Energy and the vacuum as information-selection quantities in a PLI-based two-time framework with an optional 7D Janus embedding

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Abstract

This paper formalizes a conservative relation between energy and information-based model selection in a framework guided by a Principle of Least Information (PLI), understood as a minimum-description-length prior over admissible histories. The central claim is not a direct scalar equivalence between energy and information, but that the operational generator of time translations can acquire a contribution proportional to the *rate* at which irreducible description length must be maintained along the chosen operational time direction. We introduce a dimensionless action-plus-complexity functional, $\Xi[\mathfrak{h}] = S[\mathfrak{h}]/\hbar + \lambda\mathcal{C}$, where $\mathcal{C}$ is a unitless complexity functional (either a generative MDL complexity or a constraint-dependent mode-count complexity), and derive an effective relation $E_{\text{eff}} = E + \hbar\lambda\, d\mathcal{C}/dt$, with $E = dS/dt$ the standard Noether energy. We then interpret the vacuum as the minimal-description admissible configuration consistent with symmetry and constraint data, and show how vacuum sensitivities of the Casimir/Lifshitz type are naturally expressed as gradients of admissible mode libraries. Finally, we connect the formalism to near-critical macroscopic quantum platforms (superconductors, superfluids, latching quantum readout) where small constraint or measurement perturbations can trigger rapid transitions from low-dimensional coherent dynamics to high-dimensional dissipative dynamics, enabling high-gain switching and amplification without violating conservation laws.

Keywords: energy, vacuum, algorithmic information, minimum description length, open quantum systems, decoherence, Casimir effect, critical phenomena, superconductivity

1. Introduction

Energy is routinely treated as a primitive currency of dynamics. Yet operationally, only *differences* in energy and symmetry-generated conservation laws are directly testable; the absolute zero of energy is a convention in most settings. In parallel, the role of information and compression principles has matured across statistical mechanics, inference, and computation [1, 2, 3]. This paper develops a conservative bridge between these threads: energy remains the generator of operational time translations, while an informational *selection* term is introduced to formalize how histories are preferred when they admit shorter descriptions.

The motivating picture is analogous to equilibrium thermodynamics. There, macrostates are selected by extremizing thermodynamic potentials. Here, we introduce a dimensionless

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objective functional in which conventional dynamical phase (action) is supplemented by a unitless complexity term. When this complexity term is constant on the family being compared, conventional dynamics is recovered. When constraints, topology, or measurement protocols change the effective admissible degrees of freedom, the complexity term provides a structured language for vacuum sensitivity and for threshold-triggered macroscopic transitions.

Although the broader model context motivating this work is a two-time framework with an optional seven-dimensional Janus embedding, the present derivations do not rely on a detailed geometric construction. The two-time/7D context enters primarily as an interpretive scaffold: it supplies a natural place for auxiliary degrees of freedom to be traced out (open-system reduction), and it motivates attention to constraint-sensitive vacuum structure. The formal results below are stated at the level of an action functional, a complexity functional, and an operational time coordinate.

Throughout, notation is chosen to avoid ambiguous reuse of symbols. Fine-grained histories are denoted by $\mathfrak{h}$, while the Hamiltonian operator is written in its standard form $\hat{H}$. The Hilbert space is denoted by $\mathcal{V}$ (avoiding $\mathcal{H}$).

2. Background: energy as a translation generator

In conventional mechanics and field theory, energy arises as the Noether charge associated with invariance under translations of the operational time coordinate t [4]. Formally, for an action $S[\mathfrak{h}]$ and a time-translation invariant Lagrangian, the generator of time translations is the Hamiltonian:

$$E(t) \equiv \frac{dS}{dt}, \qquad \text{and quantum evolution is generated by } \hat{H}. \tag{1}$$

In open-system settings, effective subsystem energy balances can include exchange terms with an environment, even if global dynamics is unitary [5]. The present work does not alter these foundations; instead it supplements them with an informational selection term that can be interpreted as a structured prior over admissible histories.

3. PLI as minimum description length over admissible descriptions

3.1. Generative description length

Let $\mathcal{L}$ denote a compact specification of dynamical laws (equations, symmetries, constants) and $\mathcal{B}$ denote boundary/initial data and any coarse-graining conventions that determine what is operationally distinguished. Define a generative complexity (MDL/Kolmogorov-style)

$$\boxed{\mathcal{C}_G(\mathcal{L},\mathcal{B}) \;\equiv\; K(\mathcal{L}) + K(\mathcal{B} \mid \mathcal{L}),} \tag{2}$$

where $K(\cdot)$ is description length in bits (or nats), and $K(\mathcal{B} \mid \mathcal{L})$ is conditional description length [6, 7, 3]. The framework is agnostic about coding details; only comparative statements across competing descriptions are required. In practice, $\mathcal{C}_G$ should be understood as an idealized proxy for the minimal effective information needed to specify the law-and-boundary package to the fidelity required by the operational coarse-graining.

