

## 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.

**Keywords:** 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 ( $\varepsilon \ll 1$ ,  $\varepsilon = 4 - D$ ) favors the emergence of a *Higgs-like* condensate of gauge bosons. It can be described by

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

where  $W^\pm, Z^0$  are the massive bosons of the electroweak model and  $\gamma, g$  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:

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Scalar field	Form	Composition	Mass (GeV)	Weak hypercharge	Electric charge	Color	Topological charge
SM Higgs	$\begin{pmatrix} \varphi^+ \\ \varphi^0 \end{pmatrix}$	none	$\sim 125$	$\begin{pmatrix} +1 \\ +1 \end{pmatrix}$	$\begin{pmatrix} +1 \\ 0 \end{pmatrix}$	0	0
Higgs-like condensate	$\Phi_C$	(1)	$\sim 126$	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 ( $\varepsilon = 4 - D \ll 1$ ) is that the latter resembles localization of quantum waves on random potentials, a phenomenon associated, for example, with *Anderson localization* [5].

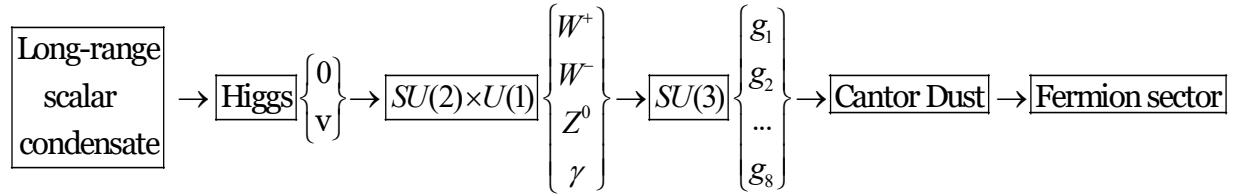
It is important to point out that, in line with [2-4], (1) is compatible with the so-called “*sum-of-squares*” relationship constraining particle masses *or* the choice of gauge, Yukawa, and scalar couplings. Taken together, these considerations hint that the condensation mechanism embodied in (1) bypasses 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

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

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

$$\varphi_0 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v \end{pmatrix} \quad (3)$$

in which  $\varphi_4 = v$  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 ( $g_1, g_2, \dots, g_8$ ), respectively, according to the period-doubling diagram



A follow up analysis of this scenario will be presented elsewhere [8].

A final observation is now in order. The most recent estimate places the SM Higgs boson mass at  $m_H^{\text{exp}} = 125.09 \pm 0.24 \text{ GeV}$ , whereas the mass of the Higgs-like condensate computed from (1) is  $m_{\Phi_c} = 125.98 \text{ GeV}$ . 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  $\Delta = m_H^{\text{exp}} - m_{\Phi_c} = -0.89 \text{ GeV}$ .

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## References

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