Quantum Information and Relativity

Sudden Death, Teleportation and the Unruh Effect

André Landulfo
Instituto de Física Teórica, UNESP

- There is a rich interplay between Relativity and Quantum information

- There is a rich interplay between Relativity and Quantum information
- A subject of intense research, with applications from cryptography to black hole information paradox

- There is a rich interplay between Relativity and Quantum information
- A subject of intense research, with applications from cryptography to black hole information paradox
- It may shed some light in the Black hole information Paradox and other issues in curved spacetimes

- There is a rich interplay between Relativity and Quantum information
- A subject of intense research, with applications from cryptography to black hole information paradox
- It may shed some light in the Black hole information Paradox and other issues in curved spacetimes
- But there is very interesting physics already in Minkowski spacetime

- Spin Entropy is not invariant under Lorentz transformations [Peres et. al, PRL 88, 230402 (2002)]

- Spin Entropy is not invariant under Lorentz transformations [Peres et. al, PRL 88, 230402 (2002)]
- Spin Entanglement not invariant under boosts [Gingrich & Adami PRL 89, 270402 (2002)]

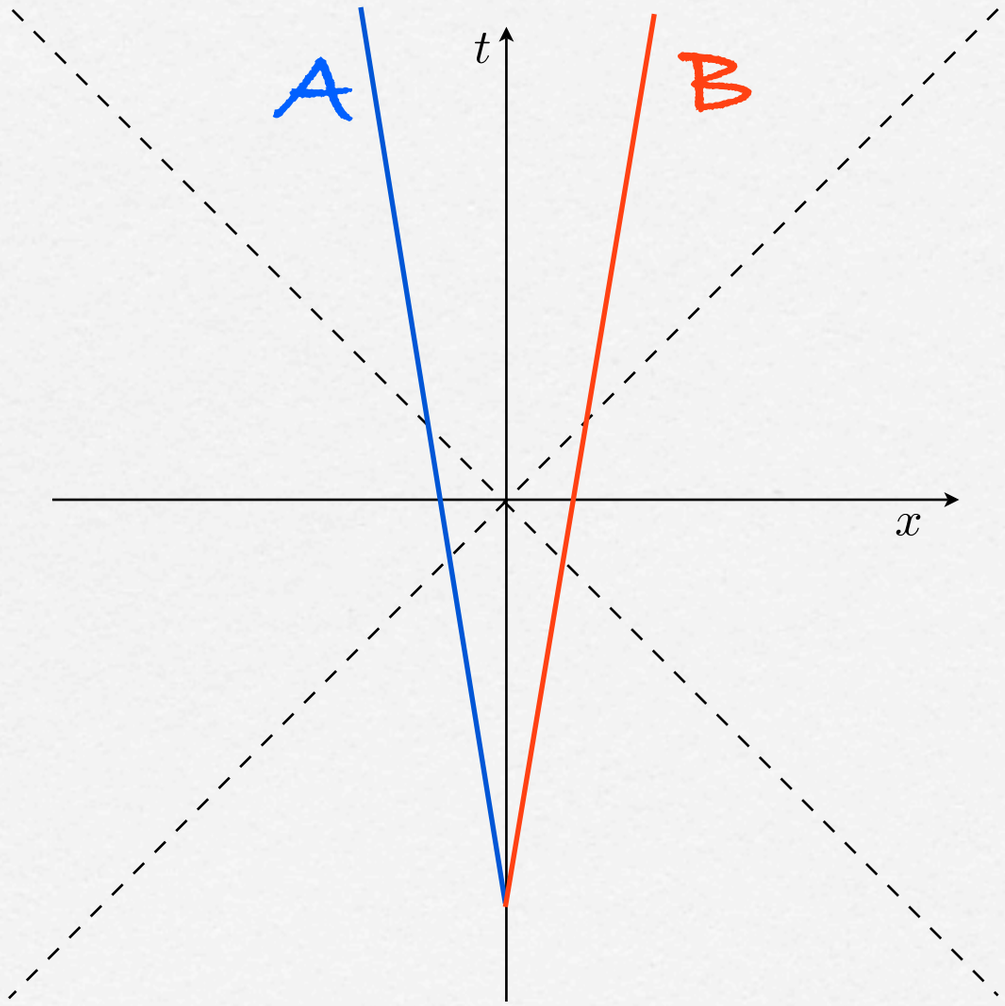
- Spin Entropy is not invariant under Lorentz transformations [Peres et. al, PRL 88, 230402 (2002)]
- Spin Entanglement not invariant under boosts [Gingrich & Adami PRL 89, 270402 (2002)]
- EPR correlations decreases for moving detector and Bell inequality may not be violated [Landulfo & Matsas PRA 79, 044103 (2009)]

