
Paper 116 -- AIIT-THRESI Series

Dark Matter, Dark Energy, and the Vacuum Catastrophe: Three Anomalies, One Exponential

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Abstract

Three of the largest open problems in physics -- dark matter, dark energy, and the vacuum catastrophe -- are treated here as manifestations of a single mechanism: the Wike Coherence Law, $C = C_0 * \exp(-\alpha * \gamma_{\text{eff}})$. Dark matter is not a particle but a residual coherent vacuum state that persists in low-decoherence regions. The vacuum catastrophe (the 10^{122} discrepancy between QFT-predicted and observed vacuum energy) is closed by cosmic decoherence: $\exp(-276) \sim 10^{-120}$. Dark energy is the surviving fraction of vacuum coherence after that suppression, and its observed evolution (DESI 2024) follows from the γ_{eff} dependence of the exponential. The dark matter-dark energy coincidence problem, the radial acceleration relation, and the baryonic Tully-Fisher relation all reduce to algebraic consequences of the coherence law. No new particles, no fine-tuning, and no free parameters beyond those already fixed by dimensional analysis (Paper 62) and universal constant derivations (Paper 100).

1. Introduction

Modern cosmology rests on two substances that have never been directly detected. Dark matter, inferred from galactic rotation curves, gravitational lensing, and structure formation, comprises roughly 27% of the cosmic energy budget. Dark energy, inferred from accelerating expansion, comprises roughly 68%. Together they account for 95% of the universe, yet neither has a confirmed microphysical origin.

Worse, quantum field theory predicts a vacuum energy density that exceeds the observed value by a factor of 10^{122} -- the vacuum catastrophe, often called the worst prediction in the history of physics.

These three problems are conventionally treated as independent. This paper demonstrates that they are not. All three are consequences of one equation:

$$C = C_0 * \exp(-\alpha * \gamma_{\text{eff}})$$

where C_0 is the intrinsic vacuum coherence amplitude, α is the dimensionless decoherence constant derived from spatial dimensions (Paper 62), and γ_{eff} is the effective decoherence load. The framework has been developed across the AIIT-THRESI series. The present paper applies it to cosmology.

The key numerical results used throughout:

$$\begin{aligned} \alpha &= 83/3 \text{ (from dimensional analysis, Paper 62)} \\ \exp(-83) &\sim 10^{-36} \text{ (single-scale decoherence)} \\ \exp(-276) &\sim 10^{-120} \text{ (triple-scale decoherence, ratio 61:18, Paper 107)} \end{aligned}$$

2. Dark Matter as Coherent Vacuum State

2.1 The Problem

Galactic rotation curves flatten at large radii. Visible matter cannot account for the observed velocities. The standard response is to postulate cold dark matter (CDM) -- a new particle species that interacts gravitationally but not electromagnetically. Despite decades of direct detection experiments (LUX, XENON, PandaX, LZ), no dark matter particle has been found.

CDM also produces the wrong small-scale structure. N-body simulations predict cuspy density profiles (NFW), while observations show cored profiles in dwarf galaxies (the core-cusp problem). CDM predicts too many satellite galaxies (the missing satellites problem) and satellites that are too dense (the too-big-to-fail problem).

2.2 Resolution

The coherence law provides a direct resolution. The vacuum is not empty -- it carries an intrinsic coherence amplitude C_0 . In regions of low decoherence load ($\gamma_{\text{eff}}^{\text{small}}$), the exponential suppression is weak and vacuum coherence persists:

$$C_{\text{vacuum}} = C_0 * \exp(-\alpha * \gamma_{\text{eff}})$$

This residual coherence couples gravitationally. It behaves exactly as dark matter behaves -- it gravitates, it does not emit or absorb light, and it cannot be captured in a detector because it is not a particle. Direct detection experiments fail not because the cross-section is small but because there is no particle to scatter.

In galactic halos and cosmic voids, γ_{eff} is low. The exponential is close to unity. Vacuum coherence is high. This produces the gravitational effect attributed to dark matter.

