

Alice and Rob Revisited:

How **quantum reference frames** can provide **new insights** into **entanglement degradation**

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Based on: [arXiv:2603.23601](https://arxiv.org/abs/2603.23601)



Motivation

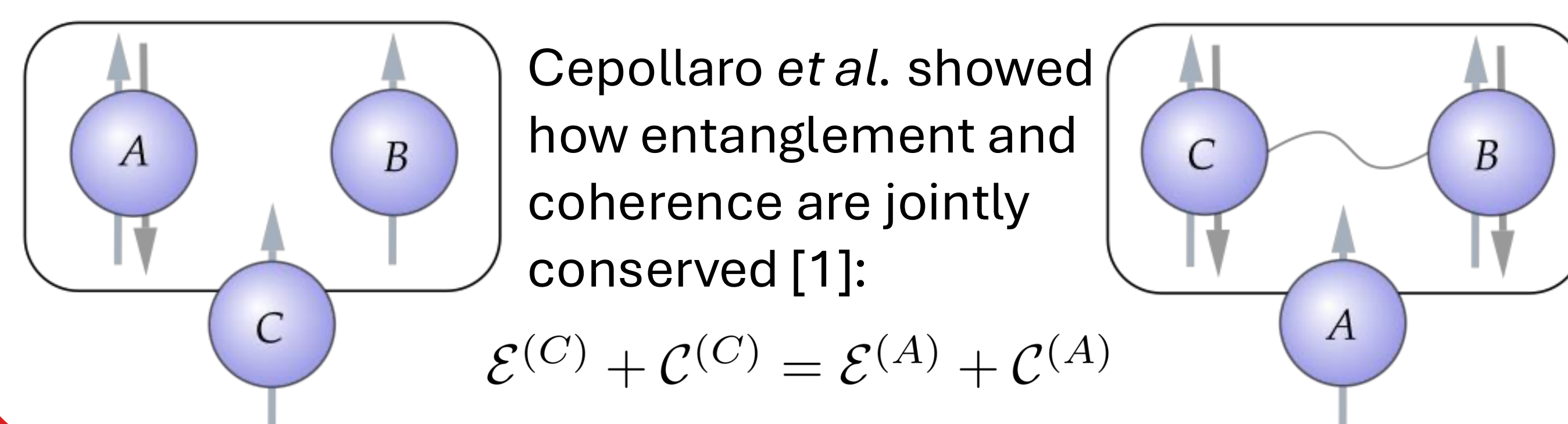
“How might we reconcile Quantum Theory with Gravity?”

- Old top-down approaches (e.g., Strings, Loops) appear stalled. But new bottom-up approaches offer hope:
- **Relativistic Quantum Information (RQI)**
 - Use quantum information tools and language to describe physics at the interface between quantum and relativity.
- **Quantum Reference Frames (QRFs)**
 - Attempts to relativize quantum theory, rather than quantize gravity directly.

