

Harvesting Correlations from the Vacuum

Alejandro Pozas-Kerstjens, Eduardo Martín-Martínez

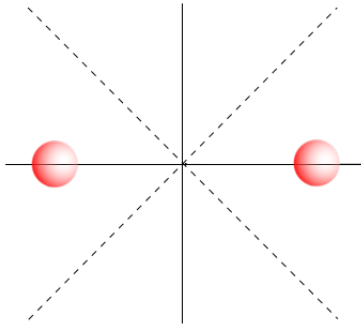
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Perimeter Institute for Theoretical Physics (Canada)

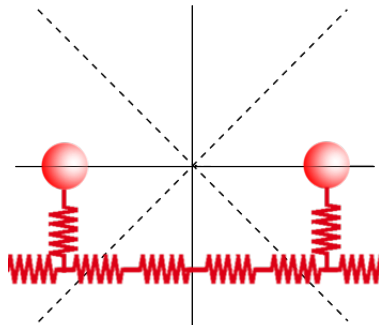
IV Postgraduate Meeting, IFT-Madrid
November 18, 2015











The Unruh-DeWitt particle detector model

$$H_I(t) = \lambda \chi(t) \mu(t) \int d^n \mathbf{x} F(\mathbf{x} - \mathbf{x}_0(t)) \phi(\mathbf{x}, t)$$

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Captures the fundamental features of L-M interaction

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A. M. Alhambra, A. Kempf and E. Martín-Martínez, Phys. Rev. A **89**, 033835 (2014)

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- $F(\mathbf{x} - \mathbf{x}_0(t))$ smearing function
- $\phi(\mathbf{x}, t) = \int \frac{d^n \mathbf{k}}{\sqrt{(2\pi)^n 2|\mathbf{k}|}} \left[a_{\mathbf{k}}^\dagger e^{i(|\mathbf{k}|t - \mathbf{k} \cdot \mathbf{x})} + a_{\mathbf{k}} e^{-i(|\mathbf{k}|t - \mathbf{k} \cdot \mathbf{x})} \right]$

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What we have studied

Little is known on how it is affected by the properties of the setup

- Energy gap
- Atoms' size and shape
- Dimensionality: $1+1D$ vs. $3+1D$
- Smoothness of the switching: Sudden vs. smooth

A. P.-K. and Eduardo Martín-Martínez, Phys. Rev. D **92**, 064042 (2015)

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A. P.-K. and Eduardo Martín-Martínez, Phys. Rev. D **92**, 064042 (2015)

- Super-oscillatory functions to maximize harvesting
B. Reznik, A. Retzker and J. Silman, Phys. Rev. A **71**, 042104 (2005)
- Non-perturbative methods on harmonic oscillator detectors
E. G. Brown, E. Martín-Martínez, N. C. Menicucci and R. B. Mann, Phys. Rev. D **87**, 084062 (2013)

HARVESTING OF ENTANGLEMENT

Entanglement harvesting

Negativity (entanglement measure) has two different contributions:

$$\mathcal{N}^{(2)} = \mathcal{M} - \mathcal{L}_{\mu\mu}$$

- Local terms (noise)

$$\mathcal{L}_{AA} \propto \lambda_A^2, \quad \mathcal{L}_{BB} \propto \lambda_B^2$$

- Non-local terms (correlations)

$$\mathcal{M} \propto \lambda_A \lambda_B$$

For entanglement to appear the non-local terms must dominate over the local noise.

ROLE OF THE SWITCHING FUNCTION

Is it true that the more abrupt the better?

Role of the switching function: Smooth vs. sudden

3 spatial dimensions,
smeared detectors

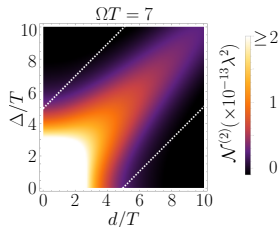
T = interaction timescale

d = spatial separation

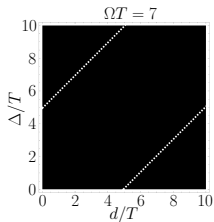
Δ = time delay

Ω = energy gap

Gaussian switching



Sudden switching



Role of the switching function: Smooth vs. sudden

3 spatial dimensions,
 smeared detectors

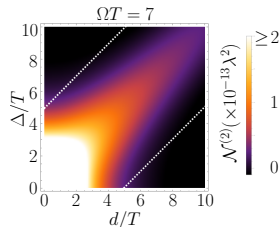
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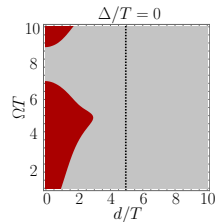
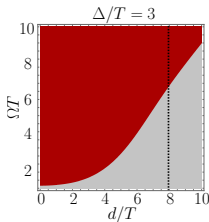
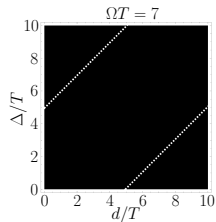
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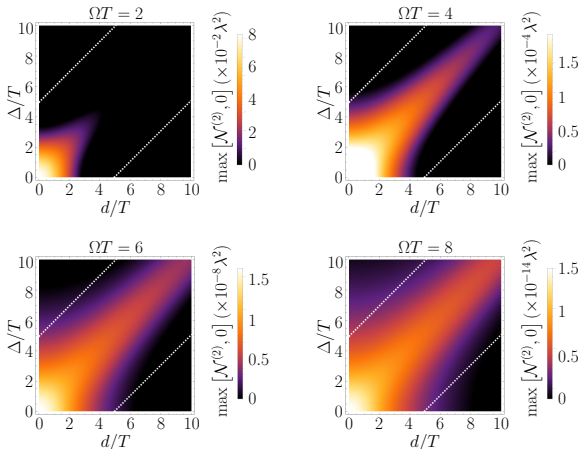
A rapid variation of the Hamiltonian excites the detectors

