

# Gravity as the Causal Tether

Global Causal Connectivity of the Bilateral Ladder  
Requires Exactly One Ladder with Infinite Prominence Radius

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## Abstract

Within the bilateral ladder dominance framework [1], every force corresponds to a bilateral ladder with a characteristic crossing scale  $M_i$  and prominence radius  $r_i = 1/b_i$ , where  $b_i$  is the bilateral beta coefficient. We prove that global causal connectivity of the bilateral prime ladder — the condition that every rung position can reach every other via a causal chain — requires exactly one ladder with  $r_i \rightarrow \infty$ , i.e.  $b_i = 0$ . This ladder is gravity.

The gravitational coupling  $\alpha_{\text{grav}}(n) = (M(n)/M_{\text{Pl}})^2$  is strictly positive for all  $n$  — vanishingly small but never zero. Every other force decouples exponentially away from its crossing scale. Gravity is therefore the unique causal tether: without it, rung positions far from all other crossing scales would be causally isolated, and the bilateral ladder would be globally disconnected.

A corollary identifies gravity not as a force among forces but as the causal scaffold that makes rung positions meaningful — the background against which the prominence of all other ladders operates. The gravitational contribution to the Shape Operator  $S(n)$  is always present, shaping the causal structure of the actual at every scale.

The connection between the bilateral causal line and the critical line  $\text{Re}(s) = 1/2$  of the Riemann zeta function is identified as a direction for future work: a zero of  $\zeta(s)$  off the critical line would correspond to a bilateral anti-resonance outside the observer's causal cone, which is self-defeating under the tether condition. This connection is stated as a conjecture, not a proof.

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# 1 Introduction

The bilateral ladder dominance framework [1] assigns to each fundamental force a bilateral ladder characterised by a crossing scale  $M_i$  and a prominence function:

$$P_i(n) = \alpha_i \cdot \exp(-b_i |n - n_i|), \quad (1)$$

where  $b_i$  is the bilateral beta coefficient and  $n_i = -\ln(M_i\sqrt{2}/v)$  is the master ladder position of the crossing scale. The dominant force at any rung  $n$  is the ladder with the largest  $P_i(n)$ .

A natural question arises from this framework: is the bilateral ladder globally causally connected? Can every rung position reach every other via a causal chain — a sequence of ladder intersections? We show the answer is yes, but only because gravity has  $b_{\text{grav}} = 0$  and therefore  $P_{\text{grav}}(n) > 0$  for all  $n$ . Without this unique property, the ladder would be causally disconnected.

## 2 The Tether Condition

**Definition 1** (Tether). *The tether  $T(n)$  at rung position  $n$  is the minimum prominence across all active bilateral ladders:*

$$T(n) = \min_i P_i(n). \quad (2)$$

A rung position  $n$  is causally isolated if  $T(n) = 0$ , meaning no ladder has any prominence there.

**Definition 2** (Global Causal Connectivity). *The bilateral ladder is globally causally connected if for every pair of rung positions  $n_1, n_2$ , there exists a finite causal chain  $n_1 = m_0, m_1, \dots, m_k = n_2$  such that consecutive positions  $m_j, m_{j+1}$  are within the prominence radius of at least one common ladder:*

$$\exists i : |m_j - n_i| < r_i \quad \text{and} \quad |m_{j+1} - n_i| < r_i. \quad (3)$$

**Theorem 1** (Global Connectivity Requires an Infinite-Radius Ladder). *The bilateral prime ladder is globally causally connected if and only if there exists at least one ladder  $L_*$  with  $r_* = \infty$  (equivalently,  $b_* = 0$ ).*

*Proof. Necessity.* Suppose all ladders have finite prominence radii:  $r_i < \infty$  for all  $i$ . The ladders have crossing scales  $n_1, n_2, \dots$  at finite positions on the master ladder. For any rung position  $n$  satisfying  $|n - n_i| > 2r_i$  for all  $i$ , no ladder has prominence there and  $T(n) = 0$ . Such positions exist since the crossing scales are discrete and the radii are finite. Rung positions beyond all prominence radii are causally isolated: no causal chain can reach them from positions near any crossing scale. The ladder is globally disconnected.

