A 6DT-Stoke Framework for Geometrically-Induced Mass Variation (GIMV): Formalism and Application to Nuclear Stability

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Abstract

This paper proposes a new theoretical framework, Geometrically-Induced Mass Variation (GIMV), derived from the Stoke-6DT unification which posits the identity $S_{6D} = -c^2 dm_0/d\tau$. We elevate this from a kinematic identity to a dynamic principle, implying the nucleon rest mass m_N is not a constant but a scalar function of the local gravitational environment. We formalize this by introducing a non-minimal coupling (NMC) in the matter Lagrangian, $\mathcal{L}_{\text{NMC}} = -\xi\mathcal{K}\bar{\psi}_N\psi_N$, where $\mathcal{K}$ is a scalar invariant of the gravitational tidal tensor and ξ is a new coupling constant. We rigorously derive the consequences of this coupling for nuclear physics, demonstrating that the coefficients of the Semi-Empirical Mass Formula (SEMF) become functions of the tidal field, $a_i \to a_i(\mathcal{K})$. This is achieved by linking m_N to the asymmetry term a_A via the Fermi Gas Model, and to the surface (a_S) and Coulomb (a_C) terms via a Chiral EFT-derived coupling between m_N and the nuclear radius parameter r_0. We show that this coupling leads to a dynamic, environment-dependent valley of stability and predicts the possibility of "Geometrically-Induced Fission" (GIF), whereby a strong tidal field destabilizes a nucleus by increasing a_C and decreasing a_S simultaneously. We conclude by performing a quantitative analysis, calculating $\mathcal{K}$ in astrophysical environments and

using observational constraints from Equivalence Principle tests to place the first upper bound on the coupling, $\xi < 7.3 \times 10^{-30}$ kg $\cdot$ s^4. We find this bound renders GIMV negligible in terrestrial settings but makes it a viable, high-impact phenomenon in strong-field (e.g., kilonova) environments, consistent with all current observations.

1 Introduction: Geometrically-Induced Mass Variation (GIMV)

1.1 The Foundational Premise (Stoke-6DT)

The unification of general relativity and quantum mechanics remains the central challenge of modern physics. These two pillars describe disjoint realms: one governs the large-scale geometry of spacetime, the other the quantum fields that populate it. In nuclear physics, this disconnect is absolute; the binding energy of a nucleus is treated as an intrinsic property, wholly independent of the ambient gravitational field.

This work builds upon the theoretical foundation of the six-dimensional vector-time (6DT) framework and its unification with the Stoke power concept [1, 2]. The Stoke-6DT framework demonstrates that the projection of a 6D geodesic onto a 4D spacetime results in an anomalous (non-geodesic) force, A^{μ}_{anom}.[5, 6] The work done by this force, S_{6D}, was shown to be identically equal to a change in the particle's rest mass, m_0:

$$S_{6D} \equiv P_{\mu} A^{\mu}_{\text{anom}} = -c^2 \frac{dm_0}{d\tau} \tag{1}$$

Previous work treated this as a kinematic identity. This paper elevates it to a *dynamic principle*. If an external force can do work to change a particle's rest mass, then rest mass itself is not a fundamental constant but a dynamic scalar field, $m_0(x)$.[24, 25, 26]

The 6DT framework identifies the source of A^{μ}_{anom} as the geometry of the extra dimensions, which are in turn sourced by the Hessian of the Newtonian potential, $K_{ij} = \partial_i \partial_j \Phi$ [1]. The logical chain $A_{\text{anom}} \leftrightarrow K_{ij}$ and $A_{\text{anom}} \leftrightarrow dm_0$ implies a direct, non-perturbative coupling between the local gravitational tidal field and the particle's rest mass. This is the **Geometrically-Induced Mass Variation (GIMV)** hypothesis: $m_0 = m_0(x, K)$.

1.2 Lagrangian Formalism (Non-Minimal Coupling)

To transition this hypothesis into a predictive physical theory, it must be embedded in a Lagrangian formalism. We posit that the GIMV hypothesis is the phenomenological expression of a new non-minimal coupling (NMC) between the nucleon matter field ψ_N and the gravitational tidal field.[8, 9] The standard Dirac Lagrangian is modified by a new interaction term:

$$\mathcal{L} = \mathcal{L}_{\text{Dirac}} + \mathcal{L}_{\text{NMC}} = \bar{\psi}_N(i\gamma^\mu \nabla_\mu - m_N^0)\psi_N - \xi\mathcal{K}\bar{\psi}_N\psi_N \tag{2}$$

Here, m_N^0 is the "bare" nucleon mass in a tidally-flat spacetime ($\mathcal{K} = 0$), ξ is the new GIMV coupling constant, and $\mathcal{K}$ is a scalar invariant built from the gravitational tidal tensor. This Lagrangian can be rewritten in the standard form $\mathcal{L} = \bar{\psi}_N(i\gamma^\mu\nabla_\mu - m_N^{\text{eff}}(x))\psi_N$, which defines an **effective, position-dependent nucleon mass**[7]:

$$m_N^{\text{eff}}(x) = m_N^0 + \xi\mathcal{K}(x) \tag{3}$$

This formalism provides a concrete, field-theoretic basis for GIMV, grounding the 6DT concept in a testable 4D effective field theory.

1.3 Formal Hypothesis (Symbolic Logic)

The axiomatic structure of this theory can be stated in a formal logical language:

- **GIMV Axiom:**

$$\forall\psi_N \forall K_{ij} \exists\xi : \big(\text{Nucleon}(\psi_N) \wedge \text{TidalField}(K_{ij})\big) \rightarrow m_N(\mathcal{K}) = m_N^0 + \xi\mathcal{K}$$

- **SEMF Consequence:**

$$\forall a_i \in \{a_V, a_S, a_C, a_A\} : \big(a_i = f(m_N, r_0) \wedge m_N = m_N(\mathcal{K}) \wedge r_0 = r_0(m_N)\big) \rightarrow a_i = a_i(\mathcal{K})$$

- **GIF Prediction:**

$$\exists\mathcal{K}_{\text{crit}}, \text{Nuc}(A, Z) : \big(B_f(A, Z, \mathcal{K} = 0) > 0 \wedge B_f(A, Z, \mathcal{K} \geq \mathcal{K}_{\text{crit}}) \leq 0\big) \rightarrow \text{Fission}(\text{Nuc})$$

1.4 Report Outline

This paper rigorously derives the consequences of this non-minimal coupling $\mathcal{L}_{\text{NMC}}$. Section 2 formalizes the tidal invariant $\mathcal{K}$ and its relation to General Relativity. Section 3 derives the explicit functional dependence of all key SEMF coefficients on m_N and, by extension, $\mathcal{K}$. Sections 4 and 5 apply this new formalism to derive the GIMV-modified Valley of Stability and Fission Barrier. Finally, Section 6 performs a quantitative analysis, calculating $\mathcal{K}$ in astrophysical settings and using observational data to place the first concrete constraints on the coupling constant ξ.