3.2. Mode-count complexity under constraints

Many physical questions are governed not by microdetails but by which degrees of freedom are *admissible* under constraints. Let C denote a constraint set (boundaries, topology, measurement protocol, etc.). Let $\mathcal{M}(C)$ be the admissible mode library. Define the mode-count complexity

$$\boxed{\mathcal{C}_M(C) \;\equiv\; \log|\mathcal{M}(C)|.} \tag{3}$$

This unitless proxy captures how constraints prune accessible degrees of freedom. Boundary-induced spectral changes in Casimir/Lifshitz settings provide a canonical example [8, 9, 10]. In this paper, $\mathcal{C}_M$ is used for qualitative and semi-quantitative reasoning about constraint gradients, rather than as a substitute for full spectral sums.

4. A dimensionless action-plus-complexity functional

4.1. Definition

Let $\mathcal{C}$ denote a unitless complexity functional. Depending on the question, $\mathcal{C}$ may be taken as $\mathcal{C}_G(\mathcal{L}, \mathcal{B})$ or as $\mathcal{C}_M(C)$ (or a controlled combination). Define a dimensionless objective functional

$$\boxed{\Xi[\mathfrak{h}] \;\equiv\; \frac{S[\mathfrak{h}]}{\hbar} \;+\; \lambda\,\mathcal{C},} \tag{4}$$

with λ a dimensionless weight. The PLI statement is that, among admissible descriptions compatible with observations, effective histories or ensembles are selected by favoring smaller Ξ. This can be viewed as a regularization prior: it biases toward descriptions that require fewer irreducible bits of specification, subject to matching the observational coarse-graining.

4.2. Derivation of an effective energy relation

Assume an operational time coordinate t has been selected (e.g., the time variable with respect to which agents and instruments implement clocks). Consider the change of Ξ along t:

$$\frac{d\Xi}{dt} \;=\; \frac{1}{\hbar}\frac{dS}{dt} \;+\; \lambda\,\frac{d\mathcal{C}}{dt}. \tag{5}$$

Using $E \equiv dS/dt$ as the conventional energy generator, multiply by $\hbar$ to obtain

$$\boxed{E_{\text{eff}} \;\equiv\; \hbar\frac{d\Xi}{dt} \;=\; E \;+\; \hbar\lambda\,\frac{d\mathcal{C}}{dt}.} \tag{6}$$

Equation (6) is the central formal result. It does *not* claim an absolute equivalence between energy and information; it identifies a structured way in which an informational selection term can contribute to the effective translation generator when the maintained complexity changes along operational time.

Two remarks are essential:

- If $\mathcal{C}$ is constant on the relevant family (e.g., within a fixed effective law/boundary specification), then $E_{\text{eff}} = E$ and conventional dynamics is recovered.
- When $\mathcal{C}$ varies—for example, when constraints activate or deactivate degrees of freedom, or when measurement/control protocols change the effective admissible library—the additional term is naturally interpreted as an information-flow contribution. This is conceptually aligned with how coarse-graining yields effective potentials and dissipation in open systems [5, 12].

5. Vacuum as minimal description under maximal symmetry

5.1. Vacuum energy: absolute offsets vs relational effects

In QFT, vacuum energy is renormalized; only differences and stress-energy responses in curved spacetime are physically meaningful, and the definition of "the vacuum" is observer- and geometry-dependent [11]. In a PLI framing, the vacuum is the minimal-description admissible configuration consistent with symmetry and constraint data. The emphasis shifts from absolute offsets to relational effects: if a constant energy shift does not change relative dynamics, transition rates, or operational records, then it is not a physically discriminating datum within the coarse-graining.

5.2. Casimir-type forces as mode-library gradients

For two conducting plates, boundary conditions eliminate classes of field modes between plates, shifting admissible spectral content. The standard ideal-plate result is the attractive pressure $F/A = -\pi^2\hbar c/(240\, d^4)$ [8]. In the present language, let $C(d)$ encode constraints at separation d. Then $\mathcal{M}(C(d))$ changes with d, and $\mathcal{C}_M(C(d))$ varies accordingly. PLI predicts a force-like tendency whenever geometry changes the admissible library; repulsive configurations correspond to reversed gradients in the constraint-dependent mode library (as occurs for certain geometries and material response functions in Lifshitz theory). The formalism does not replace spectral calculations; it provides a compact interpretation: vacuum sensitivity is an information-gradient effect because boundaries and topology alter the admissible degrees of freedom.

6. Energy, constraints, and complexity gradients

6.1. Constraints do not imply high energy; irreducible maintenance does

A state may be highly constrained yet low energy if it is highly compressible and stationary (e.g., a perfect crystal at $T \to 0$). In the present framework, what correlates with energy is not constraint count per se but the irreducible *rate* of maintained description length along operational time. This clarifies why "vacuum" can be structurally nontrivial yet energetically minimal: its defining property is maximal symmetry and minimal ongoing informational upkeep.

