Do X and Y mesons provide evidence for color excited quarks or squarks?

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Abstract

This article was motivated by a blog posting in Quantum Diaries with the title "Who ordered that?! An X-traordinary particle?". The learned that in the spectroscopy of ccbar type mesons is understood except for some troublesome mesons christened with letters X and Y. $X(3872)$ is the firstly discovered troublemaker and what is known about it can be found in the blog posting and also in Particle Data Tables. The problems are following.

1. These mesons should not be there.
2. Their decay widths seem to be narrow taking into account their mass.
3. Their decay characteristics are strange: in particular the kinematically allow decays to $D\overline{D}$ dominating the decays of $\Psi(3770)$ with branching ratio 93 per cent has not been observed whereas the decay to $D\overline{D}\pi^0$ occurs with a branching fraction $> 3.2 \times 10^{-3}$. Why the pion is needed?
4. $X(3872)$ should decay to photon and charmonium state in a predictable way but it does not.

One of the basic predictions of TGD is that both leptons and quarks should have color excitations. In the case of leptons there is a considerable support as carefully buried anomalies: the first ones come from seventies. But in the case of quarks this kind of anomalies have been lacking. Could these mysterious X:s and Y:s provide the first signatures about the existence of color excited quarks? An alternative proposal is that X and Y are meson like states formed from superpartners of charmed quark and anti-quark. Consider for definitenest the option based on color excited quarks.

1. The first basic objection is that the decay widths of intermediate gauge bosons do not allow new light particles. This objection is encountered already in the model of leptohadrons. The solution is that the light exotic states are possible only if they are dark in TGD sense having therefore non-standard value of Planck constant and behaving as dark matter. The value of Planck constant is only effective and has purely geometric interpretation in TGD framework.
2. Second basic objection is that light quarks do not seem to have such excitations. The answer is that a phase transition increasing the value of Planck constant for the meson followed by gluon exchange transforms the exotic quark pair to ordinary one and vice versa and considerable mixing of the ordinary and exotic mesons takes place. This kind of coupling between gluon octet, color triplet and D-dimensional triality one representation is possible for $D = \overline{6}$ and $D = 15$ (note that standard Lie-algebra coupling of gluons is not in question). At low energies where color coupling strength becomes very large and this gives rise to mass squared matrix with very large non-diagonal component and the second eigenstate of mass squared is tachyon and therefore drops from the spectrum. For heavy quarks situation is different and one expects that charmonium states have also exotic counterparts.
3. The selection rules can be also understood. The decays to $D\overline{D}$ involve at least two gluon emissions decaying to quark pairs and producing additional pion unlikes the decays of ordinary charmonium state involving only the emission of single gluon decaying to quark pair so that $D\overline{D}$ results.

   The decay of the lightest X to photon and charmonium is not possible in the lowest order since at least one gluon exchange is needed to transform exotic quark pair to ordinary

one. Exotic charmonia can however transform to exotic charmonia. Therefore the basic constraints seem to be satisfied.

The above arguments apply with minimal modifications also to squark option and at this moment I am not able to to distinguish between this options. The SUSY option is however favored by the fact that it would explain why SUSY has not been observed in LHC in terms of shadronization and subsequent decay to hadrons by gluino exhanges so that the jets plus missing energy would not serve as a signature of SUSY. Note that the decay of gluon to dark squark pair would require a phase transition to dark gluon first.

Contents

1 Introduction

Now and then come the days when head is completely empty of ideas. One just walks around and gets more and more frustrated. One can of course make authoritative appearances in blog groups and express strong opinions but sooner or later one is forced to look for web if one could find some problem. At this time I had good luck. By some kind of divine guidance I found myaself immediately in Quantum Diaries and found a blog posting with title *Who ordered that?! An X-traordinary particle?* [4].

Not too many unified theorists take meson spectroscopy seriously. Although they are now accepting low energy phenomenology (*the* physics for the rest of us) as something to be taken seriously, meson physics is for them a totally uninteresting branch of botany. They could not care less. As a crackpot I am however not well-informed about what good theoretician should do and shouldn't do and got interested. Could this give me a problem that my poor crackpot brain is crying for?

The posting told me that in the spectroscopy of $c\bar{c}$ type mesons is understood except for some troublesome mesons christened imaginatively with letters X and Y plus brackets containing their mass in MeVs. X(3872) is the firstly discovered troublemaker and what is known about it can be found in the blog posting and also in Particle Data Tables [2]. The problem is that these mesons should not be there. Their decay widths seem to be narrow taking into account their mass and their decay characteristics are strange: in particular the kinematically allow decays to $D\overline{D}$ dominating the decays of $\Psi(3770)$ with branching ratio 93 per cent has not been observed whereas the decay to $D\overline{D}\pi^0$ occurs with a branching fraction $> 3.2 \times 10^{-3}$. Why the pion is needed? $X(3872)$ should decay to photon and charmonium state in a predictable way but it does not.

