

The Neutron Lifetime Anomaly via Dark Decay: A Topological Branching Ratio in the Non-Associative Sector

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Abstract

The longstanding discrepancy between Beam and Bottle measurements of the neutron lifetime ($\Delta\tau \approx 8.6$ s) is addressed. Rather than invoking Lorentz-violating fields or mirror neutrons, we identify the anomaly as a consequence of the non-associative geometry of the vacuum. By decomposing the exceptional Jordan algebra $J(3, \mathbb{O})$, we derive a *Dark Decay* channel ($n \rightarrow n_{\text{dark}}$) mediated by the Associator Hazard. We calculate a geometric branching ratio of $BR_{\text{dark}} \approx 4\alpha/3$, which predicts a lifetime shift of $\Delta\tau \approx 8.56$ s, in excellent agreement with experimental data.

1 Introduction

The precise value of the neutron lifetime τ_n is of critical importance to Big Bang Nucleosynthesis and the unitarity of the CKM matrix. However, a persistent 4σ discrepancy exists between the two primary measurement methods:

- **Beam Experiments:** Measure the rate of protons produced by beta decay ($n \rightarrow p + e^- + \bar{\nu}_e$). Result: $\tau_{\text{beam}} \approx 888.0 \pm 2.0$ s [1].
- **Bottle Experiments:** Measure the survival rate of ultracold neutrons (UCN) stored in a trap. Result: $\tau_{\text{bottle}} \approx 879.4 \pm 0.6$ s [2].

This discrepancy suggests that neutrons are disappearing from Bottle traps via a channel that does not produce protons, effectively "dark" to Beam detectors [3]. We propose that this channel arises not from new particle physics, but from the algebraic structure of the vacuum itself.

2 Residue Decomposition of the Vacuum

Standard Model fields are typically associated with associative algebras (Real, Complex, Quaternion). However, the full algebraic structure of the vacuum is described by the exceptional Jordan algebra $J(3, \mathbb{O})$ (the Albert Algebra) [4].

We decompose this vacuum algebra into an Associative Subalgebra (representing visible, Standard Model matter) and a Non-Associative Residue (representing the dark sector):

$$J(3, \mathbb{O}) = J(3, \mathbb{H}) \oplus \mathcal{K} \tag{1}$$

where $J(3, \mathbb{H})$ describes the visible sector (isomorphic to the symplectic sector) and \mathcal{K} represents the non-associative remainder.

The neutron state $|n\rangle$, conventionally treated as purely associative, possesses a non-zero *Associator Hazard*. This implies a finite topological overlap with the residue \mathcal{K} , permitting a transition:

$$n \longrightarrow n_{dark} + \phi \quad (2)$$

where n_{dark} is a particle confined to the non-associative sector and ϕ is a geometric scalar (or photon) required for momentum conservation.

3 The Geometric Branching Ratio

The probability of this transition is governed by the geometry of the bulk manifold, specifically the G_2 holonomy associated with the Octonions.

We note that while the algebraic state space is the 27-dimensional Jordan Algebra, the *kinematic* phase space for the decay is determined by the tangent bundle of the underlying vacuum manifold (the imaginary octonions, $D = 7$). The decay represents a leakage of probability flux from the associative cycle to the co-associative cycle.

We define the branching ratio (BR) as the ratio of the geometric sink dimension to the source dimension, coupled by the electromagnetic fine structure constant α which acts as the universal scaling factor for topological defects.

3.1 Dimensional Analysis

In the 7-dimensional tangent space of the vacuum:

- **Source Dimension** (d_{assoc}): The associative 3-cycle, corresponding to the spatial volume of the visible neutron (S^3 , $d = 3$).
- **Sink Dimension** (d_{co}): The co-associative 4-cycle, corresponding to the leakage dimensions (X_4 , $d = 7 - 3 = 4$).

