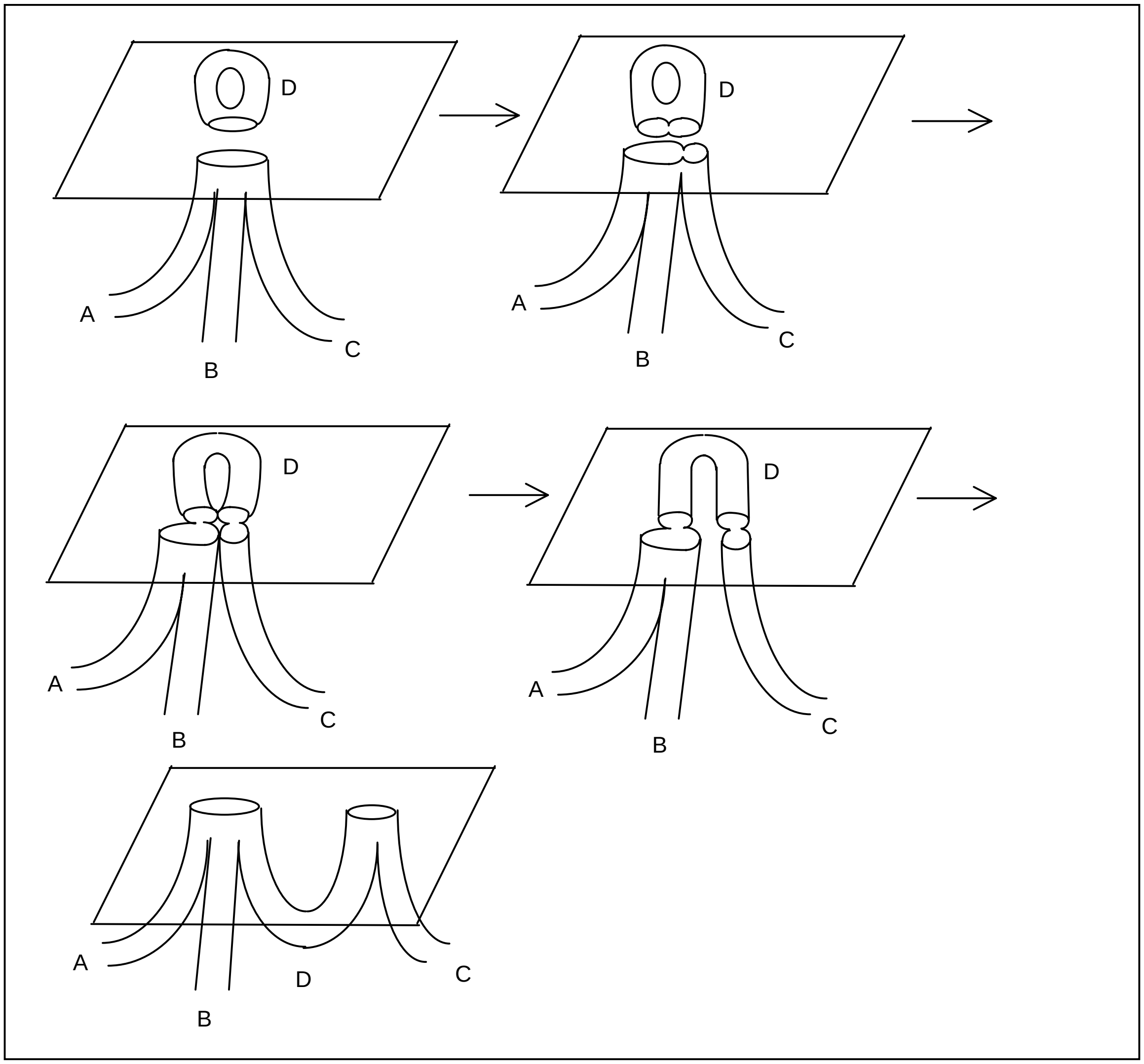

Figure 4. Dissociation of a trihole: an alternative pathway. (The fact that wormhole D sometimes points up instead of down is merely a graphical convenience.)

3. An Analog of Color

The following argument suggests a way in which the mechanism shown in Figure 4 might give rise to a kind of "charge" rather different from the one that Misner and Wheeler studied. This kind of charge involves trapped vector fields, but the role of the trapped fields is very different from the usual "charge without charge" scenario.

Consider a particular family of trihole states: the set of triholes in which exactly one throat has a trapped massless vector field as per "charge without charge." For now, we will simply ignore all other triholes besides these. Suppose that, in addition to the electromagnetic field, there are four distinct vector fields -- each of them a Maxwell field, but possibly with different couplings. (Normally we think of a Maxwell field as an electromagnetic field, but actually the Maxwell lagrangian is the simplest choice for a lagrangian of a massless vector field.) Call these four new fields S, T, U and V. These fields do not resemble anything observed in nature; however, we will see later that if these fields really existed, they might be difficult to observe.

When the fields S, T, U and V are trapped in wormholes, they give rise to effective charges, as per "charge without charge." However, since the fields are not electromagnetic, these four kinds of charges are distinct from electric charge. Let us denote these charges by the lower-case letters s, t, u and v respectively. (We reserve q for electric charge.)

