Traversable Wormholes from Non-Invertible Symmetry Defects: A Bootstrap Program

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August 26, 2025

Abstract

We propose a defect-based mechanism for boundary-engineered traversability in holography and formulate a bootstrap feasibility program with falsifiable signatures. Specifically, we conjecture that non-invertible symmetry defects in large-c conformal field theories (CFTs) can induce effective negative averaged null energy along horizon generators, sufficient to render wormholes traversable without violating boundary causality or quantum null energy conditions (QNEC). We outline the conjecture, sketch its CFT/AdS dual realization, and propose testable bootstrap constraints. Conceptual mock figures illustrate the bulk cartoon with a defect insertion and convex feasibility regions.

Keywords: Quantum Gravity, Conformal Field Theory, Non-Invertible Symmetries, Traversable Wormholes, Bootstrap Program.

1 Introduction

Traversable wormholes are typically prohibited by averaged energy conditions in quantum field theory, which constrain integrated stress along null generators and preclude sustained negative energy densities. A prominent loophole is the Gao–Jafferis–Wall double-trace deformation, where finely tuned boundary couplings briefly render a wormhole traversable; however, such couplings are difficult to realize in a physically natural setting. Meanwhile, recent progress on non-invertible symmetry defects in conformal field theories has revealed operator structures that enforce selection rules beyond ordinary group symmetries.

In this work we suggest that appropriate non-invertible defects, when inserted in large-c holographic CFTs, may realize controlled and localized violations of averaged null energy while preserving boundary consistency (including causality and crossing) and remaining compatible with the quantum null energy condition (QNEC). Our aim is to state a concrete conjecture, outline a bootstrap-based feasibility program leveraging non-invertible fusion rules and defect crossing equations, and provide falsifiable predictions. Conceptual figures illustrate the bulk cartoon of a defect-induced throat and a convex feasibility region for OPE data consistent with traversability.

2 Defect Traversability Conjecture

Conjecture 2.1 (Defect Traversability)**.** *There exist non-invertible defects $\mathcal{D}$ in large-c conformal field theories whose insertion produces a negative averaged null energy along a horizon generator, while preserving boundary causality and the quantum null energy condition.*

3 Bulk Cartoon and CFT Interpretation

In AdS/CFT duality, a defect operator corresponds to a localized modification of the bulk geometry. A non-invertible defect line along the boundary can couple to bulk modes in such a way that the effective stress tensor expectation value is shifted negative along null generators. Unlike arbitrary boundary couplings, the defect structure enforces consistency with bootstrap crossing equations and non-invertible fusion rules. The resulting bulk geometry resembles a wormhole with a localized "defect throat."

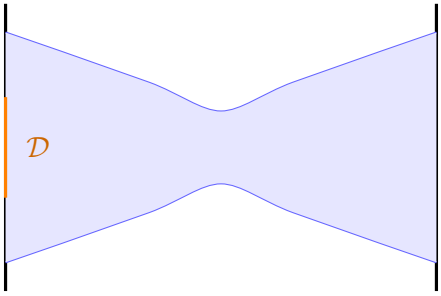

Figure 1: Conceptual cartoon: two AdS boundaries connected by a wormhole-like throat (blue). An orange segment on the left boundary indicates the non-invertible defect $\mathcal{D}$.

4 Bootstrap Program

Construct crossing equations with defect insertions, identify whether non-invertible fusion rules can produce negative contributions to averaged null energy operators, and propose a convex feasibility region for operator product expansion (OPE) coefficients consistent with traversability. Numerical bootstrap techniques can then search for CFT data realizing these inequalities.

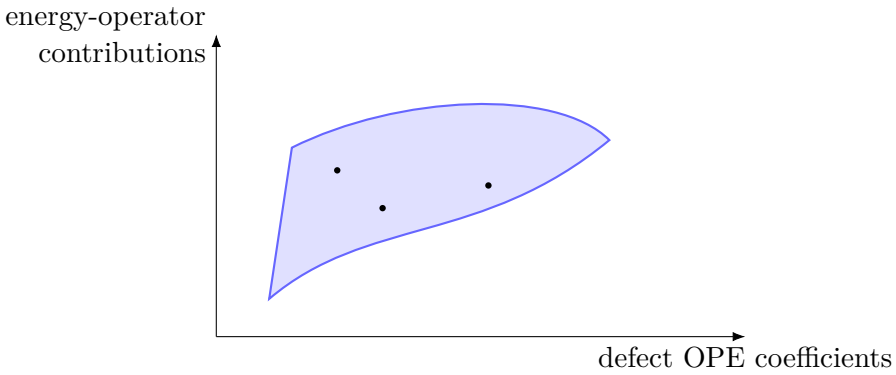

Figure 2: Conceptual feasibility region: shaded convex set of defect OPE data consistent with traversability (schematic).

5 Predictions and Falsifiability

- **Prediction 1:** Certain bootstrap bounds with non-invertible defects are incompatible with purely local EFT expectations.

- **Prediction 2:** Traversability implies a small but nonzero negative shift in averaged null energy.
- **Prediction 3:** If no feasible defect bootstrap solutions exist, the conjecture is falsified.
- **Observational analogs:** defect-induced traversability could leave imprints in entanglement wedge cross-sections or modular flow observables in holography.

6 Implications

- A successful defect traversability mechanism would broaden the space of possible holographic duals with controlled exotic causal structures.
- Failure to construct consistent bootstrap solutions would still provide a valuable "no-go" result, clarifying the role of non-invertible symmetries in holography.
- The program connects recent advances in non-invertible symmetries, bootstrap numerics, and the physics of wormholes.

7 Conclusion

We outlined a conjecture and a bootstrap program for defect-induced traversability in holography. Conceptual mock figures illustrated the bulk cartoon and feasibility curves. Whether the conjecture holds remains open, but either outcome yields new insights into the interplay between quantum information, symmetry, and gravitational causality.

Acknowledgments

AI-assisted drafting: An artificial intelligence tool generated preliminary text based on author prompts; final version reviewed and approved by the author.

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