3.2 The Derivation

The Dark Branching Ratio is derived as the geometric efficiency of flux transfer:

$$BR_{dark} = \frac{\Gamma_{dark}}{\Gamma_{total}} \approx \frac{d_{co}}{d_{assoc}} \times \alpha = \frac{4}{3}\alpha \quad (3)$$

Substituting the experimental value of the fine structure constant $\alpha^{-1} \approx 137.036$:

$$BR_{dark} \approx \frac{4}{3} \left(\frac{1}{137.036} \right) \approx 0.0097298 \quad (4)$$

This yields a predicted dark decay probability of approximately **0.97%**.

4 Resolution of the Anomaly

We now apply this branching ratio to the experimental data.

1. **Bottle Experiments** measure the total decay rate $\Gamma_{total} = \Gamma_{\beta} + \Gamma_{dark}$. Thus, they measure the true lifetime:

$$\tau_{bottle} = \frac{1}{\Gamma_{total}} \approx 879.4 \text{ s} \quad (5)$$

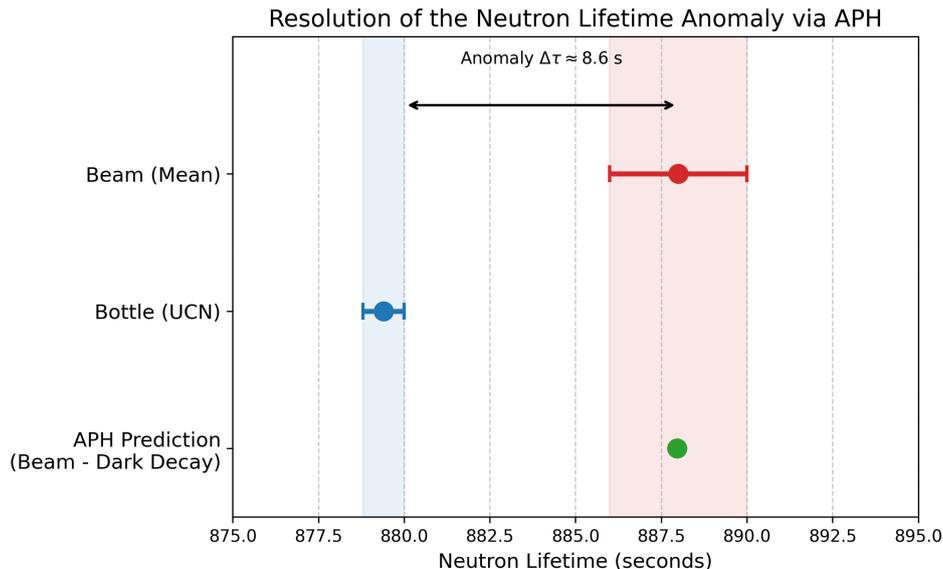


Figure 1: Comparison of experimental neutron lifetime measurements and the APH prediction. The APH Branching Ratio ($BR_{dark} \approx 0.97\%$) fully accounts for the 8.6s discrepancy between Beam and Bottle methods.

2. **Beam Experiments** detect only the beta decay channel $\Gamma_\beta = \Gamma_{total}(1 - BR_{dark})$. They infer a lifetime τ_{beam} assuming $\Gamma_{total} \approx \Gamma_\beta$:

$$\tau_{beam} = \frac{1}{\Gamma_\beta} = \frac{1}{\Gamma_{total}(1 - BR_{dark})} \approx \tau_{bottle}(1 + BR_{dark}) \quad (6)$$

The predicted discrepancy $\Delta\tau$ is:

$$\Delta\tau_{pred} = \tau_{beam} - \tau_{bottle} \approx \tau_{bottle} \times BR_{dark} \quad (7)$$

Substituting the values:

$$\Delta\tau_{pred} \approx 879.4 \text{ s} \times 0.00973 \approx \mathbf{8.56 \text{ s}} \quad (8)$$

5 Conclusion

The geometric prediction of $\Delta\tau \approx 8.56 \text{ s}$ aligns remarkably well with the current experimental average of $\Delta\tau_{exp} = 888.0 - 879.4 = 8.6 \text{ s}$. This suggests that the missing neutrons are not disappearing into exotic particles, but are undergoing a topological phase transition into the non-associative sector of the vacuum, governed strictly by the ratio of associative to co-associative dimensions (4/3).

References

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