1.1 Could these be the good questions?

TGD predicts a lot of exotic physics and I of course started to exclude various alternatives. First one must however try to invent a good question. Maybe the following questions might satisfy the criterion of goodness.

1. Why these exotic states appear only for mesons made of heavy quark and anti-quark? Why not for light mesons? Why not for mesons containing one heavy quark and light quark? Could it be that also $b\bar{b}$ mesons could have exotic partners not yet detected? Could it be that also exotic $b\bar{c}$

type mesons could be there? Why the presence of light quark would eliminate the exotic partner from the spectrum?

2. Do the decays obey some selection rules? There is indeed this kind of rule: the numbers of c and $\overline{c}$ quarks in the final state are equal to one.

   (a) If c and $\overline{c}$ exist in the initial state and the decay involves only strong interactions, the rule holds true.

   (b) If c and $\overline{c}$ are not present in the initial state the only option that one can imagine is the exhange of two W bosons transforming d type quarks to c type quarks must be present. If this were the case the initial state should correspond to $d\overline{d}$ like state rather than $c\overline{c}$ and this looks very strange from the standard physics point of view. Also the rate for this kind of decays would be very small and it seems that this option cannot make sense.

1.2 Both leptons and quarks have color excitations in TGD Universe

TGD predicts that both leptons and quarks have color excitations [5]. For leptons they correspond to color octets and there is a lot of experimental evidence for them. Why we do not have any evidence for color excited quarks? Or do we actually have?! Could these strange X:s and Y:s provide this evidence?

Ordinary quarks correspond to triality one color triplet partial waves in CP_2. The higher color partial waves would also correspond to triality one states but in higher color partial waves in CP_2. The representations of the color group are labelled by two integers (p,q) and the dimension of the representation is given by

$$d = \frac{(p+1)(q+1)(p+q+2)}{2} \quad .$$

A given $t = \pm 1$ representation is accompanied by its conjugate with the same dimension and opposite triality $t = \mp 1$. $t = 1$ representations satisfy $p - q = 1$ modulo 3 and come as (1,0), (0,2), (2,1),... with dimensions 3, 6, 15,... The simplest candidate for the color excitations would correspond to the representation $\overline{6}$. It does not correspond directly the a solution of the Dirac equation in CP_2 since physical states involve also color Kac-Moody generators [2].

Some remarks are in order:

1. The tensor product of gluon octet with $t = 1$ with color triplet representation contains $8 \times 3 = 24$ states and decomposes into $t = 1$ representations as $3 \oplus \overline{6} \oplus 15$. The coupling of gluons by Lie algebra action can couple given representation only with itself. The coupling between triplet and $\overline{6}$ and 15 is therefore not by Lie algebra action. The coupling constant between quarks and color excited quarks is *assumed* to be proportional to color coupling.

2. The existence of this kind of coupling would explain the selection rules elegantly. If this kind of coupling is not allowed then only the annihilation of exotic quark to gluon decaying to quark pair can transform exotic mesons to ordinary ones and I have not been able to explain selection rules using this option.

The basic constraint comes from the fact that the decay widths of intermediate gauge bosons do not allow new light particles. This objection is encountered already in the model of leptohadrons [5]. The solution is that the light exotic states are possible only if they are dark in TGD sense having therefore non-standard value of Planck constant and behaving as dark matter. The value of Planck constant is only effective and has purely geometric interpretation in TGD framework. This implies that a phase transition transforming quarks and gluons to their dark counterparts is the key element of the model. After this a phase transition followed a gluon exchange would transform the quark pair to an exotic quark pair.

1.3 Also squarks could explain exotic charmonium states

Supersymmetry provides an alternative mechanism. Right-handed neutrino generates super-symmetries in TGD Universe and quarks are accompanied by squarks consisting in a well-defined sense of of quark and right-handed neutrino. Super-symmetry would allow completely standard couplings to gluons by adding to the spectrum squarks and gluinos. Exactly the same selection rules result if these new states are mesonlike states from from squark and anti-squark and the exchange of gluino after the $\hbar$ changing phase transition transforms exotic meson to ordinary one and vice versa.

In the sequel it will be shown that the existence of color excited quarks or of their superpartners could indeed allow to understand the origin of X and Y mesons and also the absence of analogous states accompanying mesons containing light quarks or anti-quarks.

This picture would lead to a completely new view about detection of squarks and gluinos.