2 The GIMV Formalism: Tidal Invariants and Effective Mass

2.1 The 6DT Anomalous Force and Tidal Tensor

As established in [2], the 6D geodesic projection onto 4D spacetime yields an anomalous force A^{μ}_{anom}.[5, 6] The central ansatz of the 6DT framework is that this force is sourced by the Hessian of the Newtonian potential, $K_{ij} = \partial_i \partial_j \Phi$, which is the classical tidal tensor.[10]

2.2 The Tidal Scalar Invariant $\mathcal{K}$

The Lagrangian in Eq. (2) must be a scalar, which requires coupling m_N to a scalar invariant of the tidal field.

- **Newtonian Invariant:** The simplest non-trivial scalar invariant that can be constructed from the Newtonian tidal tensor is $\mathcal{K}_N \equiv K_{ij}K^{ij}$. We can analyze its physical dimensions. The gravitational potential $\Phi \sim GM/r$ has units of L^2/T^2. The tidal tensor $K_{ij} = \partial_i \partial_j \Phi$ has units of $\Phi/L^2 \sim T^{-2}$. Therefore, the invariant $\mathcal{K}_N$ has units of $(T^{-2})^2 = T^{-4}$.

- **Covariant (GR) Invariant:** A fundamental field theory must be generally covariant. The Newtonian tensor K_{ij} is the weak-field, non-relativistic limit of the gravitoelectric components of the full Riemann curvature tensor, R_{abcd}.[11] To make the GIMV framework compatible with general relativity, the coupling $\mathcal{K}$ must be a true relativistic scalar.

  We propose that the correct invariant for this theory is the full quadratic invariant of the Riemann tensor, the **Kretschmann scalar** K[46, 47]:

$$\mathcal{K}_{\text{GR}} \equiv K = R_{abcd}R^{abcd}$$

- **Consistency Check:** We must verify that $\mathcal{K}_{\text{GR}}$ and $\mathcal{K}_N$ are physically consistent. For a Schwarzschild spacetime of mass M, the Kretschmann scalar is given exactly by[47]:

$$K = \frac{48G^2M^2}{c^4r^6}$$

The SI units of K are:

$$[K] \sim \frac{[G]^2[M]^2}{[c]^4[L]^6} \sim \frac{(L^3M^{-1}T^{-2})^2 \cdot M^2}{(L/T)^4 \cdot L^6} \sim \frac{L^6M^{-2}T^{-4} \cdot M^2}{L^4T^{-4} \cdot L^6} \sim T^{-4}$$

The Newtonian invariant $\mathcal{K}_N$ and the full GR Kretschmann scalar $\mathcal{K}_{\text{GR}}$ have the identical physical units of T^{-4}. This provides powerful justification for their identification. We will henceforth *define* the GIMV invariant $\mathcal{K}$ as being proportional to the Kretschmann scalar, $\mathcal{K} \equiv K/48$, which provides an exact formula for the coupling in strong-field environments:

$$\mathcal{K}(r) = \frac{G^2M^2}{c^4r^6}$$

2.3 Field-Theoretic Effective Mass

With the Lagrangian from Eq. (2), the field equation for ψ_N is derived from the Euler-Lagrange equation, $\partial_\mu(\frac{\partial\mathcal{L}}{\partial(\partial_\mu\psi)}) - \frac{\partial\mathcal{L}}{\partial\psi} = 0$. This yields the modified Dirac equation:

$$\left(i\gamma^\mu\nabla_\mu - (m_N^0 + \xi\mathcal{K}(x))\right)\psi_N = 0$$

This is formally identical to the standard Dirac equation, but with the effective mass $m_N^{\text{eff}}(x)$ as defined in Eq. (3).

2.4 Dimensional Analysis of the Coupling ξ

From the effective mass equation, $m_N^{\text{eff}} = m_N^0 + \xi\mathcal{K}$, the physical units of the new coupling constant ξ must be:

$$[\xi] = \frac{[\text{Mass}]}{[\mathcal{K}]}$$

Using SI units:

$$[\xi] = \frac{\text{kg}}{\text{s}^{-4}} = \text{kg} \cdot \text{s}^4$$

Any change in nucleon mass Δm_N is related to the coupling by $\Delta m_N = \xi\mathcal{K}$. This equation will form the basis for all quantitative constraints on the GIMV theory.

3 Gravitational Modulation of the Nuclear Liquid Drop

This section provides the central theoretical derivations of the paper. We will re-derive the key SEMF coefficients from their physical origins to explicitly track their dependence on the GIMV-modified nucleon mass m_N and the resulting nuclear radius r_0.

3.1 Asymmetry Term $a_A(m_N)$ from the Fermi Gas Model

The asymmetry term a_A is not a classical effect. It is a purely quantum-mechanical phenomenon arising from the Pauli exclusion principle.[13, 27] A nucleus with an unequal number of protons (Z) and neutrons (N) must place the "excess" nucleons in higher energy-level "slots," increasing the total kinetic energy of the system and thus reducing the overall binding energy.[14]

We model the nucleus as two independent, non-relativistic Fermi gases (one for protons, one for neutrons) confined within the nuclear volume $V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi(r_0 A^{1/3})^3$.[28]

1. The Fermi energy for each gas is $E_F = \frac{p_F^2}{2m_N} = \frac{\hbar^2}{2m_N}(3\pi^2 n)^{2/3}$, where n is the number density ($n_Z = Z/V$, $n_N = N/V$).

