Phase 4: Vacuum-to-FRW Consistency and Scale Sanity

A corridor-style test of the Phase 3 global-amplitude mechanism

Origin Axiom Program

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Abstract

Phase 4 tests whether the canonical global-amplitude mechanism defined in Phase 3 can be connected, in a structurally reasonable way, to FRW-style dynamics and vacuum-energy-like observables. The goal is to probe whether the non-cancellation floor that stabilises the toy vacuum can also support scale-sane behaviour when mapped into simple cosmological modules, without claiming a full cosmological fit or a theory of everything.

1 Introduction

Phase 4 sits between the mechanism-level vacuum work of Phase 3 and any future attempts to build a unified picture of vacuum, matter, and geometry. Its mission is narrow:

- take the canonical Phase 3 global-amplitude mechanism and non-cancellation floor as given;
- define simple, explicit mappings from the floor-enforced amplitude or residue into FRW-like dynamics and vacuum-energy-like observables; and
- study the resulting behaviour of the Origin-Axiom phase parameter θ in the corridor / ledger framework of Phase 0.

The guiding question is not whether we can reproduce the full ΛCDM model or fit precise cosmological parameters, but whether the Phase 3 mechanism can be made compatible with toy FRW modules in a way that is numerically stable, structurally sane, and expressible as a θ-filter in the sense of Phase 0.

Throughout this phase we distinguish carefully between:

- *binding* outputs, which may eventually define a Phase 4 θ-filter; and
- *non-binding* diagnostics and figures, which serve only as intuition and internal checks.

The present rung does not define any concrete mappings or filters. It only provides a minimal paper skeleton so that future rungs can add well-documented mechanisms and experiments without restructuring the front matter.

2 Mapping families: first pass (F1)

Phase 4 takes as input the Phase 3 global-amplitude mechanism: a toy vacuum with an unconstrained observable $A_0(\theta)$, a non-cancellation floor ε, and a floor-enforced amplitude $A(\theta) = \max(A_0(\theta), \varepsilon)$ defined on a grid $\theta \in [0, 2\pi)$. The present paper introduces a first, explicit mapping family, denoted **F1**, from this structure to a toy vacuum-energy-like scalar.

2.1 F1: direct scalar mapping from $A(\theta)$

The F1 family is intentionally simple. For a fixed Phase 3 vacuum configuration and floor ε (taken from the Phase 3 baseline diagnostics), we define a scalar

$$E_{\text{vac}}(\theta) \;=\; \alpha\, A(\theta)^{\beta}, \tag{1}$$

where $\alpha > 0$ and $\beta > 0$ are explicit, configurable parameters. At this rung we adopt a conservative default, $\alpha = 1$ and $\beta = 2$, and focus on structural behaviour rather than numerical normalisation.

Operationally, Phase 4 reuses the Phase 3 baseline configuration `baseline_v1` and the floor ε recorded in `phase3/outputs/tables/mech_baseline_scan_diagnostics.json`. We then evaluate $A(\theta)$ and $E_{\text{vac}}(\theta)$ on a uniform grid of $N_\theta = 2048$ points in $[0, 2\pi)$. The per-grid values and summary diagnostics are written to

`phase4/outputs/tables/phase4_F1_sanity_curve.csv`,

together with metadata describing the mapping parameters and the underlying Phase 3 diagnostics.

At this stage F1 is a *non-binding* mapping family: it does not yet define a θ-corridor or a Phase 4 θ-filter. Instead it serves as a concrete, auditable bridge between the Phase 3 mechanism and simple scalar observables that later rungs can connect to FRW-like toy modules and corridor construction.

3 Diagnostics and toy corridors (draft)

At this rung Phase 4 focuses on internal diagnostics of the scalar $E_{\text{vac}}(\theta) = \alpha A(\theta)^{\beta}$ produced by the F1 mapping family, together with simple, non-binding θ-corridors. No FRW module is yet implemented; instead we prepare the ground for later FRW-like tests.

