Quantum Coherence from Quantum Spacetime

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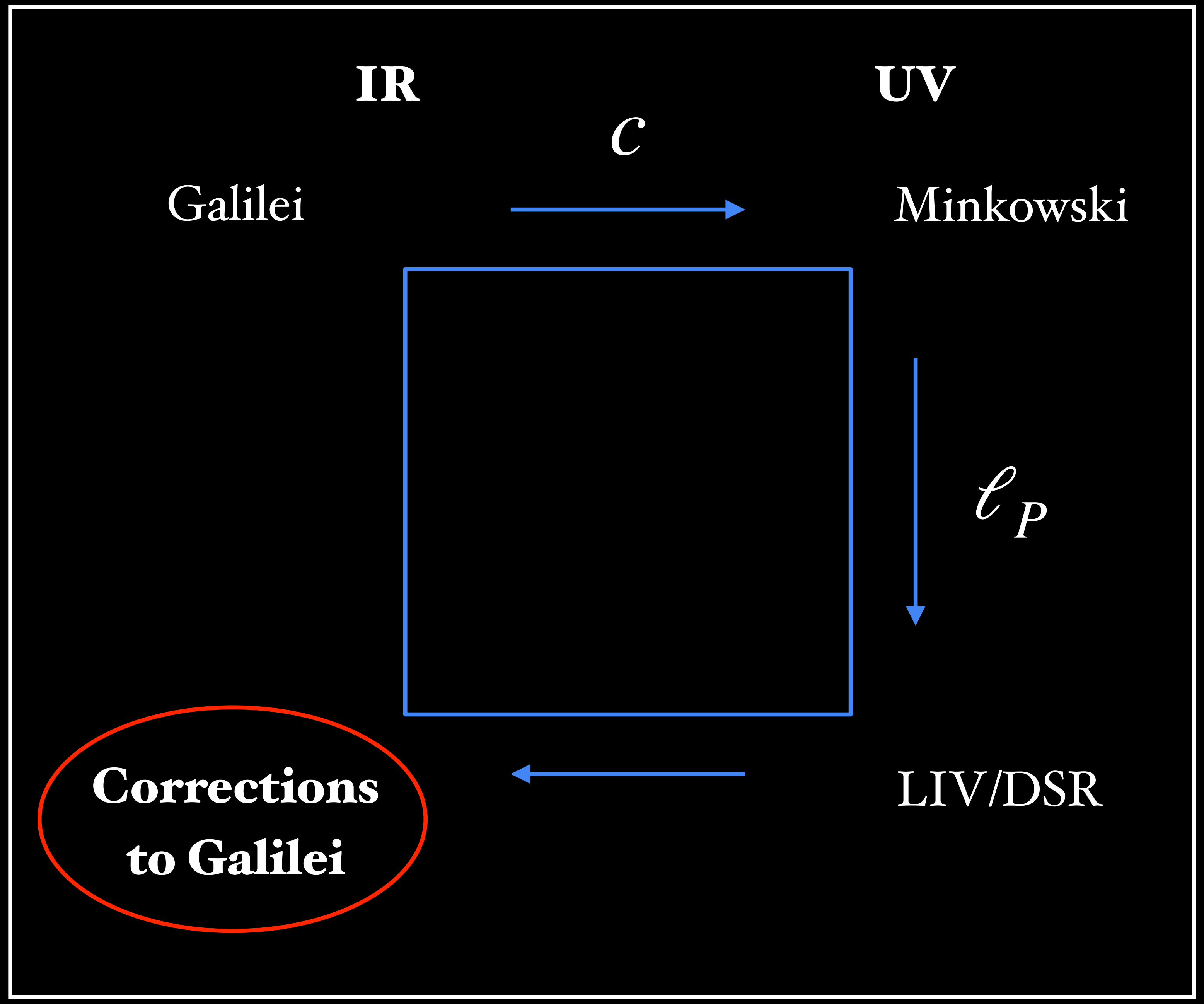

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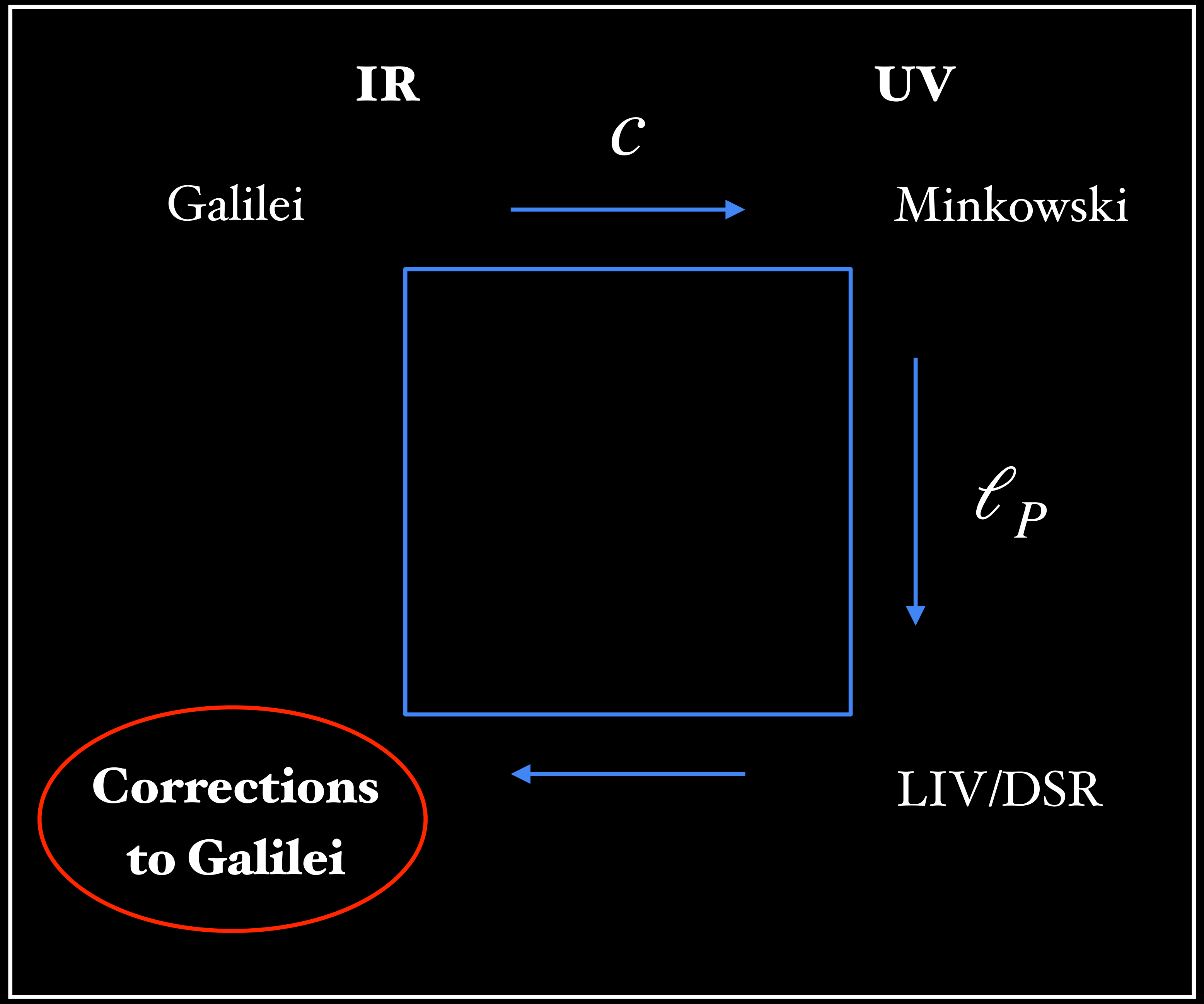

