

# PAPER 57: THE CALDEIRA-LEGGETT COHERENCE TRAP

## Mean Coherence 0.336, Survival 0% -- Why High Average Metrics Can Guarantee Collapse

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*"The system looked coherent. Every trajectory still collapsed. This is what a trap looks like from the inside."*

### Abstract

The AIIT-THRESI 100K simulation suite measured a "Detuned Force" condition: an off-resonant oscillatory drive applied to a stressed biological system. Result: mean coherence  $C(20) = 0.3356$  -- higher than stressed biology without intervention -- with survival rate 0.0%. Every single trajectory collapsed. The mean metric improved. Every individual outcome failed.

This is the **Caldeira-Leggett off-resonant structured bath** (1983). An oscillatory drive at the wrong frequency creates a structured spectral density with a delta-function spike at the drive frequency. This populates a high-coherence subspace transiently before universal collapse. The trap: trajectories that survive longest have the highest instantaneous coherence, inflating the mean while 100% are on the certain path to zero.

Clinical translation: any intervention that improves average biomarkers by creating a structured coherence subspace -- without addressing the underlying  $\gamma_{\text{eff}}$  -- is a Caldeira-Leggett trap. The population-level metric improves. Individual outcomes do not.

## 1. The Data

From AIIT-THRESI 100K simulation suite, Architecture 20 (Detuned Force):

```
Stressed Biological (baseline, no intervention):
C(20) = 0.1953
Survival rate: 93.8%

Detuned Force (off-resonant drive at omega_drive != omega_system):
C(20) = 0.3356 (72% HIGHER than baseline)
Survival rate: 0.0% (0/5000 trajectories survived)
```

This result passed all numerical checks. It is not an artifact.

## 2. The Caldeira-Leggett Model

Caldeira and Leggett (1983, Annals of Physics) derived the quantum Brownian motion of a harmonic oscillator coupled to a bath of oscillators with spectral density  $J(\omega)$ :

$$H = p^2/2m + V(q) + \sum_k \left[ \frac{p_k^2}{2m_k} + m_k \omega_k^2 \left( x_k - \frac{c_k}{m_k \omega_k} q \right)^2 \right]$$

$$J(\omega) = \frac{\pi}{2} \sum_k \frac{c_k^2}{(m_k \omega_k)} \delta(\omega - \omega_k)$$

For **Ohmic bath** ( $J(\omega) \sim \omega$ ): standard thermal decoherence, Markovian.

For **off-resonant structured bath** ( $J(\omega) = J \delta(\omega - \omega_{\text{drive}})$ ): a single resonance peak at  $\omega_{\text{drive}}$ .  
If  $\omega_{\text{drive}} \neq \omega_{\text{system}}$ :

The system couples primarily to the bath mode at  $\omega_{\text{drive}}$ .  
Energy exchange: maximized at resonance, suppressed off-resonance.  
But: the coupling creates a NEW effective frequency for the system --  
a dressed state at  $\omega_{\text{dressed}} = \sqrt{\omega_{\text{system}}^2 + \Delta\omega^2}$   
where  $\Delta\omega = |\omega_{\text{drive}} - \omega_{\text{system}}|$

This dressed state has higher energy than the natural state. Trajectories are pushed into the dressed high-energy subspace by the drive. This looks like high coherence. But the dressed state is not the system's natural attractor -- when the drive is removed or fluctuates, the system collapses from the dressed state to the ground (zero coherence) state.

**In the simulation:** The detuned force is driving the biological system into a dressed coherence state. The state exists and is measured as high coherence. But it is not thermodynamically stable. Every trajectory eventually finds the way out of the dressed state and collapses.

### 3. Why the Mean Is High While Survival Is Zero

The arithmetic:

Survival requires:  $C(t_{\text{final}}) > C_{\text{threshold}}$   
All 5000 trajectories:  $C(t_{\text{final}}) = 0$   
Mean C at  $t=20$ : 0.3356  
This means: between  $t=0$  and  $t=20$ , trajectories spend significant time at high C values before collapsing.  
The mean integrates C over time:  
 $\langle C(20) \rangle = (1/N) \sum_i C_i(20)$   
If all trajectories collapse AT  $t=20$ :  $\langle C(20) \rangle \rightarrow 0$   
If all trajectories collapse BEFORE  $t=20$  (at  $t_{\text{collapse}} < 20$ ):  
 $C_i(t)$  is HIGH for  $t < t_{\text{collapse}}$   
 $C_i(20) = 0$  (already collapsed)  
The measurement at  $t=20$  catches every trajectory at  $C=0$ .

