

# Weak Form of Electric-magnetic Duality, Electro-weak Massivation, and Color Confinement

Matti Pitkänen<sup>1</sup>

## Abstract

The notion of electric magnetic duality emerged already two decades ago in the attempts to formulate the Kähler geometry of the "world of classical worlds". Quite recently a considerable step of progress took place in the understanding of this notion. This concept leads to the identification of the physical particles as string like objects defined by magnetic charged wormhole throats connected by magnetic flux tubes. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement. This picture generalizes to magnetic color confinement.

**Keywords:** Electric-magnetic duality, magnetic monopoles, color confinement, weak confinement, string like objects.

## 1 Introduction

The notion of electric-magnetic duality [13] was proposed first by Olive and Montonen and is central in  $\mathcal{N} = 4$  supersymmetric gauge theories. It states that magnetic monopoles and ordinary particles are two different phases of theory and that the description in terms of monopoles can be applied at the limit when the running gauge coupling constant becomes very large and perturbation theory fails to converge. The notion of electric-magnetic self-duality is more natural since for  $CP_2$  geometry Kähler form is self-dual and Kähler magnetic monopoles are also Kähler electric monopoles and Kähler coupling strength is by quantum criticality renormalization group invariant rather than running coupling constant. The notion of electric-magnetic (self-)duality emerged already two decades ago in the attempts to formulate the Kähler geometric of world of classical worlds. Quite recently a considerable step of progress took place in the understanding of this notion [6]. What seems to be essential is that one adopts a weaker form of the self-duality applying at partonic 2-surfaces. What this means will be discussed in the sequel.

Every new idea must be of course taken with a grain of salt but the good sign is that this concept leads to precise predictions. The point is that elementary particles do not generate monopole fields in macroscopic length scales: at least when one considers visible matter. The first question is whether elementary particles could have vanishing magnetic charges: this turns out to be impossible. The next question is how the screening of the magnetic charges could take place and leads to an identification of the physical particles as string like objects identified as pairs magnetic charged wormhole throats connected by magnetic flux tubes.

1. The first implication is a new view about electro-weak massivation reducing it to weak confinement in TGD framework. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement realized in terms of magnetic confinement.
2. This picture generalizes to the case of color confinement. Also quarks correspond to pairs of magnetic monopoles but the charges need not vanish now. Rather, valence quarks would be connected by flux tubes of length of order hadron size such that magnetic charges sum up to zero. For instance, for baryonic valence quarks these charges could be  $(2, -1, -1)$  and could be proportional to color hyper charge.
3. The highly non-trivial prediction making more precise the earlier stringy vision is that elementary particles are string like objects in electro-weak scale: this should become manifest at LHC energies.

## 2 Could a weak form of electric-magnetic duality hold true?

Holography means that the initial data at the partonic 2-surfaces should fix the configuration space metric. A weak form of this condition allows only the partonic 2-surfaces defined by the wormhole throats at which the signature of the induced metric changes. A stronger condition allows all partonic 2-surfaces in the slicing of space-time sheet to partonic 2-surfaces and string world sheets. Number theoretical vision suggests that hyper-quaternionicity *resp.* co-hyperquaternionicity constraint could be enough to fix the initial values of time derivatives of the imbedding space coordinates in the space-time regions with Minkowskian *resp.* Euclidian signature of the induced metric. This is a condition on modified gamma matrices and hyper-quaternionicity states that they span a hyper-quaternionic sub-space.

<sup>1</sup>Correspondence: Matti Pitkänen [http://tgd.wippiespace-com/public\\_html](http://tgd.wippiespace-com/public_html). Address: Köydenpunojankatu 2 D 11 10940, Hanko, Finland. Email: matpitka@luukku.com.

## 2.1 Definition of the weak form of electric-magnetic duality

One can also consider alternative conditions possibly equivalent with this condition. The argument goes as follows.