6.2. Simplicity pumps and threshold releases (conceptual)

Equation (6) suggests practical leverage arises from engineering changes in $d\mathcal{C}/dt$ or in constraint-dependent $\mathcal{C}$. A *simplicity pump* is a loading protocol that concentrates free energy into a low-dimensional collective coordinate (low effective mode accessibility) while remaining metastable; a small perturbation can then trigger a rapid opening of dissipation channels (high effective mode accessibility), producing a large release of stored free energy. This perspective emphasizes amplification and switching, not "free energy": the released energy originates from the pre-loaded reservoir, while the informational threshold controls when and how that reservoir couples to many modes.

7. Discussion and falsifiability

The PLI energy relation (6) yields conservative, testable statements when $\mathcal{C}$ is tied to operational proxies such as mode-library accessibility or measurement-induced record redundancy:

- **Threshold behavior:** if a platform exhibits sharp transitions in effective mode accessibility, decoherence and relaxation channels can show cliff-like onset near threshold, beyond smooth weak-coupling expectations.
- **Geometry sensitivity:** vacuum-sensitive forces should correlate with changes in admissible spectral libraries; repulsive configurations correspond to reversed gradients in $\mathcal{C}_M$.
- **Amplification constraints:** a small control/measurement perturbation can trigger large energy release only when a reservoir or metastable store is already present.

These statements can be explored in near-critical macroscopic quantum platforms where microscopic perturbations nucleate macroscopic transitions, and where order-parameter collapse maps naturally to a sudden growth of accessible dissipative channels.

8. Conclusion

We have formalized a bridge between energy and information-selection principles by introducing a dimensionless action-plus-complexity functional and deriving an effective relation $E_{\text{eff}} = E + \hbar\lambda \, d\mathcal{C}/dt$. The framework preserves conventional Noether and open-system results while providing a coherent vocabulary for vacuum sensitivity and threshold-triggered macroscopic transitions. The appendix highlights how near-critical macroscopic quantum systems provide concrete platforms in which small perturbations can induce rapid transitions from low-dimensional coherent dynamics to high-dimensional dissipative dynamics, enabling high-gain switching and amplification.

Appendix A. Supercritical macroscopic quantum systems and rapid energy release

Appendix A.1. Why macroscopic quantum phases are natural threshold platforms

Superconductors and superfluids exhibit collective order parameters whose stability depends sharply on control variables (temperature, current, field, geometry). Near critical surfaces, small perturbations can nucleate vortices or phase slips, rapidly opening dissipation channels and converting stored free energy into heat and quasiparticle excitations [13, 14, 15]. This is an archetype of a "complexity-threshold" transition: the effective description shifts from a small number of collective coordinates (coherent phase) to many dissipative degrees of freedom (quasiparticles, vortices, phonons, electromagnetic modes).

Appendix A.2. A minimal load–hold–trigger–release cycle

A safe conceptual cycle is:

1. **Load:** pump energy into a coherent collective coordinate (e.g., persistent current in a loop, population inversion, or phase stiffness).
2. **Hold near criticality:** bias near a stability threshold (critical current, critical field, or critical temperature).
3. **Trigger:** apply a small constraint or measurement perturbation that increases effective mode accessibility (e.g., nucleate a vortex, induce a phase slip, seed a resistive hotspot).
4. **Release:** the system transitions into a high-dissipation manifold, rapidly releasing stored free energy into many modes.

Such behavior underlies threshold detectors and amplifiers; it does not violate conservation laws because the released energy originates from the stored reservoir.

Appendix A.3. Examples

Superconducting nanowire single-photon detectors.. In superconducting nanowires biased near critical current, a small perturbation can drive a resistive hotspot that propagates and produces a macroscopic voltage pulse [16]. In PLI terms, the trigger increases effective accessible modes by destroying global phase coherence locally; the avalanche corresponds to a rapid increase in the engaged mode library and record redundancy.

Josephson bifurcation and latching readout.. Nonlinear superconducting circuits can be biased near bifurcation points so that small signals cause transitions between long-lived attractors, providing high-gain measurement [17]. This is consistent with a "minimal trigger, large response" regime governed by metastability and feedback.

SMES as coherent-mode loading.. Persistent currents store energy in electromagnetic fields and can, in principle, release it rapidly when coherence is lost or circuits are opened [18]. Practical limits are set by fields, materials, and cryogenics; conceptually, the example illustrates the separation between a low-dimensional coherent store and high-dimensional dissipative release.

Appendix B. Notation summary

Symbol	Meaning
$\mathfrak{h}$	fine-grained history
$S[\mathfrak{h}]$	action functional
$\hat{H}$	Hamiltonian operator
$\mathcal{L}$	law specification package
$\mathcal{B}$	boundary/specification package
$\mathcal{C}_G$	generative (MDL) complexity, Eq. (2)
$\mathcal{M}(C)$	admissible mode library under constraints C
$\mathcal{C}_M$	mode-count complexity, Eq. (3)
Ξ	dimensionless objective functional, Eq. (4)
λ	dimensionless weight of complexity term

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