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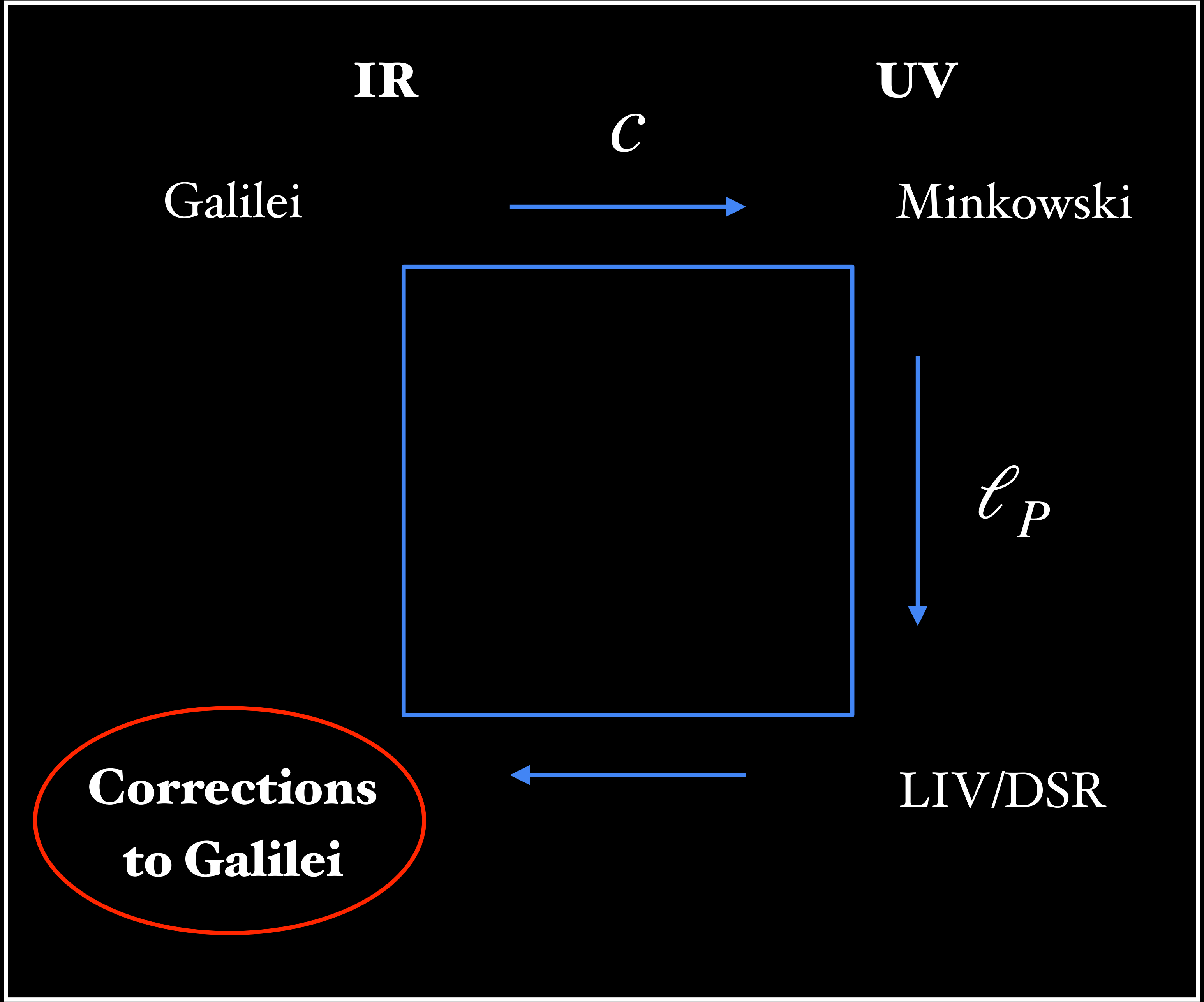

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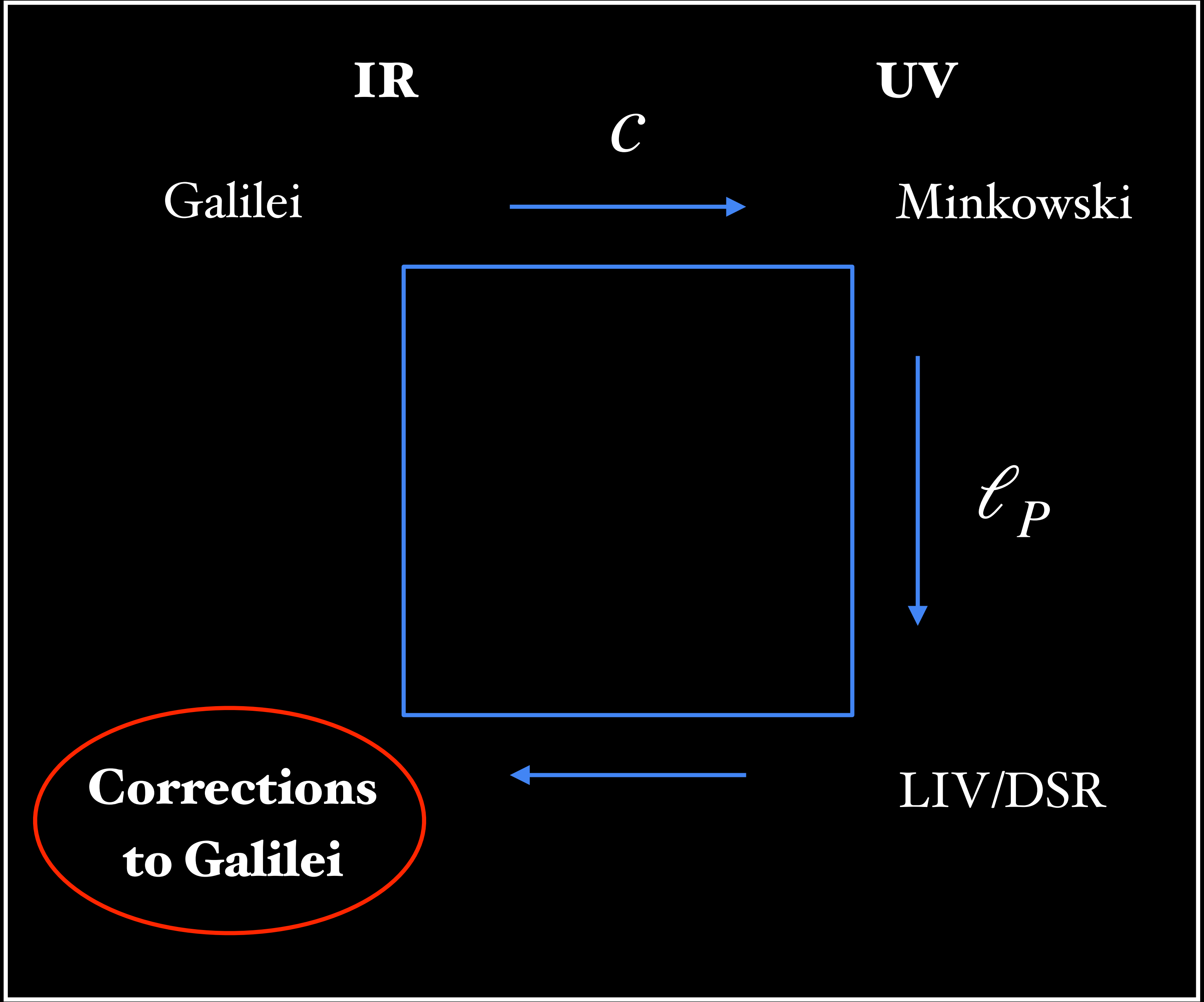

