**Article**

# 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 ($\varepsilon$ << 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 | ~ 125 | $\begin{pmatrix}+1\\ +1\end{pmatrix}$ | $\begin{pmatrix}+1\\ 0\end{pmatrix}$ | 0 | 0 |
| Higgs-like condensate | $\Phi_C$ | (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 $\varphi_i$ $(i = 1,2,3,4)$ are real valued field components [6]. Spontaneous breaking of gauge symmetry is introduced by choosing a preferential direction in $SU(2)$ space as in

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

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 period-doubling diagram

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

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 $m_H^{\exp} = 125.09 \pm 0.24$ 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.

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## References

[1] Goldfain E., "*Fractal Spacetime as Underlying Structure of the Standard Model*", Quantum Matter, **3**(3), (2014), pp. 256-263. A draft of this article can be located at: https://bit.ly/3tt9aa1

[2] Goldfain E., "*Introduction to Fractional Field Theory*", (2015), Aracne Editrice. Same reference can be located at: https://bit.ly/3b4DscM

[3] https://bit.ly/3b8mpGU

[4] https://arxiv.org/pdf/1305.4208.pdf

[5] http://web.mit.edu/8.334/www/grades/projects/projects19/GuanChenguang.pdf

[6] see, e.g., Ryder L. H., "Quantum Field Theory", Cambridge Univ. Press, 1989.

[7] Goldfain E., "A Bifurcation Model of the Quantum Field", Physica A 165: 399-419 (1990). A copy of this reference is available at: https://bit.ly/2RuMJ7c

[8] Goldfain E., "Universal Bifurcations and the Structure of the Standard Model", in progress.