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## Higgs resonance: mode of the vacuum, not the cause of mass

Curvature of a Jordan potential around  $\langle H \rangle$

**Key Insight.** In the Standard Model narrative, the Higgs field “gives mass” to particles. In the octonionic/Jordan picture this story is inverted: masses arise from the eigenvalues of a mass map  $\Pi(\langle H \rangle)$ , constructed from a vacuum element  $\langle H \rangle \in H_3(\mathbb{O})$ . The observed 125 GeV Higgs particle is then a *resonance* of this vacuum — a fluctuation mode around  $\langle H \rangle$  determined by the curvature of the Jordan potential, not the fundamental origin of mass itself.

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**I**N the usual Standard Model story, the Higgs field “gives” particles their mass: all particles move through an omnipresent field, and the stronger they couple, the heavier they are. The Higgs boson discovered at the LHC in 2012 is then seen as the quantum of this field — the carrier of the mass-giving mechanism.

The octonionic picture inverts this narrative. Here, masses come from the eigenvalues of a mass map  $\Pi(\langle H \rangle)$  built from a vacuum configuration  $\langle H \rangle$  inside the Albert algebra  $H_3(\mathbb{O})$ . The vacuum is a distinguished element in this exceptional algebra, chosen by minimising a Jordan-invariant potential  $V_J(H)$ . Once this vacuum is fixed, the mass map acts on the internal space of one generation, and its eigenvalues are the candidate fermion masses.

In this view, mass is a property of how the vacuum sits inside  $H_3(\mathbb{O})$ , not a “gift” handed out by an external scalar field.

So where does the 125 GeV Higgs boson fit in? It is reinterpreted as a resonance of the vacuum — a fluctuation mode around  $\langle H \rangle$  determined by the curvature of  $V_J(H)$ . Think of the vacuum as a ball resting at the bottom of a valley. If you nudge the ball slightly, it will oscillate with a frequency set by the shape of the valley near the minimum. In the octonionic model, the 125 GeV Higgs is precisely such an oscillation: a mode that measures how steeply the potential curves around the vacuum point.

What changes is the underlying language. Instead of a fundamental scalar field added by hand, we have a Jordan element  $\langle H \rangle$  in  $H_3(\mathbb{O})$ . Instead of ad-hoc Yukawa couplings, we have a linear mass map  $\Pi(\langle H \rangle)$  whose structure is fixed by exceptional symmetry.

### Masses from the vacuum configuration

The octonionic model encodes internal structure in the Albert algebra  $H_3(\mathbb{O})$ . A vacuum configuration is a fixed Jordan element

$$\langle H \rangle \in H_3(\mathbb{O}),$$

and the mass map is a linear operator

$$\Pi(\langle H \rangle) : V_{\text{int}} \rightarrow V_{\text{int}},$$

acting on the internal space of one generation. Its eigenvalue equation

$$\Pi(\langle H \rangle)\Psi_i = m_i \Psi_i$$

provides candidate fermion masses  $m_i$ ; the  $\Psi_i$  define mass eigenstates.

### Jordan potential and vacuum stability

The vacuum  $\langle H \rangle$  is determined by a Jordan-invariant potential  $V_J(H)$  on  $H_3(\mathbb{O})$ :

$$V_J : H_3(\mathbb{O}) \rightarrow \mathbb{R}, \quad H \mapsto V_J(H),$$

invariant under an  $F_4$  action on the Albert algebra. The true vacuum is a minimum of this potential,

$$\frac{\partial V_J}{\partial H} \Big|_{H=\langle H \rangle} = 0, \quad \frac{\partial^2 V_J}{\partial H^2} \Big|_{H=\langle H \rangle} > 0 \text{ (in suitable directions).}$$

Fluctuations  $\delta H$  around  $\langle H \rangle$  see a quadratic approximation

$$V_J(\langle H \rangle + \delta H) \approx V_J(\langle H \rangle) + \frac{1}{2} \delta H \cdot \mathcal{M}_J \cdot \delta H + \dots,$$

where  $\mathcal{M}_J$  is the Hessian (second derivative) at the minimum.

### The Higgs as a curvature mode

Among the many possible fluctuation directions  $\delta H$  there is a distinguished one that largely preserves the internal alignment of  $\langle H \rangle$  but changes its *magnitude*. This direction corresponds to the traditional electroweak order parameter and gives rise to the observed Higgs resonance.