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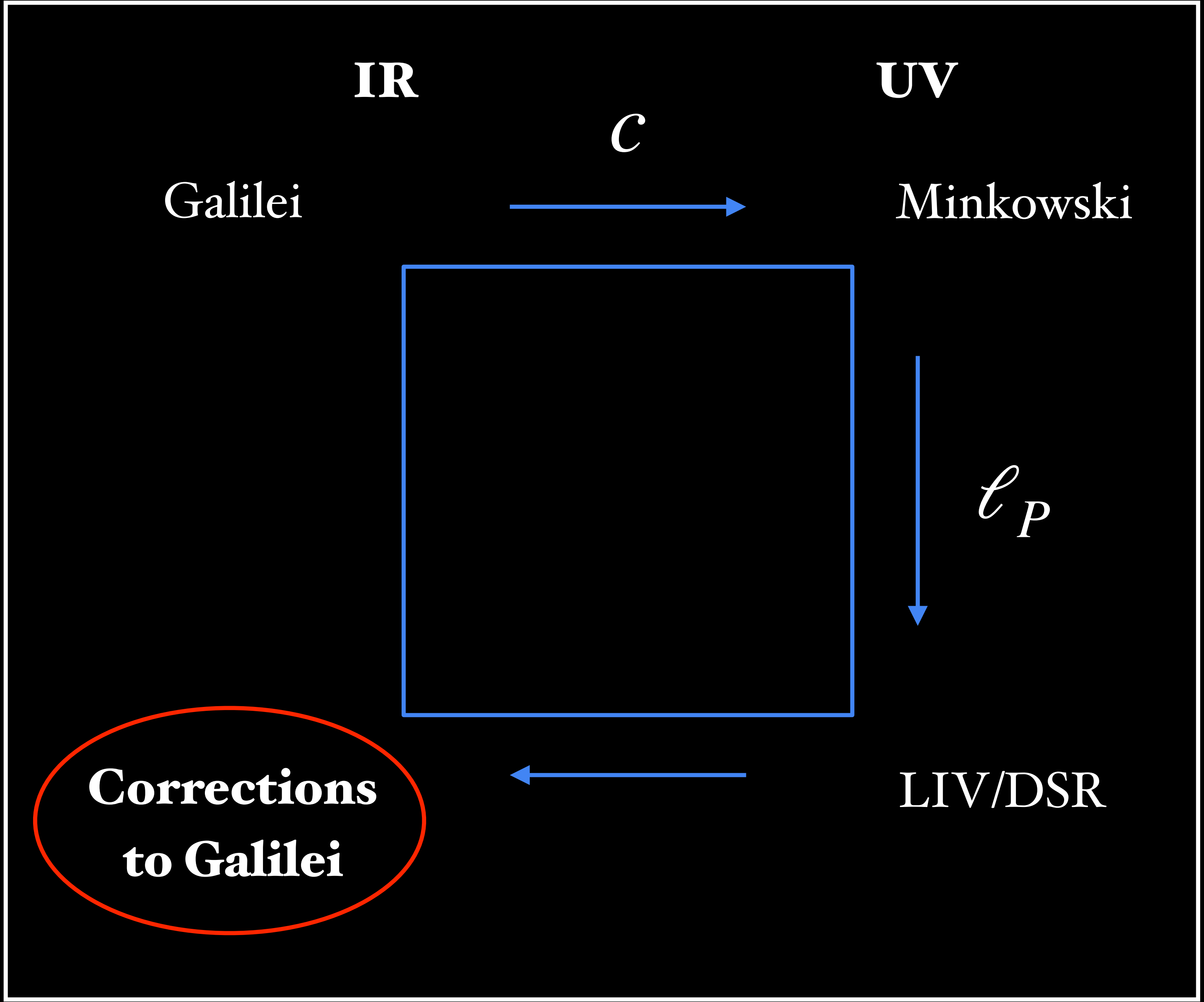

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We will focus here on deformations of the energy composition law

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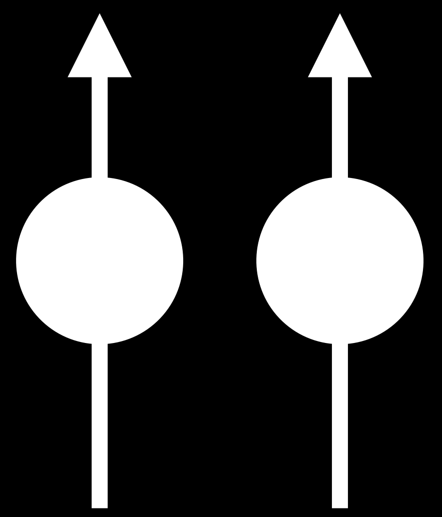

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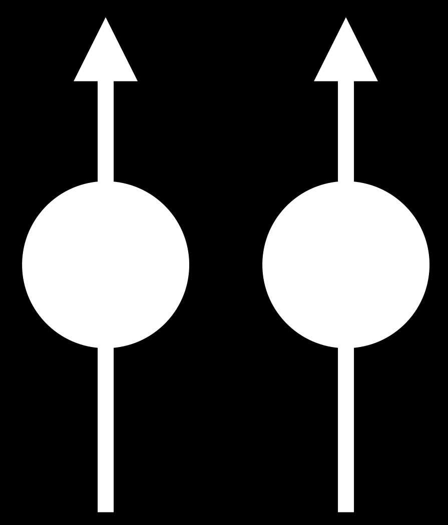

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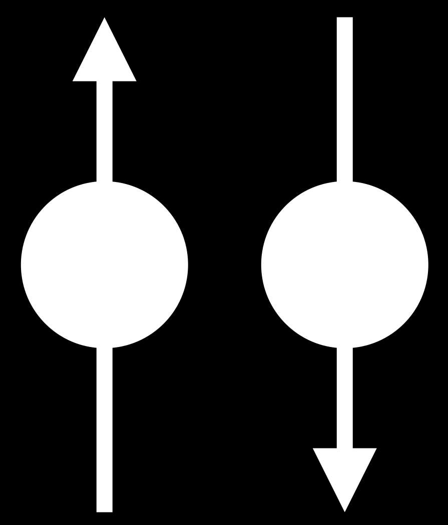

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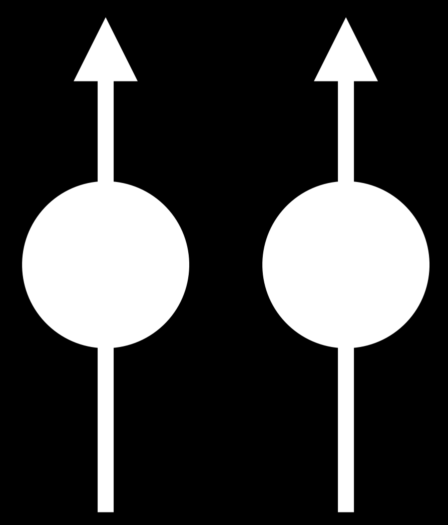

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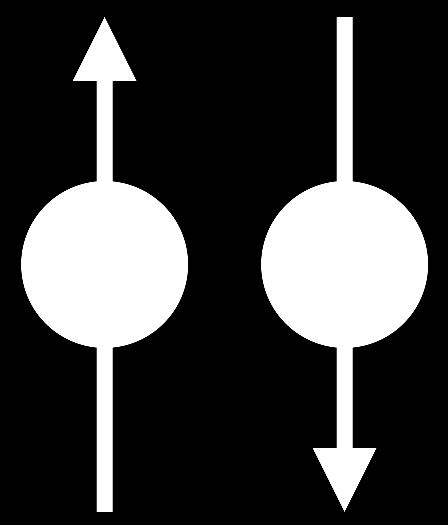

