An Information-Theoretic Higgs Mechanism: MaxEnt References, Modular Spectra, and Effective Mass Scales

Nesen Oleg

Abstract

We develop an information-theoretic interpretation of the Higgs mechanism within the UMD program. A phase is specified by access data $F = (P^{\mathcal{A}_F, Z_F})$ and a canonical MaxEnt reference state σ_F (equivalently, an I-projection). We define a Higgs candidate as a robust scalar eigenmode of the linearized modular+GKSL response operator $\mathcal{L}_F$ around σ_F, and interpret its characteristic scale as an emergent mass/stiffness proxy. Near phase boundaries, we outline an EFT-compatible reduction: a scalar order parameter h (mode amplitude or MaxEnt-coordinate fluctuation) inherits quadratic stiffness from linear response and admits a Landau-type expansion $V_{\text{eff}}(h) = a(\lambda)h^2 + bh^4 + \cdots$. We connect this construction to reproducible spectral diagnostics (quantile coordinates k_q, commutator probes L, running exponents ν) and formulate falsifiable criteria for Higgs-like regimes in modular RG-proxy flows, while explicitly separating structural/EFT compatibility from phenomenological Standard Model parameter matching.

1 Introduction

The Standard Model Higgs sector selects a phase (symmetry breaking), generates a mass scale, and supplies a stable scalar excitation. In a foundations program, the question is whether these functions can arise as stable features of state space, dynamics, and coarse-grained access—without postulating a fundamental Higgs field.

Within the UMD series: Paper A yields a canonical state ρ; Paper B yields modular RG-proxy dynamics with CPTP completion; Paper C defines phases and locality via access structure and MaxEnt/I-projection; Paper D supplies reproducible spectral diagnostics; Paper E2 defines criticality as partition instability. Here we propose an information-theoretic Higgs mechanism: the Higgs is a *phase-stable scalar response mode* around the canonical reference σ_F, and "mass" is an *emergent stiffness scale* in modular response.

2 Compatibility claim (explicit)

Claimed level: Level 2 (EFT-compatible mapping). We claim (i) a role-level and structural correspondence (phase selection $\leftrightarrow$ access-structure change; Higgs excitation $\leftrightarrow$ robust scalar response mode; mass scale $\leftrightarrow$ response stiffness), and (ii) an EFT-compatible reduction near phase boundaries yielding a scalar order parameter with a Landau-type expansion. We do *not* claim Standard Model parameter matching ($m_H \approx 125$ GeV, $v \approx 246$ GeV), nor a full reconstruction of gauge groups and Yukawa textures (Level 3).

3 Setup: phases, references, and modular response

Fix a phase $F = (P^{\mathcal{A}_F, Z_F})$. Let σ_F be the canonical MaxEnt reference for constraints $\{Q_a\} \subset \mathcal{A}_F$,

$$\sigma_F = \arg\max_{\tau} \Big\{ S(\tau) \;\Big|\; \mathrm{Tr}(\tau Q_a) = \mathrm{Tr}(\rho Q_a) \Big\},$$

equivalently the minimizer of $D(\rho\|\cdot)$ over the associated exponential family (information projection).

Consider a perturbation $\rho = \sigma_F + \delta\rho$ with $\mathrm{Tr}(\delta\rho) = 0$. Linearizing the modular+GKSL dynamics (Paper B) around σ_F yields

$$\dot{\delta\rho} \approx \mathcal{L}_F(\delta\rho),$$

where $\mathcal{L}_F$ is the phase-specific linear response generator.

4 Main proposal: Higgs as a robust scalar eigenmode

Definition 1 (Higgs candidate mode)**.** A Higgs candidate is a fluctuation direction X_H (a tangent operator at σ_F) such that:

1. $\mathcal{L}_F(X_H) \approx \lambda_H X_H$ (approximate eigenmode),
2. the eigenpair (X_H, λ_H) is robust within the phase (stable under small micro-variations),
3. the mode is gap-separated from neighboring modes (isolated response scale),
4. X_H is scalar relative to phase symmetries (singlet under effective symmetries encoded in $\mathcal{A}_F/Z_F$).

Remark 1 (Mass/stiffness proxy)**.** The characteristic scale $|\lambda_H|$ acts as a canonical phase-internal stiffness (decay/response scale). Complementary proxies can be defined from modular spectra, e.g. $m_{\mathrm{spec}} = k_{q_2} - k_{q_1}$ with $k_q = -\log \lambda_q(\rho)$.