Since S, T, U and V are classical Maxwell fields, the formalism of classical free field electrodynamics can be applied to them. The ideas of "charge without charge" also can be applied to them: for example, a wormhole with a trapped S field will appear, to a coarse-grained observer, to have an s charge at each end, and these two charges will be different and may be labeled with opposite signs. We can label charges of types s, t, u and v as positive or negative after selecting a positive reference charge for each of the charges s, t, u and v.

Note that in an n-hole, each throat may trap fields separately. Hence each throat in an n-holemay contribute a positive or negative charge of type s, t, u or v to the n-hole. Because of this, an n-hole may have various combinations of the charges s, t, u and v, with either sign. These last two statements will be important in the rest of this paper.

Now we will make an important stipulation about the set of wormholes that we wish to consider. We will arbitrarily restrict attention to wormholes which, if they contain trapped fields S, T, or U, *also* contain trapped field V, *and with the same mouth positively charged for both of the trapped fields*. This means, for example, that a wormhole which contains a trapped T field also must have a trapped V field, with the +t mouth also being the +v mouth. However, a wormhole with no trapped S, T or U field does not have to have a trapped V field. We also will arbitrarily restrict attention to wormholes that have a V field without one of the fields S, T, U.

These restrictions on the set of wormholes are completely arbitrary. There does not appear to be any physical argument or plausible assumption that we can make to motivate these restrictions. For now, the only rationale for these restrictions is that they will make our model come out nice in the end. Perhaps if we understood the mass spectrum and stability of triholes more thoroughly, we could find some real reason for restrictions like these. (Are the states left out too unstable? Too massive to observe?) For now, we will just ignore states that don't obey these restrictions.

Now we will make a further assumption about the stability of n-holes:

> *Assumption 2.* There are no stable diholes in which each mouth has the same sign of one of the charges s, t, u or v.

This means, for example, that if one pushes together two mouths with positive s, one does not get a stable dihole. This assumption has some plausibility by analogy with electrostatics (recall that S, T, U and V are Maxwell fields, and hence behave formally like electromagnetic fields). However, for the triholes that we are considering, Assumption 2 also has another consequence. For the family of triholes that we are considering, any mouth with positive s, t or u charge will also have a positive v charge -- and likewise with "positive" replaced by "negative." Thus, if we put together mouths with *any* two positive charges selected from the set {+s, +t, +u}, or with *any* two negative charges selected from the set {-s, -t, -u}, then we will not get a stable dihole. For future reference, we will give this corollary of Assumption 2 a name.

> *Rule 3.* There are no stable diholes in which each mouth has the same sign of one of the charges s, t, or u.

Imagine a trihole in which one throat has a trapped S field. Assume for concreteness that the trihole has a +s charge. The charged throat can dissociate from the trihole via the mechanism shown in Figure 4. Now suppose that the initial closed dihole involved in this mechanism also has a trapped S field. The open dihole in the final state must have two throats that contribute opposite s charges (this follows from Rule 3). Thus, the -s end of the initial dihole must end up with the dissociated +s end of the throat from the trihole, leaving the +s end of the initial dihole to end up in the final trihole. Thus, the final state will contain a trihole with a +s charge (like the initial trihole), plus a dihole with a trapped S field in each throat and a net charge of 0. (See Figure 5.)