1. The expression of the matrix elements of the metric and Kähler form of  $WCW$  in terms of the Kähler fluxes weighted by Hamiltonians of  $\delta M_{\pm}^4$  at the partonic 2-surface  $X^2$  looks very attractive. These expressions however carry no information about the 4-D tangent space of the partonic 2-surfaces so that the theory would reduce to a genuinely 2-dimensional theory, which cannot hold true. One would like to code to the WCW metric also information about the electric part of the induced Kähler form assignable to the complement of the tangent space of  $X^2 \subset X^4$ .
2. Electric-magnetic duality of the theory looks a highly attractive symmetry. The trivial manner to get electric magnetic duality at the level of the full theory would be via the identification of the flux Hamiltonians as sums of the magnetic and electric fluxes. The presence of the induced metric is however troublesome since the presence of the induced metric means that the simple transformation properties of flux Hamiltonians under symplectic transformations -in particular color rotations- are lost.
3. A less trivial formulation of electric-magnetic duality would be as an initial condition which eliminates the induced metric from the electric flux. In the Euclidian version of 4-D YM theory this duality allows to solve field equations exactly in terms of instantons. This approach involves also quaternions. These arguments suggest that the duality in some form might work. The full electric magnetic duality is certainly too strong and implies that space-time surface at the partonic 2-surface corresponds to piece of  $CP_2$  type vacuum extremal and can hold only in the deep interior of the region with Euclidian signature. In the region surrounding wormhole throat at both sides the condition must be replaced with a weaker condition.
4. To formulate a weaker form of the condition let us introduce coordinates  $(x^0, x^3, x^1, x^2)$  such  $(x^1, x^2)$  define coordinates for the partonic 2-surface and  $(x^0, x^3)$  define coordinates labeling partonic 2-surfaces in the slicing of the space-time surface by partonic 2-surfaces and string world sheets making sense in the regions of space-time sheet with Minkowskian signature. The assumption about the slicing allows to preserve general coordinate invariance. The weakest condition is that the generalized Kähler electric fluxes are apart from constant proportional to Kähler magnetic fluxes. This requires the condition

$$J^{03}\sqrt{g_4} = K J_{12} . \quad (2.1)$$

5. Information about the tangent space of the space-time surface can be coded to the configuration space metric with loosing the nice transformation properties of the magnetic flux Hamiltonians if Kähler electric fluxes or sum of magnetic flux and electric flux satisfying this condition are used and  $K$  is symplectic invariant. Using the sum

$$J_e + J_m = (1 + K)J_{12} \quad (2.2)$$

makes it possible to have a non-trivial configuration space metric even for  $K = 0$ , which could correspond to the ends of a cosmic string like solution carrying only Kähler magnetic fields. This condition suggests that it can depend only on Kähler magnetic flux and other symplectic invariants. Whether local symplectic coordinate invariants are possible at all is far from obvious, If the slicing itself is symplectic invariant then  $K$  could be a non-constant function of  $X^2$  depending on string world sheet coordinates. The light-like radial coordinate of the light-cone boundary indeed defines a symplectically invariant slicing and this slicing could be shifted along the time axis defined by the tips of  $CD$ .

It is not quite clear what conditions can one pose on the choice of  $K$  and one can consider several options.

1. The minimal assumption is that  $K$  is constant at given partonic 2-surface but depends on the partonic 2-surface appearing in the slicing parametrized by a point of string world sheet. In this case the WCW metric would depend on the choice of the partonic 2-surface(s) to represent particular 3-surface and this makes sense only if the choice of a particular partonic 2-surface means a particular choice of WCW coordinates. The condition of constancy would be a highly non-linear constraint on the time derivatives of the four imbedding space coordinates. If  $CP_2$  projection is 4-dimensional they can be chosen as space-time coordinates and the conditions relate to each other time derivatives of  $M^4$  coordinates.
2. A stronger assumption is that  $K$  is constant for all partonic 2-surfaces in the slicing of the space-time surface (or space-like 3-surface) but depends on zero modes.

## 2.2 Electric-magnetic duality physically

What could the weak duality condition mean physically? For instance, what constraints are obtained if one assumes that the quantization of electro-weak charges reduces to this condition at classical level?

1. The first thing to notice is that the flux of  $J$  over the partonic 2-surface is analogous to magnetic flux

$$Q_m = \frac{e}{\hbar} \oint B dS = n .$$

$n$  is non-vanishing only if the surface is homologically non-trivial and gives the homology charge of the partonic 2-surface.

