Entanglement and decoherence in cosmology and in analogue gravity experiments

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Amaury Micheli

Supervisors : Jerome Martin, IAP (Paris) ; Scott Robertson, IJCLab (Orsay)

INTRODUCTION : PRIMARY EXAMPLES

Classical inhomogeneous / time varying background

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Take home message 1

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but... can we prove these predictions ?

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Take home message 2

Consensus on the difficulty of proving the quantum origin of Quantum Field Theory in curved space-time predictions in astrophysical and cosmological contexts.

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Insist ! Study **same systems with new tools** e.g. study inflationary perturbations using quantum information tools.

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Insist ! Study **same systems with new tools** e.g. study inflationary perturbations using quantum information tools.

Study laboratory systems where we can make the same predictions : **Analogue gravity**.

Good laboratory system analogue to classical background + quantum field ?

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For suitable modulation of trap size : $\bar{\phi}(t)$ leads to the same equations as preheating, **production of pairs of quasi-particles (phonons) in resonant modes k_{res}** !

ANALOGUE GRAVITY : SYNTHESIS

Take home message 3

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Same questions of observability, treated with the same formalism

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Illustration using (non-)separability of the state of subsystems.

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NB : Due to the lower bound detection requires high precision on $n_{\mathbf{k}}$ and $c_{\mathbf{k}}$, and gets harder as $n_{\mathbf{k}}$ increases

SEPARABILITY : LINEAR MODELS

Inflationnary perturbations

Preheating analogue

SEPARABILITY : LINEAR MODELS

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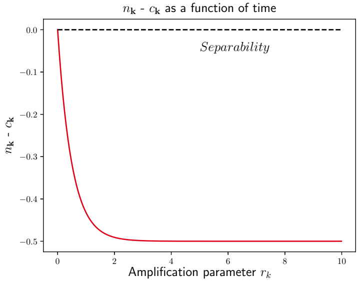

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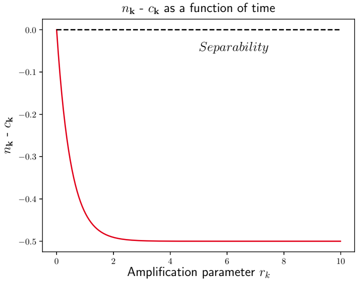

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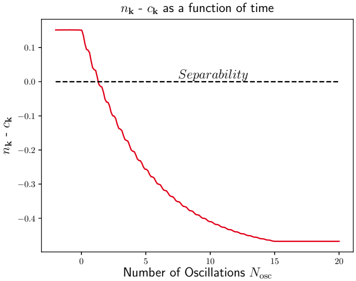

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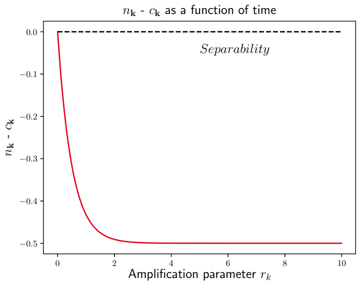

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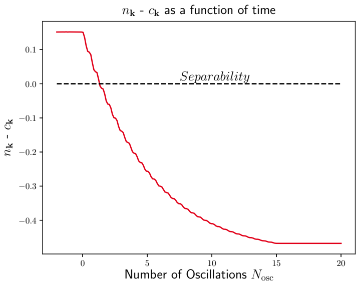

Evolution generically leads to a non-separable i.e. "quantum" state !

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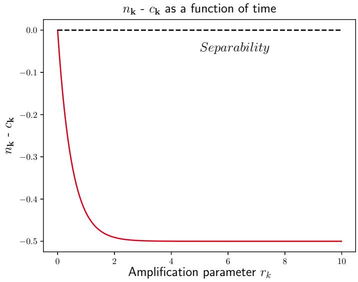

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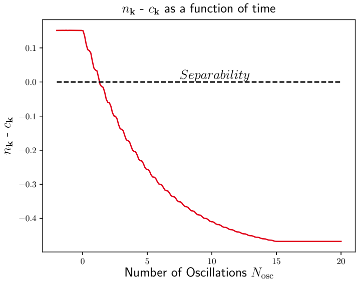

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Oversimplification ?

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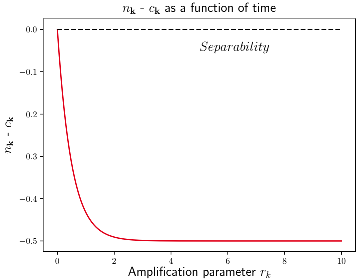

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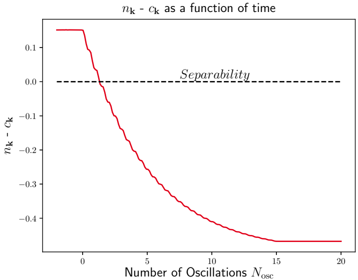
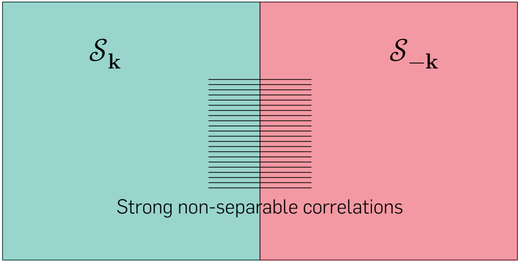


Evolution generically leads to a non-separable i.e. "quantum" state !
Oversimplification ? Yes e.g. [Jaskula et al., 2012] report having measure $n_\mathbf{k} > c_\mathbf{k}$, need to include non-linearities / interactions in the model.