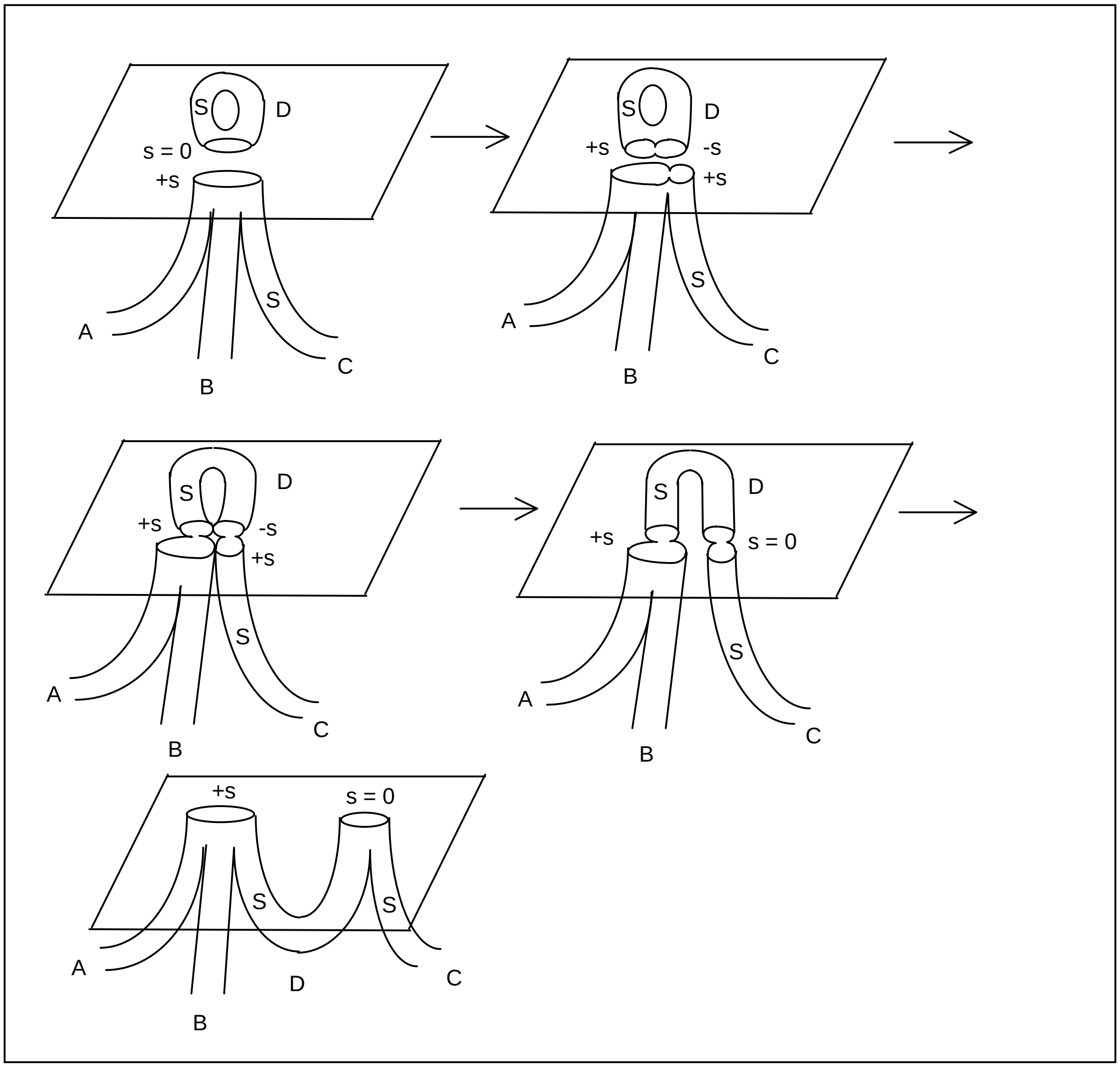

Figure 5. Dissociation of a trihole with a trapped field. Throats with trapped S fields are labeled with an S. The symbols +s, -s and s = 0 near the mouths represent the s charges of the mouths.

Now imagine a similar scenario with the same initial trihole, but with an initial closed dihole having a trapped T field. (This is depicted in Figure 6.) We can analyze the outcome of this scenario by analogy with the first scenario above. The +s end of the dissociating throat from the trihole will end up associated with the -t end from the original dihole (not with the +t end, on account of Rule 3). Thus, the final dihole will have both a +s charge and a -t charge. The final trihole will have a +t charge.