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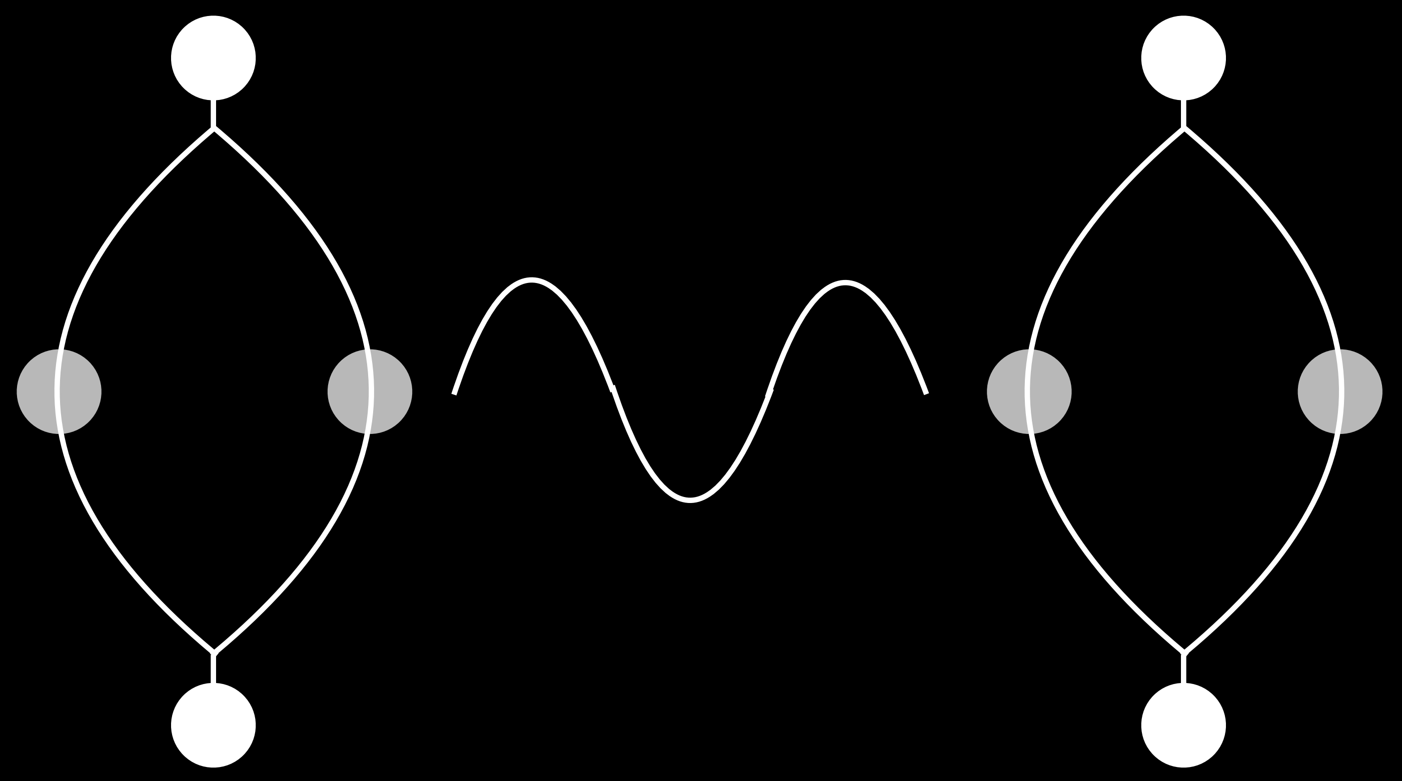
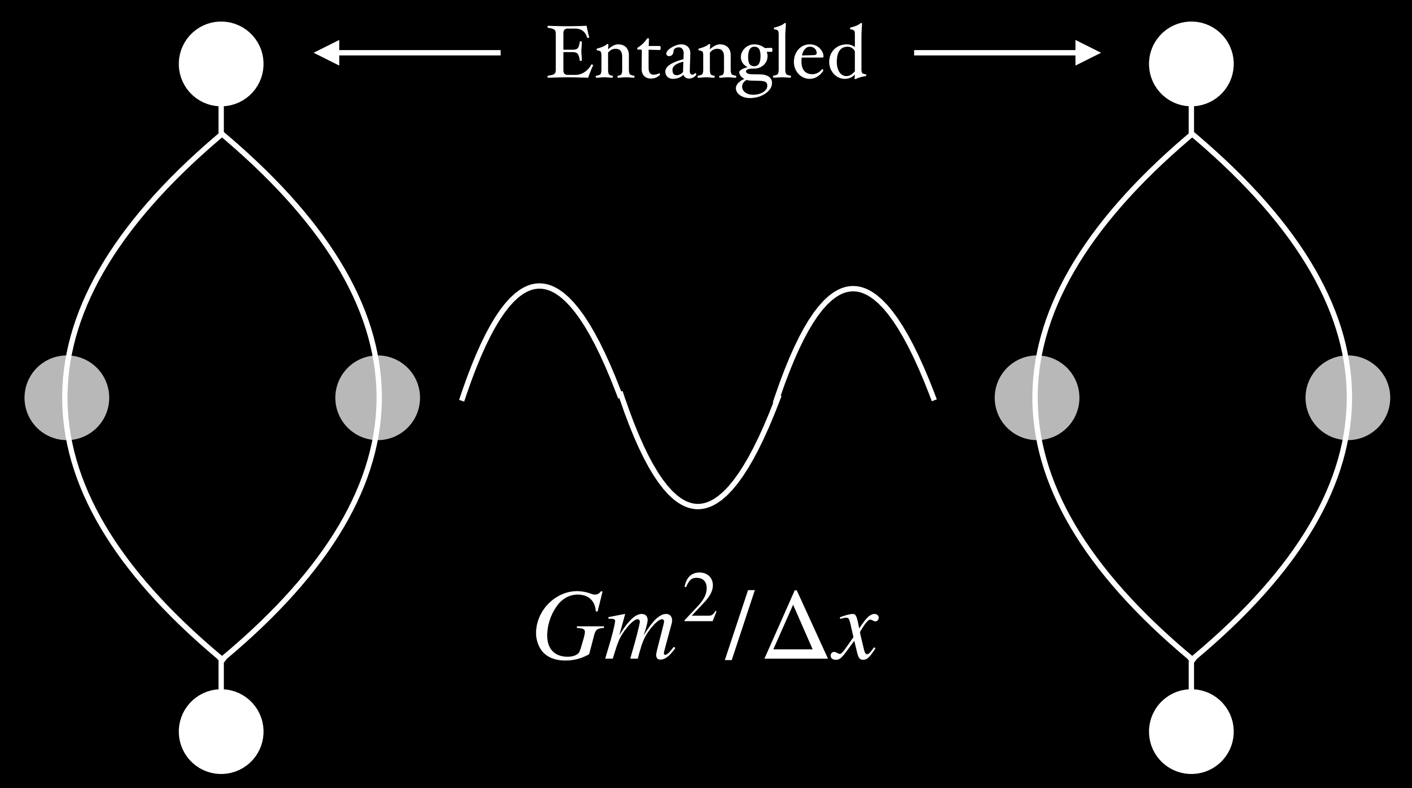
Analogy with Gravitationally-Induced Entanglement