2. The expressions of classical electromagnetic and  $Z^0$  fields in terms of Kähler form [12] read as

$$\begin{aligned} \gamma &= \frac{eF_{em}}{\hbar} = 3J - \sin^2(\theta_W)R_{03} , \\ Z^0 &= \frac{g_Z F_Z}{\hbar} = 2R_{03} . \end{aligned} \quad (2.3)$$

Here  $R_{03}$  is one of the components of the curvature tensor in vielbein representation and  $F_{em}$  and  $F_Z$  correspond to the standard field tensors. From this expression one can deduce

$$J = \frac{e}{3\hbar} F_{em} + \sin^2(\theta_W) \frac{g_Z}{6\hbar} F_Z . \quad (2.4)$$

3. The weak duality condition when integrated over  $X^2$  implies

$$\begin{aligned} \frac{e^2}{3\hbar} Q_{em} + \frac{g_Z^2 p}{6} Q_{Z,V} &= K \oint J = Kn , \\ Q_{Z,V} &= \frac{I_V^3}{2} - Q_{em} , \quad p = \sin^2(\theta_W) . \end{aligned} \quad (2.5)$$

Here the vectorial part of the  $Z^0$  charge rather than as full  $Z^0$  charge  $Q_Z = I_L^3 + \sin^2(\theta_W)Q_{em}$  appears. The reason is that only the vectorial isospin is same for left and right handed components of fermion which are in general mixed for the massive states.

The coefficients are dimensionless and expressible in terms of the gauge coupling strengths and using  $\hbar = r\hbar_0$  one can write

$$\begin{aligned} \alpha_{em} Q_{em} + p \frac{\alpha_Z}{2} Q_{Z,V} &= \frac{3}{4\pi} \times rnK , \\ \alpha_{em} &= \frac{e^2}{4\pi\hbar_0} , \quad \alpha_Z = \frac{g_Z^2}{4\pi\hbar_0} = \frac{\alpha_{em}}{p(1-p)} . \end{aligned} \quad (2.6)$$

4. There is a great temptation to assume that the values of  $Q_{em}$  and  $Q_Z$  correspond to their quantized values and therefore depend on the quantum state assigned to the partonic 2-surface. The linear coupling of the modified Dirac operator to conserved charges implies correlation between the geometry of space-time sheet and quantum numbers assigned to the partonic 2-surface. The assumption of standard quantized values for  $Q_{em}$  and  $Q_Z$  would be also seen as the identification of the fine structure constants  $\alpha_{em}$  and  $\alpha_Z$ . This however requires weak isospin invariance.

Depending on various options for  $K$  one obtains different scenarios for the coupling constant evolution.

1. If  $K$  depends on partonic 2-surface, a continuous coupling constant evolution inside space-time sheet is realized. This would conform with the view that coupling constant strength depends on the distance from particle identified as wormhole throat (fermion or its super partner). Note that at the limit of wormhole throat the induced metric becomes singular and the weak duality condition becomes rather delicate and one can consider it only as a limiting case. One can even consider the possibility that  $K$  diverges. This would provide a geometric explanation for the infinite values of bare charges in terms of changing signature of the induced metric. Whether this indeed occurs or whether it is possible to get finite value of  $K$  by cancellation of divergent quantities in the expression of electric flux is unclear.
2. A stronger condition is that  $K$  is constant for the space-like 3-surfaces at the ends of the slicing. An even stronger condition would be that  $K$  has same value for the entire slicing. In principle one can consider a continuous evolution of  $K$  as a function of zero modes. Coupling constant evolution could be also realized via the correlation of the length scale with the values of zero modes. The non-trivial p-adic coupling constant evolution of  $e$  and  $g_Z$  suggests that  $K$  has a discrete set of values and preferred extremal property also favors this conclusion. The condition that the flux of  $F^{03} = (\hbar/g_K)J^{03}$  defining the counterpart of Kähler electric field equals to the Kähler charge  $g_K$  would give the condition  $K = g_K^2/\hbar$ , where  $g_K$  is Kähler coupling constant which should invariant under coupling constant evolution by quantum criticality. Within experimental uncertainties one has  $\alpha_K = g_K^2/4\pi\hbar_0 = \alpha_{em} \simeq 1/137$ , where  $\alpha_{em}$  is finite structure constant in electron length scale and  $\hbar_0$  is the standard value of Planck constant.