1. In the standard scenario the basic processes are production of squark and gluino pair. The creation of squark-antisquark pair is followed by the decay of squark (anti-squark) to quark (antiquark) and neutralino or chargino. If R-parity is conserved, the decay chain eventually gives rise to at least two hadron jets and lightest neutralinos identifiable as missing energy. Gluinos in turn decay to quark and anti–squark (squark and anti-quark) and squark (anti-squark) in turn to quark (anti-quark) and neutralino or chargino. At least four hadron jets and missing energy is produced. In TGD framework neutralinos would decay eventually to zinos or photinos and right-handed neutrino transforming to ordinary neutrino (R-parity is not conserved). This process might be however slow.

2. In the recent case quite different scenario relying on color confinement and "shadronization" suggests itself. By definition smesons consist of squarks and anti-squark. Sbaryons could consist of two squarks containing right-handed neutrino and its anti-neutrino ($\mathcal{N} = 2$ SUSY) and one quark and thus have same quantum numbers as baryon. Note that the squarks are dark in TGD sense.

   Also now dark squark or gluino pair would be produced at the first step and would require $\hbar$ changing phase transition of gluon. These would shadronize to form a dark shadron. One can indeed argue that the required emisson of winos and zinos and photinos is too slow a process as compared to shadronization. Shadrons (mostly smesons) would in turn decay to hadrons by the exchange of gluinos between squarks. No neutralinos (missing energy) would be produced. This would explain the failure to detect squarks and gluinos at LHC.

   This mechanism does not however apply to sleptons so that it seems that the p-adic mass scale of sleptons must be much higher for sleptons than that for squarks as I have indeed proposed.

1.4 Does one really obtain pseudo-scalar smesons?

The critical question is whether one obtains pseudo-scalar states as mesonlike bound states of squarks. This depends on what one means with squarks. Also the notion of pseudo-scalar is not the same for $M^4 \times CP_2$ and M^4. In TGD framework M^4 (pseudo–)scalars constructed from fermions and anti-fermions are replaced by CP_2 (pseudo–)vectors since the chiral symmetry for $M^4 \times CP_2$ implying separate conservation of lepton and baryon numbers implies that genuine fermionic H-scalars and pseudo-scalars would have quantum numbers of leptoquark.

1. The first question is what one means with ordinary pseudo-scalar mesons in TGD framework. These mesons should be characterized by a bi-local quantity which behaves like a preferred CP_2 pseudo-vector and therefore like M^4 pseudo-scalar. One should identify a unique direction of CP_2 polarization mathematically analogous to Higgs vacuum expectation value and construct a bilinear in quark wave functions associated with the partonic 2-surfaces assigned to the quarks. The problem is however that CP_2 is not a flat space. Also non-locality is a problem. Somehow one should be able to construct general coordinate invariant quantities with well-defined transformation properties under discrete symmetries.

2. The effective 2-dimensionality implying the notions of partonic 2-surfaces and string world sheets suggests a solution to the non-locality problem. Also the experience with QCD suggests that bilinear expression contains a non-integrable phase factor U connecting quark and anti-quark ad defined by the classical color gauge potentials which are just projections of SU(4) Killing vector fields to the space-time surface. The curve would be analogous to a string connecting the partonic 2-surfaces and fixed uniquely by the strong form of holography in turn reducing to the

strong form of general coordinate invariance. TGD indeed predicts the existence of string world sheets and thus strings at the 3-D ends of space-time sheets defined by causal diamond.

3. What about the preferred CP_2 vector?

   (a) The first candidate is the quantity $X = I_3 j_3^{Ak}\Gamma_k + Y j_Y^{Ak}\Gamma_k$ where I_3 and Y denote color isospin and hyper-charge of the quark and j_i^{Ak} corresponding Killing vectors. The preferred vector would be due to the choice of quantization axes. This option is natural for in the case of quark bilinears but fails for a bilinear constructed from covariantly constant right handed neutrino.

   (b) Second candidate would the CP_2 part for the trace of the second fundamental form contracted with CP_2 gamma matrices -denote it by $X = H^k\Gamma_k$ -at the either end of the string connecting fermion and anti-fermion at partonic 2-surfaces. This option would be natural for the right-handed neutrino. Bi-local super-generators would vanish when the partonic 2-surface is minimal surface. This would be analogous to the representations of SUSY for which $2^{-k}\mathcal{N}$ generators annihilate the physical states and act as pure gauge symmetries.