Work in Progress

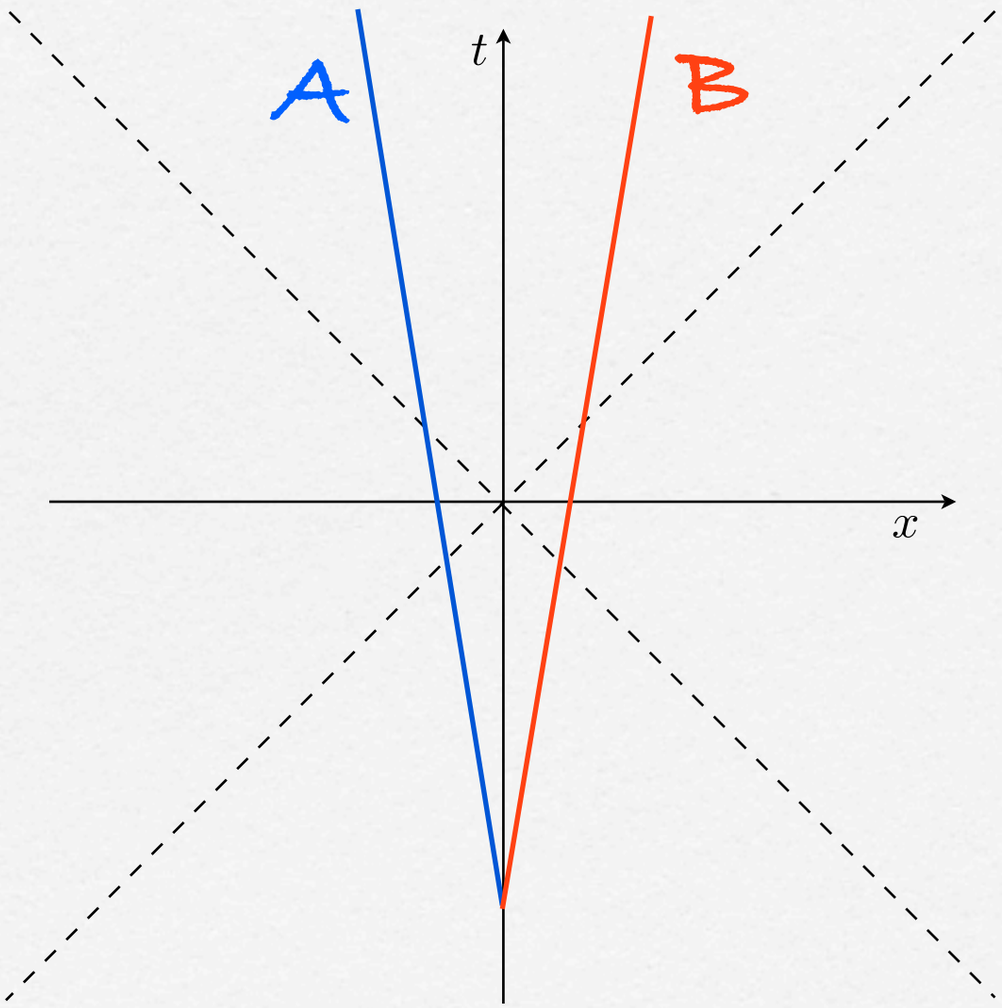
Work in Progress

- More careful analysis on the influence of the Unruh effect in entanglement and Teleportation