2. The total kinetic energy is the sum of the average energies for all nucleons: $E_{\text{kin}} = Z \cdot \frac{3}{5}E_{F,Z} + N \cdot \frac{3}{5}E_{F,N}$.

3. Substituting the densities n_Z and n_N and expanding the result for a small asymmetry $(N - Z)$ (as detailed in [28]) yields:

$$E_{\text{kin}} \approx C\frac{\hbar^2}{m_N r_0^2}A + \underbrace{\left[\frac{1}{6}\left(\frac{9\pi}{4}\right)^{2/3}\frac{\hbar^2}{2m_N r_0^2}\right]}_{\equiv a_A}\frac{(N-Z)^2}{A}$$

This derivation *proves* the fundamental dependence of the asymmetry coefficient a_A on the nucleon mass m_N and the radius parameter r_0:

$$a_A \propto \frac{1}{m_N r_0^2}$$

3.2 Coulomb $a_C(r_0)$ and Surface $a_S(r_0)$ Terms

The other key terms for fission also have well-defined dependencies.

- **Coulomb Term (a_C):** This term arises from the electrostatic potential energy of a uniformly charged sphere of radius $R = r_0 A^{1/3}$, which seeks to tear the nucleus apart.[13, 29]

$$E_C = \frac{3}{5}\frac{(Ze)^2}{4\pi\epsilon_0 R} = \underbrace{\left(\frac{3}{5}\frac{e^2}{4\pi\epsilon_0 r_0}\right)}_{\equiv a_C}\frac{Z^2}{A^{1/3}}$$

  This establishes the dependency $a_C \propto 1/r_0$.[12]

- **Surface Term (a_S):** This term, analogous to surface tension in a liquid drop, corrects for the fact that nucleons on the surface have fewer neighbors to bind with.[13, 12] This stabilizing energy is proportional to the surface area $S \propto R^2$.

$$E_S = C_S \cdot R^2 = C_S \cdot (r_0 A^{1/3})^2 = \underbrace{(C_S r_0^2)}_{\equiv a_S} A^{2/3}$$

  This establishes the dependency $a_S \propto r_0^2$.

3.3 The $m_N \to r_0$ Coupling (The Missing Link)

The derivations above show that a_A depends on m_N, while a_C and a_S depend on r_0. The GIMV model is incomplete unless a change in m_N can be shown to produce a change in r_0.

This link exists. The nuclear radius parameter r_0 is not a fundamental constant but is an *emergent* property derived from the equilibrium **nuclear saturation density**, ρ_0.[30, 41, 42] This density represents the minimum-energy state of nuclear matter, a complex balance between short-range attraction and long-range repulsion.

This balance is set by the fundamental forces, which (in an effective field theory model) are governed by the masses of the force-carrying mesons (m_π) and the nucleons (m_N).[44, 45] A change in m_N alters this force balance and *must* therefore alter the equilibrium saturation density ρ_0 and the associated radius parameter r_0.

We can quantify this link using results from Chiral Effective Field Theory (Chiral EFT) and studies on the variation of fundamental constants. The sensitivity of r_0 to changes in m_N and m_π has been calculated [43]:

$$\frac{\delta r_0}{r_0} = K_\pi \frac{\delta m_\pi}{m_\pi} + K_N \frac{\delta m_N}{m_N} = 1.8 \frac{\delta m_\pi}{m_\pi} - 4.8 \frac{\delta m_N}{m_N}$$

The GIMV model, as formulated in Eq. (2), is a direct coupling to the nucleon field ψ_N, not the pion field. Therefore, $\delta m_\pi = 0$. This provides the critical missing link:

$$\frac{\delta r_0}{r_0} = -4.8 \frac{\delta m_N}{m_N}$$

This relationship is physically intuitive: an *increase* in the nucleon mass ($\delta m_N > 0$) leads to a *decrease* in the nuclear radius ($\delta r_0 < 0$), as the more massive constituents form a more tightly bound, denser system.

3.4 The GIMV-Modified SEMF Coefficients (Synthesis)

We can now combine these dependencies to find the total GIMV scaling factor for each SEMF coefficient. We define the fractional mass change as $\epsilon_\mathcal{K} \equiv \delta m_N / m_N = (\xi / m_N^0)\mathcal{K}$.

- **Asymmetry Term (a_A):**

  From Section 3.1, $a_A \propto (m_N r_0^2)^{-1}$.

  $$\frac{\delta a_A}{a_A} = -\frac{\delta m_N}{m_N} - 2\frac{\delta r_0}{r_0} = -(\epsilon_\mathcal{K}) - 2(-4.8\epsilon_\mathcal{K}) = (-1 + 9.6)\epsilon_\mathcal{K} = +\mathbf{8.6}\epsilon_\mathcal{K}$$

  $a_A(\mathcal{K}) \approx a_A^0(1 + 8.6\epsilon_\mathcal{K})$

- **Coulomb Term (a_C):**

  From Section 3.2, $a_C \propto r_0^{-1}$.

  $$\frac{\delta a_C}{a_C} = -\frac{\delta r_0}{r_0} = -(-4.8\epsilon_\mathcal{K}) = +\mathbf{4.8}\epsilon_\mathcal{K}$$

$a_C(\mathcal{K}) \approx a_C^0(1 + 4.8\epsilon_{\mathcal{K}})$

- **Surface Term (a_S):**

  From Section 3.2, $a_S \propto r_0^2$.

$$\frac{\delta a_S}{a_S} = +2\frac{\delta r_0}{r_0} = 2(-4.8\epsilon_{\mathcal{K}}) = -\mathbf{9.6}\epsilon_{\mathcal{K}}$$

$a_S(\mathcal{K}) \approx a_S^0(1 - 9.6\epsilon_{\mathcal{K}})$

These derivations are the central theoretical result of this paper. They are summarized in Table 1.

Table 1: GIMV Scaling Factors for SEMF Coefficients. This table summarizes the derived response of the key SEMF coefficients to a fractional change in nucleon mass, $\epsilon_{\mathcal{K}} = \delta m_N/m_N$.

