Modal Theory Note: Information as a Geometric Property of the Locked Phase Landscape

(No semantics, no observers, no bits)

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Abstract

This note frames "information" in Modal Theory as a purely geometric, field-theoretic property: the persistence, propagation, and loss of phase-field configurations under the locked vacuum landscape. No semantics, observers, computation, or bit-level assumptions are introduced. Information is identified with the distribution of phase values, gradients, and coherence-domain structure in the scalar phase difference field $\Delta\theta(x, t)$, evolving under a stiff-gradient term and a relic-structured potential with a global lock near $\Delta\theta \approx 255^\circ$. The framework yields concrete, falsifiable signatures: (i) preferred propagation channels along low-gradient domains, (ii) relic pockets acting as frequency-selective buffers, and (iii) anisotropic loss induced by chiral bias. The note also gives a compact mapping from these concepts to sandbox metrics used in thrust-proxy simulations (slip rates, per-slip impulse, harmonic ratios, and directionality factor).

1 Scope and non-claims

This document is deliberately conservative:

- **Not claimed:** semantics, meaning, consciousness, computation, observer effects, or "information is fundamental".
- **Claimed:** *geometric information* in Modal Theory is the behavior of phase configurations under dynamical constraints: what patterns *persist*, *propagate*, *filter*, and *decay*.
- **Operational meaning:** two initial phase configurations are distinguishable (carry different information) if their subsequent evolution produces measurably different phase patterns, spectra, or domain structure.

2 Minimal MT ingredients used here

2.1 Fields and phase

Modal Theory contains two real scalar fields, conveniently represented by an amplitude and relative phase:

$$\Phi_1(x,t),\ \Phi_2(x,t) \quad \Rightarrow \quad \Delta\theta(x,t) \equiv \theta_1(x,t) - \theta_2(x,t).$$

The global vacuum is phase-locked at (or near) a preferred value

$$\Delta\theta \approx \theta_\star \equiv 255^\circ.$$

2.2 Effective phase dynamics (schematic)

For this note, only the qualitative structure matters: a potential term with relic structure and a gradient-stiffness penalty:

$$\mathcal{L}_{\Delta\theta} \sim \frac{I}{2}(\partial_t\Delta\theta)^2 - \frac{\lambda}{2}|\nabla\Delta\theta|^2 - V(\Delta\theta), \tag{1}$$

where I is an effective phase inertia (set by amplitude scale) and $\lambda > 0$ penalizes sharp spatial phase variations.

A minimal toy potential capturing relic structure is:

$$V(\Delta\theta) = -g_{\mathrm{mode}}\cos(N\,\Delta\theta) + b\cos(\Delta\theta - \theta_\star), \tag{2}$$

where $N = 3$ corresponds to the Z_3 relic structure (generalization to $N = 2, 4, \ldots$ is useful as a control).

The corresponding equation of motion (with phenomenological damping γ to model coupling to environment) is:

$$I\,\partial_t^2\Delta\theta + \gamma\,\partial_t\Delta\theta - \lambda\,\nabla^2\Delta\theta + \partial_{\Delta\theta}V(\Delta\theta) = S(x,t), \tag{3}$$

where S is any drive/source term (mechanical, EM-coupled, etc.).

3 Definition: geometric information in MT

3.1 Geometric state variables

Define the *geometric information state* at time t as the triple:

$$\mathcal{I}(t) \equiv \Big(\Delta\theta(x,t),\ \nabla\Delta\theta(x,t),\ \mathcal{D}(t)\Big), \tag{4}$$

where $\mathcal{D}(t)$ is the partition of space into coherence domains (defined below). This contains:

- **Phase information:** local values $\Delta\theta(x,t)$.
- **Gradient information:** spatial variations $\nabla\Delta\theta(x,t)$ (costly under λ).

- **Domain information:** where the field is smooth/locked vs. where it is defected or transitioning.

3.2 Coherence domains

Define a *coherence domain* at time t as a connected region $\Omega \subset \mathbb{R}^3$ satisfying:

$$|\nabla \Delta\theta(x,t)| \le \epsilon_g \quad \text{and} \quad |\Delta\theta(x,t) - \theta_\star| \le \epsilon_\theta \qquad \forall x \in \Omega, \tag{5}$$

for thresholds $\epsilon_g, \epsilon_\theta$ set by measurement resolution or model scale. The set of domains $\mathcal{D}(t)$ (and their sizes, lifetimes, connectivity) is part of the information state.