Inertial Qubits-Singlet State

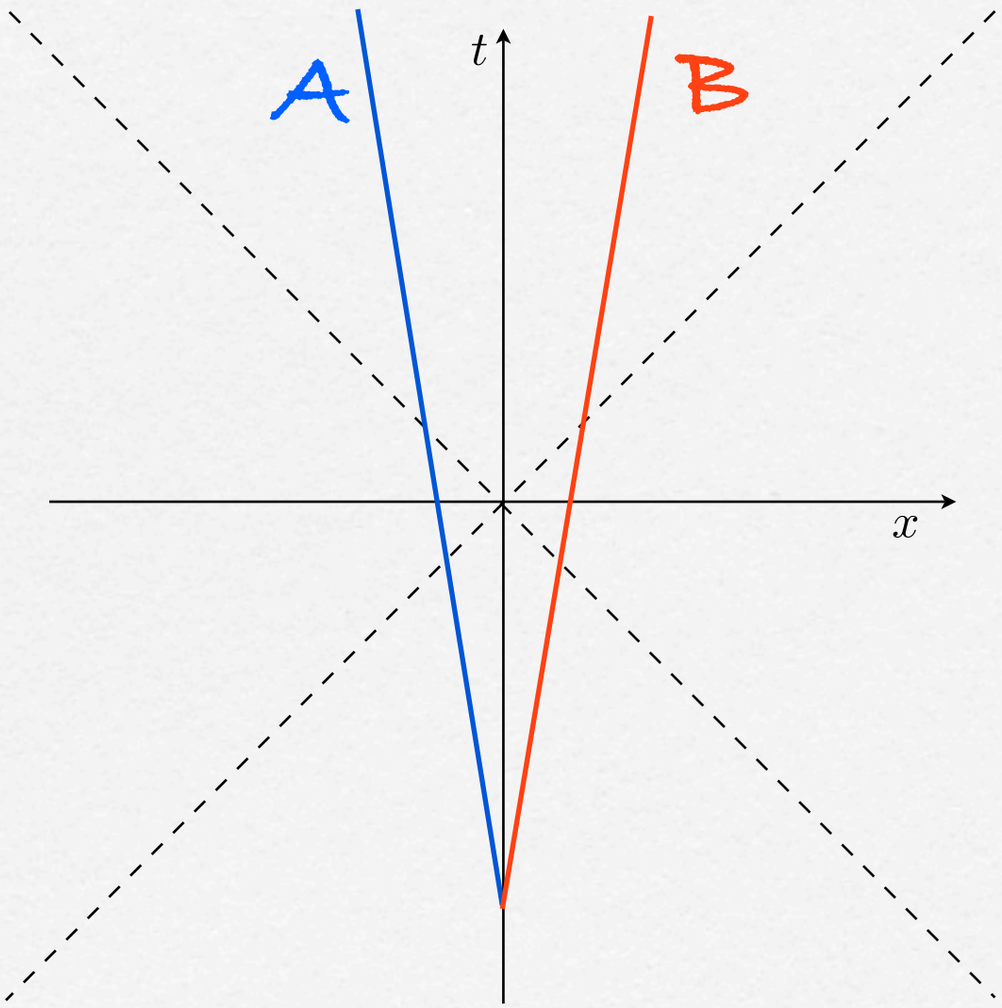


Inertial Qubits-Singlet State

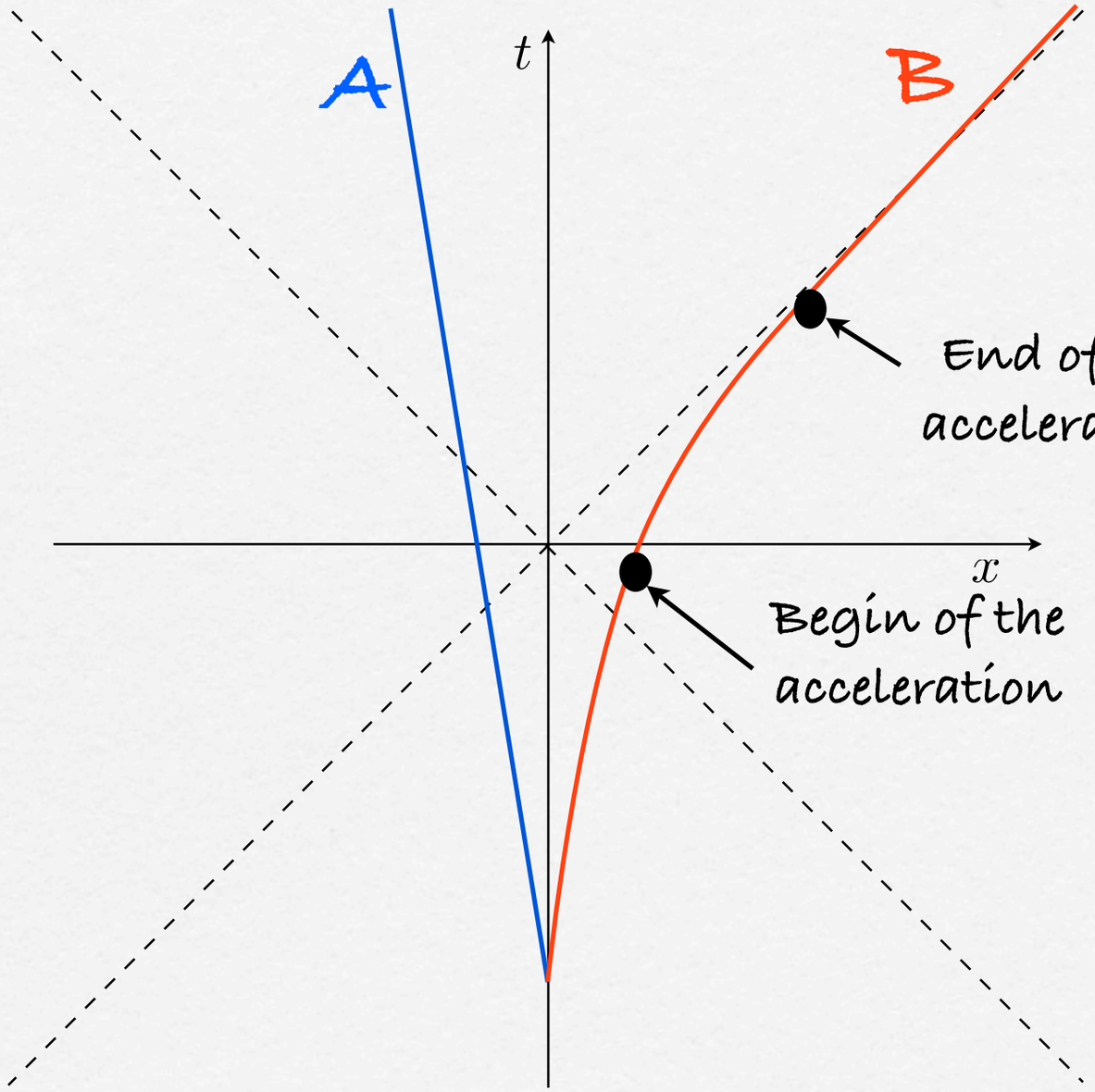


- example: Pair of free electrons entangled in spin

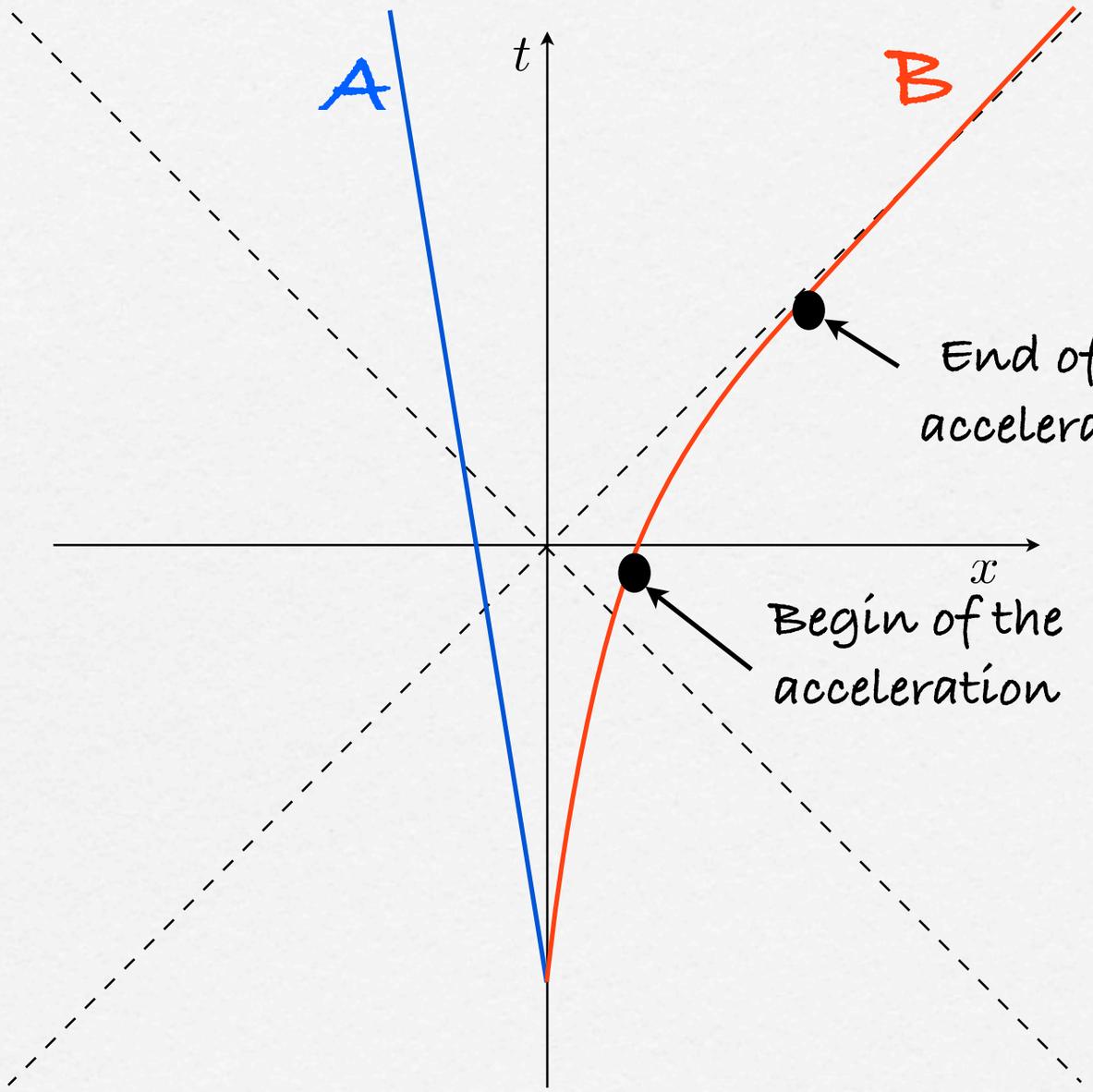
Inertial Qubits-Singlet State



- example: Pair of free electrons entangled in spin
- Nothing happens to the state: Concurrence, purity, mutual information don't change



- Qubit B accelerates for a proper time Δ



- Qubit B accelerates for a proper time Δ
- During the acceleration the qubit interacts with the Unruh Thermal Bath

- Real massless scalar field

- Real massless scalar field $\nabla^a \nabla_a \phi = 0$

- Real massless scalar field $\nabla^a \nabla_a \phi = 0$
- Field is in the Minkowski vacuum state $|0_M\rangle$

- Real massless scalar field $\nabla^a \nabla_a \phi = 0$
- Field is in the Minkowski vacuum state $|0_M\rangle$
- For uniformly accelareted observers in the right Rindler wedge the Minkowski vacuum is a Thermal state with temperature $T = \frac{a}{2\pi}$