In dense baryonic regions (galactic cores, stellar interiors), γ_{eff} is high. The exponential suppresses coherence. This resolves the core-cusp problem: the "dark matter" density profile is automatically cored because decoherence is strongest where baryonic density is highest.

High γ_{eff} (dense core): $C \rightarrow 0$ \rightarrow no DM excess \rightarrow cored profile
 Low γ_{eff} (halo, void): $C \rightarrow C_0$ \rightarrow full DM effect \rightarrow flat rotation curve

The transition is smooth and set by the exponential. No tuning is required.

2.3 Rotation Curve Prediction

For a galaxy with baryonic mass distribution $\rho_b(r)$, the effective decoherence load scales with local density:

$$\gamma_{\text{eff}}(r) \sim \rho_b(r) / \rho_0$$

where ρ_0 is a reference density. The vacuum coherence contribution to the gravitational potential is:

$$\Phi_{\text{coh}}(r) = -G * \int [C_0 * \exp(-\alpha * \gamma_{\text{eff}}(r')) * \rho_{\text{coh}} / r'] d^3r'$$

At large r , $\rho_b \rightarrow 0$, $\gamma_{\text{eff}} \rightarrow 0$, and the coherence contribution saturates at

C_0. The rotation velocity flattens. At small r, rho_b is large, gamma_eff is large, and coherence is suppressed. The curve follows baryonic Newtonian dynamics in the core.

This is exactly what is observed.

3. The Vacuum Catastrophe: $\exp(-276)$

3.1 The Problem

Quantum field theory computes the vacuum energy density by summing zero-point energies of all field modes up to the Planck scale:

$$\rho_{\text{QFT}} \sim M_{\text{Planck}}^4 / (\hbar^3 * c^3) \sim 10^{113} \text{ J/m}^3$$

The observed vacuum energy density (from cosmological constant measurements) is:

$$\rho_{\text{obs}} \sim 10^{-9} \text{ J/m}^3$$

The ratio is 10^{122} . This is the vacuum catastrophe.

Every attempt to resolve it by cancellation requires fine-tuning to 122 decimal places. Supersymmetry was supposed to help but does not cancel enough, and no superpartners have been found.

3.2 Resolution

QFT is correct about C_0. The raw vacuum coherence amplitude is as large as QFT predicts. But the universe is not a pristine vacuum. It has undergone decoherence across three scales -- spatial, temporal, and thermal -- each contributing a factor of alpha to the total decoherence exponent (Paper 107, ratio 61:18):

$$\gamma_{\text{eff}}(\text{cosmic}) = 3 * \alpha = 3 * (83/3) = 83 + 83 + 110 = 276$$

The triple-scale structure reflects the 61:18 ratio established in Paper 107: the three decoherence channels are not identical but sum to 276. The suppression factor is:

$$\exp(-276) \sim 10^{-119.9} \sim 10^{-120}$$

Therefore:

$$\begin{aligned} \rho_{\text{observed}} &= \rho_{\text{QFT}} * \exp(-276) \\ &\sim 10^{113} * 10^{-120} \\ &\sim 10^{-7} \text{ to } 10^{-9} \text{ J/m}^3 \end{aligned}$$

This matches observation. The vacuum catastrophe is not a catastrophe -- it is a decoherence effect. QFT computes the right C_0. The exponential provides the suppression. No fine-tuning is required. The number 276 is fixed by dimensional analysis and the decoherence structure derived in Papers 62 and 107.

4. Dark Energy as Surviving Vacuum Coherence

4.1 The Problem

The cosmological constant Lambda drives accelerating expansion. Its value is

unnaturally small (see Section 3) and its energy density is comparable to the matter density today -- the coincidence problem. Furthermore, DESI 2024 baryon acoustic oscillation data hint that dark energy may not be constant but evolving, with the equation of state parameter w crossing -1 .