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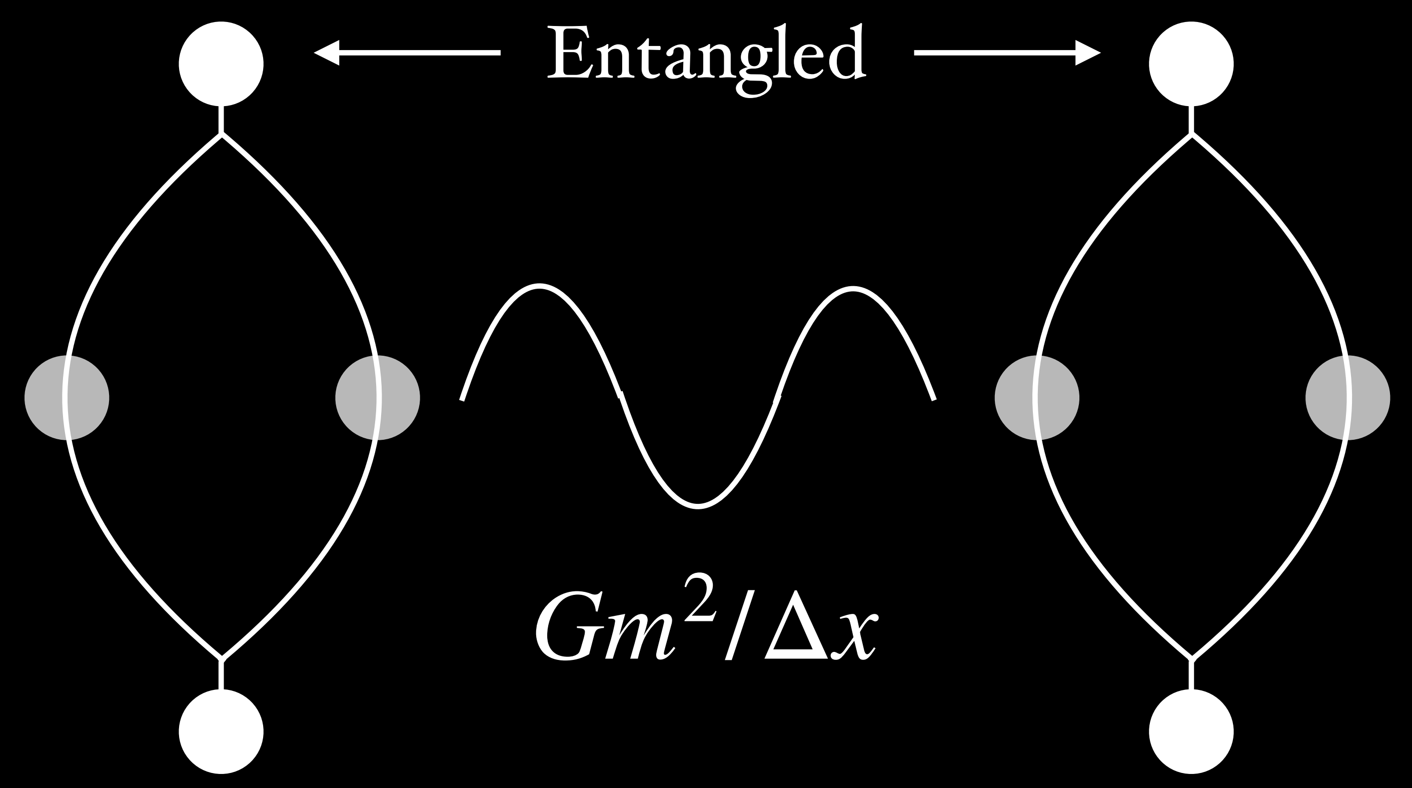

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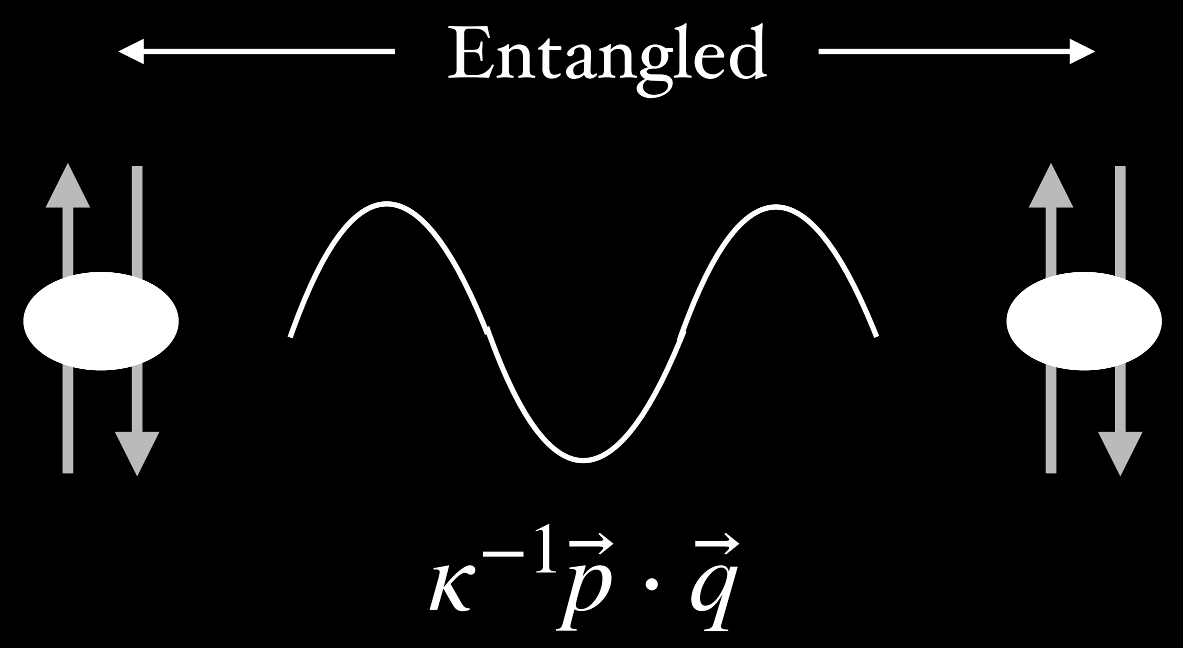
Does uncertainty in the direction of momenta reflect in entanglement due to a deformed composition law?



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Suppose that each particle is a two-level system, for example defined by a non-minimal coupling with an electromagnetic field

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For the **deformed** case we have also **two** directions in momenta.
Our system needs **four** indices for the energies and directions $|i, j, \alpha, \beta\rangle$, where $\{\alpha, \beta\} = \{+-\}$

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The operator that has $|\pm\rangle$ as eigenstates is the x-Pauli matrix σ_x

Hamiltonian of our model

$$\mathcal{H} = \epsilon(\mathbb{1})^4 + \frac{\omega}{2}\left(\sigma_z \otimes \mathbb{1} \otimes \mathbb{1} \otimes \mathbb{1} + \mathbb{1} \otimes \sigma_z \otimes \mathbb{1} \otimes \mathbb{1}\right) + \ell|P| \otimes |P| \otimes \sigma_x \otimes \sigma_x,$$

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Each block H_{ab} is a 4×4 matrix of the kind

$$H_{ab} = \begin{pmatrix} \epsilon + \frac{a+b}{2}\omega & 0 & 0 & \ell m\sqrt{(\epsilon + a\omega)(\epsilon + b\omega)} \\ 0 & \epsilon + \frac{a+b}{2}\omega & \ell m\sqrt{(\epsilon + a\omega)(\epsilon + b\omega)} & 0 \\ 0 & \ell m\sqrt{(\epsilon + a\omega)(\epsilon + b\omega)} & \epsilon + \frac{a+b}{2}\omega & 0 \\ \ell m\sqrt{(\epsilon + a\omega)(\epsilon + b\omega)} & 0 & 0 & \epsilon + \frac{a+b}{2}\omega \end{pmatrix}$$

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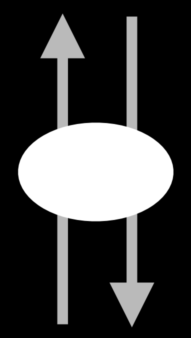