- Real massless scalar field $\nabla^a \nabla_a \phi = 0$
- Field is in the Minkowski vacuum state $|0_M\rangle$
- For uniformly accelareted observers in the right Rindler wedge the Minkowski vacuum is a Thermal state with temperature $T = \frac{a}{2\pi}$

$$\rho = \prod_i (C_i^2 \sum_{n_i} e^{\frac{-2\pi n_i \omega_i}{a}} |n_{iR}\rangle\langle n_{iR}|)$$

- The interaction Hamiltonian between the qubit and the field is

- The interaction Hamiltonian between the qubit and the field is

$$H_{int}(\tau) = \epsilon(\tau) \int_{\Sigma} \phi(x)[\psi(x)B + \overline{\psi}(x)B^{\dagger}]\sqrt{-g}d^3x$$

- The interaction Hamiltonian between the qubit and the field is

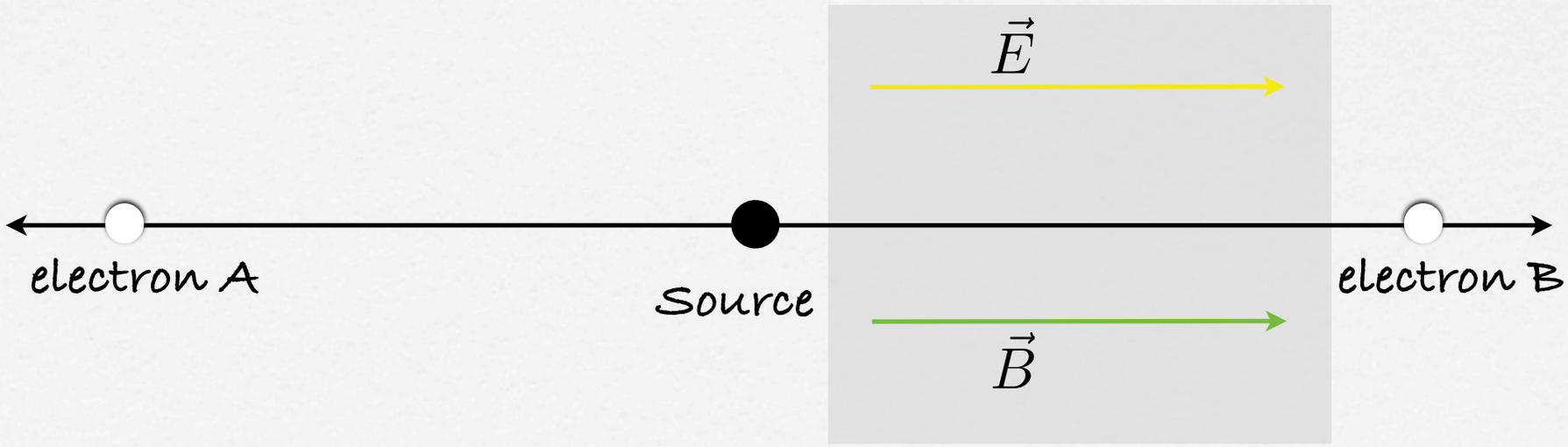
$$H_{int}(\tau) = \epsilon(\tau) \int_{\Sigma} \phi(x)[\psi(x)B + \overline{\psi}(x)B^{\dagger}]\sqrt{-g}d^3x$$

- Pair of electrons entangled in spin (singlet state) and one of them passes through a region with an electric and magnetic field

- The interaction Hamiltonian between the qubit and the field is

$$H_{int}(\tau) = \epsilon(\tau) \int_{\Sigma} \phi(x)[\psi(x)B + \overline{\psi}(x)B^{\dagger}]\sqrt{-g}d^3x$$