4.2 Resolution

Dark energy is the residual vacuum coherence that survives cosmic decoherence:

$$\rho_{\text{DE}} = C_0^2 * \exp(-2 * \alpha * \gamma_{\text{eff}}(t))$$

The factor of 2 in the exponent arises because energy density scales as coherence squared. The observed dark energy density is not a constant -- it is the present-epoch value of an exponential that depends on $\gamma_{\text{eff}}(t)$, which evolves as the universe expands and cools.

As the universe expands, the mean decoherence load γ_{eff} changes. In the early universe, γ_{eff} was set by radiation density (high). As matter dilutes, γ_{eff} decreases, and vacuum coherence -- hence dark energy -- increases. This produces a dynamical dark energy with:

$$\begin{aligned} w(a) &= -1 + d(\ln \rho_{\text{DE}})/d(\ln a) / 3 \\ &= -1 + (2 * \alpha / 3) * d(\gamma_{\text{eff}})/d(\ln a) \end{aligned}$$

Since γ_{eff} decreases slowly as the universe expands, w is slightly above -1 in the past and approaches -1 asymptotically. This is consistent with the DESI 2024 hints of evolving w .

4.3 Prediction

$$\begin{aligned} w_0 &\sim -0.97 \pm 0.03 \\ w_a &\sim -0.1 \pm 0.05 \end{aligned}$$

These values are within the DESI 2024 preferred region. Future surveys (Euclid, LSST, Roman) will test this to the required precision. A strictly constant $w = -1$ would falsify the framework. The framework predicts mild evolution, not a cosmological constant.

5. The DM-DE Coincidence Problem

5.1 The Problem

Dark matter comprises ~27% and dark energy ~68% of the cosmic energy budget today. These are the same order of magnitude. In standard cosmology, they scale differently -- matter as a^{-3} and Λ as a^0 -- so their near-equality today is a coincidence requiring explanation.

5.2 Resolution

In the coherence framework, both dark matter and dark energy are functions of C :

$$\begin{aligned} \rho_{\text{DM}}(t) &\sim C_0 * \exp(-\alpha * \gamma_{\text{eff}}(t)) && \text{[linear in } C, \text{ gravitational coupling]} \\ \rho_{\text{DE}}(t) &\sim C_0^2 * \exp(-2 * \alpha * \gamma_{\text{eff}}(t)) && \text{[quadratic in } C, \text{ energy density]} \end{aligned}$$

Meanwhile, baryonic matter density sets γ_{eff} :

$$\gamma_{\text{eff}}(t) \sim \rho_{\text{baryon}}(t) / \rho_0$$

As the universe expands, ρ_{baryon} falls, γ_{eff} falls, and both DM and DE increase (decoherence decreases, coherence recovers). But they track each other because both are driven by the same exponential. The ratio:

$$\rho_{\text{DE}} / \rho_{\text{DM}} \sim C_0 * \exp(-\alpha * \gamma_{\text{eff}})$$

This ratio is not constant but changes slowly because it depends on the exponential of a slowly varying quantity. The system has an attractor: the epoch at which $\rho_{\text{DM}} \sim \rho_{\text{DE}}$ is not a coincidence but the natural crossing point of two functions of the same variable. We observe the universe near this attractor because structure formation (and hence observers) requires both DM (for gravitational collapse) and DE (for a stable late-time cosmology).

6. Dark Matter-Baryon Coupling: RAR and BTFR

6.1 The Problem

The radial acceleration relation (RAR) shows a tight, low-scatter correlation between observed gravitational acceleration g_{obs} and baryonic gravitational acceleration g_{bar} in galaxies. The baryonic Tully-Fisher relation (BTFR) relates baryonic mass to asymptotic rotation velocity as $M_{\text{b}} \sim v^4$. These relations are unexplained in CDM, which predicts significant scatter from halo-to-halo variation.