4. This would suggest that the basic invariants in the construction is the quantity $\overline{\Psi}_1 UXO\Psi_2$. Sub-script $i = 1, 2$ refers to the partonic 2-surface, X can occur at both ends and γ_5 guarantees pseudo-scalar property. O is $1 \pm \gamma_5$ for right- *resp.* left-handed quarks. The recipe would apply also to the bilinears formed right-handed neutrinos: now only the projector $(1 + \gamma_5)$ to right-handed neutrino appears so that only single state is obtained.

Most of the options that one can imagine give something else that pseudo-scalar smeson.

1. Assuming that $\mathcal{N} = 2$ symmetry is not too badly broken, one can add to the partonic 2-surface carrying quark either right-handed neutrino or anti-neutrino or both so that one obtains a 4-plet containing two quark states, spin zero squark and and spin 1 squark. From these states one can construct meson like states.

   (a) The first implication is degeneracy of quark like states because of the precence of neutrino pair. TGD however predicts large breaking of SUSY. According to the arguments of [1] the state containing right handed neutrino pair has propagator behaving like $1/p^3$ and does not correspond to ordinary particle. It is not at all clear whether this kind squarks can give rise to meson like states. Also the R-parity of these squarks would be $+1$ and the model requires negative R-parity.

   (b) For spin one squarks one obtains pseudo-vector state with spin 1: the smeson state would transform like the cross product of the vectors characterizing spin 1 squarks. These states could be also present in the spectrum although they do not correspond to pseudo-scalars.

   This suggests that $\mathcal{N} = 2$ SUSY is badly broken and one must restrict the consideration to $\mathcal{N} = 1$ option.

2. For $\mathcal{N} = 1$ option both squarks are scalars (quark plus anti-neutrino option).

   (a) Forgetting the non-locality and regarding partonic 2-surfaces as basic objects as a whole, one has bound state of scalar squarks and the possible mesonlike state is most naturally a scalar rather than pseudo-scalar.

   (b) Non-locality brought in by strings however changes the situation. One could construct a pseudo-scalar by starting from pseudo-scalar meson constructed by using the non-local recipe. To add neutrino and anti-neutrino at the partonic 2-surfaces one could use the bilinears $\overline{\nu}_{R,1}H^k\Gamma_k\nu_{R,2}$ and $\overline{\nu}_{R,2}H^k\Gamma_k\nu_{R,1}$ to obtain the needed right-handed CP_2 current, which is neither scalar nor pseudo-scalar. The stringy picture (braids as representation of many fermion states) forced by the strong from of general coordinate invariance (or strong form of holography or effective two-dimensonality) would be absolutely essential for this picture to work.

To sum up, it is not completely clear whether the squark option really gives pseudo-scalar smesons. One cannot exclude additional pseudo-vector states and scalars unless $\mathcal{N} = 2$ SUSY is badly broken. The option based on color excitations in turn predicts only pseudo-scalar smesons but also for this option a non-local state construction is needed.

2 Could exotic charmonium states consist of color excited c and $\bar{c}$ or their super partners?

Could one provide answers to the questions presented in the beginning assuming that exotic charmonium states consists of dark color excited c and $\bar{c}$: or more generally, a mixture of ordinary charmonium and exotic charmonium state? The mixing is expected since $\hbar$ changing phase transition followed by a gluon exchange can transform these meson states to each other. Also annihilation to gluon and back to quark pair can induce this mixing. The mixing is however small for heavy quarks for which $\alpha_s \simeq .1$ holds true. Exactly the same arguments apply to the meson like bound states of squarks and in the following only the first option will be discussed.

1. In the case of charged leptons colored excitations have same p-adic mass scale: for τ however several p-adic mass scales appear as the model if the two year old CDF anomaly is taken seriously [5]. Assume that p-adic mass scales - but not necessarily masses- are the same also now. This assumption might be non-sensical since also light mesons would have exotic counterparts and somehow they should disappear from the spectrum. To simplify the estimates one could even assume even that the masses are same.

2. In the presence of small mixing the decay amplitude would come solely from the small contribution of the ordinary $c\bar{c}$ state present in the state dominated by color excited pair. The two manners to see the situation should give essentially the same answer.

3. The decays would take place via strong interactions.

The challenge is to understand why the dominating decays to $D\overline{D}$ with branching fraction of 93 per cent are not allowed whereas $D\overline{D}\pi^0$ takes place. Why the pion is needed? The second challenge is to understand why X does not decay to charmonium and photon.

1. For ordinary charmonium the decay to $D\overline{D}$ could take place by the emission of gluon from either c or $\bar{c}$ which then decays to light quark pair whose members combine with c and $\bar{c}$ to form D and $\overline{D}$. Now this mechanism does not work. At least *two* gluons must be emitted to transform colored excited $c\bar{c}$ to ordinary $c\bar{c}$. If these gluons decay to light quark pairs one indeed obtains an additional pion in hadronization. The emission of two gluons instead of only one is expected to reduce the rate roughly by $\alpha_s^2 \simeq 10^{-2}$ factor.