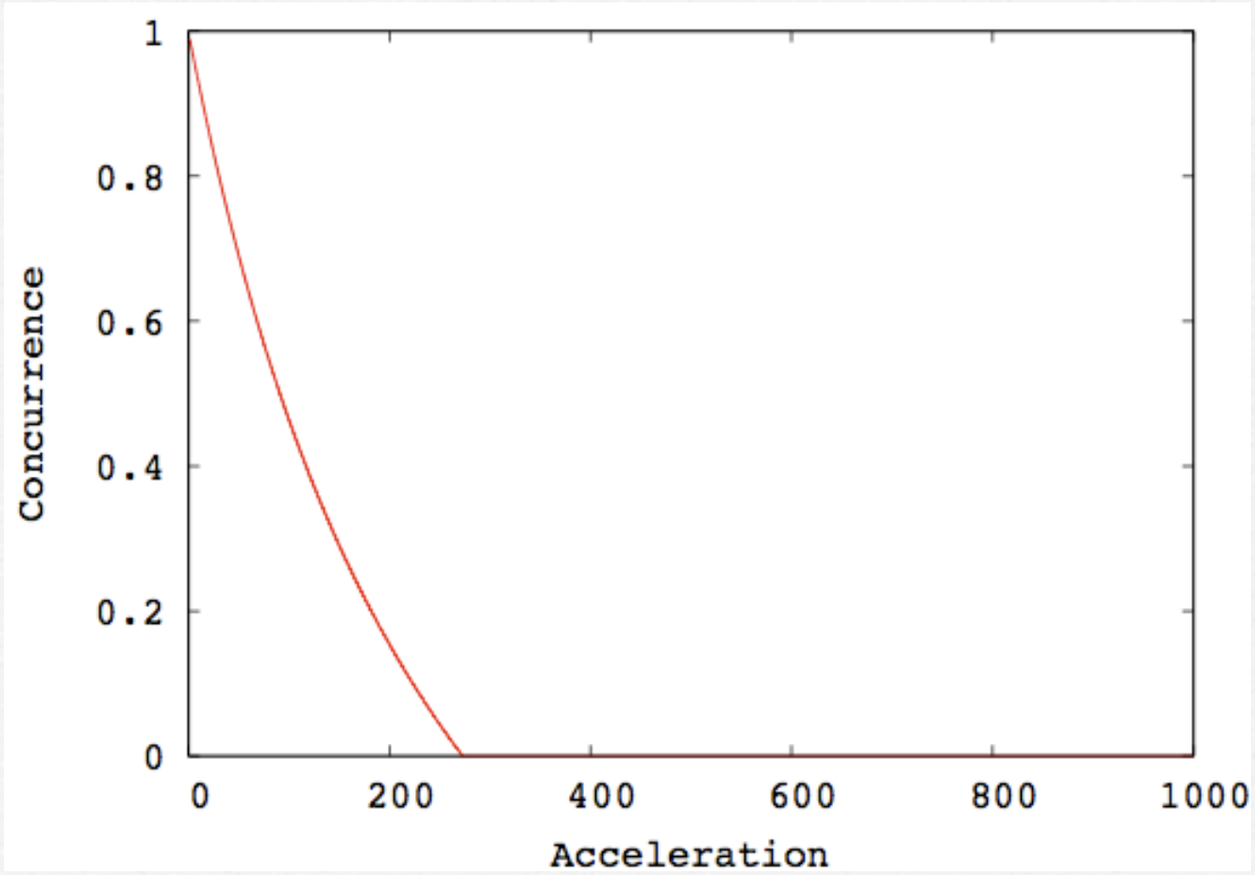
- Pair of electrons entangled in spin (singlet state) and one of them passes through a region with an electric and magnetic field



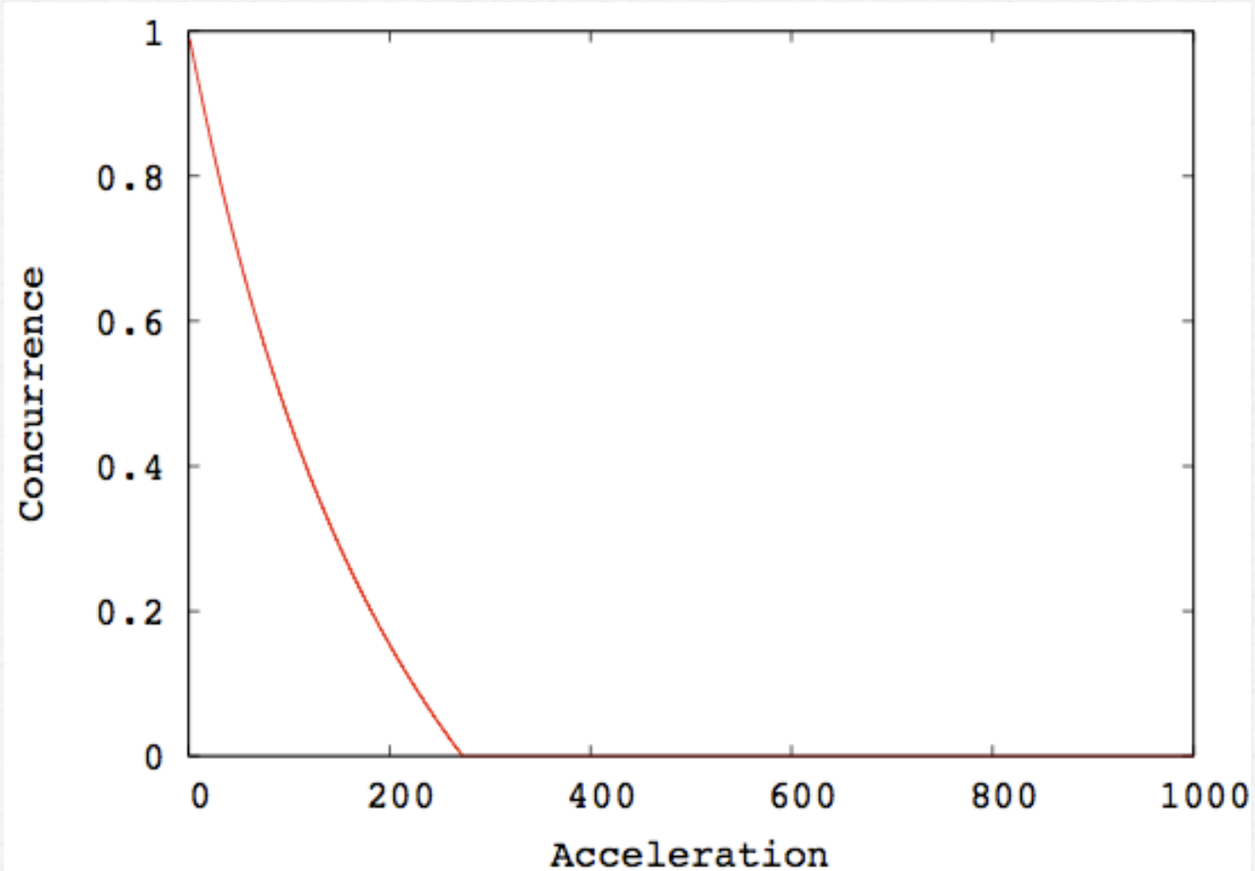
- After the acceleration, the system ends up with less mutual information, purity and entanglement (their values decreases as the acceleration increase)