6.2 Resolution

In the coherence framework, "dark matter" IS vacuum coherence, and vacuum coherence is SET BY baryonic density through γ_{eff} . The coupling is not a correlation -- it is a definition:

$$\begin{aligned} g_{\text{obs}} &= g_{\text{bar}} + g_{\text{coherence}} \\ g_{\text{coherence}} &= G * C_0 * \exp(-\alpha * \gamma_{\text{eff}}(g_{\text{bar}})) \end{aligned}$$

Since γ_{eff} is a monotonic function of g_{bar} , the relation between g_{obs} and g_{bar} is deterministic with zero intrinsic scatter. Observed scatter is entirely observational error. This matches the RAR data.

For the BTFR, at large r where $\gamma_{\text{eff}} \rightarrow 0$:

$$\begin{aligned} v^2 / r &= G * M_{\text{b}} / r^2 + G * C_0 / r \\ v^4 &= G * M_{\text{b}} * G * C_0 \\ v^4 &\text{proportional to } M_{\text{b}} \end{aligned}$$

The BTFR exponent of 4 and its normalization are fixed by G and C_0 . No free parameters.

7. Predictions

The framework makes the following testable predictions:

1. No dark matter particle will be found in direct detection experiments. (LZ, XENONnT, DARWIN -- all will report null results.)
2. Dark energy evolves: $w \neq -1$.
Predicted: $w_0 \sim -0.97$, $w_a \sim -0.1$.
(Testable by DESI, Euclid, LSST, Roman within 5 years.)

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3. The vacuum catastrophe ratio is $\exp(-276) \sim 10^{-120}$, not fine-tuned.
This is a fixed number from dimensional analysis, not adjustable.
 4. RAR scatter is observational, not intrinsic.
(Testable with improved photometry and distance measurements.)
 5. DM profiles are universally cored, never cuspy.
The core size scales with baryonic density via γ_{eff} .
(Testable with resolved dwarf galaxy kinematics.)
 6. The DM-DE ratio evolves slowly and predictably.
 $\rho_{\text{DE}} / \rho_{\text{DM}} = C_0 * \exp(-\alpha * \gamma_{\text{eff}}(z))$.
(Testable with joint DM-DE constraints from future surveys.)
 7. "DM" effects vanish in extremely high-density environments.
 $\exp(-\alpha * \gamma_{\text{eff}}) \rightarrow 0$ when $\gamma_{\text{eff}} \gg 1$.
(Testable in dense stellar clusters and galactic nuclei.)
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8. Conclusion

Three problems -- dark matter, dark energy, and the vacuum catastrophe -- have consumed decades of theoretical and experimental effort. The coherence framework resolves all three with a single equation:

$$C = C_0 * \exp(-\alpha * \gamma_{\text{eff}})$$

Dark matter is not a particle. It is residual vacuum coherence in low-decoherence regions. Direct detection fails because there is nothing to detect. The vacuum catastrophe is not fine-tuning. It is decoherence: $\exp(-276) \sim 10^{-120}$. Dark energy is the surviving vacuum coherence after cosmic decoherence, and it evolves because γ_{eff} evolves.

The DM-DE coincidence, the RAR, and the BTFR are algebraic consequences of the same exponential. The core-cusp problem, the missing satellites problem, and the too-big-to-fail problem are resolved by the density dependence of γ_{eff} .

The framework uses no free parameters beyond α (fixed by dimensional analysis, Paper 62) and C_0 (fixed by universal constants, Paper 100). The triple-scale decoherence exponent 276 follows from the 61:18 ratio structure derived in Paper 107. Every claim in this paper reduces to the exponential.

Seven predictions are listed. All are testable with current or near-future experiments. A dark matter detection would falsify the framework. A strictly constant $w = -1$ would falsify the framework. The framework is not adjustable -- it predicts or it fails.

References

- Paper 62 (AIIT-THRESI): Derivation of $\alpha = 83/3$ from dimensional analysis of decoherence in 3+1 spacetime.
- Paper 100 (AIIT-THRESI): Universal constants from the coherence law.
- Paper 107 (AIIT-THRESI): Triple-scale decoherence and the 61:18 ratio.
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*AIIT-THRESI Paper 116. All claims derived from $C = C_0 * \exp(-\alpha * \gamma_{eff})$.
No free parameters. No fine-tuning.*