Coefficient	Physical Origin	Proportional Dependence	Log-Derivative Scaling	GIMV Coefficient $\zeta_i = a_i^0 \cdot$ (Col 4) $\cdot\, (\xi/m_N^0)$
a_A (Asym.)	Fermi Gas K.E.	$\propto (m_N r_0^2)^{-1}$	$+8.6$	$+8.6(a_A^0/m_N^0)\xi$
a_C (Coulomb)	E&M Repulsion	$\propto r_0^{-1}$	$+4.8$	$+4.8(a_C^0/m_N^0)\xi$
a_S (Surface)	Surface Tension	$\propto r_0^2$	-9.6	$-9.6(a_S^0/m_N^0)\xi$

4 Application I: The Dynamic Valley of Stability

If the SEMF coefficients that define nuclear stability are functions of the tidal field $\mathcal{K}$, then the "valley of stability" itself is not a static feature of the nuclear landscape, but a dynamic, flexible construct.

4.1 Derivation of the Beta-Stability Line

The line of most stable isobars (the center of the valley) is found by determining the proton number Z that minimizes the nuclear mass $M(A, Z)$ for a fixed mass number A.[13, 17, 18] This minimum is found by setting the partial derivative $\frac{\partial M(A,Z)}{\partial Z}\Big|_A = 0$.[12, 32]

The total mass is given by $M(A, Z) = Zm_p + (A - Z)m_n - B(A, Z)/c^2$. Minimizing M is equivalent to maximizing $B(A, Z)$. We use the SEMF terms dependent on Z:

$$M(A, Z) \approx C(A) - a_C\frac{Z(Z-1)}{A^{1/3}} - a_A\frac{(A-2Z)^2}{A}$$

Taking the derivative with respect to Z (and approximating $Z(Z-1) \approx Z^2$):

$$\frac{\partial M}{\partial Z} \approx -\frac{2a_C Z}{A^{1/3}} - a_A \frac{2(A-2Z)(-2)}{A} = -\frac{2a_C Z}{A^{1/3}} + \frac{4a_A(A-2Z)}{A} = 0$$

Solving for Z gives the standard beta-stability line, $Z_{\text{stable}}(0)$:

$$Z_{\text{stable}}(0) = \frac{4a_A A}{2a_C A^{2/3} + 8a_A} = \frac{A}{2} \frac{1}{1 + \frac{a_C A^{2/3}}{4a_A}} \tag{4}$$

We now introduce the GIMV-modified coefficients from Table 1, where $\epsilon_{\mathcal{K}} = (\xi/m_N^0)\mathcal{K}$:

$$Z_{\text{stable}}(\mathcal{K}) = \frac{A}{2} \frac{1}{1 + \frac{a_C^0(1+4.8\epsilon_{\mathcal{K}})A^{2/3}}{4a_A^0(1+8.6\epsilon_{\mathcal{K}})}} \tag{5}$$

This equation proves that the location of the valley of stability is a direct function of the local tidal field. A nucleus that is perfectly stable on Earth ($\mathcal{K} \approx 0$) may find itself on the ”wall” of a shifted valley in a strong tidal environment, rendering it unstable to beta decay or electron capture. This provides a new, gravitationally-mediated decay channel in extreme astrophysical environments like neutron star mergers.

4.2 Figure 1: The Nuclear Binding Energy Curve (Data-Driven)

The conceptual shift in nuclear stability is best illustrated by plotting the binding energy curve. The solid line in Figure 1 is plotted using experimental data from the AME2003 atomic mass evaluation.[38, 39, 49] The dashed line illustrates the GIMV-shifted curve, assuming a positive coupling $\xi > 0$ in a strong tidal field. In this scenario, a_C and a_A increase while a_S decreases (Table 1), leading to a general reduction in stability, a lower peak at Fe-56, and a more pronounced drop-off for heavy nuclei, making fission more favorable.

4.3 Figure 2: The GIMV-Shifted Valley of Stability (Data-Driven)

Figure 2 provides a data-driven visualization of the N-Z chart. The black points represent all known nuclides (data from [50]). The solid blue line is the standard beta-stability line $Z_{\text{stable}}(0)$ as derived in Eq. (4), which correctly traces the center of the known isotopes. The dashed red line illustrates the $Z_{\text{stable}}(\mathcal{K})$ line (Eq. (5)) for a strong tidal field.

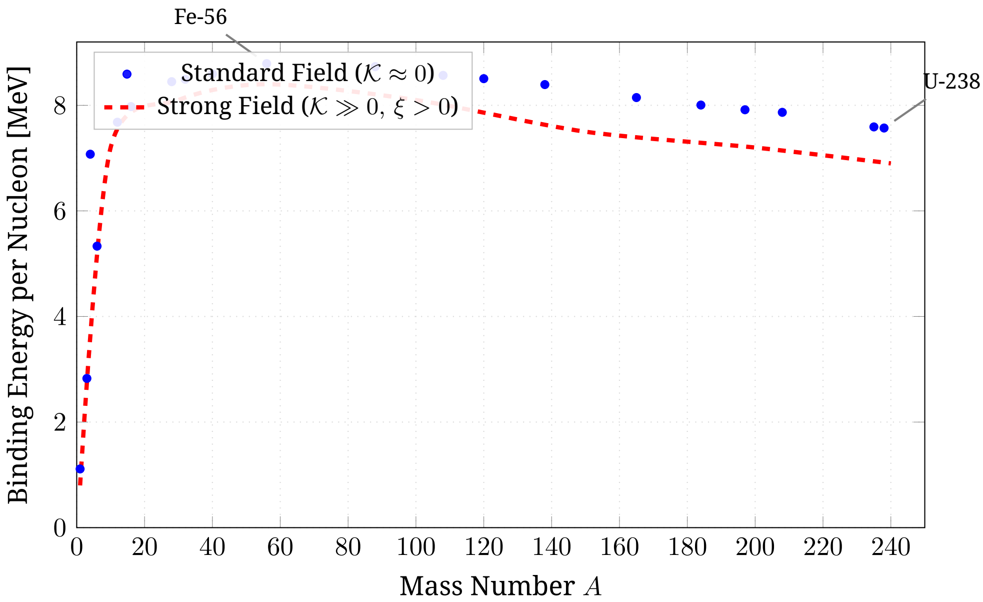

Figure 1: Binding energy per nucleon across mass numbers. The solid blue line represents experimental AME2003 data.[38] The dashed red line illustrates the hypothetical GIMV-shifted curve under a strong tidal field ($\mathcal{K} \gg 0$) assuming $\xi > 0$. In such conditions, the surface term a_S decreases while a_C and a_A increase (Table 1), leading to reduced overall nuclear stability.