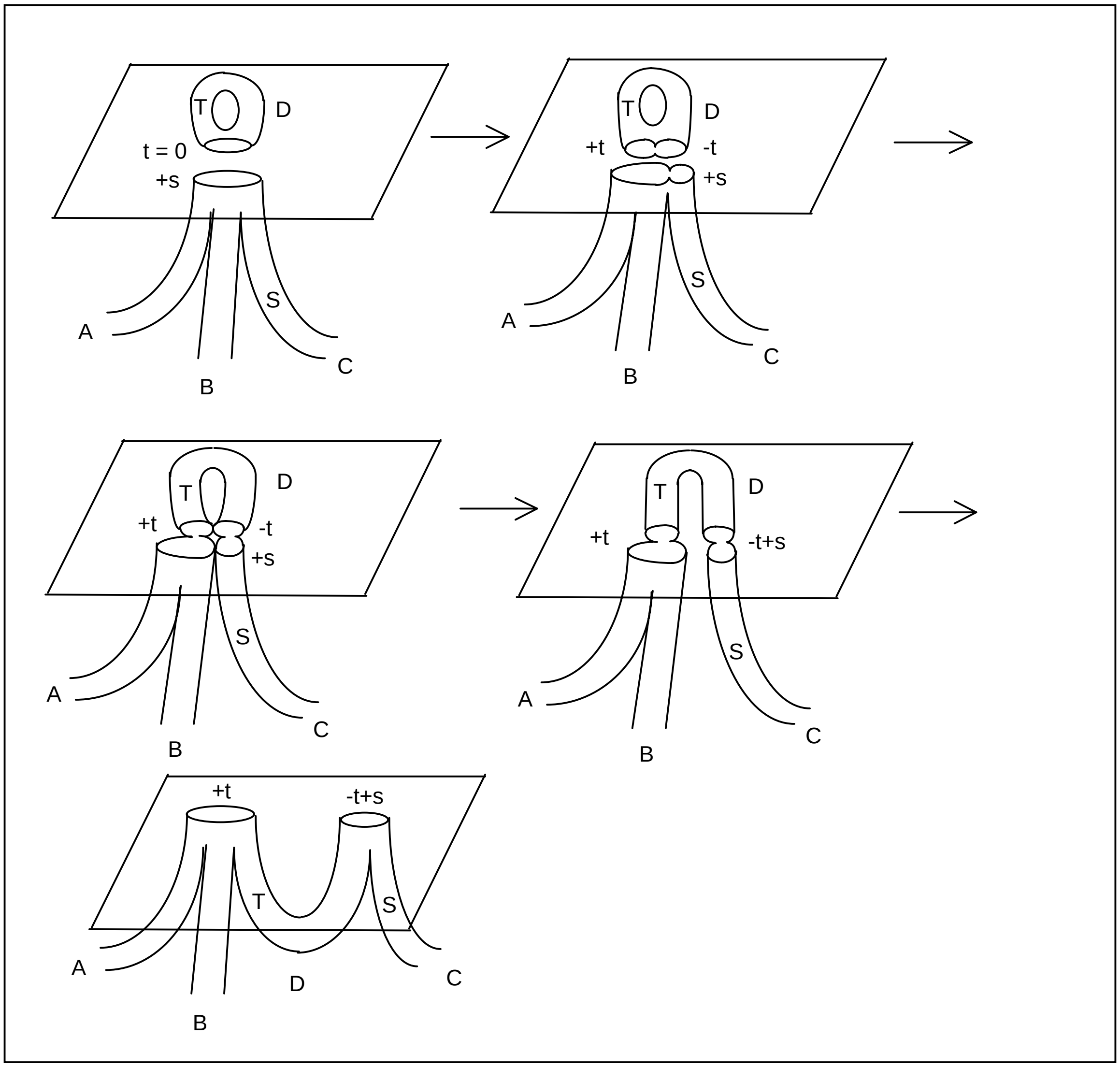

Figure 6. Dissociation of a trihole with a trapped field. Throats with trapped S or T fields are labeled with an S or T. The symbols +s, -s, and s = 0 represent the s charges of the mouths (and similarly with t in place of s). The symbol -t+s denotes a mouth with both a -t charge and an s charge.

Overall, the process we are considering will look as follows: a trihole with positive s charge emits a dihole having both positive s charge and negative t charge, leaving behind a trihole with positive t charge.

In the next few paragraphs, we will examine a few more possible processes involving triholes and diholes. It will help to have a compact notation for the various n-hole states. Where X = s, t or u, a "+X trihole" is a trihole having positive charge X in one throat, and no other s, t or u charges. Thus, there are +s triholes, +t triholes, and +u triholes. Similarly, a "-X trihole" is a trihole having a negative X charge. Thus, there are -s triholes, -t triholes, and -u triholes. Where X = s, t or u, and Y = s, t or u, a "+X-Y dihole" is a dihole in which one throat contributes a positive X charge and the other throat contributes a negative Y charge. Thus, there are +s-s diholes, +s-t diholes, etc. Rule 3 forbids some combinations of diholes, such as +s+s and +s+t (the latter is forbidden because of the v charges, which are not shown in the notation).

Using this notation, we can describe the process in Figure 6 as follows: a +s trihole emits a +s-t dihole, leaving behind a final +t trihole. The only other particle involved in this process is the initial +t-t dihole, which is part of the background sea of transient diholes.

We also can picture a process of dihole *absorption* analogous to the process of dihole emission just described. This is pictured in Figure 7. In this process, a +s trihole absorbs a -s+t dihole, resulting in a +t trihole and a +s-s dihole. This last dihole might persist in the virtual wormhole sea; alternatively, it might be annihilated by whatever mechanism is responsible for topology change (since there are no charge conservation laws to forbid such a transition).