Quantum Reference Frames

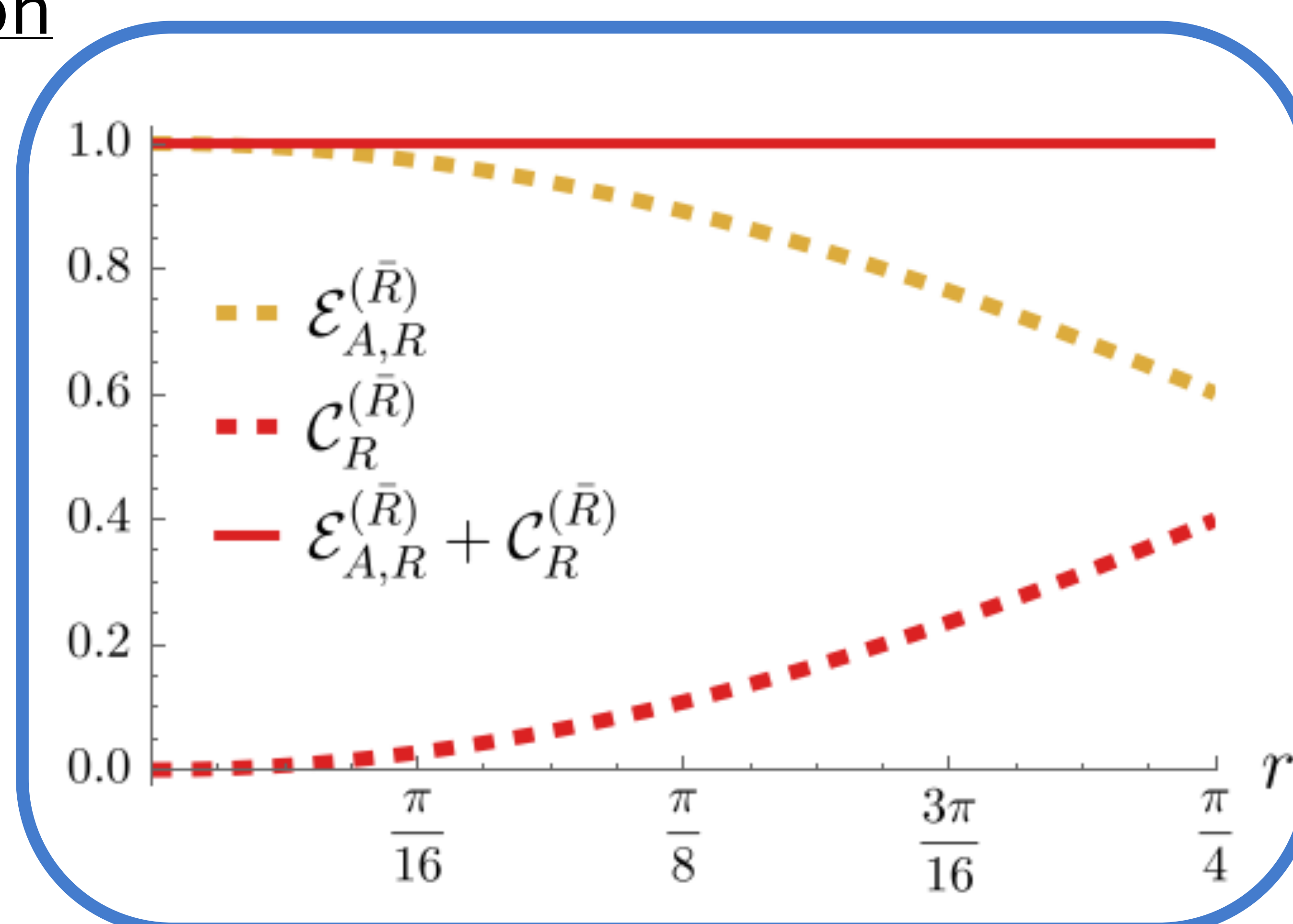
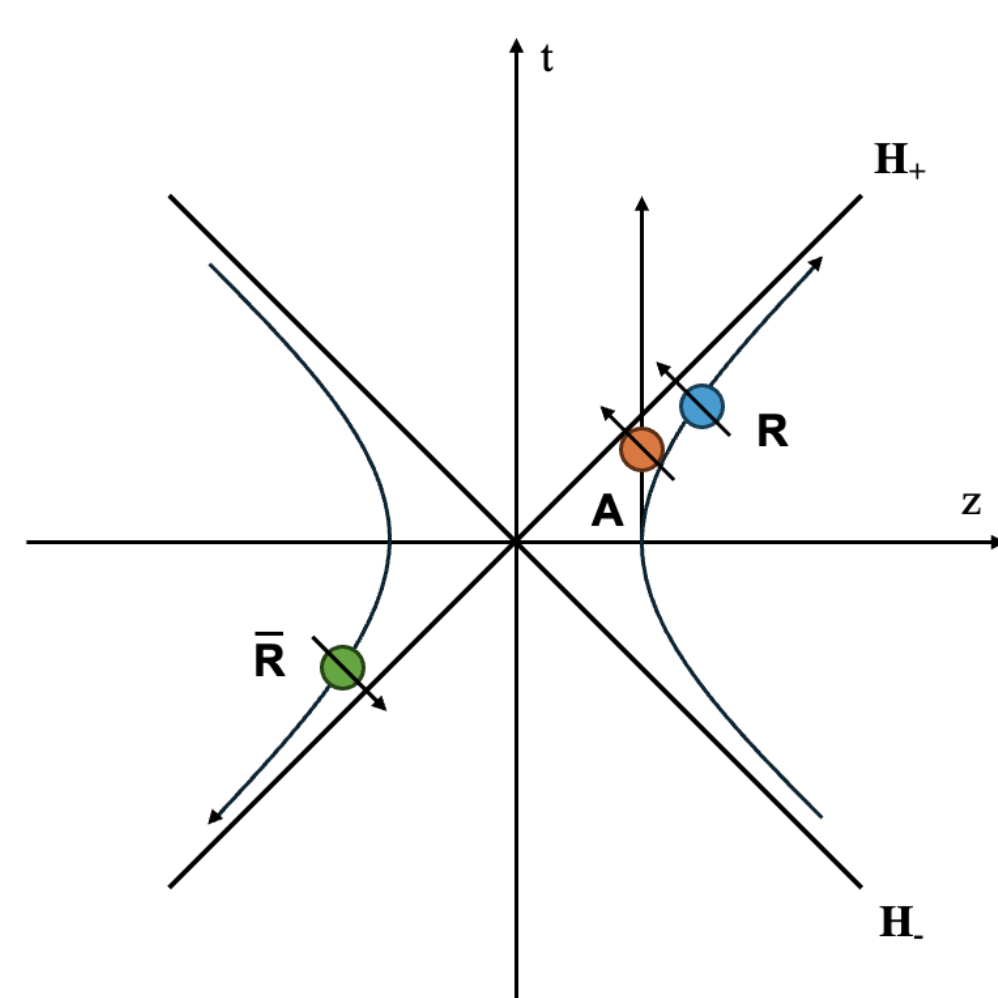
“How would a quantum observer perceive the Universe?”