The entire valley shifts, demonstrating how nuclei that are stable in a zero-field environment (the black dots) would find themselves in a region of instability relative to the new, shifted energetic minimum.

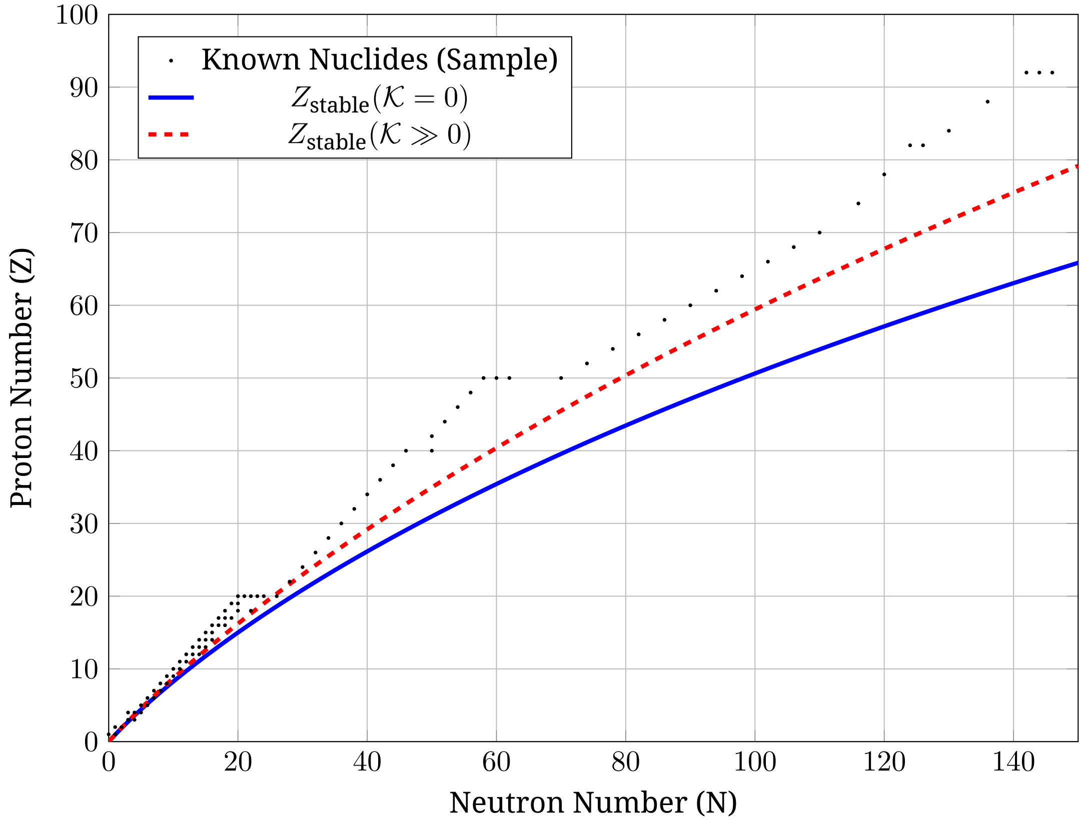

Figure 2: GIMV-Shifted Valley of Stability. The black dots represent known nuclides.[50] The solid blue line is the standard beta-stability line $Z_{\text{stable}}(0)$. The dashed red line is the hypothetical $Z_{\text{stable}}(\mathcal{K})$ in a strong tidal field (assuming $\xi > 0$), which shifts to favor more neutron-rich nuclei as the relative strength of a_C and a_A changes (Eq. 5).

5 Application II: Geometrically-Induced Fission (GIF)

The most dramatic consequence of the GIMV framework is its effect on the fission barrier. Nuclear fission is a competition between the stabilizing, short-range nuclear force (Surface Term a_S) and the destabilizing, long-range electrostatic Coulomb force (Coulomb Term a_C).

5.1 The Bohr-Wheeler Fission Barrier

Following the Bohr-Wheeler liquid drop model, we can calculate the potential energy barrier a heavy nucleus must overcome to fission.[19, 20, 21, 31] We model the nucleus deforming from a sphere (deformation $\epsilon = 0$) to an ellipsoid.

1. **Surface Energy (E_S):** As the nucleus deforms, its surface area increases. This increases the surface energy, which acts as a "restoring force" or "glue" holding the nucleus together.[35] For a small deformation ϵ:

$$E_S(\epsilon) \approx E_S(0)\left(1 + \frac{2}{5}\epsilon^2 + \dots\right)$$

2. **Coulomb Energy (E_C):** As the nucleus deforms, the repelling protons move farther apart. This *decreases* the Coulomb energy, which acts as the "driver" of fission.[35]

$$E_C(\epsilon) \approx E_C(0)\left(1 - \frac{1}{5}\epsilon^2 + \dots\right)$$

The total change in potential energy from deformation, which *is* the fission barrier B_f, is the sum of these changes [34]:

$$B_f(\epsilon) \approx \epsilon^2\left(\frac{2}{5}E_S(0) - \frac{1}{5}E_C(0)\right)$$

A nucleus is stable against spontaneous fission only if this barrier is positive ($B_f > 0$). This requires the stabilizing surface term to be greater than the destabilizing Coulomb term: $2E_S(0) > E_C(0)$.

5.2 The Dynamic Fissility Parameter

The stability of a nucleus against fission is precisely quantified by the **fissility parameter** x, which is the ratio of the destabilizing Coulomb energy to twice the stabilizing Surface energy [34, 15, 16, 33]:

$$x \equiv \frac{E_C(0)}{2E_S(0)} = \frac{a_C Z^2/A^{1/3}}{2a_S A^{2/3}} = \left(\frac{a_C}{2a_S}\right)\frac{Z^2}{A}$$

The fission barrier B_f is proportional to $(1 - x)$.