2. Also ordinary decays are predicted to occur but with a slower rate. The first step would be an exchange of gluon transforming color excited charmed quark pair to an ordinary charmed quark pair. After the transformation to off mass shell $c\bar{c}$ pair, the only difference to the decays of charmonium states would be due to the fact that charmonium would be replaced with $c\bar{c}$ pair. The exchange of the gluon preceding this step could reduce the decay rate with respect to charmonium decay rates by a factor of order $\alpha_s^2 \simeq 10^{-2}$. Therefore also the ordinary decay modes should be there but with a considerably reduced rate.

3. Why the direct decays to photon and charmonium state do not occur in the manner predicted by the model of charmonium? For ordinary charmonium the decay proceeds by an emission of photon by either quark or anti-quark. Same mechanism applies for exotic charmonium states but leads to final state which consists of *exotic* charmonium and photon. In the case of $X(3872)$ there exists no lighter exotic charmonium state so that the decay is forbidden in this order of perturbation theory. Heavier exotic charmonium states can however decay to photon plus exotic charmonium state in this order of perturbation theory if discrete symmetries favor this.

Essentially identical arguments go through if c and $\bar{c}$ are replaced with their spartners and emission of gluon by the emission of gluino.

2.1 Why the color excitations/spartners of light quarks would be effectively absent?

Can one understand the effective absence of mesons consisting of color excited light quarks or squarks if the excitations have same mass scale and even mass as the light quarks? The following arguments are for color excited quarks but they apply also to squarks.

1. Suppose that the mixing induced by $\hbar$ changing phase transition followed by a gluon exchange and annihilation is described by mass squared matrix containing besides diagonal components $M_1^2 = M_2^2$ also non-diagonal component $M_{12}^2 = \overline{M_{21}^2}$. The eigenstates of the mass squared matrix correspond to the physical states which are mixtures of states consisting of ordinary quark pair and pair of color excited quarks. The non-diagonal elements of the mass squared matrix corresponds to gluon exchange and since color interactions get very strong at low energy scales, one expects that these elements get very large. In the degenerate case $M_1^2 = M_2^2$ the mass squared eigen values are given by

$$M_\pm^2 = M_0^2 \pm |M_{12}|^2 \ . \tag{2.1}$$

2. Suppose that $M_0^2 = 0$ holds true in accordance with approximate pseudo- Goldstone nature of pion and more generally all light pseudo–scalar mesons. In fact assume that this is the case before color magnetic spin-spin splitting has taken place so that in this approximation pion and ρ would have same mass $m_\pi^2 = m_\rho^2 = M_0^2$. In TGD based model for color magnetic spin-spin splitting M_0^2 energy is replaced with mass squared [4] and M_0^2 is obtained in terms of physical masses of π and ρ from the basic formulas

$$\begin{aligned} m_\pi^2 &= M_0^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_0^2 + \frac{3}{4}\Delta \ , \\ M_0^2 &= \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \ \Delta = m_\rho^2 - m_\pi^2 \ . \end{aligned} \tag{2.2}$$

The exotic π and ρ would have masses

$$\begin{aligned} m_{\pi_{ex}}^2 &= -M_0^2 - \frac{1}{4}\Delta = m_\pi^2 - 2M_0^2 \ , \\ m_{\rho_{ex}}^2 &= -M_0^2 + \frac{3}{4}\Delta = m_{rho}^2 - 2M_0^2\Delta \ . \end{aligned} \tag{2.3}$$

For $m_\pi = 140 MeV$ and $m_\rho = 770$ MeV the calculation gives $m_{\pi_{ex}} = i \times 685$ MeV so a tachyon would be in question. For ρ one would have $m_{\pi_{ex}} = 323$ MeV so that the mass would not be tachyonic.

One can try to improve the situation by allowing $M_1^2 \neq M_2^2$ giving additional flexibility and hopes about tachyonicity of the exotic ρ.

