Supersymmetry with composite bosons

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Abstract

We note that hadronic susy (empirical quark-diquark) symmetry can be expanded into the lepton sector, and that for three generations the counting of degrees of freedom is the one we need to build charged supermultiplets. For this to cure hierarchy, Higgs modeling becomes restricted.

Quark-Diquark supersymmetry has been an ongoing topic since the early works of Lichtenberg[2] and Miyazawa[6] in 1968. At these times the second generation of quarks and leptons was just coming out of the closet.

Now we have three (and no more) generations of quarks and leptons, and one of them, the top, is unable to form mesons, nor diquarks. In this situation hadronic supersymmetry presents a curious phenomena: it provides the bosonic degrees of freedom needed to cancel fermion loops. Of if you prefer, to build supersymmetric multiplets.

To be precise, we can form 15 different diquarks (and its corresponding antiquarks). Of them, we have 6 with charge -2/3, 6 with charge +1/3, and 3 spurious -we hope- ones with charge +4/3. Leaving aside for a moment the later ones, we can start to be intrigued about the coincidence.

If, departing from the venerable lines of pure hadronic thinking, we turn now our view to the leptons, our intrigue grows to surprise as the diquarks turn mesons: they provide us 6 charged +1 degrees of freedom, ready to fit with the charged leptons, and of course the corresponding 6 antiparticles to fit charged antileptons. We have also 13 neutral mesons, and some of them should be susy to neutrinos before the application of the seesaw mechanism. How many of them we can not tell, because it is model dependent. Also, group theoretical arguments could be used to decrease the available neutral degrees.

To resume: for three generations of quarks and charged leptons, we find that diquarks (and mesons) provide just the exact number of scalars needed to build the corresponding charged supermultiplets. There are also extra 4/3 scalars, and a plethora of neutral ones, but the interesting point here is that we have a triple coincidence, for up, down, and electron types.

One could check that this coincidence needs a minimum of three generations, and it is unique if only one quark lacks mesons. Consider N generations, with D down-type quarks able to build mesons, and U up type quarks in the same condition. Asking for coincidence, we obtain two equations

$$\begin{aligned} D\,U &= 2N \\ D(D+1)/2 &= 2N \end{aligned}$$

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The minimal solution needs N=3, and an extra condition, such as $U-D=1$, fixes this solution to be unique.

The extension of quark-diquark supersymmetry to a fundamental symmetry including leptons solves another amusing phenomenological question: what the heck are muon and tau doing at the same energy levels that hadronic quantities? Up to now, the only valid answer was to relate them to the masses of strange of bottom, running down from a GUT scale. The relation with down-kind quarks remains, because the mesons supersymmetric to charged leptons are the ones having the same composition that the diquarks supersymmetric to down-kind quarks.

Marginally, lets point out that both down-like quarks and charged leptons are known to fulfill Koide's relationship, a relation between three generations of composite particles that amazingly works for leptons. Here we have a way to explain this relationship: charged leptons are not composite, but they are supersymmetric to composite particles.

What about the hierarchy problem? In the standard model, diquarks (mesons) are just higher loop quark (lepton) corrections to the Higgs self energy. In order for them to be able to cancel the one loop quark (or lepton) corrections, the Higgs structure must be such that it couples with diquarks at the same coupling intensity than it couples with quarks. It does not seem an impossible task to fulfill, e.g. with composite Higgs models. If additionally the interaction with double-up diquarks (the 4/3 ones) is not favored, then we have got to get rid of our three spurious degrees of freedom.

The possibility to control the hierarchy problem is insinuated by Miyazawa in a short 1983 note [7], but leptons are not worked out, nor the full third generation.

Finally, how has this supersymmetry been broken? One conjecture, based in the preservation of Koide's formula for leptons, could be that the symmetry has been broken in the meson side, and that for some value of the strong coupling constant the supersymmetry could be restored. On other side the top quark is very far from their candidate partners, and we could suspect that the same mechanism breaking electroweak symmetry also breaks symmetry.

We should investigate new ways to break supersymmetry. As a suggestion, let me point out that the algebra of functions over superspace has not been yet worked inside Connes formalism, and we know that this formalism has proved strong enough to produce the usual standard model and higgs. Still, the most naive connection, that susy restoration happens when the discrete dirac operator becomes infinitesimal, works in opposite sense to our desires because an infinite Higgs mass could imply an infinitely massive top quark.

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4/3	1/3	-2/3
		bb
	cb	sb
	ub	db
cc	cs	ss
	us	
uc		ds
	dc	
uu	ud	dd

Table 1: All the possible diquark pairings, ordered according electric charge. Note that in the 1/3 and -2/3 columns there are the exact number we need to form susy multiplets with three generations of (anti)quarks. The antiparticles follow the same pattern.

+1	0	-1
	bb	
cb	sb bs	bc
ub	db bd	bu
cs	ss	sc
	cc	
us		su
	ds sd	
	cu uc	
dc		dc
ud	dd	du
	uu	

Table 2: all the possible quark/antiquark (meson) pairings, ordered according electric charge. The charged ones are exactly the needed number to from three generations of susy multiplets with the charged leptons

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