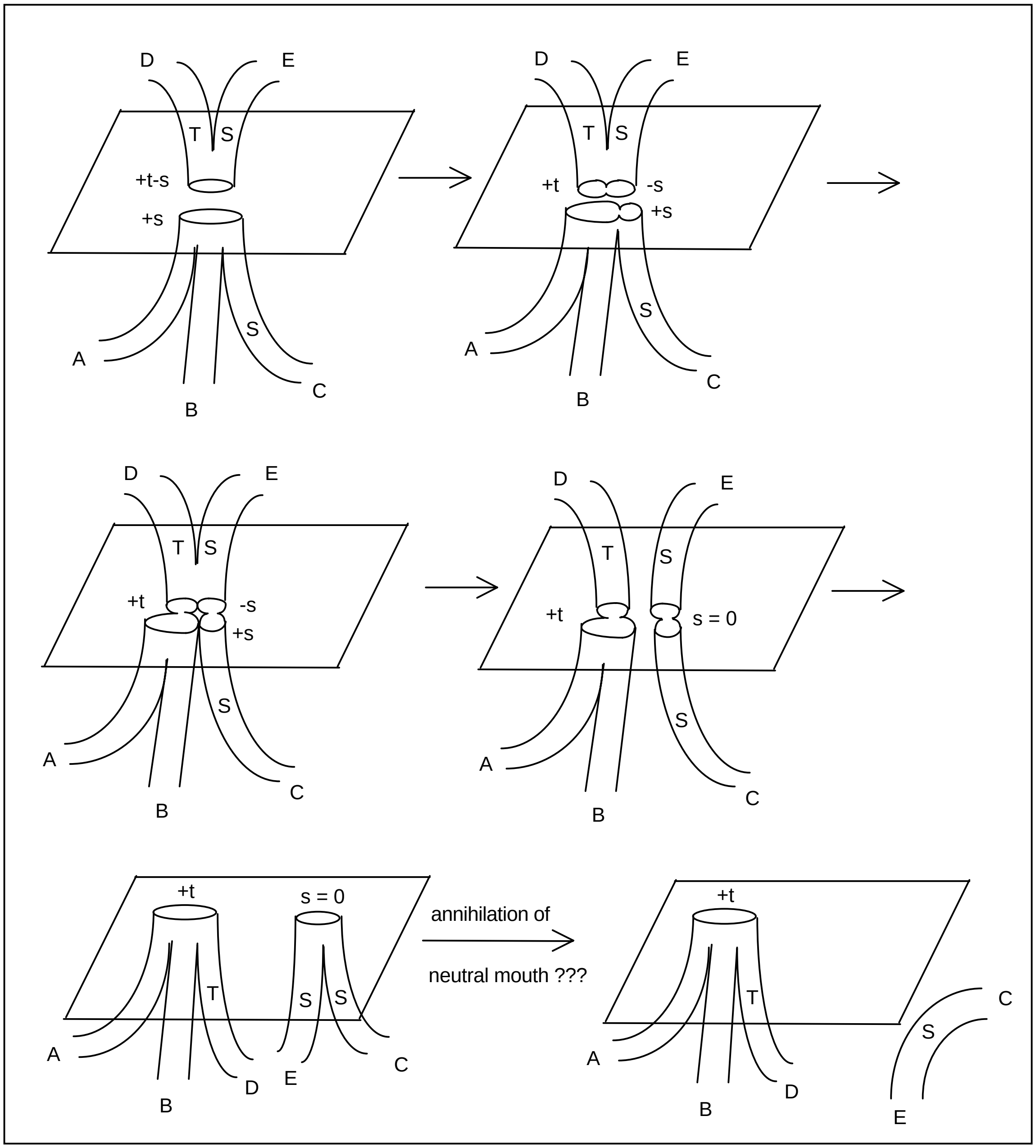

Figure 7. Absorption, by a trihole, of a dihole with trapped fields. (The notation for trapped fields and charges is the same as in Figure 6.)

Further, it is possible for two diholes to interact with each other via processes similar to their interactions with triholes. One example (an absorption process) is given in Figure 8.