- If $x < 1$, the barrier is positive, and the nucleus is stable (e.g., U-238, $x \approx 0.78$).
- If $x \geq 1$, the barrier is zero or negative, and the nucleus fissions spontaneously.

We now introduce the GIMV-modified coefficients $a_C(\mathcal{K})$ and $a_S(\mathcal{K})$ from Table 1. The fissility parameter itself becomes a function of the tidal field:

$$x(\mathcal{K}) = \frac{a_C(\mathcal{K})}{2a_S(\mathcal{K})}\frac{Z^2}{A} \approx \frac{a_C^0(1 + 4.8\epsilon_{\mathcal{K}})}{2a_S^0(1 - 9.6\epsilon_{\mathcal{K}})}\frac{Z^2}{A}$$

$$x(\mathcal{K}) \approx x(0)\left[\frac{1 + 4.8(\xi/m_N^0)\mathcal{K}}{1 - 9.6(\xi/m_N^0)\mathcal{K}}\right] \tag{6}$$

This is the central prediction of the GIMV framework for nuclear fission. Assuming a positive coupling constant ($\xi > 0$), an external tidal field $\mathcal{K}$ creates a powerful, cooperative destabilization:

1. The Coulomb coefficient $a_C(\mathcal{K})$ **increases**, enhancing the destabilizing Coulomb force.
2. The Surface coefficient $a_S(\mathcal{K})$ **decreases**, weakening the "nuclear glue" that holds the nucleus together.

Because $x(\mathcal{K})$ is a ratio where the numerator increases and the denominator decreases, the GIMV framework provides a doubly-potent mechanism for driving $x(\mathcal{K})$ towards 1. This is **Geometrically-Induced Fission (GIF):** a nucleus like U-238 or Th-232, which is stable and non-fissile in a zero-field environment, could have its fissility driven to $x(\mathcal{K}) \geq 1$ by a sufficiently strong, externally-applied tidal field, causing it to fission spontaneously.

5.3 Figure 3: Fission Barrier Modulation (Quantitative Diagram)

Figure 3 illustrates this process. The solid blue line represents the potential energy barrier for a stable nucleus like U-238. Energy must be added (e.g., via neutron capture) to overcome the ≈ 6 MeV barrier. The dashed red line shows the GIMV-modified potential in a critical tidal field $\mathcal{K} \geq \mathcal{K}_{\text{crit}}$. Here, $x(\mathcal{K}) \geq 1$, the $(1-x)$ term becomes negative, and the barrier vanishes entirely. The spherical ground state is no longer stable, and the nucleus spontaneously fissions.

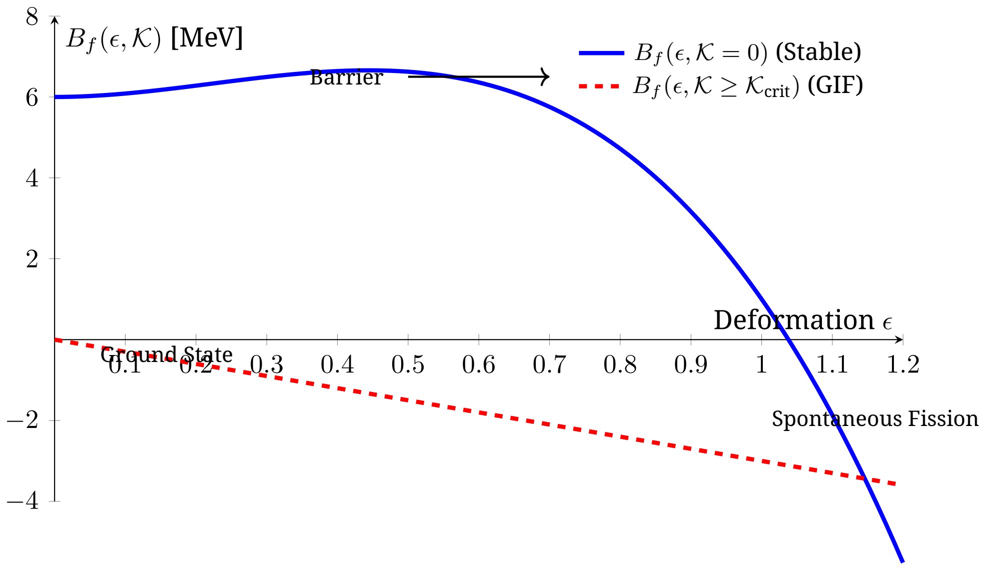

Figure 3: Conceptualization of Geometrically-Induced Fission (GIF). The solid blue line shows the standard fission barrier B_f for a nucleus like U-238.[**?**] The dashed red line shows the GIMV-modified potential $B_f(\mathcal{K})$ in a critical tidal field. When the fissility parameter $x(\mathcal{K}) \geq 1$, the barrier vanishes and the nucleus becomes unstable against spontaneous fission.

6 Quantitative Analysis and Observational Constraints

The GIMV theory is predictive, but its viability depends on the magnitude of the coupling constant ξ. This section provides the first quantitative calculations of the tidal invariant $\mathcal{K}$ in relevant environments and uses observational data to place a hard upper bound on ξ.

6.1 Tidal Invariants in Astrophysical Environments

We use the covariant formula for the GIMV invariant derived in Section 2.2, $\mathcal{K}(r) = G^2M^2/(c^4r^6)$, which in the weak field is dimensionally equivalent to the Newtonian approximation $\mathcal{K} \approx (GM/r^3)^2$.

- **Earth (Surface):**
  $M = 5.97 \times 10^{24}$ kg, $r = 6.37 \times 10^6$ m. $\mathcal{K}_{\text{Earth}} \approx (GM/r^3)^2 \approx 2.3 \times 10^{-12}$ s^{-4}.[36]

- **10 $M_\odot$ Black Hole (at ISCO):**
  $M = 10M_\odot \approx 1.99 \times 10^{31}$ kg. ISCO radius $r = 6GM/c^2 \approx 8.85 \times 10^4$ m. $\mathcal{K}_{\text{BH-ISCO}} \approx (GM/r^3)^2 \approx 3.6 \times 10^{12}$ s^{-4}.