- After the acceleration, the system ends up with less mutual information, purity and entanglement (their values decreases as the acceleration increase)

- After the acceleration, the system ends up with less mutual information, purity and entanglement (their values decreases as the acceleration increase)

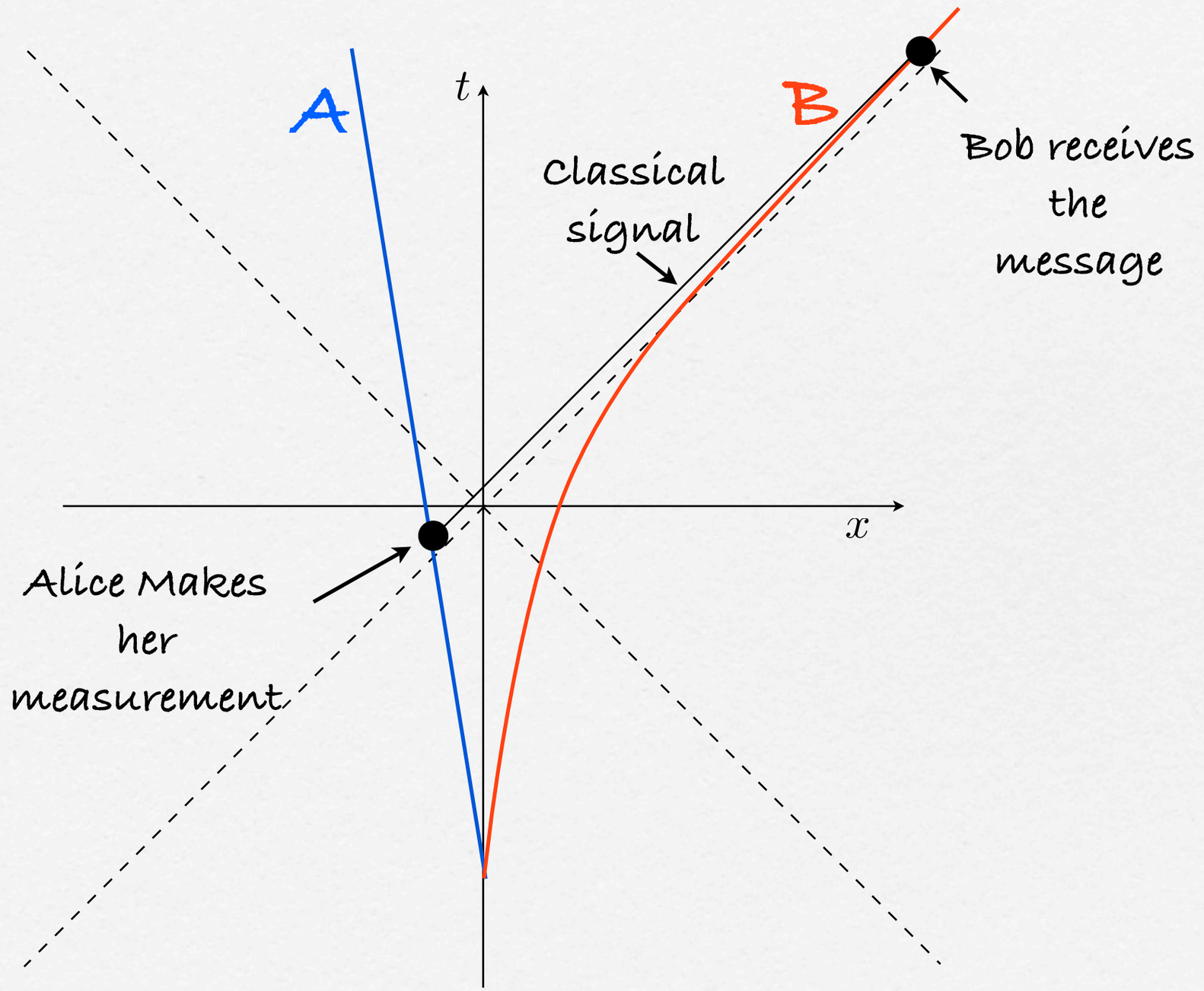


- After the acceleration, the system ends up with less mutual information, purity and entanglement (their values decreases as the acceleration increase)