Its mass is set by a particular eigenvalue of the Hessian:

$$m_H^2 \sim \left. \frac{\partial^2 V_J}{\partial h^2} \right|_{h=0},$$

where  $h$  parametrises the relevant fluctuation mode. The 125 GeV resonance is therefore a curvature property of  $V_J$  at  $\langle H \rangle$ , not the mechanism that created the fermion masses in the first place.

## What is different from the Nobel-prize Higgs story?

The 2012 discovery of a 125 GeV scalar at the LHC and the subsequent Nobel Prize to Englert and Higgs cemented a specific narrative: there is a fundamental scalar field  $H(x)$ , added to the Standard Model Lagrangian, whose vacuum expectation value  $\langle H \rangle$  and Yukawa couplings *cause* particle masses. In this picture

- the Higgs field is a basic ingredient of the theory, on the same footing as the gauge fields,
- fermion masses are free Yukawa parameters multiplied by  $\langle H \rangle$ ,
- the Higgs boson is the quantum of this fundamental field.

The octonionic/Jordan framework keeps all experimentally established facts — a 125 GeV scalar, a non-zero order parameter, mass relations for gauge bosons and fermions — but reorganises the underlying explanation:

1. **The vacuum is primary, not the field.** The central object is a distinguished Jordan element  $\langle H \rangle \in H_3(\mathbb{O})$ , selected by minimising a Jordan-invariant potential  $V_J(H)$ . There is no separate, fundamental Higgs field; there is an exceptional vacuum living in the Albert algebra.
2. **Masses come from a fixed mass map, not from arbitrary Yukawas.** Once  $\langle H \rangle$  is chosen, it defines a linear mass map  $\Pi(\langle H \rangle) : V_{\text{int}} \rightarrow V_{\text{int}}$  whose eigenvalues are the candidate fermion masses. The pattern of masses is controlled by the embedding of the vacuum into  $H_3(\mathbb{O})$  and by exceptional symmetry, not by an independent set of Yukawa couplings.
3. **The Higgs boson is an excitation of the vacuum, not the agent of mass.** Small fluctuations of  $H$  around  $\langle H \rangle$  decompose into normal modes given by the Hessian  $\mathcal{M}_J$  of  $V_J$ . The observed 125 GeV state is one particular normal mode: a quantised oscillation of the exceptional vacuum. Its mass  $m_H^2$  measures the curvature of  $V_J$  at the minimum; it does not by itself explain the fermion mass hierarchy.
4. **Cause vs. symptom is reversed.** The Nobel-prize story takes the Higgs field as the cause

and the vacuum as a consequence of its potential. Here we start from a structured exceptional vacuum and derive both the mass spectrum and the Higgs resonance as consequences. The Higgs particle is a *diagnostic mode* of the vacuum geometry, not the mechanism that “gives” mass.

From the viewpoint of LHC measurements, both descriptions agree on what is seen: a scalar resonance at 125 GeV with specific couplings. The difference is conceptual: in the octonionic/Jordan model, the Higgs is a collective excitation of an exceptional vacuum, and mass generation is tied to the eigenstructure of  $\Pi(\langle H \rangle)$  rather than to a freely adjustable scalar field with many Yukawa knobs.

## Decoupling the narrative: cause vs. symptom

This leads to a clean conceptual split:

- **Cause of masses:** the spectrum of  $\Pi(\langle H \rangle)$ , i.e. how the vacuum embeds into  $H_3(\mathbb{O})$  and how this embedding acts on internal states.
- **Symptom of the vacuum:** the Higgs resonance as one particular fluctuation of  $\langle H \rangle$  encoded in the curvature of  $V_J$ .

## Why this matters for the bigger picture

The Higgs day shows how a cornerstone of the Standard Model (the Higgs mechanism) can be embedded into a more rigid algebraic framework without losing contact with experiment. It supports the general thesis that many “fundamental fields” are better viewed as collective modes of an exceptional vacuum, determined by internal geometry rather than arbitrary Lagrangian terms.

If future measurements further constrain Higgs couplings and self-interactions, they will test not only the Standard Model but also any candidate for the underlying exceptional vacuum structure that produces the observed 125 GeV mode.

## References

- [1] P. W. Higgs, “Broken symmetries and the masses of gauge bosons,” *Phys. Rev. Lett.* **13**, 508–509 (1964).
- [2] P. Jordan, J. von Neumann and E. Wigner, “On an algebraic generalization of the quantum mechanical formalism,” *Ann. Math.* **35**, 29–64 (1934).

*The Higgs is not the cause of mass but a resonance of an exceptional vacuum: a single curvature mode of a Jordan potential on  $H_3(\mathbb{O})$ .*