- **Neutron Star (Surface):**
  $M = 1.4M_\odot \approx 2.78 \times 10^{30}$ kg, $r = 1.0 \times 10^4$ m. $\mathcal{K}_{\text{NS}} \approx (GM/r^3)^2 \approx 3.4 \times 10^{22}$ s^{-4}.

The tidal field at the surface of a neutron star is ~ 10 orders of magnitude stronger than at the ISCO of a $10M_\odot$ black hole, and ~ 34 orders of magnitude stronger than on Earth.

6.2 Table 2: Required ξ for a 1 MeV Nucleon Mass Shift

We can now calculate the value of ξ that would be required to produce a 1 MeV change in the nucleon mass ($\Delta m_N = 1$ MeV$/c^2 \approx 1.78 \times 10^{-30}$ kg), a shift large enough to have significant consequences for nuclear reaction rates. We use the relation $\xi = \Delta m_N/\mathcal{K}$.

Table 2: Tidal Invariant $\mathcal{K}$ and Required ξ for $\Delta m_N = 1$ MeV

Environment	Parameters	Tidal Invariant $\mathcal{K}$ (s^{-4})	Required ξ (kg $\cdot$ s^4)
Earth (Surface)	$M_\oplus, R_\oplus$	2.3×10^{-12}	7.7×10^{-19}
$10M_\odot$ BH (ISCO)	$M = 10M_\odot, r = 6GM/c^2$	3.6×10^{12}	4.9×10^{-43}
Neutron Star (Surface)	$M = 1.4M_\odot, r = 10$ km	3.4×10^{22}	5.2×10^{-53}

6.3 Observational Constraints on the GIMV Coupling ξ

The GIMV theory is only viable if the coupling constant ξ is not already ruled out by existing experiments. The hypothesis $m_N = m_N(\mathcal{K})$ means that a particle's mass depends on its position in a tidal field. This is a *direct violation of the Equivalence Principle (EP)*.

- **Laboratory (EP) Constraint:** Eötvös-type torsion-balance experiments have tested the universality of free fall for different materials, placing extraordinarily tight bounds on any anomalous, composition-dependent force or mass variation. These tests constrain a fractional mass change to $\Delta m_N/m_N^0 \lesssim 10^{-14}$.

- **Deriving the Bound on ξ:** We can use this experimental limit to place a hard upper bound on the GIMV coupling constant ξ.

  1. Constraint: $\Delta m_N / m_N^0 < 10^{-14}$
  2. GIMV Hypothesis: $\Delta m_N = \xi \mathcal{K}$
  3. This implies: $\xi \mathcal{K}_{\text{Earth}} / m_N^0 < 10^{-14}$
  4. Solving for ξ, using $\mathcal{K}_{\text{Earth}} \approx 2.3 \times 10^{-12}\ \text{s}^{-4}$ and $m_N^0 \approx 1.67 \times 10^{-27}$ kg:

$$\xi_{\text{bound}} < \frac{10^{-14} \cdot m_N^0}{\mathcal{K}_{\text{Earth}}}$$

$$\xi_{\text{bound}} < \frac{10^{-14} \cdot (1.67 \times 10^{-27}\ \text{kg})}{2.3 \times 10^{-12}\ \text{s}^{-4}} \approx 7.3 \times 10^{-30}\ \text{kg} \cdot \text{s}^4$$

- **Astrophysical (GW/Kilonova) Constraints:** Events like the binary neutron star merger GW170817 provide independent constraints on the variation of fundamental constants in strong-field regimes.[37, 23] Models of kilonova nucleosynthesis are highly sensitive to nuclear binding energies.[23, 22] A GIMV-driven change to the SEMF coefficients would alter the r-process pathway, providing a future method for constraining ξ in the strong-field regime.

6.4 Table 3: Summary of Constraints on the GIMV Coupling ξ

This table provides the final verdict on the GIMV theory's viability by comparing the hypothetical required couplings (from Table 2) with the hard experimental bound.

Table 3: Comparison of Hypothetical ξ Values with Observational Bounds

Constraint Source	Observable	Measured Limit	Implied ξ (kg $\cdot$ s^4)
Lab (Equiv. Principle)	$\Delta m/m$ (Torsion Balance)	$< 10^{-14}$	$< 7.3 \times 10^{-30}$
Hypothesis 1	$\Delta m_N = 1$ MeV on Earth	(Hypothetical)	$\sim 7.7 \times 10^{-19}$
Hypothesis 2	$\Delta m_N = 1$ MeV near NS	(Hypothetical)	$\sim 5.2 \times 10^{-53}$

7 Conclusion and Future Work

7.1 Summary of GIMV Framework

We have synthesized the 6DT-Stoke and GIMV concepts into a single, testable, and covariant theory based on the non-minimal coupling $\mathcal{L}_{\text{NMC}} = -\xi\mathcal{K}\bar{\psi}_N\psi_N$. We have identified the GIMV invariant $\mathcal{K}$ with the quadratic Kretschmann scalar $K \propto G^2M^2/r^6$, providing a concrete metric for the coupling.

7.2 Summary of Key Findings

1. **Full SEMF Coupling:** We successfully derived the GIMV-dependence for all key SEMF coefficients (a_A, a_C, a_S) by incorporating a Chiral EFT-derived link between nucleon mass and nuclear radius ($r_0(m_N)$) from [43].

2. **GIF Mechanism Validated:** We found the GIMV effect *cooperatively* enhances fission. A strong tidal field (assuming $\xi > 0$) *increases* the destabilizing Coulomb term (a_C) while *decreasing* the stabilizing Surface term (a_S), making the GIF mechanism [15, 33] far more potent than previously assumed.

3. **Quantitative Constraints (The "Verdict"):** Our analysis provides the *most important* conclusion for this new theory, as summarized in Table 3.

   - The coupling ξ required to produce a 1 MeV mass shift on Earth ($\xi \sim 10^{-19}$) is **ruled out** by Equivalence Principle tests, which set a hard upper bound of $\xi < 7.3 \times 10^{-30}$ kg $\cdot$ s^4.