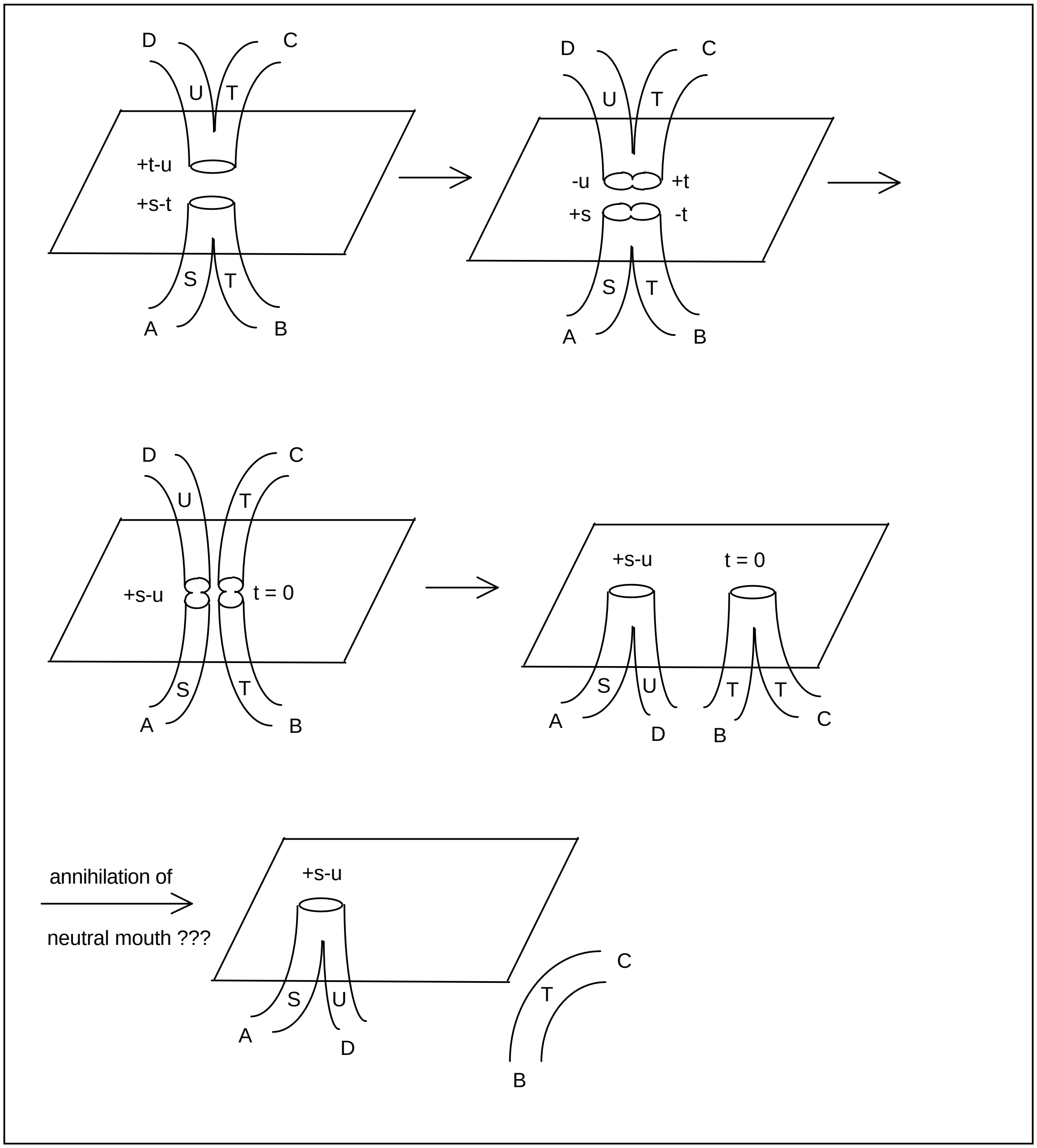

Figure 8. Merging of diholes with trapped fields. (The notation for trapped fields and charges is the same as in Figure 7, except here the fields are S, T, and U.)

Needless to say, all of the above processes for n-holes with charges s and t can occur with any two distinct charges from the set {s, t, u} in place of s and t. Also, the same processes can occur with the positive and negative signs interchanged consistently throughout the process.

Summing all this up, we get the following overall picture of the behavior of the restricted family of triholes and diholes that we have been considering.

(1) Each trihole may carry one of three different charges (s, t and u; we don't need to consider the v charge separately, because it only "rides along with" these other charges). Each of these three charges can have either of two signs (positive and negative -- or, if you prefer, "charge" and "anticharge").

(2) The triholes interact with each other through the emission and absorption of diholes, each of which bears a charge and an anticharge. This interaction can change the kind of charge present on the trihole (for example, changing +s to +t).

In its broad outlines (though not in detail), the behavior of the particular triholes and diholes has begun to look somewhat like the interaction of quarks and gluons in QCD. The correspondence, which as yet is very far from exact, is visible if we make the following identifications:

quark: trihole
gluon: dihole
colors: charges +s, +t or +u
anticolors: charges -s, -t, or -u

The most glaring gap in this very rough correspondence is that the number of gluons is wrong. In our picture, there are 9 possible "gluons," each having a "color" and an "anticolor." Also, there is no hint of anything like SU(3) symmetry, which is crucial to QCD. However, our picture of the behavior of these topological objects is not yet complete. Two more important details need to be considered.

So far, we have not made any assumptions about the relative energies of wormhole mouths having s, t and u charges. If we assume that the S, T and U fields are very much like each other, so that n-holes having the charges s, t and u but identical in other respects are degenerate, then the physics of n-holes with these charges will be symmetric under the replacement of any two of the charges by one another. If we could quantize these n-holes so that they are described as particles with associated fields,[2] then this symmetry would induce a symmetry on the lagrangian of the fields. This symmetry of the lagrangian is physically rooted in the interchangeability of the three "colors," and hence might well turn out to be SU(3), although of course we have not proved this conclusion.

If such a symmetry existed, then the fields describing the "white" diholes +s-s, +t-t, and +u-u would have to be mixed in the way familiar from QCD. Our model, as it stands, does not provide a mechanism for this mixing, but it suggests a possible mechanism. The degeneracy of the three kinds of white diholes leaves open the possibility that these diholes can change into each other. One way that this could happen is for a dihole to be annihilated and a new (closed) dihole created. (This could not happen with colored diholes, for which the breaking of trapped field lines would result.) This would lead to mixing among the three white dihole fields. The possibility of this mixing depends upon the details of the dynamics of spacetime geometry, so we cannot assess this possibility.

Earlier I said that the fields S, T, U and V might be difficult to observe in practice. This would be the case if these fields existed only in close association with particles that couple more strongly to other fields. If we think of the triholes and diholes as quarks and gluons, then the S, T, U and V fields would exist only in association with strongly interacting particles. If the couplings of these fields were much weaker than that of the strong force, then they might give rise to small corrections to QCD that are hard to detect. Further, the forces due to these fields surrounding quarks and gluons might be screened, Debye-style, by the s, t, u and v charges on virtual quarks and gluons. This might make the S, T, U and V fields even more difficult to detect.

Of course, our classical model of "quarks" and "gluons" still does not resemble real quarks and gluons very closely at all. We do not even know what the spins and electric charges of the quarks and gluons are. To begin to address this question, we must look at the possible charge and spin states of triholes.