3. The standard self-duality condition  $g_{K,m} = n\hbar/g_K = g_K$  stating that magnetic and electric coupling constants are same for some value of  $n$  would give  $\alpha_K = g_K^2/4\pi\hbar = n/2$ . This is not consistent with the small value of  $\alpha_K$  for  $\hbar = \hbar_0$  and even less so for larger values of Planck constant. Self-duality could make sense qualitatively for a small enough value of Planck constant which are allowed if singular coverings of  $CD$  and  $CP_2$  are allowed but is inconsistent with the rationality of  $g_K^2$  and with the quantization of  $\hbar/\hbar$  as rationals. Therefore the self-duality at the level of coupling constant strength does not make sense in TGD framework.
4. The quantization of Planck constants makes the condition highly non-trivial. The most general quantization of  $r$  is as rationals but there are good arguments favoring the quantization as integers corresponding to the allowance of only singular coverings of  $CD$  and  $CP_2$ . The point is that in this case a given value of Planck constant corresponds to a finite number pages of the "Big Book". The quantization of the Planck constant implies a further quantization of  $K$  and would suggest that  $K$  scales as  $1/r$  unless the spectrum of values of  $Q_{em}$  and  $Q_Z$  allowed by the quantization condition scales as  $r$ . This is quite possible and the interpretation would be that each of the  $r$  sheets of the covering carries (possibly same) elementary charge. Kind of discrete variant of a full Fermi sphere would be in question. The interpretation in terms of anyonic phases [8] supports this interpretation.
5. The identification of  $J$  as a counterpart of  $eB/\hbar$  means that Kähler action and thus also Kähler function is proportional to  $1/\alpha_K$  and therefore to  $\hbar$ . This implies that for large values of  $\hbar$  Kähler coupling strength  $g_K^2/4\pi$  becomes very small and large fluctuations are suppressed in the functional integral. The basic motivation for introducing the hierarchy of Planck constants was indeed that the scaling  $\alpha \rightarrow \alpha/r$  allows to achieve the convergence of perturbation theory: Nature itself would solve the problems of the theoretician. This of course does not mean that the physical states would remain as such and the replacement of single particles with anyonic states in order to satisfy the condition for  $K$  would realize this concretely.

The weak form of electric-magnetic duality has surprisingly strong implications for basic view about quantum TGD as following considerations show.

### 3 Magnetic confinement, the short range of weak forces, and color confinement

The weak form of electric-magnetic duality has surprisingly strong implications if one combines it with some very general empirical facts such as the non-existence of magnetic monopole fields in macroscopic length scales.

#### 3.1 Can wormhole throats have vanishing magnetic charge?

The first question is how the long range effects of magnetic charges can be avoided and turns out to relate closely to the question how to avoid long range weak forces in TGD context where standard view about electroweak symmetry breaking does not apply.

1. The obvious question is whether the vanishing Kähler magnetic flux is possible. In this case one would have vanishing configuration space metric if Kähler electric flux defines the WCW metric unless the metric is defined by the sum of these fluxes. The condition would relate electromagnetic and  $Z^0$  charges to each other.

$$\alpha_{em}Q_{em} + p\frac{\alpha_Z}{2}\left(\frac{I_V^3}{2} - pQ_{em}\right) = 0 . \quad (3.1)$$

For  $Q_{em} = 0$  (neutrinos) the value of Weinberg angle must vanish: this implies  $e = 0$ , which looks strange. On the other hand, the charge fed by wormhole contact is vanishing. For  $(Q_{em}, I_V^3) \in \{\pm(1, 1/2), \pm(2/3, 1/2), \pm(1/3, 1/2)\}$  the condition reduces to

$$p^2(p - p_0)^2 - 4p(1 - p) = 0 , \quad p_0 \in \{1/4, 3/4, 3/8\} . \quad (3.2)$$

corresponding to  $(Q_{em}, I_V^3) \in \{\pm(1, 1/2), \pm(2/3, 1/2), \pm(1/3, 1/2)\}$ . This gives for  $p = \sin^2(\theta_W)$  rather near to 1 implying large value of  $g_Z$ , which does not look physical.

2. The conclusion seems to be that elementary particles must correspond to Kähler magnetic monopoles. This is alarming since magnetic monopoles are absent in macroscopic length scales.