- sudden death of entanglement

Teleportation



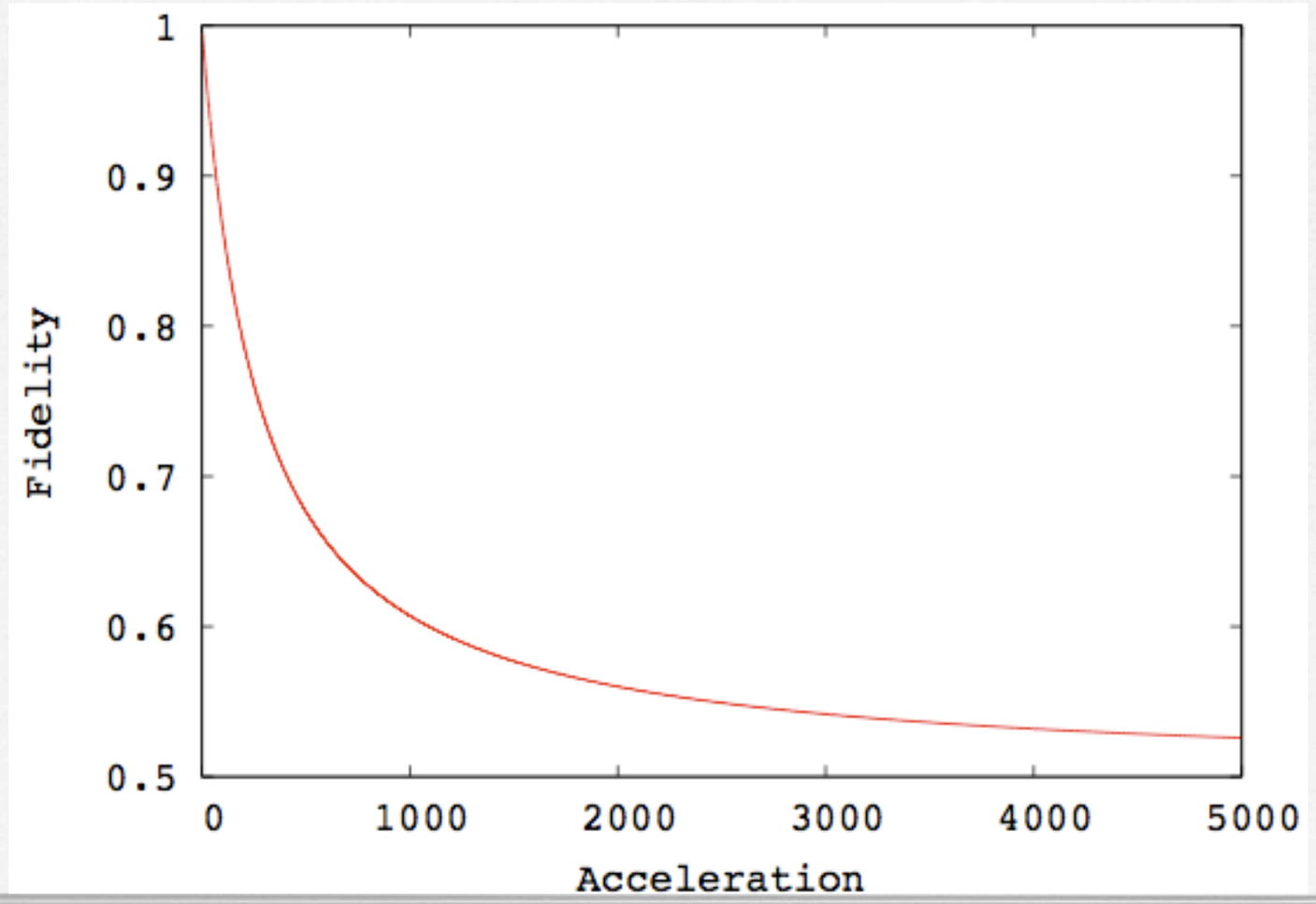
- We calculate de Fidelity of the Teleportation $F = \langle \varphi | \rho_f | \varphi \rangle$

- We calculate de Fidelity of the Teleportation $F = \langle\varphi|\rho_f|\varphi\rangle$

- It decreases with increasing acceleration

- We calculate de Fidelity of the Teleportation $F = \langle\varphi|\rho_f|\varphi\rangle$

- It decreases with increasing acceleration



Conclusions

Conclusions

- The Unruh effect leads to desentanglement of the qubits (possibly leading to sudden death)

Conclusions

- The Unruh effect leads to desentanglement of the qubits (possibly leading to sudden death)
- There is loss of fidelity in teleportation

Conclusions

- The Unruh effect leads to desentanglement of the qubits (possibly leading to sudden death)
- There is loss of fidelity in teleportation
- Hopefully our predictions can be measured in laboratory