4. Electric Charges of Multi-throated Wormholes

Each throat of a trihole can trap the electric field; hence a trihole can have its own electric charge. In previous sections we restricted our attention rather arbitrarily to limited families of n-hole states. We will now do this again. This time, we will consider only triholes in which each throat contributes an electric charge of either 0 or ±1/3. Here we deal with *electric* charges; in this section, we ignore the hypothetical charges s, t, u, and v, and the trapped fields that produce them. The restriction to throats with charges 0 or ±1/3 arbitrarily eliminates a great many possible trihole states; we do not have any a priori reason for eliminating these, but it will be convenient to focus attention on the states with charge 0 or ±1/3 for the time being. (If we knew more about the physics of triholes, perhaps we could cook up better reasons for ignoring these states -- reasons like instability or excessively high mass. Also, we would have to ask whether the charges of wormhole mouths are quantized.)

Under this restriction, a trihole can have a variety of charge states. There can be a trihole having three throats with charge 0; a trihole having two throats with charge 0 and one throat with charge +1/3; a trihole having one throat with charge 0 and two throats with charge -1/3; and so forth. We adopt the following notation for trihole charge states: (q_1 q_2 q_3) denotes the state in which the throats have charges q_1, q_2, and q_3. In this symbol, we will abbreviate -1/3 and +1/3 to - and + respectively; thus, (0 + -) is a trihole whose throats have charges 0, +1/3, and -1/3. Note that this symbol is symmetric under permutations of the throats (for example, (0 - 0) = (- 0 0)).

There are several resemblances (admittedly very superficial) between the triholes just discussed and the particles of a single generation in the Standard Model. First, there is a trihole with charge -1, namely (- - -). If we look only at the charge of this trihole (and ignore its other properties), then we can say that this particle resembles a lepton. The corresponding positive state, (+ + +), then corresponds to the antilepton. There also are two neutral particles, (0 0 0) and (0 + -). These resemble the neutrino and antineutrino, at least in their electric neutrality, and in the fact that the two particles are not quite symmetric to each other in some respects. Finally, there are four other triholes with fractional charges: (+ + 0) (- 0 0) (- - 0) (+ 0 0). These have the same charges as the u and d quarks and the u and d antiquarks, respectively. There also are states (+ + -) and (- - +), which we will ignore for the time being -- just as we have ignored many other possible n-hole states.

Presumably, we could model multiple generations of particles by assuming that all of these triholes exist in several different mass states. However, a prediction of the ladder of states would require far more knowledge of quantum wormhole physics than we now have.

These trihole states that I have just described bear a vague resemblance to the fermions of the Standard Model. Of course, the resemblance is still very, very vague, and there are many gaps and loose ends -- quite apart from the restrictions on charge, the two ignored states, and the undetermined number of generations. (For example, we have said nothing about the spins of the particles; we do not even know that they are fermions. Also, we have not said why only the particles with fractional electric charges have color.) We will not try to close these numerous gaps here. To do so, we would have to know much about the energetics of the states involved, and perhaps about other things as well.[3]

5. Modeling Electroweak Charges

There is another way in which a trihole might emit an n-hole. This way does not involve any extra trapped fields, like the fields S, T and U described in an earlier section. Instead, it just involves electrically charged n-holes. In this section, we will ignore the possible presence of s, t and u charges and will examine other features of triholes.

First, consider the trihole (- - -), which we identified in Section 4 as an analog of the electron. Once again, we adopt Assumption 1, and we assume that a process like the one shown in Figure 4 is possible. Applied to the trihole (- - -), this process could convert the trihole (- - -) into another (- - -) trihole, or, perhaps more interestingly, into a (+ - -) or a (0 - -) trihole. However, we can envision an alternative process in which the throats in the trihole dissociate all at once, instead of dissociating one at a time. The dissociation of each throat would take place via a mechanism like the one in Figures 4. Each departing throat would pair up with one end of a sea dihole, resulting in a new dihole; the remaining ends of the sea diholes would remain behind in the trihole. (This is just the dissociation process from Section 3, repeated three times and without the charges s, t and u.) The resulting process can be written as:

(- - -) + 3 (- +) from background $\rightarrow$ (- - -) + 3 (- +)

Now what if a wormhole mouth with *six* throats were more stable than three separate diholes? To assume this would be no more venturesome than assuming that triholes are more stable than single mouths. If this were the case, then the three diholes in the final state would tend to combine, giving rise to the following net process (with the sea diholes not shown):

(- - -) $\rightarrow$ (- - -) + (- - - + + +)

The object on the right is a mouth with six throats -- a "hexahole."

There are many other conceivable processes of this sort -- for example,

(- - -) → (0 0 0) + (- - - 0 0 0)

(+ + +) → (0 0 0) + (+ + + 0 0 0)

(- - -) + (0 0 0 + + +) → (0 0 0) + (- - - + + +)

... etc.