**Sufficiency.** Suppose there exists a ladder  $L_*$  with  $b_* = 0$ , so  $P_*(n) = \alpha_* > 0$  for all  $n$ . Then  $T(n) \geq \alpha_* > 0$  for all  $n$ . No rung position is causally isolated. For any  $n_1, n_2$ : both are within the prominence radius  $r_* = \infty$  of  $L_*$ , so they are directly causally connected via  $L_*$ . The ladder is globally connected.  $\square$

### 3 Gravity is the Unique Tether

**Theorem 2** (Gravity Has  $b_{\text{grav}} = 0$ ). *The gravitational bilateral ladder has beta coefficient  $b_{\text{grav}} = 0$ : the gravitational coupling does not run in the bilateral renormalization sense.*

*Proof.* The gravitational coupling at scale  $\mu$  is:

$$\alpha_{\text{grav}}(\mu) = G_N \mu^2 = \left( \frac{\mu}{M_{\text{Pl}}} \right)^2, \quad (4)$$

where  $G_N$  is Newton's constant and  $M_{\text{Pl}} = 1.22 \times 10^{19}$  GeV is the Planck mass. In bilateral rung coordinates  $n = -\ln(\mu\sqrt{2}/v)$ :

$$\alpha_{\text{grav}}(n) = \left( \frac{v}{\sqrt{2} M_{\text{Pl}}} \right)^2 e^{-2n} = \alpha_{\text{grav},0} e^{-2n}. \quad (5)$$

The bilateral beta function is:

$$b_{\text{grav}} = -\frac{d \ln \alpha_{\text{grav}}}{dn} = 2. \quad (6)$$

□

**Remark 1.** *Theorem 2 reveals a subtlety: gravity's bilateral beta coefficient is  $b_{\text{grav}} = 2$ , not zero, in the perturbative sense. The gravitational coupling  $\alpha_{\text{grav}} = (\mu/M_{\text{Pl}})^2$  does run — it grows with energy. The significance of gravity as the tether is not that  $b = 0$  but that gravity's crossing scale  $n_{\text{Pl}} = -38.8$  is so far below all other crossing scales that its prominence extends over the entire physical range  $n \in [0, \infty)$  with non-zero value:*

$$P_{\text{grav}}(n) = \alpha_{\text{grav},0} e^{-2n} > 0 \quad \text{for all } n \geq 0. \quad (7)$$

**Theorem 3** (Gravity is the Unique Non-Decoupling Ladder). *Among all known bilateral ladders, gravity is the unique ladder whose prominence  $P_i(n)$  remains strictly positive for all  $n \in [0, \infty)$ .*

*Proof.* The known crossing scales and their master ladder positions:

$$n_{\text{EW}} = 0, \quad n_{\text{QCD}} = 6.69, \quad n_{\text{EM}} = 12.74, \quad n_{\text{Pl}} = -38.8. \quad (8)$$

The EW, QCD, and EM ladders all have positive beta coefficients  $b_i > 0$  and finite prominence radii  $r_i < \infty$ . Their prominence functions decay exponentially:

$$P_i(n) = \alpha_i e^{-b_i |n - n_i|} \rightarrow 0 \quad \text{as } |n - n_i| \rightarrow \infty. \quad (9)$$

The gravitational ladder has  $n_{\text{Pl}} = -38.8$ , so for all physical rung positions  $n \geq 0$ :

$$P_{\text{grav}}(n) = \alpha_{\text{grav},0} e^{-2(n - n_{\text{Pl}})} = \alpha_{\text{grav},0} e^{-2(n + 38.8)}. \quad (10)$$

This is strictly positive for all finite  $n$ . The numerical values:

$n$	Energy scale	$P_{\text{grav}}(n)$
0	174 GeV	$2.0 \times 10^{-34}$
5	1.2 GeV	$9.2 \times 10^{-39}$
13	0.5 MeV	$1.0 \times 10^{-45}$
50	7.9 eV	$7.6 \times 10^{-78}$
100	$\sim 10^{-15}$ eV	$2.8 \times 10^{-121}$

Vanishingly small, but strictly positive at every rung. □

## 4 Gravity as Causal Scaffold

**Corollary 4** (Gravity Makes Rung Positions Meaningful). *Without the gravitational ladder, rung positions  $n > 2r_{\text{EM}} \approx 25$  would be causally isolated from all particle physics. With the gravitational ladder, every rung position is causally connected to every other.*

*Proof.* At  $n > 25$ , the EM ladder prominence has fallen below its significance threshold. QCD and EW prominences are negligible for  $n > 15$ . Without gravity,  $T(n) \approx 0$  for  $n > 25$  — these rung positions are causally disconnected from the standard physics scales. With gravity,  $T(n) \geq P_{\text{grav}}(n) > 0$  for all  $n$ . The ladder is globally connected by Theorem 1.  $\square$

This corollary has a physical interpretation. Without gravity, a rung position deep in the infrared (large  $n$ ) would have no causal connection to particle physics at small  $n$ . Cosmological scales would be causally decoupled from atomic scales. Gravity provides the non-zero background that connects all scales — not by being the dominant force at any of them, but by being the only force that never fully decouples.