NON-LINEARITIES, INTERACTIONS : DECOHERENCE



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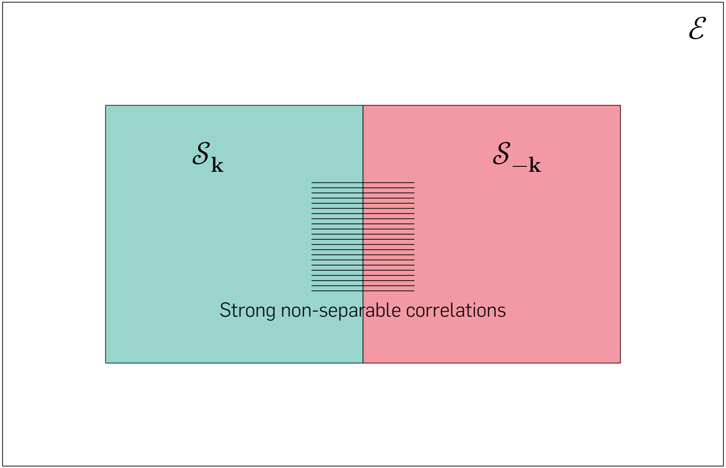

In fact $\mathcal{S}_k$ has an environment $\mathcal{E}$ (e.g. $\mathcal{S}_{k'}$ with $k' \neq k$)

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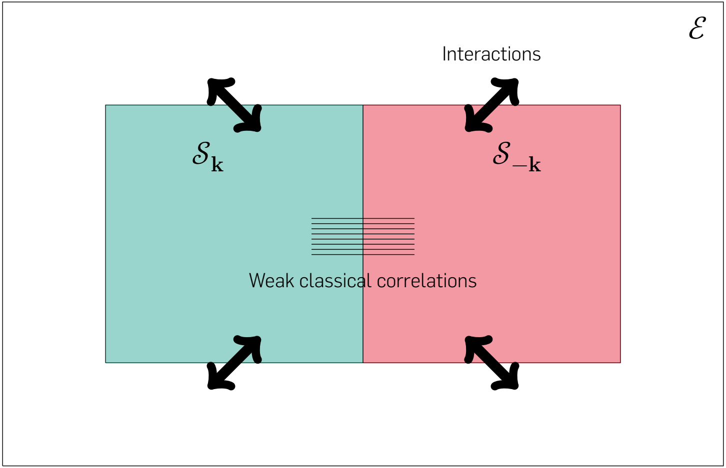

Interactions $\mathcal{S}_k$ / $\mathcal{E}$ destroy correlations $\mathcal{S}_{\mathbf{k}}$ / $\mathcal{S}_{-\mathbf{k}}$: decoherence

NON-LINEARITIES, INTERACTIONS : DECOHERENCE

Take home message 4

Quantum features of a state are fragile against interactions with extra degrees of freedom.

EFFECT OF DECOHERENCE : CURRENT WORK

Inflationnary perturbations | **Preheating analogue**

EFFECT OF DECOHERENCE : CURRENT WORK

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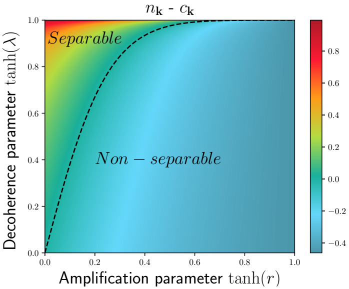

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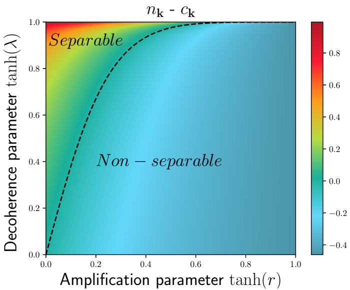

Level of decoherence λ model-dependent : might still be quantumness to see.

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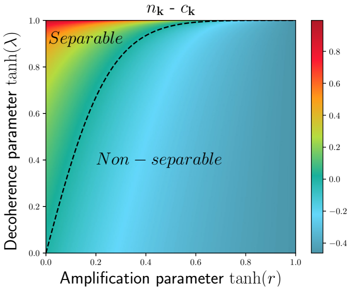

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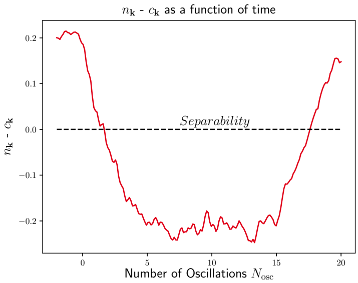

Decoherence from ab-initio numerical simulations of BEC + perturbations : confirm lost of entanglement.

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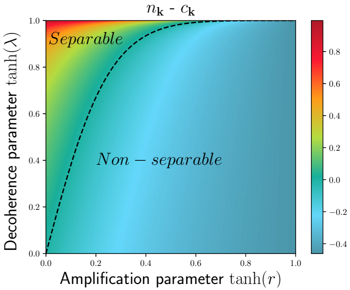

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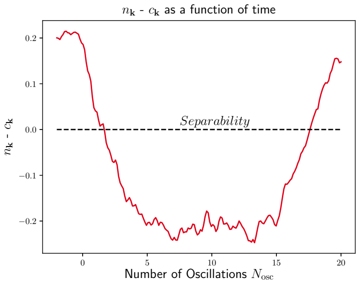

Goal : **Predict dependence on physical parameters to optimize experimental observability.**

Thank you for your attention !

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