4 Three mechanisms: propagation, buffering, anisotropic loss

4.1 (1) Preferred propagation channels (low-gradient transport)

Because $\lambda > 0$, sharp spatial variations carry an energy cost:

$$E_{\text{grad}}(t) = \frac{\lambda}{2} \int d^3x \, |\nabla \Delta\theta|^2.$$

Therefore, phase perturbations propagate and persist preferentially along trajectories that maintain small $|\nabla \Delta\theta|$. Operational consequence:

> *Phase disturbances launched in a smooth coherence domain propagate farther and retain structure longer than disturbances launched across domain walls.*

4.2 (2) Relic pockets as frequency-selective buffers (spectral memory)

When $V(\Delta\theta)$ contains multiple basins or shoulders (e.g. from the $-g\cos(N\Delta\theta)$ term), small oscillations about different basins have different effective curvature:

$$\omega_{\text{loc}}^2 \sim \frac{1}{I} V''(\Delta\theta_{\text{basin}}).$$

Metastable basins and shoulders act as *spectral traps*: perturbations near corresponding frequencies experience longer retention times. Operational consequence:

> *Certain harmonics/subharmonics survive longer and amplify near threshold drive, reflecting the landscape symmetry (e.g.* $3\omega, 9\omega$ *for* $N = 3$*).*

4.3 (3) Anisotropic information loss from chiral bias

The locked angle $\theta_\star = 255^\circ$ introduces a chiral asymmetry (e.g. via $\cos\theta_\star < 0$ in MT-derived projectors). The conservative framing is:

$$\gamma \;\to\; \gamma(\Delta\theta, \partial_t \Delta\theta, \dots) \quad \text{with} \quad \gamma(\text{one handedness}) \neq \gamma(\text{opposite handedness}), \tag{6}$$

i.e. effective dissipation may depend on phase orientation/handedness within the relic-structured landscape. Operational consequence:

Two perturbations with equal magnitude but opposite "phase-handedness" can decay at different rates, producing directional robustness in one sector and faster loss in the other.

5 Constraints view ("forbidden zones")

A useful way to state the above is as constraints that the locked landscape imposes:

- **Forbidden:** arbitrary phase discontinuities.
  Reason: gradient penalty makes sharp walls energetically costly; discontinuities either smooth, pin, or nucleate defects with measurable signatures.

- **Forbidden:** runaway growth of effective coupling response under repeated cycling (in regimes where chiral suppression applies).
  Reason: chiral bias acts as a stabilizing projector, suppressing certain feedback channels.

- **Forbidden:** perfectly symmetric transport in a relic-structured landscape.
  Reason: relic basins and chiral bias break isotropy in phase space; propagation, damping, and retention become direction-dependent.

- **Forbidden:** "instant" loss of structured perturbations in the presence of relic buffers.
  Reason: metastable pockets store/echo specific spectral content (especially near activation thresholds).

6 Mapping to sandbox observables (practical bridge)

Even in a 0D phase-ODE sandbox (no spatial ∇ term), the landscape still expresses these mechanisms through basin structure, slips, and spectra.

6.1 Toy model used in sandbox

A common sandbox choice is the driven, damped phase coordinate $\theta(t)$ in a multiwell potential:

$$I\,\ddot{\theta} + \gamma\,\dot{\theta} + \partial_\theta V(\theta) = S(t), \tag{7}$$

$$V(\theta) = -g\cos(N\theta) + b\cos(\theta - \theta_\star), \tag{8}$$

with a dual-tone drive $S(t) = A\sin(\omega t) + A_2\sin(\omega_2 t)$.

6.2 Slip events as "information transitions" between basins

Define basins by minima $\{\theta_k\}$ of $V(\theta)$; assign each time sample $\theta(t_i)$ to its nearest minimum (on the circle). A basin switch corresponds to a discrete transition of the information state ("which basin am I in").

The following event-level quantities are particularly informative:

- **Slip rate:** $\#(\text{basin switches})/\Delta t$.