3.1 Vacuum-curve sanity check

The first diagnostic is a direct sanity check of the F1 mapping. Using the Phase 3 baseline configuration and floor recorded in `phase3/outputs/tables/mech_baseline_scan_diagnostics.json`, we evaluate $A(\theta)$ and $E_{\text{vac}}(\theta)$ on a uniform grid of $N_\theta = 2048$ points in $[0, 2\pi)$. The script

`phase4/src/phase4/run_f1_sanity.py`

writes the per-grid values to

`phase4/outputs/tables/phase4_F1_sanity_curve.csv`,

together with mapping metadata and a summary of basic moments.

For the baseline configuration used here, $E_{\text{vac}}(\theta)$ is strictly positive and remains on a small, controlled scale, reflecting the scale of the underlying amplitude and the chosen (α, β). This establishes that the F1 mapping is at least numerically well behaved and correctly wired to the Phase 3 mechanism.

3.2 Toy shape diagnostics and non-binding corridor

The second diagnostic probes the *shape* of $E_{\text{vac}}(\theta)$. The script

`phase4/src/phase4/run_f1_shape_diagnostics.py`

rebuilds the same F1 curve and computes:

- global extrema and moments ($E_{\mathrm{vac,min}}, E_{\mathrm{vac,max}}, \mathrm{mean}, \mathrm{std}$);
- a toy, non-binding θ-corridor defined by

$$E_{\mathrm{vac}}(\theta) \leq E_{\mathrm{vac,min}} + k_\sigma \sigma, \quad k_\sigma = 1;$$

- the fraction of the grid lying inside this corridor and the induced θ-range.

The resulting summary is written to

`phase4/outputs/tables/phase4_F1_shape_diagnostics.json`,

while a per-θ mask, indicating membership in the toy corridor, is written to

`phase4/outputs/tables/phase4_F1_shape_mask.csv`.

This corridor is explicitly labelled as *exploratory and non-binding.* It does not define a canonical $\theta_\star$ or a Phase 4 θ-filter; it is only a structured way of selecting a low-E_{vac} region that later rungs can reuse when designing FRW-like toy modules.

3.3 FRW-like toy diagnostics (design only)

To keep the Phase 4 narrative aligned with the Phase 0 contract, we separate the internal diagnostics above from any FRW-like behaviour tests. A separate design note

`phase4/FRW_TOY_DESIGN.md`

specifies a minimal FRW-inspired toy module in which the F1 scalar acts as a driving term for a dimensionless scale factor $a(\tau)$ and Hubble-like quantity $H(\tau)$.

At the present rung this module is *not* implemented, and no FRW-style diagnostics enter the claims table. The only purpose of the design work is to:

- define clear, auditable interfaces between $E_{\mathrm{vac}}(\theta)$, the toy corridor mask, and FRW-like quantities; and
- constrain future work so that any FRW-like diagnostics remain simple, reproducible, and explicitly non-claiming unless promoted to a Phase 4 θ-filter.

Subsequent rungs may instantiate this toy module in code or, if it proves unhelpful, retire it in favour of alternative diagnostics. In either case, the Phase 4 paper will distinguish binding θ-filters from non-binding exploratory diagnostics in line with the Phase 0 corridor semantics.

4 Limitations and outlook

Phase 4 is intentionally narrow in scope. Even once the mappings and diagnostics are implemented, the phase will not claim:

- a full derivation of cosmological parameters;
- a proof that the Origin Axiom is realised in nature; or
- a unique mechanism for connecting vacuum structure to FRW dynamics.

Instead, the goal is to provide a clean yes-or-no style test for a specific question:

> Can the Phase 3 global-amplitude mechanism support scale-sane FRW-like behaviour, in at least one simple mapping family, without producing a degenerate or empty θ-corridor?

If the answer is "no" for all tested mapping families, Phase 4 will record this as a structured negative result, signalling that either the Phase 3 mechanism or the mapping strategy needs revision before further unification attempts.

Appendix A: Phase 4 claims table (draft)

Table 1 summarises the intended Phase 4 claims. At this rung all entries are draft and non-binding.

Table 1: Draft Phase 4 claims. Binding status will be updated once the phase is complete and audited.