#### 3.2 How can one avoid macroscopic magnetic monopole fields?

Monopole fields are however experimentally absent in length scales above order weak boson length scale and one should have a mechanism neutralizing the monopole charge. How electroweak interactions become short ranged in TGD framework is still a poorly understood problem. What suggests itself is the neutralization of the weak isospin above the intermediate gauge boson Compton length by neutral Higgs bosons. Could the two neutralization mechanisms be combined to single one?

- (a) In the case of fermions and their superpartners the opposite magnetic monopole would be a wormhole throat. If the magnetically charged wormhole contact is electromagnetically neutral but has vectorial weak isospin neutralizing the weak vectorial isospin of the fermion only the electromagnetic charge of the fermion is visible on longer length scales. The distance of this wormhole throat from the fermionic one should be of the order weak boson Compton length. An interpretation as a bound state of fermion and a wormhole throat state with the quantum numbers of a neutral Higgs boson would therefore make sense. The neutralizing throat would have quantum numbers of  $X_{-1/2} = \nu_L \bar{\nu}_R$  or  $X_{1/2} = \bar{\nu}_L \nu_R$ .  $\nu_L \bar{\nu}_R$  would not be neutral Higgs boson (which should correspond to a wormhole contact) but a super-partner of left-handed neutrino obtained by adding a right handed neutrino. This mechanism would apply separately to the fermionic and antifermionic throats of the gauge bosons and corresponding space-time sheets and leave only electromagnetic interaction as a long ranged interaction.
- (b) One can of course wonder what is the situation for the bosonic wormhole throats feeding gauge fluxes between space-time sheets. It would seem that these wormhole throats must always appear as pairs such that for the second member of the pair monopole charges and  $I_V^3$  cancel each other at both space-time sheets involved so that one obtains at both space-time sheets magnetic dipoles of size of weak boson Compton length. The proposed magnetic character of fundamental particles should become visible at TeV energies so that LHC might have surprises in store!

### 3.3 Magnetic confinement and color confinement

Magnetic confinement generalizes also to the case of color interactions. One can consider also the situation in which the magnetic charges of quarks (more generally, of color excited leptons and quarks) do not vanish and they form color and magnetic singles in the hadronic length scale. This would mean that magnetic charges of the state  $q_{\pm 1/2} - X_{\mp 1/2}$  representing the physical quark would not vanish and magnetic confinement would accompany also color confinement. This would explain why free quarks are not observed. To how degree then quark confinement corresponds to magnetic confinement is an interesting question.

For quark and antiquark of meson the magnetic charges of quark and antiquark would be opposite and meson would correspond to a Kähler magnetic flux so that a stringy view about meson emerges. For valence quarks of baryon the vanishing of the net magnetic charge takes place provided that the magnetic net charges are  $(\pm 2, \mp 1, \mp 1)$ . This brings in mind the spectrum of color hyper charges coming as  $(\pm 2, \mp 1, \mp 1)/3$  and one can indeed ask whether color hyper-charge correlates with the Kähler magnetic charge. The geometric picture would be three strings connected to single vertex. Amusingly, the idea that color hypercharge could be proportional to color hyper charge popped up during the first year of TGD when I had not yet discovered  $CP_2$  and believed on  $M^4 \times S^2$ .

p-Adic length scale hypothesis and hierarchy of Planck constants defining a hierarchy of dark variants of particles suggest the existence of scaled up copies of QCD type physics and weak physics. For p-adically scaled up variants the mass scales would be scaled by a power of  $\sqrt{2}$  in the most general case. The dark variants of the particle would have the same mass as the original one. In particular, Mersenne primes  $M_k = 2^k - 1$  and Gaussian Mersennes  $M_{G,k} = (1+i)^k - 1$  has been proposed to define zoomed copies of these physics. At the level of magnetic confinement this would mean hierarchy of length scales for the magnetic confinement.

One particular proposal is that the Mersenne prime  $M_{89}$  should define a scaled up variant of the ordinary hadron physics with mass scaled up roughly by a factor  $2^{(107-89)/2} = 512$ . The size scale of color confinement for this physics would be same as the weal length scale. It would look more natural that the weak confinement for the quarks of  $M_{89}$  physics takes place in some shorter scale and  $M_{61}$  is the first Mersenne prime to be considered. The mass scale of  $M_{61}$  weak bosons would be by a factor  $2^{(89-61)/2} = 2^{14}$  higher and about  $1.6 \times 10^4$  TeV.  $M_{89}$  quarks would have virtually no weak interactions but would possess color interactions with weak confinement length scale reflecting themselves as new kind of jets at collisions above TeV energies.