Proposition 1 (Canonical background and tangent decomposition)**.** *Fix a phase F and its MaxEnt reference σ_F. The decomposition $\rho = \sigma_F + \delta\rho$ is canonical at the phase level: σ_F is uniquely determined by constraints, and $\delta\rho$ captures deviations not fixed by the macro-constraints.*

Proof sketch. Uniqueness follows from the MaxEnt/I-projection characterization (faithful case and fixed constraints). Any ρ with the same constraint values differs from σ_F by a traceless $\delta\rho$ orthogonal to constraints in the linear sense. □

Proposition 2 (Mass scale proxy from the linearized spectrum)**.** *If $\mathcal{L}_F$ has a gap-separated scalar eigenmode X_H with eigenvalue λ_H, then $|\lambda_H|$ defines a canonical phase-internal scale (a mass/stiffness proxy) controlling response of scalar perturbations.*

Proof sketch. For $\dot{X} = \mathcal{L}_F X$, eigenmodes determine characteristic response scales. Gap separation ensures dominance of the isolated scalar mode over long scales. □

5 Level-2 EFT reduction near phase boundaries

5.1 Scalar order-parameter coordinate

We introduce a scalar coordinate h in either canonical form: (i) mode amplitude $\delta\rho \sim h X_H + \cdots$, or (ii) MaxEnt coordinate fluctuation: writing $\sigma_F(\beta) = e^{-\sum_a \beta_a Q_a}/Z$, define $h \equiv \delta\beta_H$ for a distinguished constraint direction.

5.2 Quadratic stiffness from response / information geometry

Near σ_F, the leading response is quadratic. Stiffness may be read from the response spectrum of $\mathcal{L}_F$ (via λ_H) and/or from curvature of information potentials around σ_F (e.g., second variation of $D(\rho\|\sigma_F)$), consistent with monotone metrics (BKM) used in Paper C.

5.3 Landau-type effective potential

Near phase boundaries (where E2 flatness/instability markers appear), assume a Landau-type expansion

$$V_{\text{eff}}(h) = a(\lambda)h^2 + bh^4 + \cdots, \qquad b > 0,$$

with control parameter λ (RG-proxy scale or family parameter). A sign change of $a(\lambda)$ corresponds to the onset of a symmetry-broken regime with $h \neq 0$. In UMD terms, this coincides with reorganization of phase data and emergence/sharpening of the scalar response mode.

6 Reproducible diagnostics and falsifiable criteria

Using Paper D diagnostics, one can track quantile flows $k_q(\lambda)$, commutator probes $L(\rho; O)$, and running exponents $\nu(\lambda)$ via pre-registered fits, and test whether emergence/sharpening of X_H (response gap + robustness) co-varies with phase-transition markers (changes in P, growth of $\mathcal{T}_P$, or closure degradation near critical windows).

Falsifiability. If no robust gap-separated scalar mode can be identified across phase boundaries where order-parameter behavior is expected, or if stiffness proxies fail to correlate with transition markers under reproducibility rules, the proposed identification is disfavored in that domain.

7 Discussion

This framework provides an EFT-compatible reinterpretation: "Higgs" is a stable scalar response degree of freedom in modular state dynamics, and "mass" is a stiffness scale in linear response and spectral tail structure. The proposal is intentionally domain-aware and does not attempt SM numerical matching without a separate scale-identification program.

8 Conclusion

Scientific value

We formulate an information-theoretic Higgs mechanism within UMD by identifying the Higgs sector with a phase-stable scalar response mode around a canonical MaxEnt reference σ_F. The framework maps phase selection to access-structure transitions and defines emergent mass scales as spectral stiffness in modular response, yielding a foundations-level bridge between modular spectral flow and effective scalar degrees of freedom.

Degree of development (depth)

We provide (i) a Higgs-candidate definition as a robust, gap-separated scalar eigenmode of $\mathcal{L}_F$, (ii) canonical order-parameter coordinates (mode amplitude or MaxEnt coordinate), and (iii) an EFT-compatible Landau expansion near phase boundaries. The proposal is coupled to reproducible diagnostics and domain statements established in Paper D and tied conceptually to criticality markers of Paper E2.

Applied value and future directions

Practically, the framework yields an implementable protocol for detecting Higgs-like scalar modes and mass proxies in modular RG-proxy simulations: identify σ_F, estimate $\mathcal{L}_F$, test scalar mode gap/stability, and correlate stiffness with spectral diagnostics and locality measures. Future directions include: (1) numerical extraction of response spectra across phases/channels; (2)

mapping correlations between stiffness, $\mathcal{T}_P$, and partition stability; (3) extending constraint algebras to approach gauge/matter structure; (4) deriving EFT scaling predictions for $a(\lambda)$ and universality classes; and (5) only then attempting phenomenological anchoring to SM scales (Level 3).

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