$$\mathcal{N}^{(2)} = \mathcal{M} - \mathcal{L}_{\mu\mu}$$

Sudden switching increases the local noise and
reduces the entanglement harvested

Influence of the energy gap

1 spatial dimension,
 Gaussian switching,
 spatially smeared
 detectors

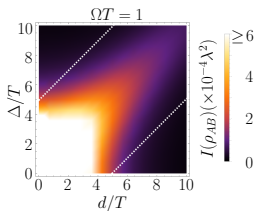


HARVESTING OF MUTUAL INFORMATION

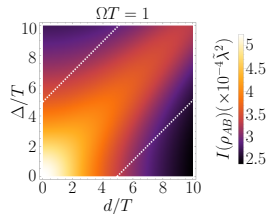
$$I(\rho_{AB}) = S(\rho_A) + S(\rho_B) - S(\rho_{AB})$$

Effect of dimensionality

Gaussian switching,
spatially smeared
detectors

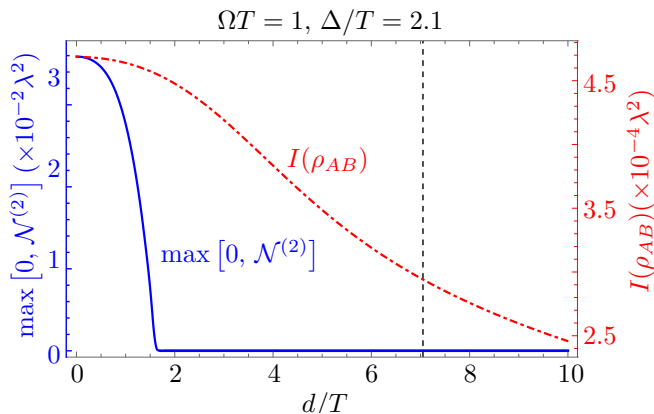


3 spatial dimensions



1 spatial dimension

Spacelike correlations harvesting



1 spatial dimension, Gaussian switching,
spatially smeared detectors

Conclusions & future directions

Conclusions

- Harvesting of (classical and quantum) correlations is strongly dependent on the properties of the detectors and the background spacetime.
- In particular, switching the interaction suddenly has negative consequences for entanglement harvesting.
- “Damping and leakage” effect in harvesting of both entanglement and correlations.

Thank you for your attention



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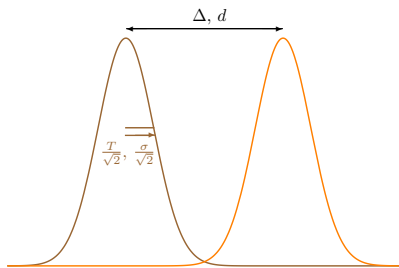
Questions? Comments?

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Phys. Rev. D **92**, 064042 (2015) - arXiv:1506.03081

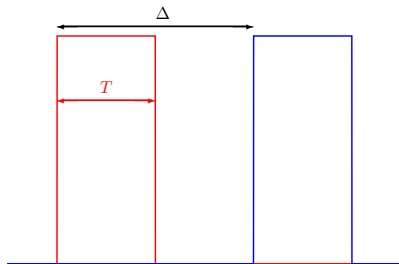


Spacelike separation



For pointlike detectors
with sudden switching,
 $d_{lc} = \Delta \pm T$

For all the rest,
 $d_{lc} = \Delta \pm \frac{7}{\sqrt{2}} \max [T, \sigma]$

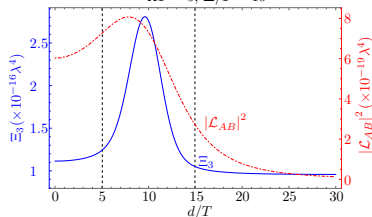


4th-order corrections

$$\mathcal{N}^{(4)} = |\mathcal{L}_{AB}|^2 - \Xi_3$$

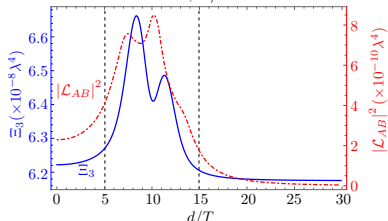
3 spatial dimensions, spatially smeared detectors

$\Omega T = 5, \Delta/T = 10$



Gaussian switching

$\Omega T = 5, \Delta/T = 10$



Sudden switching