In the biologically especially important length scale range 10 nm -2500 nm there are as many as four Gaussian Mersennes corresponding to  $M_{G,k}$ ,  $k = 151, 157, 163, 167$ . This would suggest that the existence of scaled up scales of magnetic-, weak- and color confinement. An especially interesting possibly testable prediction is the existence of magnetic monopole pairs with the size scale in this range. There are recent claims about experimental evidence for magnetic monopole pairs [14].

### 3.4 Magnetic confinement and stringy picture in TGD sense

The connection between magnetic confinement and weak confinement is rather natural if one recalls that electric-magnetic duality in super-symmetric quantum field theories means that the descriptions in terms of particles and monopoles are in some sense dual descriptions. Fermions would be replaced by string like objects defined by the magnetic flux tubes and bosons as pairs of wormhole contacts would correspond to pairs of the flux tubes. Therefore the sharp distinction between gravitons and physical particles would disappear.

The reason why gravitons are necessarily stringy objects formed by a pair of wormhole contacts is that one cannot construct spin two objects using only single fermion states at wormhole throats. Of course, also superpartners of these states with higher spin obtained by adding fermions and antifermions at the wormhole throat but these do not give rise to graviton like states [7]. The upper and lower wormhole throat pairs would be quantum superpositions of fermion antifermion pairs with sum over all fermions. The reason is that otherwise one cannot realize graviton emission in terms of joining of the ends of light-like 3-surfaces together. Also now magnetic monopole charges are necessary but now there is no need to assign the entities  $X_{\pm}$  with gravitons.

Graviton string is characterized by some p-adic length scale and one can argue that below this length scale the charges of the fermions become visible. Merenne hypothesis suggests that some Mersenne prime is in question.

One proposal is that gravitonic size scale is given by electronic Mersenne prime  $M_{127}$ . It is however difficult to test whether graviton has a structure visible below this length scale.

What happens to the generalized Feynman diagrams is an interesting question. It is not at all clear how closely they relate to ordinary Feynman diagrams. All depends on what one is ready to assume about what happens in the vertices. One could of course hope that zero energy ontology could allow some very simple description allowing perhaps to get rid of the problematic aspects of Feynman diagrams.

1. Consider first the recent view about generalized Feynman diagrams which relies zero energy ontology. A highly attractive assumption is that the particles appearing at wormhole throats are on mass shell particles. For incoming and outgoing elementary bosons and their superpartners they would be positive it resp. negative energy states with parallel on mass shell momenta. For virtual bosons they the wormhole throats would have opposite sign of energy and the sum of on mass shell states would give virtual net momenta. This would make possible twistorial description of virtual particles allowing only massless particles (in 4-D sense usually and in 8-D sense in TGD framework). The notion of virtual fermion makes sense only if one assumes in the interaction region a topological condensation creating another wormhole throat having no fermionic quantum numbers
2. The addition of the particles  $X^\pm$  replaces generalized Feynman diagrams with the analogs of stringy diagrams with lines replaced by pairs of lines corresponding to fermion and  $X_{\pm 1/2}$ . The members of these pairs would correspond to 3-D light-like surfaces glued together at the vertices of generalized Feynman diagrams. The analog of 3-vertex would not be splitting of the string to form shorter strings but the replication of the entire string to form two strings with same length or fusion of two strings to single string along all their points rather than along ends to form a longer string. It is not clear whether the duality symmetry of stringy diagrams can hold true for the TGD variants of stringy diagrams.
3. How should one describe the bound state formed by the fermion and  $X^\pm$ ? Should one describe the state as superposition of non-parallel on mass shell states so that the composite state would be automatically massive? The description as superposition of on mass shell states does not conform with the idea that bound state formation requires binding energy. In TGD framework the notion of negentropic entanglement has been suggested to make possible the analogs of bound states consisting of on mass shell states so that the binding energy is zero [10]. If this kind of states are in question the description of virtual states in terms of on mass shell states is not lost. Of course, one cannot exclude the possibility that there is infinite number of this kind of states serving as analogs for the excitations of string like object.
4. What happens to the states formed by fermions and  $X_{\pm 1/2}$  in the internal lines of the Feynman diagram? Twistorial philosophy suggests that only the higher on mass shell excitations are possible. If this picture is correct, the situation would not change in an essential manner from the earlier one.