Earlier we suggested that triholes with net charge 0 and ±1 are analogous to leptons in some respects. If we restrict our attention only to these triholes and the hexaholes that they can emit, then the resulting set of particles looks, in its broadest outlines (though not in detail), like the leptons and the W and Z bosons. Here is the correspondence:

leptons: triholes

W bosons: charged hexaholes

Z boson: neutral hexahole

Note that there are two possible hexahole states corresponding to the Z boson: (0 0 0 0 0 0) and (- - - + + +). Conceivably these might be rapidly interconverted by topology change -- as were the "white" diholes in Section 3. Note that the hexahole state (0 0 0 0 0 0), if it had spin 1, would resemble a photon, inasmuch as it is a spin 1 geometric object, massless (at least in the absence of any Higgs mechanisms), and without any trapped fields. One can ask whether the mixing of B and W_3 fields in the Weinberg-Salam theory, resulting in the physical A and Z fields, might have any analogy with this similarity. For example, could the formal fields B and W_3 actually be thought of as mixtures of fields corresponding to these neutral hexaholes, with interconversion of the (- - - + + +) and the (0 0 0 0 0 0) hexaholes taking place by some mechanism like the one that mixed the "gluons" in the last subsection? If we could quantize spacetime and wormholes, then perhaps a vector field associated with a neutral hexahole could serve as the electromagnetic field which other wormholes can trap. But it is much too early to know whether these questions even make sense, or to ask any questions about the precise relationship between this picture and the Weinberg-Salam model -- given that we have not yet made our picture quantitative at all, and that we know nothing about the energetics of the n-holes.

We have not yet tried to find n-hole states analogous to the Higgs bosons. Given the abundance of possible n-hole states, it should not be difficult to find potential candidates. One could try to find topological processes corresponding to the "eating" of Higgs bosons -- but it also might be fruitful to ask whether a Higgs mechanism is necessary in a model of weak forces based on spacetime topology, in which the gauge symmetries are only derivative.

6. Concluding Remarks

The extensions of "charge without charge" that I have presented in this note are intended to serve as topological analogs for the charges of the strong and electroweak interactions. These qualitative models are much too tentative, incomplete and gappy to be thought of as anything more than that. Further, these models are entirely classical; the question of their quantization, and of the effect upon them of the quantization of spacetime geometry, have not been addressed at all (but see [Sharlow, 2003], [Sharlow, 2004a] and [Sharlow, 2004b] for ideas that may be useful in this regard). Nevertheless, the rough correspondence between wormhole topologies and the particles of the Standard Model may eventually turn out to be of physical interest. Classical analogs of quantum mechanical phenomena can be instructive and illuminating, even if no one believes that the classical phenomenon has anything to do with the quantum phenomenon that it resembles. However, it is conceivable, as an outside possibility, that the models described here may have some other uses as well. Despite the predominance of string theory today, there still are other serious candidates for the fundamental theory of physics (particularly loop quantum gravity), so the question of the structure of spacetime in the small has not yet been settled. Thus, in spite of all the current trends and the promise of string theory, a set of conjectural wormhole states that looks a bit like the Standard Model might be worthy of further study.

Notes

1. Wheeler himself realized that "charge without charge" cannot be identified naively with the charges on elementary particles; the relationship would have to be more complex. See, for example, [Wheeler, 1968].

2. One hint about how this might be done is found in [Sharlow, 2003], [Sharlow, 2004a] and [Sharlow, 2004b].

3. One can ask whether triholes and diholes that resemble familiar particles, but that have the wrong spins, might serve as models of the *supersymmetric partners* of the familiar particles, and allow us to develop a classical wormhole analog of supersymmetry.

References

Kalinowski, M.W., and G. Kunstatter (1984). Spherically symmetric solution in the nonsymmetric Kaluza-Klein theory. *Journal of Mathematical Physics,* vol. 25, no. 1, pp. 117-130.

Misner, C.W. and J.A. Wheeler (1957). Classical physics as geometry. Gravitation, electromagnetism, unquantized charge, and mass as properties of curved empty space. *Annals of Physics*, vol. 2, no. 6, pp. 525-603. (Reprinted in Wheeler (1962).)

Misner, C.W., K. S. Thorne, and J.A. Wheeler (1973). *Gravitation*. San Francisco: W.H. Freeman and Company.

Sharlow, M.F. (2003). The quantum mechanical path integral: toward a realistic interpretation. http://www.eskimo.com/~msharlow/path.pdf

Sharlow, M.F. (2004a). What branching spacetime might do for physics. http://www.eskimo.com/~msharlow/branch.pdf

Sharlow, M.F. (2004b). "Charge without charge" in the stochastic interpretation of quantum mechanics. http://www.eskimo.com/~msharlow/charge.pdf

Visser, M. (1995). *Lorentzian Wormholes: From Einstein to Hawking* (Woodbury, NY: AIP Press).

Wheeler, J.A. (1968). Superspace and the nature of quantum geometrodynamics. In *Battelle Rencontres: 1967 Lectures in Mathematics and Physics*, ed. C.M. DeWitt and J.A. Wheeler (New York and Amsterdam: W.A. Benjamin).

Wheeler, J.A. (1962). *Geometrodynamics*. N.Y. and London: Academic Press.

Wheeler, J.A. (1957). On the nature of quantum geometrodynamics. *Annals of Physics*, vol. 2, no. 6, pp. 604-614.

Wheeler, J.A. (1955). Geons. *Physical Review*, vol. 97, no. 2, pp. 511-536.