Higgs Mass from Topological Condensation of Vector Bosons

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Abstract

We suggest here that the Higgs scalar amounts to a weakly-bounded condensate of gauge bosons. According to this interpretation, the Higgs mass may be approximated from the sum of vector boson masses on spacetime endowed with minimal fractality.

Key words: minimal fractal manifold, fractional field theory, Higgs scalar, topological condensation, vector bosons, gluon-gluon fusion.

In [1-2] we have advanced the idea that a four-dimensional spacetime with minimal fractality ($\varepsilon << 1,\ \varepsilon = 4 - D$) favors the emergence of a *Higgs-like* condensate of gauge bosons. It can be described by

$$\Phi_C = \frac{1}{4}[(W^+ + W^- + Z^0 + \gamma + g) + (W^+ + W^- + Z^0 + \gamma + g)] \tag{1}$$

where $W^{\pm}, Z^0$ are the massive bosons of the electroweak model and γ, g the photon and gluon, respectively.

A remarkable feature of (1) is that it represents a weakly-coupled cluster of gauge fields having *zero topological charge* [1-2]. Compliance with this requirement motivates the duplicate construction of (1), which contains (W^+W^-), (Z^0Z^0), photon and gluon doublets. Stated differently, (1) is the most basic combination of gauge field doublets that is free from all gauge and topological charges. Tab. 1 presents a comparative display of properties carried by the Standard Model (SM) Higgs versus the Higgs-like condensate:

Scalar field	Form	Composition	Mass (GeV)	Weak hypercharge	Electric charge	Color	Topological charge
SM Higgs	$\begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix}$	none	~ 125	$\begin{pmatrix} +1 \\ +1 \end{pmatrix}$	$\begin{pmatrix} +1 \\ 0 \end{pmatrix}$	0	0
Higgs-like condensate	Φ_C	(1)	~ 126	0	0	0	0

Tab. 1: SM Higgs doublet versus the Higgs-like condensate

Following the way (1) is built up, one needs (at least) a pair of Z^0 bosons to secure a spin-less and neutral mixture of vector particles. As explained in [1, 2], (1) emerges from a mass-generation mechanism rooted in the low fractality of spacetime above the electroweak scale. In particular, the key distinction between *Bose-Einstein condensation* on smooth spacetime and boson condensation on the minimal fractal manifold ($\varepsilon = 4 - D$ $<< 1$) is that the latter resembles localization of quantum waves on random potentials, a phenomenon associated, for example, with *Anderson localization* [5].

It is important to point out that, in line with [2-4], (1) is compatible with the so-called "*sum-of-squares*" relationship constraining particle masses *or* the choice of gauge, Yukawa, and scalar couplings. Taken together, these considerations hint that the condensation mechanism embodied in (1) bypasses the standard electroweak symmetry breaking, *yet it imitates its function*. To elaborate on this point, recall that the SM Higgs stems from a $SU(2)$ doublet of complex scalar fields

$$\varphi = \begin{pmatrix} \varphi^{+} \\ \varphi^{0} \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} \varphi_1 + i\varphi_2 \\ \varphi_3 + i\varphi_4 \end{pmatrix} \tag{2}$$

where φ_i $(i = 1, 2, 3, 4)$ are real valued field components [6]. Spontaneous breaking of gauge symmetry is introduced by choosing a preferential direction in $SU(2)$ space as in

$$\varphi_0 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \mathrm{v} \end{pmatrix} \tag{3}$$

in which $\varphi_4 = \mathrm{v}$ stands for the Higgs vacuum and $\varphi_1 = \varphi_2 = \varphi_3 = 0$. Appealing to the bifurcation model of quantum fields reported in [7], one may consider a scenario where (3) sequentially splits up into the electroweak quartet $(W^{+}, W^{-}, Z^{0}, \gamma)$ and gluon octet $(g_1, g_2, ..., g_8)$, respectively, according to the *Feigenbaum diagram*

$$\boxed{\begin{matrix}\text{Long-range}\\ \text{scalar}\\ \text{condensate}\end{matrix}} \rightarrow \boxed{\text{Higgs}} \begin{Bmatrix} 0 \\ \mathrm{v} \end{Bmatrix} \rightarrow \boxed{SU(2) \times U(1)} \begin{Bmatrix} W^{+} \\ W^{-} \\ Z^{0} \\ \gamma \end{Bmatrix} \rightarrow \boxed{SU(3)} \begin{Bmatrix} g_1 \\ g_2 \\ \dots \\ g_8 \end{Bmatrix} \rightarrow \boxed{\text{Cantor Dust}} \rightarrow \boxed{\text{Fermion sector}}$$

The Feigenbaum diagram reflects the geometry of a self-contained multifractal set, which is ordered according to the *Sharkovsky theorem* [9]. A follow-up analysis of the relationship between the Feigenbaum diagram and the physics of SM will be presented elsewhere [8].

A final observation is now in order. The most recent estimate places the SM Higgs boson mass at $m_H^{\exp} = 125.09 \pm 0.24$ GeV, whereas the mass of the Higgs-like condensate computed from (1) is $m_{\Phi_c} = 125.98$ GeV. The slight deviation between the two numbers may be tentatively attributed to the binding energy of *gluon-gluon fusion*, a process stemming from the nonperturbative nature of Quantum Chromodynamics (QCD). In this case, the expectation value for the energy deficit carried by the gluon "doublet" amounts to $\Delta = m_H^{\exp} - m_{\Phi_c} = -0.89$ GeV.

References

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