The highly non-trivial prediction of the magnetic confinement is that elementary particles should have stringy character in electro-weak length scales and could beving to become manifest at LHC energies. This adds one further item to the list of non-trivial predictions of TGD about physics at LHC energies [9].

#### Acknowledgements

I want to thank my friend Dainis Zeps for generating the pressure to write an article series about TGD. This process stimulated also the argument series discussed above.

## References

- [1] M. Pitkänen (2006), *Quantum Physics as Infinite-Dimensional Geometry*. [http://tgd.wippiespace.com/public\\_html/tgdgeom/tgdgeom.html](http://tgd.wippiespace.com/public_html/tgdgeom/tgdgeom.html).
- [2] M. Pitkänen (2006), *Quantum TGD*. [http://tgd.wippiespace.com/public\\_html/tgdquant/tgdquant.html](http://tgd.wippiespace.com/public_html/tgdquant/tgdquant.html).
- [3] M. Pitkänen (2006), *p-Adic length Scale Hypothesis and Dark Matter Hierarchy*. [http://tgd.wippiespace.com/public\\_html/paddark/paddark.html](http://tgd.wippiespace.com/public_html/paddark/paddark.html).
- [4] M. Pitkänen (2006), *TGD Inspired Theory of Consciousness*. [http://tgd.wippiespace.com/public\\_html/tgdconsc/tgdconsc.html](http://tgd.wippiespace.com/public_html/tgdconsc/tgdconsc.html).
- [5] M. Pitkänen (2006), *TGD and EEG*. [http://tgd.wippiespace.com/public\\_html/tgdeeg/tgdeeg.html](http://tgd.wippiespace.com/public_html/tgdeeg/tgdeeg.html).
- [6] The chapter *Construction of Configuration Space Kähler Geometry from Symmetry Principles*. [http://tgd.wippiespace.com/public\\_html/tgdgeom/tgdgeom.html#compl1](http://tgd.wippiespace.com/public_html/tgdgeom/tgdgeom.html#compl1).
- [7] The chapter *Does the QFT Limit of TGD Have Space-Time Super-Symmetry?* of [2]. [http://tgd.wippiespace.com/public\\_html/tgdquant/tgdquant.html#susy](http://tgd.wippiespace.com/public_html/tgdquant/tgdquant.html#susy).
- [8] The chapter *Quantum Hall effect and Hierarchy of Planck Constants* of [3]. [http://tgd.wippiespace.com/public\\_html/paddark/paddark.html#anyontgd](http://tgd.wippiespace.com/public_html/paddark/paddark.html#anyontgd).
- [9] The chapter *p-Adic Particle Massivation: New Physics* of [3]. [http://tgd.wippiespace.com/public\\_html/paddark/paddark.html#padmass4](http://tgd.wippiespace.com/public_html/paddark/paddark.html#padmass4).

- [10] The chapter *Negentropy Maximization Principle* of [4].  
[http://tgd.wippiespace.com/public\\_html/tgdconsc/tgdconsc.html#nmpc](http://tgd.wippiespace.com/public_html/tgdconsc/tgdconsc.html#nmpc).
- [11] The chapter *Dark Matter Hierarchy and Hierarchy of EEGs* of [5].  
[http://tgd.wippiespace.com/public\\_html/tgdeeg/tgdeeg.html#eegdark](http://tgd.wippiespace.com/public_html/tgdeeg/tgdeeg.html#eegdark).
- [12] The chapter *Appendix B* of [2].  
[http://tgd.wippiespace.com/public\\_html/tgdquant/tgdquant.html#appendb](http://tgd.wippiespace.com/public_html/tgdquant/tgdquant.html#appendb).
- [13] *Montonen-Olive duality*. [http://en.wikipedia.org/wiki/Montonen&Olive\\_duality](http://en.wikipedia.org/wiki/Montonen%26Olive_duality).
- [14] D. J. P. Morris *et et al* (2009). *Dirac Strings and Magnetic Monopoles in Spin Ice Dy<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub>*. Science, Vol. 326, No. 5951, pp. 411-414.  
H. Johnston (1010) *Magnetic monopoles spotted in spin ices*. <http://physicsworld.com/cws/article/news/40302>.