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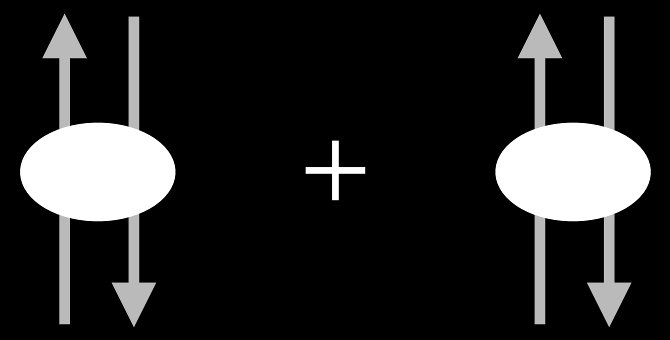

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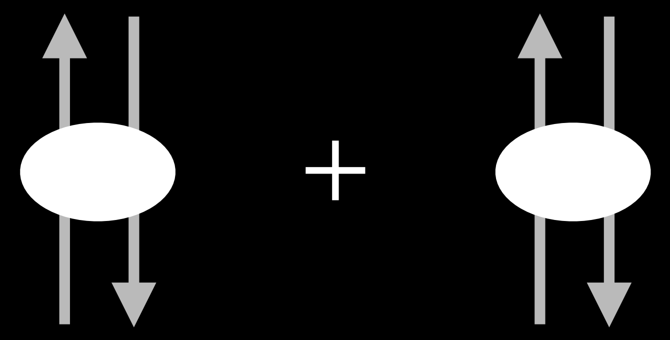

The Lindblad equation can be written as 4 blocks of X-shaped matrices

Lindblad equation for each of the 4 subsystems

$$\partial_t \rho_{ab} + i\,[H_{ab}, \rho_{ab}] + \frac{\ell}{2}\left(\mathcal{P}_{ab}^2 \rho_{ab} + \rho_{ab}\mathcal{P}_{ab}^2 - 2\mathcal{P}_{ab}\rho_{ab}\mathcal{P}_{ab}\right) = 0.$$

There is 25 % chance for each value of $\{a, b\}$ with elements

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We considered the initial state

$$|\Psi\rangle = \sin\theta|01\rangle + \cos\theta|10\rangle,$$

which when $\theta = 0$ is unentangled, and when $\theta = \frac{\pi}{4}$ is maximally entangled (Bell state).

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$$\mathcal{C} = 2\max\left\{|\bar{\rho}_{23}| - \sqrt{\bar{\rho}_{11}\bar{\rho}_{44}}, |\bar{\rho}_{14}| - \sqrt{\bar{\rho}_{22}\bar{\rho}_{33}}|, 0\right\},$$

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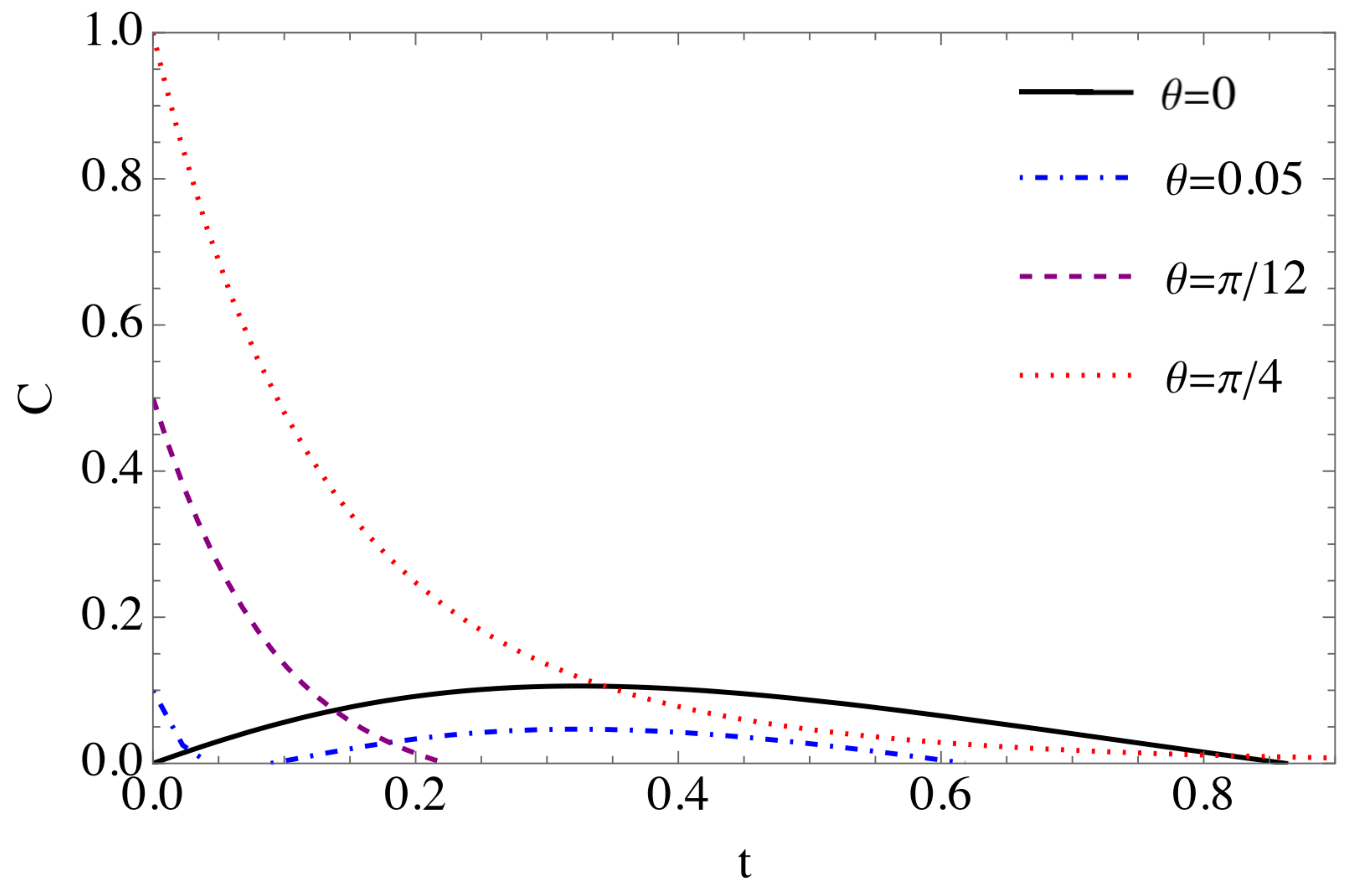

Figure 1: Concurrence for different initial conditions determined by θ. The parameters used are $\ell = 1$, $m = 1$, $\epsilon = 1$, and $\omega = 0.5$.