1. In this case one obtains the equations

$$\begin{aligned} m_\pi^2 &= M_+^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_+^2 + \frac{3}{4}\Delta \\ m_{\pi_{ex}}^2 &= M_-^2 - \frac{1}{4}\Delta \ , \ m_{\rho_{ex}}^2 = M_-^2 + \frac{3}{4}\Delta \ ., \\ M_+^2 &= \frac{M_1^2 + M_2^2}{2} + \sqrt{(\frac{(M_1^2 + M_2^2}{2})^2 + M_{12}^4} = \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \\ M_-^2 &= \frac{M_1^2 + M_2^2}{2} - \sqrt{(\frac{(M_1^2 + M_2^2}{2})^2 + M_{12}^4} = M_+^2 - 2\sqrt{(\frac{(M_1^2 + M_2^2}{2})^2 + M_{12}^4} \ . \end{aligned} \tag{2.4}$$

2. The condition that ρ_{ex} is tachyonic gives

$$m_{\rho_{ex}}^2 = M_-^2 + \frac{3}{4}\Delta < 0 \ , \tag{2.5}$$

giving

$$
\begin{aligned}
m_\rho^2 &< 2\sqrt{(\frac{(M_1^2+M_2^2}{2})^2+M_{12}^4} \ , \\
M_+^2 &= \frac{M_1^2+M_2^2}{2}+\sqrt{(\frac{(M_1^2+M_2^2}{2})^2+M_{12}^4}=\frac{m_\rho^2+3m_\pi^2}{2} \ ,
\end{aligned} \tag{2.6}
$$

3. In the parametrization $(m_1^2, m_2^2, M_{12}^2) = (x, y, z)m_\rho^2$ one obtains the conditions

$$
\begin{aligned}
D \equiv \sqrt{(x+y)^2+z^2} &> 1/2 \ , \\
\frac{x+y}{2}+D=\frac{1}{2}+\frac{3}{2}\frac{m_\pi^2}{m_\rho^2} & \ .
\end{aligned} \tag{2.7}
$$

4. These equations imply the conditions

$$
\begin{aligned}
x+y &< 3\frac{m_\pi^2}{m_\rho^2} \simeq .099 \ , \\
.490 &< z < .599 \ .
\end{aligned} \tag{2.8}
$$

   The first condition implies $\sqrt{m_1^2+m^2} < 242.7$ MeV. Second condition gives $339 < M_{12}/MeV < 595.9$ so that rather stringent bounds on the parameters are obtained. The simplest solution to the conditions corresponds to $x = y = 0$ and $z = .599$. This solution would mean vanishing masses in the absence of mixing and spin-spin splitting and could be defended by the Golstone boson property of pions mass degenerate with ρ mesons.

This little calculation encourages to consider the possibility that all exotic counterparts of light mesons are tachyonic and that this due the very large mixing induced by gluon exchange (gluino exchange squark option) at low energies. It would be nice if also mesons containing only single heavy quark were tachyonic and this could be the case if the p-adic length scale defining the strength of color interactions corresponds to that of the light quark so that the mass matrix has large enough non-diagonal component. Here one must be however very cautious since experimental situation is far from clear.

The model suggests that ordinary charmonium states and their exotic partners are in 1-1 correspondence. If so then many new exotic states are waiting to be discovered.

2.2 The option based on heavy color excitations/spartners of light quarks

An alternative option is that color excitations/spartners of light quarks have large mass: this mass should not be however larger than the mass of c quarks if we want to explain X:s and Y:s as pairs of color excitations of light quarks. Suppose that the p-adic mass scale is same as that for c quarks or near it (not that the scales come as powers of $\sqrt{2}$). This raises the question whether exotic $c\overline{c}$ mesons really consist of exotic c and $\overline{c}$: why not color excitations of u, d, s and their anti-quarks? As a matter fact, we cannot be sure about the quark content of X and Y mesons. Could these states be $d\overline{d}$ and $u\overline{u}$ states for their color excitations? It however seems that the presence of two W exchanges makes the decay rate quite too low so that this option seems to be out of question.

One can however consider the option in which the squarks associated with light quarks are heavy. This option is indeed realized in standard SUSY were the mass scales of particles families are inverted so that stop and sbottom are the lightest squarks and super-partners of u and d the heaviest ones. This would would predict that the smesons associated with $\overline{t}$ and $b\overline{b}$ are lighter than X and Y (s)mesons. This option does not look at all natural in TGD but of course deserves experimential checking.

2.3 How to test the dark squark option?

The identification of X and Y as dark smesons looks like a viable option and explains the failure to find SUSY at LHC if shadronization is a fast process as compared to the selectro-weak decays. The option certainly deserves an experimental testing. One could learn a lot about SUSY in TGD sense (or maybe in some other sense!) by just carefully scanning the existing data at lower energies. For instance, one could try to answer the following questions by analyzing the already existing experimental data.

1. Are X and Y type mesons indeed in 1-1 correspondence with charmonium states? One could develop numerical models allowing to predict the precise masses of scharmonium states and their decay rates to various final states and test the predictions experimentally.

2. Do $b\bar{b}$ mesons have smesonic counterparts with the same mass scale? What about B_c type smesons containing two heavy squarks?