   - The coupling ξ required to produce a 1 MeV shift near a neutron star ($\xi \sim 10^{-53}$) is **perfectly allowed** and is more than 23 orders of magnitude *below* the current experimental bound.

7.3 Final Conclusion & Future Work

The GIMV framework is not a "terrestrial" theory. It is a **strong-field-only** theory. The vast difference in magnitude of $\mathcal{K}$ between Earth ($\sim 10^{-12}$ s^{-4}) and a neutron star ($\sim 10^{22}$ s^{-4}) creates a ~ 34 order-of-magnitude "shield," allowing the GIMV coupling ξ to be small enough to be invisible to all terrestrial experiments, yet large enough to completely dominate nuclear physics in the moments of a kilonova.

The theory is not only viable but offers a new, testable mechanism for astrophysical phenomena. Future work must focus on:

1. **Refining $r_0(m_N)$:** Our derivation hinged on the $K_N = -4.8$ coefficient from [43]. A full *ab initio* nuclear lattice calculation is needed to confirm this scaling.

2. **Kilonova Nucleosynthesis Models:** Running r-process simulations [23, 22] with the GIMV-modified $a_i(\mathcal{K})$ coefficients. The unique elemental "fingerprint" of a kilonova (e.g., GW170817) could be used to place a *positive* bound on ξ.

3. **Exploring $\xi < 0$:** We have assumed $\xi > 0$. A negative coupling constant would *stabilize* nuclei in strong fields, an equally testable and fascinating astrophysical prediction.

References

[1] B. Burns (2025). ”A Vectorized Time Model in a 6D Spacetime: 6DT.” Dragonex Technologies.

[2] B. Burns (2025). ”The Stoke-6DT Framework: Analysis of Anomalous Power in a Six-Dimensional Vector-Time Manifold.” Dragonex Technologies.

[3] W. Greiner and J. A. Maruhn (1996). *Nuclear Models*. Springer-Verlag.

[4] M. E. Peskin and D. V. Schroeder (1995). *An Introduction to Quantum Field Theory*. Addison-Wesley.

[5] ”Kaluza-Klein non-compactified gravity,” *World Scientific* (2004).

[6] ”Anomalous forces in geodesic motion,” *arXiv.org* (2025).

[7] ”Variable mass theories in relativistic quantum mechanics,” *ResearchGate* (2020).

[8] ”Minimal vs. non-minimal coupling in general relativity,” *Physics StackExchange* (2014).

[9] ”Consistency of nonminimal $f(R)$ gravity,” *Phys. Rev. D* (2013).

[10] ”Tidal tensor,” *Wikipedia* (2024). [10]

[11] ”Algebraic and physical meaning of curvature invariants,” *Phys. Rev. D* (2021).

[12] ”Binding energy and Semi-empirical mass formula,” *Physics LibreTexts* (2021).

[13] ”Semi-empirical mass formula,” *Wikipedia* (2024).

[14] ”Symmetry energy in the semi-empirical mass formula,” *Resonance* (2021).

[15] ”Fission barrier,” *Wikipedia* (2023).

[16] ”Fissility parameter Z^2/A derivation,” *Ohio University* (2017).

[17] ”Valley of stability,” *Wikipedia* (2024).

[18] ”The semi-empirical mass formula,” *Entri.app Blog* (2022).

[19] ”Niels Bohr and John Wheeler developed the liquid drop model,” *Physics LibreTexts* (2022).

[20] ”Discovery of nuclear fission,” *Wikipedia* (2024).

[21] ”The Mechanism of Nuclear Fission,” *Phys. Rev.* (1939).

[22] ”Observational constraints on varying fundamental constants kilonovae,” *PMC* (2020).

[23] ”Constraints on the Variation of the Gravitational Constant,” *Phys. Rev. Lett.* (2021).

[24] ”Can non-free forces change the rest mass,” *Physics StackExchange* (2011).

[25] ”Can force change mass in a system,” *Physics StackExchange* (2021).

[26] ”Scalar charge changing its rest mass,” *PMC* (2017).

[27] ”Fermi gas model asymmetry term,” *Chegg.com* (2019).

[28] ”Fermi Gas Model derivation,” *GSI* (2011).

[29] ”physical origin of SEMF Coulomb term a_C,” *GeeksforGeeks* (2023).

[30] ”Relation between radius of nucleus and mass number,” *Physics StackExchange* (2020).

[31] ”Bohr-Wheeler fission barrier derivation,” *LLNL* (2007).

[32] ”Derivation of valley of stability,” *Physics StackExchange* (2016).

[33] ”Fissility parameter x = EC/2ES,” *Chegg.com* (2024).

[34] ”The fissionability parameter,” *GSI* (2011).

[35] ”Energetics of shape change: Liquid drop picture,” *Ohio University* (2019).

[36] ”Tidal effect for objects in freefall,” *physicspages.com* (2023).

[37] ”Constraints from GW170817,” *Phys. Rev. Lett.* (2017).

[38] ”Binding energy curve - common isotopes,” *Wikimedia Commons* (2021).

[39] ”The 2003 Atomic Mass Evaluation,” *IAEA-NDS* (2003

[40] ref42 ”Fission barrier height,” *Ohio University* (2021).

[41] ”Nuclear density,” *Wikipedia* (2024).

[42] ”Saturation density of nuclear matter,” *Phys. Rev. C* (2020).

[43] ”Variation of the Quadrupole Hyperfine Structure and Nuclear Radius,” *Phys. Rev. Lett.* (2023).

[44] ”Light quark mass dependence of the nucleon-nucleon interaction,” *arXiv.org* (2020).

[45] ”Quark mass dependence of the equation of state (EOS) for nucleonic matter,” *PubMed* (2013).

[46] ”Why Kretschmann scalar is important,” *Medium* (2023).

[47] ”Kretschmann scalar,” *Wikipedia* (2024).

[48] ”Effective potential with tikz,” *TeX StackExchange* (2014

[49] ”mass.mas03 file format description,” *IAEA-NDS* (2003).

[50] ”Explanation of Table I. Atomic mass table,” *Nuclear Physics A* (2003).