ID	Binding?	Summary
C4.1	no	Existence of at least one explicit mapping from the Phase 3 global amplitude or residue into an FRW-like or vacuum-energy-like observable with numerically stable behaviour.
C4.2	no	Existence of a non-empty, non-trivial θ-corridor for at least one such mapping.
C4.3	no	Structured negative result if all tested mappings yield empty or pathological corridors.

Appendix B: Reproducibility notes (draft)

At this rung, Phase 4 builds on the Phase 3 toy vacuum mechanism and its non-cancellation floor, introduces the F1 mapping family, and adds internal diagnostics and a toy, non-binding corridor. This appendix summarises how to rebuild the Phase 4 artifacts used in the paper.

Directory structure

Phase 4 lives in the top-level directory `phase4/` with the following relevant subdirectories:

- `phase4/paper/`: LaTeX sources for the Phase 4 paper (including this appendix).
- `phase4/src/phase4/`: Python source for the F1 mapping family and diagnostics.
- `phase4/outputs/`:
  - `outputs/paper/`: built Phase 4 PDF;
  - `outputs/tables/`: CSV/JSON artifacts from F1 diagnostics.
- `phase4/artifacts/`: canonical Phase 4 PDF artifact exported by the gate script.

Upstream Phase 3 prerequisites

Phase 4 assumes that the Phase 3 baseline scan and binding-certificate artifacts have been generated at least once. In practice this can be ensured by running, from the repository root:

```
bash scripts/phase3_gate.sh --level A
```

and, if needed, explicitly running the Phase 3 scripts:

```
python phase3/src/phase3_mech/run_baseline_scan.py
python phase3/src/phase3_mech/run_binding_certificate.py
```

These commands populate:

- `phase3/outputs/tables/mech_baseline_scan.csv`
- `phase3/outputs/tables/mech_baseline_scan_diagnostics.json`
- `phase3/outputs/tables/mech_binding_certificate.csv`
- `phase3/outputs/tables/mech_binding_certificate_diagnostics.json`

The F1 mapping family reads `mech_baseline_scan_diagnostics.json` to reuse the quantile-based floor and grid configuration.

Phase 4 F1 mapping and diagnostics

With the Phase 3 prerequisites in place, the current Phase 4 diagnostics can be rebuilt via:

```
python phase4/src/phase4/run_f1_sanity.py
python phase4/src/phase4/run_f1_shape_diagnostics.py
```

These scripts write:

- `phase4/outputs/tables/phase4_F1_sanity_curve.csv` (per-θ values of $E_{\mathrm{vac}}(\theta)$ and associated metadata);
- `phase4/outputs/tables/phase4_F1_shape_diagnostics.json` (summary statistics and toy corridor definition);
- `phase4/outputs/tables/phase4_F1_shape_mask.csv` (per-θ Boolean mask indicating membership in the toy corridor).

At this rung these diagnostics are explicitly non-binding: they do not define a canonical θ-filter, but they are used in the Phase 4 paper to illustrate the behaviour of the F1 mapping.

Building the Phase 4 paper and artifact

The Phase 4 paper and its canonical PDF artifact can be rebuilt from the repository root via:

```
bash scripts/phase4_gate.sh --level A
```

This gate script runs a Snakemake workflow in `phase4/workflow/Snakefile` that invokes `latexmk` on `phase4/paper/main.tex` and copies the resulting PDF to:

- `phase4/outputs/paper/phase4_paper.pdf`
- `phase4/artifacts/origin-axiom-phase4.pdf`

The gate currently covers the Phase 4 paper only; F1 diagnostics are rebuilt by the explicit Python commands above.

Planned extensions

The design note `phase4/FRW_TOY_DESIGN.md` specifies a minimal FRW-inspired toy module that may be implemented in later rungs. If such a module is added, this appendix will be extended to include:

- the relevant Python scripts and configuration files;
- any additional JSON/CSV outputs; and
- updated gate levels if FRW-like diagnostics become part of the canonical Phase 4 artifact.

Until then, reproducibility for Phase 4 consists of:

1. regenerating the Phase 3 baseline and binding-certificate artifacts;
2. regenerating the Phase 4 F1 diagnostics; and
3. rebuilding the Phase 4 paper and artifact via the Level A gate.

References