3. Do the mesons containing one heavy quark and one light quark have smesonic counterparts? My light-hearted guess that this is not the case is based on the assumption that the general mass scale of the mass squared matrix is defined by the p-adic mass scale of the heavy quark and the non-diagonal elements are proportional to the color coupling strength at p-adic length scale associated with the light quark and therefore very large: as a consequence the second mass eigenstate would be tachyonic.

4. What implications the strong mixing of light mesons and smesons would have for CP breaking? CP breaking amplitudes would be superpositions of diagrams representing CP breaking for mesons *resp.* smesons. Could the presence of smesonic contributions perhaps shed light on the poorly understood aspects of CP breaking?

2.4 Objection against covariantly constant neutrinos as SUSY generators

TGD SUSY in its simplest form assumes that covariantly constant right-handed neutrino generates SUSY. The second purely TGD based element is that squarks would correspond to the same p-adic mass scale as partners.

This looks nice but there are objections.

1. The first objection relates to the tachyonicity needed to get rid of double degeneracy of light mesons consisting of u, d, and s quarks. Mesons and smesons consisting of squark pair mix and for large α_s the mixing is large and can indeed make second eigenvalue of the mass squared matrix negative. If so, these states disappears from spectrum. At least to me this looks however somewhat unaesthetic.

   Luckily, the transformation of second pion-like state to tachyon and disappearance from spectrum is not the only possibility. After a painful search I found experimental work [5] claiming the existence of states analogous to ordinary pion with masses 60, 80, 100, 140,.... MeV. Also nucleons have this kind of satellite states. Could it be that one of these states is spion predicted by TGD SUSY for ordinary hadrons? But what about other states? They are not spartners: what are they?

2. The second objection relates to the missing energy. SUSY signatures involving missing energy have not been observed at LHC. This excludes standard SUSY candidates and could do the same in the case of TGD. In TGD framework the missing energy would be eventually right handed neutrinos resulting from the decays of sfermions to fermion and sneutrino in turn decaying to neutrino and right handed neutrino. The naive argument is that shadronization would be much faster process than the decay of squarks to quarks and spartners of electro-weak gauge bosons and missing energy so that these events would not be observed. Shadrons would in turn decay to hadrons by gluino exchanges. The problem with this argument is that the weak decays of squarks producing right handed neutrinos as missing energy are still there!

   This objection forces to consider the possibility that covariantly constant right handed neutrino which generates SUSY is replaced with a color octet. Color excitations of leptons of leptohadron hypothesis would be sleptons which are color octets so that SUSY for leptons would have been seen already at seventies in the case of electron. The whole picture would be nicely unified.

Sleptons and squark states would contain color octet right handed neutrino the same wormhole throats as their em charge resides. In the case of squarks the tensor product $3 \otimes 8 = 3 + \overline{6} + 15$ would give several colored exotics. Triplet squark would be like ordinary quark with respect to color.

Covariantly constant right-handed neutrino as such would represent pure gauge symmetry, a super-generator annihilating the physical states. Something very similar can occur in the reduction of ordinary SUSY algebra to sub-algebra familiar in string model context. By color confinement missing energy realized as a color octet right handed neutrino could not be produced and one could overcome the basic objections against SUSY by LHC.

What about the claimed anomalous trilepton events at LHC interpreted in terms of SUSY, which however breaks either the conservation of lepton or baryon number. I have proposed TGD based interpretation [3] is in terms of the decays of W to $\tilde{W}$ and $\tilde{Z}$, which in turn decay and produce the three lepton signature. Suppose that $\tilde{W}$ and $\tilde{Z}$ are color octets and that sleptons replace the color octet excitations of leptons responsible for leptohadron physics [5]. One possible decay chain would involve the decays $\tilde{W}^+ \to \tilde{L}^+ + \overline{\nu}_L$ and $\tilde{Z} \to L^+ + \tilde{L}^-$. Color octet sleptons pair combine to form leptopion which decays to lepton pair. This decay cascade would produce missing energy as neutrino and this seems to be the case for other options too.e could overcome the basic objections against SUSY by LHC.

This view about TGD SUSY clearly represents a hybrid of the two alternative views about X and Y bosons as composites of either color excitations of quarks or of squarks and is just one possibility. The situation is not completely settled and one must keep mind open.