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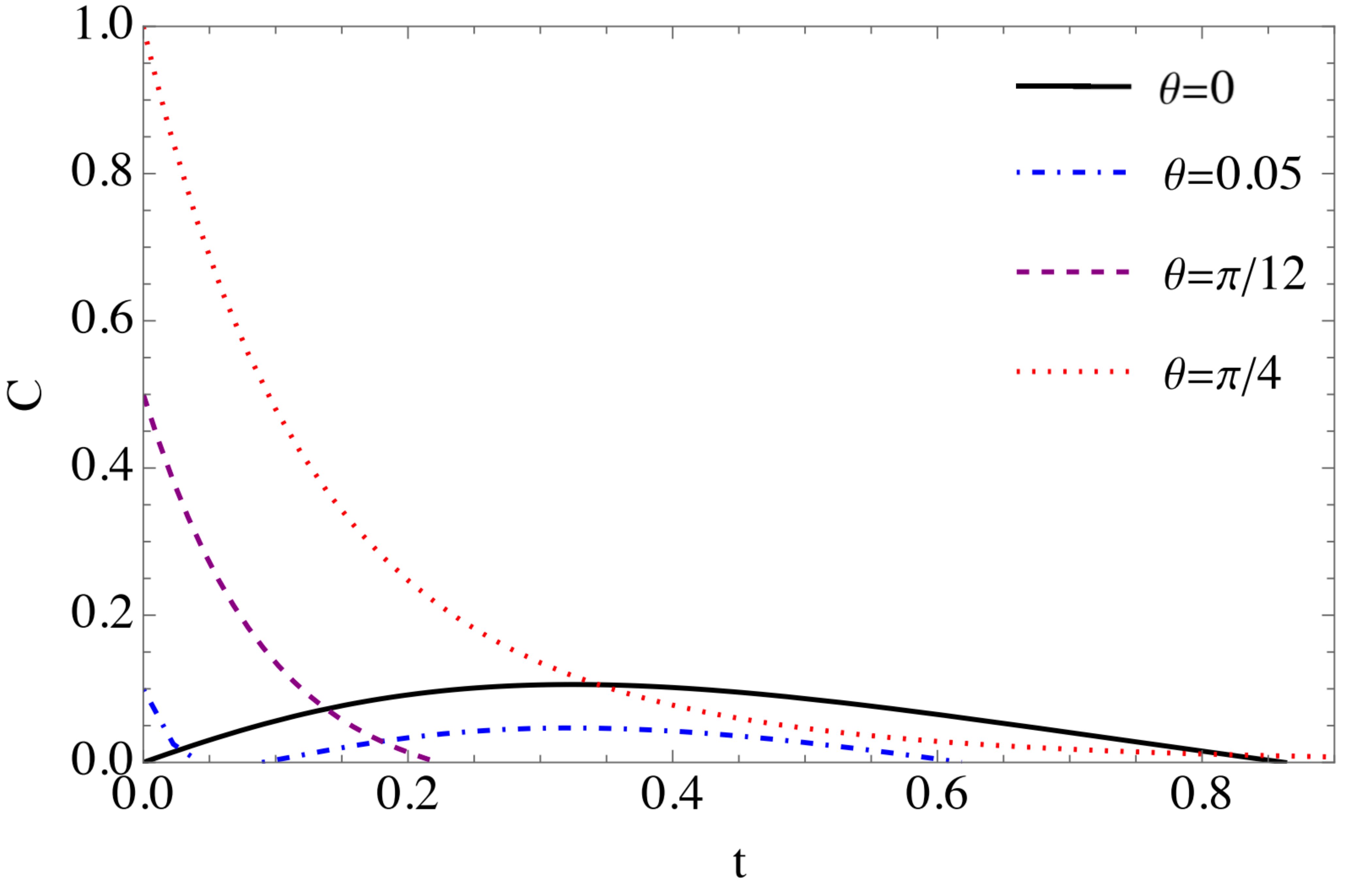

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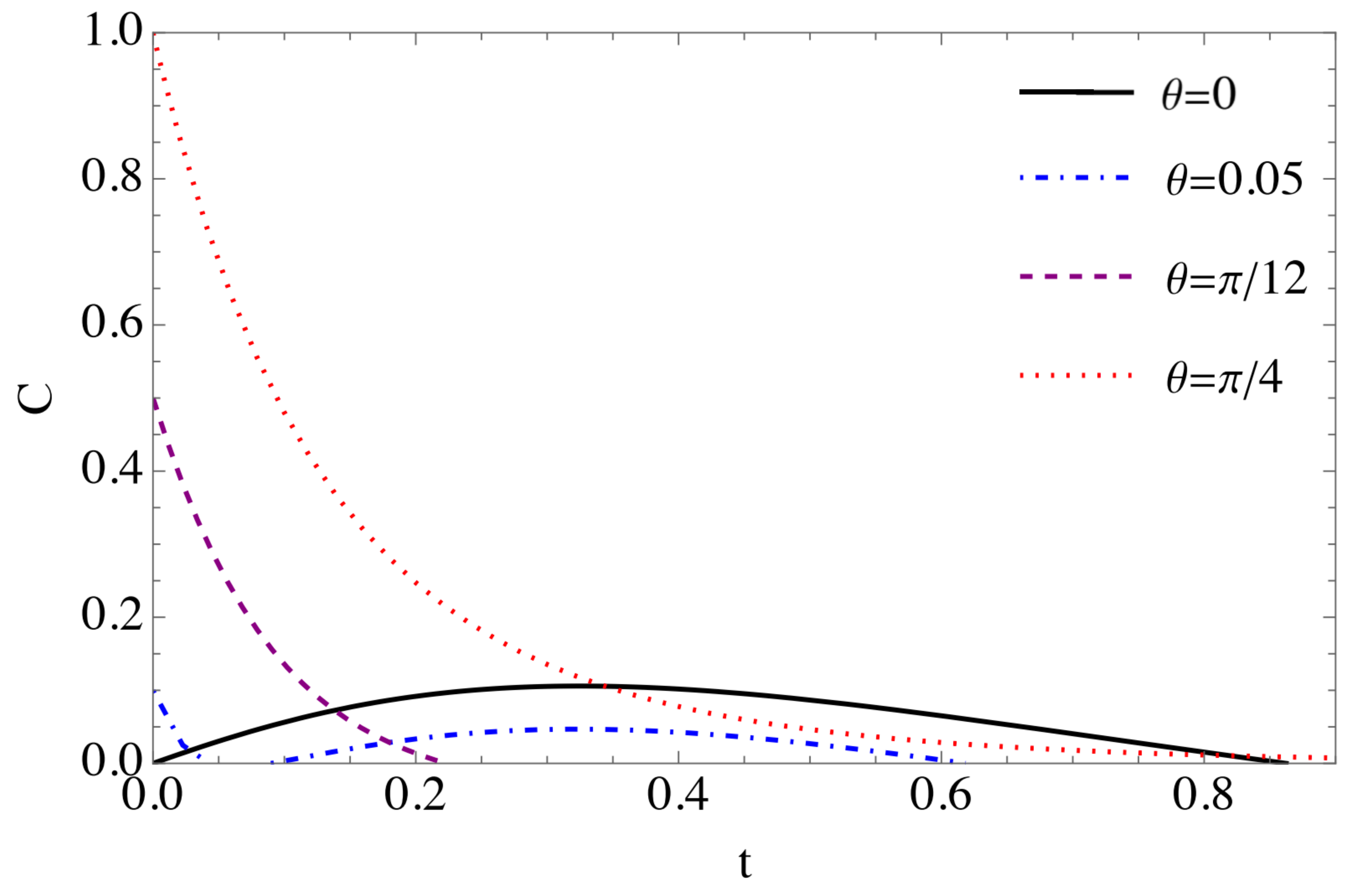

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The modified composition law creates entanglement while the Lindblad evolution destroys it.