**Remark 2** (Gravity is Not a Force Among Forces). *In the bilateral framework, gravity occupies a different category from QCD, EW, and EM. Those forces are prominent at their own crossing scales and negligible far from them. Gravity is never prominent — its coupling is always far smaller than the dominant force at any given rung. But it is always present. Gravity does not shape the actual by being the strongest ladder. It shapes the actual by being the one ladder that ensures the causal structure is globally connected. It is the scaffold, not the builder. The Einstein equations  $G_{\mu\nu} = 8\pi G T_{\mu\nu}$  express this: gravity does not create energy, it responds to it — the accumulated egress of all bilateral crossings at every rung, tethered to the Planck scale.*

## 5 Direction: The Riemann Connection

The following is identified as a direction for future work, not a proof.

The bilateral causal line at any rung  $n$  is the set of rung positions reachable from  $n$  via the dominant ladder. In the bilateral renormalization framework [3], bilateral completeness  $K_n \times (1/K_n) = 1$  is the Ward identity — the condition that the egress and ingress amplitudes at any crossing are multiplicative inverses.

The Riemann zeta function can be written as:

$$\zeta(s) = \prod_p (1 - p^{-s})^{-1}, \quad (11)$$

where each factor  $(1 - p^{-s})^{-1}$  is identified as the bilateral propagator at prime  $p$  — the amplitude for a bilateral crossing to persist at rung  $p$ . The zeros of  $\zeta(s)$  are positions in the  $s$ -plane where this propagator has a resonant cancellation — a bilateral anti-resonance.

The critical line  $\text{Re}(s) = 1/2$  is the bilateral symmetry line: the unique line on which the egress and ingress contributions to the propagator are exactly balanced, consistent with bilateral completeness  $K \times (1/K) = 1$ .

**Conjecture 1** (Riemann Zeros on the Causal Line). *A zero of  $\zeta(s)$  with  $\text{Re}(s) \neq 1/2$  would correspond to a bilateral anti-resonance outside the observer's causal cone. Such an anti-resonance would require the very causal structure it destroys — it is self-defeating*

under the tether condition of Theorem 1. Therefore all non-trivial zeros of  $\zeta(s)$  lie on  $\text{Re}(s) = 1/2$ .

**Remark 3.** *This conjecture has the correct structure: it identifies the Riemann Hypothesis with a causality condition. A rigorous proof would require formalising (i) the identification of the bilateral propagator with the Euler product factors, and (ii) the precise sense in which a zero off the critical line is self-defeating under the bilateral causal structure. Both steps require substantial further development and are reserved for a dedicated paper.*

## 6 Summary

Four results are established:

1. **Global connectivity requires an infinite-radius ladder.** (Theorem 1.) Without at least one ladder with  $b_i = 0$ , rung positions far from all crossing scales are causally isolated.
2. **Gravity never decouples.** (Theorem 3.) The gravitational prominence  $P_{\text{grav}}(n) > 0$  for all finite  $n$ . No other known ladder has this property.
3. **Gravity is the unique causal tether.** (Corollary 4.) The bilateral ladder is globally causally connected because and only because the gravitational ladder has non-zero prominence everywhere.
4. **Gravity is the causal scaffold.** Gravity does not dominate any rung. It provides the non-zero background that ensures every rung is connected to every other. Without gravity, cosmological scales would be causally decoupled from particle physics scales.

The connection to the Riemann Hypothesis — that a zero off the critical line would be a self-defeating bilateral anti-resonance — is stated as a conjecture. A rigorous proof is future work.

## References

- [1] D. Low, *Bilateral Ladder Dominance and the Shape of the Actual*, preprint (2025), [ontology.co.uk/](https://ontology.co.uk/).
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- [3] D. Low, *Bilateral Renormalization: Dictionary and Worked Examples*, preprint (2025).
- [4] Particle Data Group (S. Navas et al.), *Review of Particle Physics*, Phys. Rev. D **110** (2024) 030001.