- Perspectival approach to quantum reference frames describes states $|\psi\rangle$ relative to subsystem A as $|\psi\rangle^{(A)}$.
- What properties are invariant under QRF transformations?



Acceleration induced Entanglement Degradation

- One of the first results of RQI [2].
- Alice and Rob share a Bell state encoded in Minkowski field modes $|\phi\rangle \sim |00\rangle + |11\rangle$
- Rob undergoes uniform acceleration parametrized by r
- State in accelerated frame is $|\phi_r\rangle \sim \cos r|000\rangle + \sin r|011\rangle + |110\rangle$



Details

- Spin-1/2 Dirac field.
- Von Neumann entropy $\mathcal{S}(\rho) = -\text{Tr}(\rho \log \rho)$
- Entropy of Entanglement $\mathcal{E}(\rho_{AB}) = \mathcal{S}(\rho_A)$
- Relative Entropy of Coherence $\mathcal{C}(\rho_A) = \mathcal{S}(\rho_A) - \mathcal{S}(\rho_{A,d})$
- Rob's Minkowski modes are related to Rob and Anti-Rob's Rindler modes by Bogoliubov transformation.
- Novel 'perspective assignment' procedure introduced to relate 'global' states to perspectival ones [3].

Beyond this poster

- **Relativistic/Relational Quantum Resource Theory?**
- What might other quantum resources tell us about quantum gravity?
- How do perspectival resources relate to the standard 'global' quantities found in quantum information?
 - Entanglement Transference [3] offers a partial answer*: $\mathcal{E}_{B,C}^{(A)} + \mathcal{C}_B^{(A)} = \mathcal{E}_{AB,C}$
- QRFs are being applied beyond quantum foundation/gravity, including in Quantum Error Correction.

References

- [1] C. Cepollaro, *et al.*, PRL 135, 010201 (2025) [arXiv:2406.19448](https://arxiv.org/abs/2406.19448)
- [2] P. M. Alsing, *et al.*, PRA 74, 032326 (2006) 10.1103/phys-reva.74.032326
- [3] **E. A. Patterson**, Sijia Wang, and Robert B. Mann, [arXiv:2603.23601](https://arxiv.org/abs/2603.23601) (2026)

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