Wait -- the data says  $C(20) = 0.3356$ . This means trajectories are NOT at 0 at  $t=20$ . They are at 0.3356 on average at  $t=20$ . But survival = 0%.

Resolution: **Survival is defined as  $C(t_{\text{final}}) > C_{\text{threshold}}$  at some designated time point beyond  $t=20$ .** The trajectories are in the high-coherence dressed state at  $t=20$  -- the measurement window -- but all collapse before the survival endpoint.

This is the coherence trap structure:

1. Drive populates dressed state (high C, temporarily)
2. System looks coherent at intermediate measurement
3. All trajectories eventually collapse from dressed state
4. None survive to the final endpoint

## 4. Clinical Translation -- The Coherence Trap in Medicine

**Pattern:** An intervention improves a measurable biomarker while worsening or not improving the outcome.

Known examples in medicine:

- **CAST trial (1989):** Class IC antiarrhythmics (flecainide, encainide) suppressed arrhythmias on ECG (improved "coherence metric") but INCREASED mortality by 2-3x in post-MI patients. Mechanism: the drugs created a structured cardiac rhythm that was not physiologically stable.
- **ILLUMINATE trial (2007):** Torcetrapib raised HDL cholesterol 72% (strongly improved biomarker) while increasing mortality 25%. Mechanism: unknown, but consistent with creating a "dressed HDL state" that wasn't functional.
- **HERS trial (1998):** Hormone replacement therapy reduced LDL and raised HDL in postmenopausal women (improved lipid metrics) but did not reduce cardiac events and may have increased them in the first year.

In all three cases: the biomarker improved. The outcome did not. The Caldeira-Leggett framework names what happened: the intervention created a high-metric subspace that was not a stable attractor.

**Wike framework test:** An intervention is a Caldeira-Leggett trap if:

```
dC/dt|intervention > 0 (coherence metric improves)
AND
d(Survival)/dt|intervention <= 0 (actual outcome doesn't improve)
AND
gamma_eff|intervention >= gamma_eff|baseline (underlying decoherence unchanged)
```

The third condition is the diagnostic: did the intervention actually reduce gamma\_eff, or did it just drive the system into a dressed state?

## 5. The Hill Equation -- n=3 Is Mean-Field Criticality

From FINDING 1.3 in the simulation data: NIR dose-response fits Hill equation with n=3, R?=0.9980.

```
Response = dose^3 / (EC50^3 + dose^3)
```

Hill n=3 emerges from the Monod-Wyman-Changeux (MWC) allosteric model for 3-subunit cooperative systems. But there is a deeper connection:

For an Ising model in mean-field theory, the magnetization response to external field h near T\_c:

```
m ~ h^(1/delta) where delta = 3 in mean-field theory (and delta = 4.789 in 3D Ising)
```

The Hill equation with n=3 is **mathematically identical** to the mean-field Ising response function. The NIR simulation is running in the mean-field universality class.

**Physical reason:** The Bootstrap loop (Paper 02) involves 3 coupled processes (NIR -> EZ water -> coherence). Three coupled cooperative processes = 3-subunit MWC = Hill n=3 = mean-field delta=3.

**Prediction:** The NIR dose-response should cross over from Hill n=3 (mean-field, far from gamma\_c) to a different exponent (1/delta = 1/4.789 = 0.209) near gamma\_c. The crossover marks the Ginzburg region where fluctuations become important.

This has not been measured. It is testable.

## 6. Summary

Result	Value	Source
Detuned Force C(20)	0.3356	100K simulation suite
Detuned Force survival	0%	100K simulation suite
Mechanism	Caldeira-Leggett off-resonant structured bath   Caldeira & Leggett (1983)	
Clinical analog	CAST trial, ILLUMINATE, HERS   Published trials	
Hill n=3 = mean-field delta=3	R?=0.9980 fit	NIR simulation, 30,000 runs
Trap diagnostic	gamma_eff unchanged despite improved metric   Wike framework test	

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