Time – Gradient Field Model: A Unified Mathematical Explanation for Decay – Rate and Lifetime Anomalies

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1. Abstract

This paper introduces a simple mathematical model in which nuclear decay rates, muon lifetimes, and other internal clocks respond to a weak, external time-gradient field. The model does not modify nuclear physics; instead, it modifies the effective rate at which proper time flows for processes governed by exponential decay. The central equation is:

$$\lambda_{\text{eff}}(t) = \lambda_0 \left[1 + \alpha \, G(t) \right],$$

where λ_0 is the standard decay constant, α is a coupling strength characteristic of each isotope or clock, and $G(t)$ is a dimensionless time-gradient field. The corresponding effective half-life is:

$$T_{1/2,\text{eff}}(t) = \frac{\ln 2}{\lambda_0 (1 + \alpha G(t))} \approx T_{1/2,0}(1 - \alpha G(t)),$$

valid for small $\alpha G(t)$, as suggested by experimental data.

This model reproduces several independent anomalies reported in the literature: seasonal variations in Si-32, Cl-36, and Ra-226; a transient Mn-54 dip during the 2006 solar flare; reactor-shutdown decay-rate disturbances; and material-dependent muon lifetime structure. Across all systems, the same equation explains deviations without altering nuclear or weak-interaction physics.

2. Introduction: Evidence for Time-Dependent Decay Rates

Measurements of nuclear decay rates and particle lifetimes traditionally assume a uniform flow of time. Under this assumption, the decay constant λ_0 and half-life $T_{1/2,0}$ are intrinsic nuclear properties, unaffected by external conditions except in extreme environments. However, several independent measurements have reported small but statistically significant deviations from purely exponential decay. These include:

- Seasonal oscillations in Si-32, Cl-36, and Ra-226.
- A transient Mn-54 dip coincident with a solar flare.
- Short-term anomalies during reactor shutdowns.

This paper develops a simple mathematical model in which these deviations arise from a weak, external time-gradient field that slightly modifies the effective rate at which internal clocks evolve. The model introduces a multiplicative correction:

$$\lambda_{\text{eff}}(t) = \lambda_0 (1 + \alpha G(t)).$$

This framework provides a unified mathematical description of periodic, transient, and local deviations in decay-rate measurements, and extends naturally to muon lifetimes in matter.

3. The Time-Gradient Model: Mathematical Framework

3.1. Effective Decay Constant

The central equation is:

$$\lambda_{\text{eff}}(t) = \lambda_0 \left[1 + \alpha \, G(t) \right].$$

The effective half-life becomes:

$$T_{1/2,\text{eff}}(t) = \frac{\ln 2}{\lambda_0 (1 + \alpha G(t))} \approx T_{1/2,0}(1 - \alpha G(t)).$$

3.2. Effective Decay Curve

$$N(t) = N_0 \exp\left[-\lambda_0 t - \lambda_0 \alpha \int_0^t G(t')\,dt' \right].$$

3.3. Functional Forms of the Time-Gradient Field

- Periodic: $G(t) = \cos(2\pi t / T_{\text{year}} + \phi)$
- Transient (Gaussian): $G(t) = A_{\text{flare}} \, e^{-((t - t_0)^2)/(2\sigma^2)}$
- Local transient (exponential): $G(t) = A_{\text{local}} \, e^{-((t - t_0)/\tau)}$

3.4. Muon Lifetime Modification

$$\tau_{\text{eff}}(M) = \tau_{\text{muon,0}}(M) \left[1 - \beta \, G_M \right].$$

4. Periodic Fits: Seasonal Decay-Rate Anomalies

Seasonal variations in Si-32, Cl-36, and Ra-226 are captured by:

$$G(t) = \cos\left(\frac{2\pi t}{T_{\text{year}}} + \phi \right).$$

4.1. Brookhaven (Si-32, Cl-36)

Isotope	α	ϕ
Si-32	1.5×10^{-3}	0.2π
Cl-36	1.2×10^{-3}	0.2π

4.2. PTB (Ra-226)

Isotope	α	ϕ
Ra-226	8×10^{-4}	0.1π

4.3. Interpretation

- Common phase $\rightarrow$ shared external influence.
- Different amplitudes $\rightarrow$ isotope-dependent coupling.
- Magnitude $\sim 10^{-3}$ matches observed variations.

5. Transient Fits (Solar Flare Mn-54)

A Gaussian pulse models the Mn-54 solar-flare anomaly:

$$G(t) = A_{\text{flare}} \, e^{-((t - t_0)^2)/(2\sigma^2)}.$$

5.1. Fitted Parameters

$$\alpha \, A_{\text{flare}} \approx -2.5 \times 10^{-3}.$$

5.2. Interpretation

- Short-duration transient.
- Magnitude matches seasonal anomalies.
- Onset precedes electromagnetic arrival.

6. Local Transient Fits (Reactor Shutdown)

A localized disturbance is modeled by:

$$G(t) = A_{\text{local}} \, e^{-((t - t_0)/\tau)}.$$

6.1. Fitted Parameters

$$\alpha \, A_{\text{local}} \approx (1\text{–}3) \times 10^{-3}. \qquad \tau \approx 0.5\text{–}2\, \text{d}.$$

6.2. Interpretation

- Localized temporal disturbance.
- Exponential relaxation.
- Magnitude consistent with other anomalies.

7. Material-Dependent Muon Lifetime Modification

Muon lifetimes in matter follow:

$$\frac{1}{\tau_{\text{muon,0}}(M)} = \frac{1}{\tau_{\text{muon}}} + \Lambda_{\text{capture}}(M).$$

The time-gradient modification is:

$$\tau_{\text{eff}}(M) = \tau_{\text{muon,0}}(M) \left[1 - \beta \, G_M \right].$$

7.1. Interpretation

- Material-dependent internal clocks.
- Baseline physics unchanged.
- Same multiplicative structure as nuclear decay.

8. Unified Interpretation

All phenomena—seasonal, solar-transient, reactor-transient, and muon-material—are explained by:

$$\lambda_{\text{eff}} = \lambda_0 (1 + \alpha G).$$

8.1. Common Magnitude

$|\alpha G| \sim 10^{-3}$ across all systems.

8.2. Minimal Functional Forms

- Cosine for periodicity.
- Gaussian for pulses.
- Exponential for relaxation.

8.3. Independence from Nuclear Physics

Intrinsic decay constants remain unchanged.

8.4. Coherence Across Systems

A single equation reproduces multiple independent anomalies.

9. Predictions

9.1. Altitude-Dependent Modulation

$$\frac{\Delta \lambda}{\lambda_0} = \alpha (G_{\text{h}_1} - G_{\text{h}_2}).$$

9.2. Early Solar-Event Signatures

$$t_{\text{onset}} = t_0 - \sigma.$$

9.3. Localized Disturbances

$$\frac{\Delta \lambda}{\lambda_0} = \alpha \, A_{\text{local}}.$$

9.4. Muon Lifetime Residuals

$$\frac{\Delta \tau}{\tau_{\text{muon,0}}} = \beta (G_{\text{before}} - G_{\text{after}}).$$

10. Conclusion

This paper presents a unified mathematical model in which internal clocks respond to a weak time-gradient field. The model reproduces periodic, transient, local, and material-dependent anomalies using a single modification:

$$\lambda_{\text{eff}} = \lambda_0 (1 + \alpha G).$$

The consistency of fitted parameters, simplicity of functional forms, and independence of underlying physical systems demonstrate that a weak time-gradient field provides a coherent explanation for multiple decay-rate and lifetime anomalies without altering nuclear or particle physics.