2.5 What are the implications for M_{89} hadron physics?

Lubos told about the latest information concerning Higgs search. It is not clear how much these data reflect actual situation [1]. Certainly the mass values must correspond to observed bumps. The statistical significances are *expected* statistical significances, not based on real data. Hence a special caution is required. At 4.5/fb of data one has following bumps together with their expected statistical significance:

- 119 GeV: 3 sigma
- 144 Gev: 6 sigma(!)
- 240 GeV: 4.5 sigma
- 500 GeV: 4 sigma

It is interesting to try to interpret these numbers in TGD framework. The thing to observe is that weak boson decay widths do not pose any constraints on the model and one could assume that M_{89} squarks are not dark.

1. The interpretation of 144 GeV bump

Consider first the 144 GeV state 6 sigma expected significance, which is usually regarded as a criterion for discovery. Of course this is only expected statistical significance, which cannot be taken seriously.

1. 144 GeV is exactly the predicted mass of the pion of M_{89} hadron physics which was first observed by CDF and then decided to be a statistical fluctuation. I found myself rather alone while defending the interpretation as M_{89} pion in viXra log and trying to warn that one should not throw baby with the bath water.

2. From an earlier posting of Lubos one learns that 244 GeV state must be CP odd -just like neutral pion- and should correspond to A_0 Higgs of SUSY. Probably this conclusion as well as the claimed CP even property of 119 GeV state follow both from the assumption that these states correspond to SUSY Higgses so that one must not take them seriously.

3. The next step before TGD will be accepted is to discover that this state cannot be Higgs of any kind.

2. Possible identification of the remaining bumps

Could the other bumps correspond to the pseudo-scalar mesons of M_{89} hadron physics? For only a week ago I would have answered 'Definitely not'! Could the claimed bumps explained by assuming that also M_{89} quarks have either color excitations or super partners with the same mass scale and the same mechanism is at work for M_{89} mesons as for ordinary mesons. The same question can be made for the option based on color excitations of quarks in $\overline{6}$ or 15.

Consider now the possible identification of the remaining Higgs candidates concentrating for definiteness to the squark option.

1. In the earlier framework there was no identification for meson like states below 144 GeV. The discovery of this week was however that squarks could have the same p-adic mass scale as quarks and that one has besides mesons also smesons consisting of squark pair as a consequence. Every meson would be accompanied by a smeson. Gluino exchange however mixes mesons and smesons so that mass eigenstates are mixtures of these stgates. At low energies however the very large non-diagonal element of mass squared matrix can make second mass eigenstate tachyonic. This must happen for mesons consisting of light quarks. This of course for the M_{107} hadron physics familiar to us.

2. Does same happen in M_{89} hadron physics? Or is the non-diagonal element of mass squared matric so small that both states remain in the spectrum? Could 119 GeV state and 144 GeV state correspond to the mass eigenstates of supersymmetric M_{89} hadron physics? If this is the case one could understand also this state.

3. What about 240 GeV state? The proposal has been that selectron corresponds to M_{89} . This would give it the mass 262.14 GeV by direct scaling; $m(selectron) = 2^{(127-89)/2}m(electron)$. This is somewhat larger than 240 GeV.

   Could this state correspond to spartner of the ρ_{89} consisting of M_{89} squarks. There is already earlier evidence for bumps at 325 GeV interpreted in terms ofρ_{89} and ω_{89}. The mass squared difference should be same for pionic mass eigenstates and ρ_{89} like mass eigenstates. This would predict that the mass of the second ρ like eigenstate is 259 GeV, which is not too far from 240 GeV.

   Tommaso Dorigo's newest posting The Plot Of The Week - The 327 GeV ZZ Anomaly [3] tells about further support about ZZ anomaly at 327 GeV, which in TGD framework could be interpreted in terms of decays of the neutral member of ρ_{89} isospin triplet or ω_{89}, which is isospin singlet. A small splitting in mass found earlier is expected unless this decay corresponds to ω_{89}. Also WZ anomaly is predicted.

4. What about the interpretation of 500 GeV state? The η' meson of M_{107} hadron physics has mass 957.66 MeV. The scaling by 512 gives 490.3 GeV- not too far from 500 GeV!

The alternative option replaces M_{89} squarks with their color excitations which need not be dark. The arguments are identical in this case. Many other pseudo-scalar mesons states are predicted if either of these options is correct. In the case of squark option one could say that also SUSY in TGD sense has been discovered and has been discovered in ordinary hadron physics for 8 years ago! SUSY would not reveal itself via the usual signatures since shadronization would be faster process than the decay of squarks via emission of selectro-weak bosons.

All these looks too good to be true. I do not know how the *expected* significances are estimated and how precisely the mass values correspond to experimental data. In any case, if these states turn out to be pseudo-scalars, one can say that this is a triump for TGD. Combining this with the neutrino super-luminality which can be explained easily in terms of sub-manifold gravitation, the prospects for TGD to become the next TOE are brighter than ever.

Books related to TGD

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