- **Per-slip impulse proxy:** a signed quantity built from a chiral projector evaluated at the event.
- **Harmonic ratio:** e.g. $(|X(3f_1)| + |X(9f_1)|)/|X(f_1)|$ for $N = 3$.
- **Directionality factor:** measures "structured vs random" impulse sign coherence:

$$\text{dir\_factor} \equiv \frac{|\langle I_{\text{slip}} \rangle|}{\langle |I_{\text{slip}}| \rangle + \varepsilon}, \qquad \varepsilon \ll 1. \tag{9}$$

  Near 1: slips are mostly same-sign (high directional structure). Near 0: signs cancel (chaos/randomization).

6.3 Interpretation

Within this conservative framing:

- The **quiet regime** (no slips, low harmonics) corresponds to stable retention of a single basin label (information is static and smoothly transported).
- The **sweet spot** corresponds to controlled, structured basin transitions: maximal distinguishability per event (high per-slip impulse, high dir_factor), with harmonics rising but not overwhelming.
- The **chaotic regime** corresponds to rapid basin randomization: slip rate increases but directional structure collapses (dir_factor falls) and harmonics dominate.

7 Cheap tests suggested by this framing (materials and devices)

These are phrased as "constraint tests" rather than "new-physics claims".

7.1 Test 1: anisotropic fatigue / retention in chiral-aligned composites (low effort)

Constraint target: symmetric transport/fatigue is disfavored in a relic-structured, chirally biased medium.

Protocol (simple):

- Prepare matched coupons of a candidate composite (e.g. HX-treated vs control).
- Apply cyclic excitation in two orientations (rotate sample 180° or swap polarity/handedness of drive).
- Measure: (i) fatigue curve, (ii) hysteresis area, (iii) residual memory (property drift after rest), (iv) spectral content during cycling.

Pass criterion (indicative): statistically significant directional difference (orientation/polarity) in fatigue or memory metrics beyond control samples.

7.2 Test 2: relic-buffer spectral persistence near activation threshold (low-to-moderate effort)

Constraint target: fast decoherence without relic buffering is disfavored.

Protocol (device or material):

- Drive at a main resonance f_1 with a slow envelope/gate.
- Sweep amplitude across activation threshold.
- Record spectrum; compute harmonic ratios (e.g. $(3f_1 + 9f_1)/f_1$).
- Look for a threshold-aligned growth of N-fold harmonics and persistence/decay time differences for those harmonics.

Pass criterion (indicative): harmonics turn on sharply with regime transition and persist longer than nearby non-matched frequencies.

8 Conclusions (conservative)

1. In Modal Theory, "information" can be framed minimally as the *state of the phase landscape*—phase values, gradients, and coherence domains—and how these evolve under the locked potential and stiffness constraints.
2. The λ-stiffness term enforces a real, testable preference for smooth propagation channels and penalizes discontinuities (geometric filtering).
3. Relic structure functions as a physically grounded buffering/filtering mechanism: selective spectral retention near landscape-defined basins and shoulders.
4. Chiral bias naturally motivates anisotropic loss: equal-magnitude perturbations can decay differently depending on phase-handedness, producing measurable direction-dependence in retention and response.
5. Sandbox metrics (slip rate, per-slip impulse, harmonic ratios, dir_factor) provide a practical, falsifiable bridge between this geometric-information framing and laboratory diagnostics.

Status: This note is a framing and constraint map. It introduces no new fundamental postulates beyond the phase landscape, stiffness, and relic structure already used in Modal Theory.

Appendix A: Minimal pseudocode for key metrics (optional)

```
# Given theta(t) samples th2, and minima centers for a given Nfold:
# basin assignment and switch detection
dist = np.abs((th2[:, None] - centers[None, :]) % (2*np.pi))
dist = np.minimum(dist, 2*np.pi - dist)
```

```
basin = np.argmin(dist, axis=1)

switch_idx = np.where(basin[1:] != basin[:-1])[0]
slip_rate = len(switch_idx) / (t2[-1] - t2[0])

# Example chiral projector (toy)
chir = np.sin(th2[switch_idx] - th_lock) * np.cos(th2[switch_idx])

# Sign by unwrapped direction of transition
thu = np.unwrap(th2)
sign = np.sign(thu[switch_idx + 1] - thu[switch_idx])

impulses = chir * sign

mean_signed = np.mean(impulses) if len(impulses) else 0.0
mean_abs    = np.mean(np.abs(impulses)) if len(impulses) else 0.0

dir_factor = abs(mean_signed) / (mean_abs + 1e-12)
```