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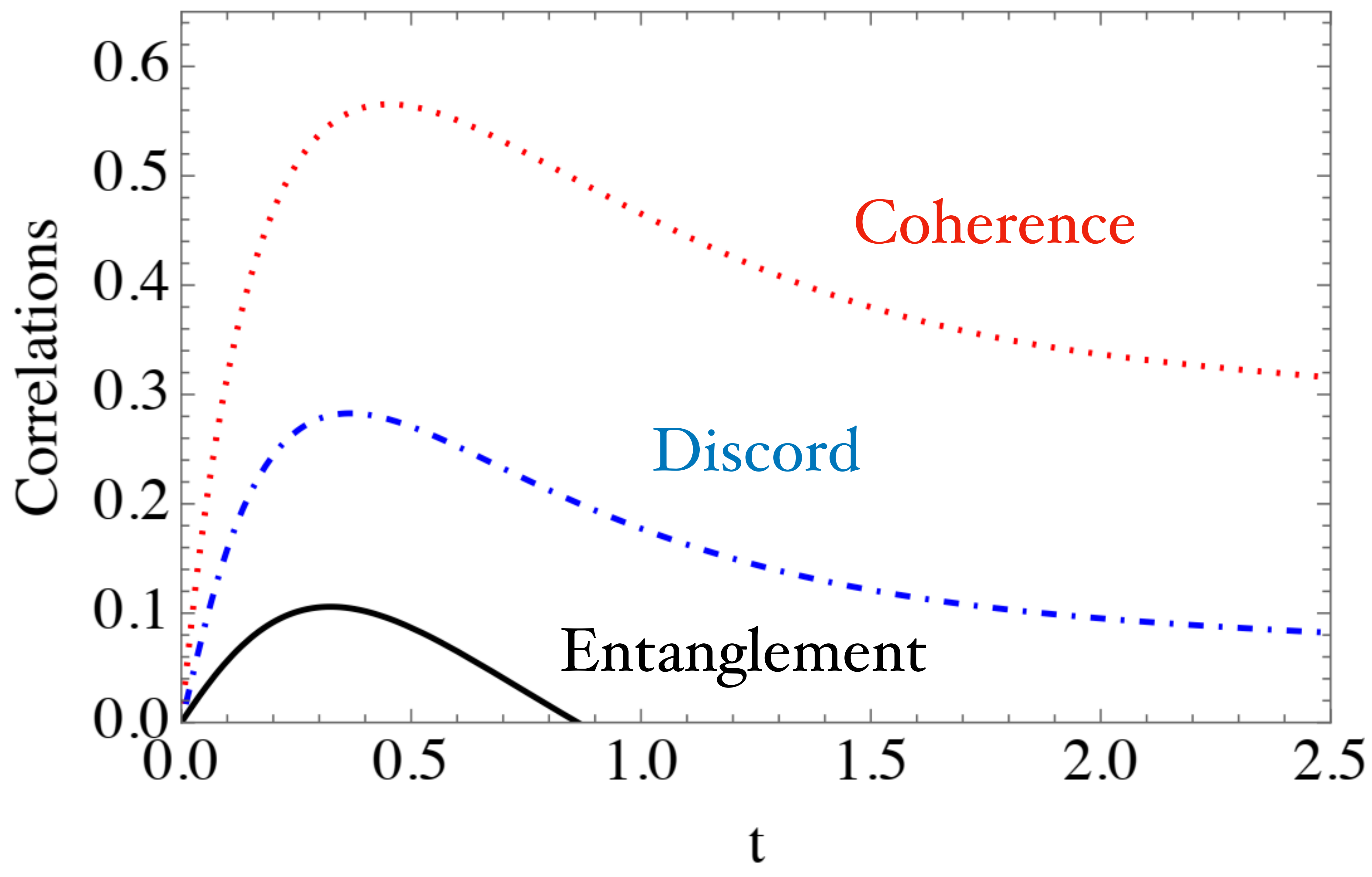

Figure 4: Comparison of the different quantifiers for coherence, discord and entanglement studied in the paper for $\theta = 0$. The red/dotted curve represents the l_1-norm of coherence. The blue/dash-dotted curve represents quantum discord. The black/solid curve represents concurrence.

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We have a **competition** between the action of the deformed Hamiltonian, and due to the Lindblad-like contact of the quantum system with the “quantum spacetime environment”

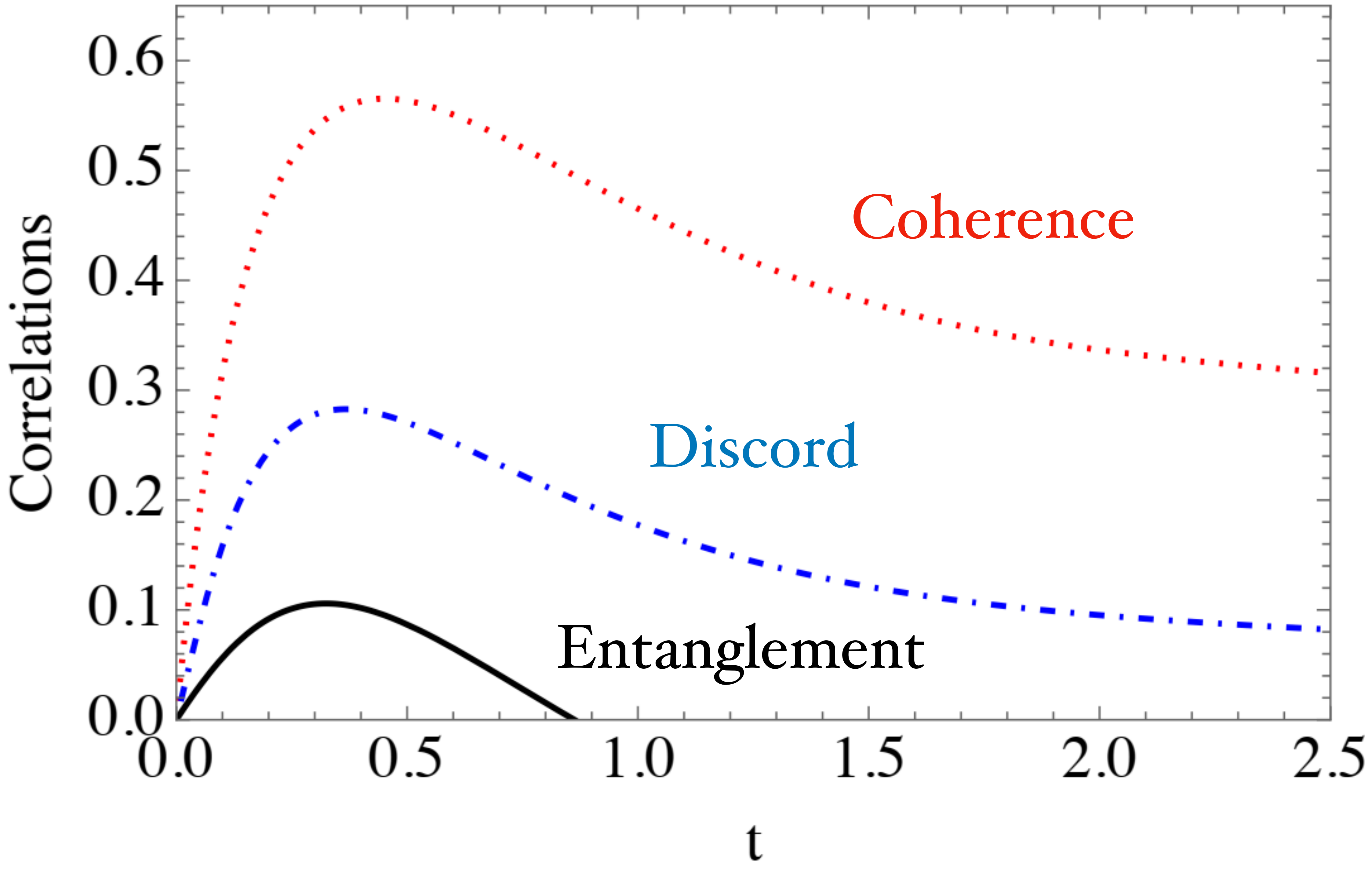

Figure 4: Comparison of the different quantifiers for coherence, discord and entanglement studied in the paper for $\theta = 0$. The red/dotted curve represents the l_1-norm of coherence. The blue/dash-dotted curve represents quantum discord. The black/solid curve represents concurrence.

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The entanglement time scale depends on the uncertainty in the potential (momentum in our case)
$T_{ent} = (\ell \Delta P^2)^{-1}$ [Yang, PRD (2018)] . In our case, $T_{ent} = \hbar E_{QG}/2mc^2E$ (similar to decoherence time scale)

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→ Are these smoking guns of Deformed Relativity?

Thank you!

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