**PhD Opportunity: Out-of-Equilibrium Quantum Dynamics with Tensor Networks**

**Advisors:** Luca Tagliacozzo and Esperanza Lopez
**Location:** IFF-CSIC (Madrid, Spain) and IFT-UAM/CSIC
**Group:** QUINFOG — Quantum Information and Foundations

**Project summary.**
How can simple microscopic constituents give rise to the rich diversity of phases and phenomena we see in nature? Much of this beauty stems from collective emergence in many-body systems. Equilibrium physics is by now well charted and dictated by a balance of energy and entropy. Genuinely quantum effects (e.g., superconductivity, superfluidity, topologically ordered phases) typically show up at very low temperatures where the entropy is sufficiently suppressed. Out of equilibrium, new questions arise: What strongly correlated states can we produce that are not present at equilibrium? In general, systems locally thermalize and thus localized quantum effects are washed out. Can specific protocols evade relaxation and protect genuine quantum features? What is the ultimate computational complexity we need to face to describe the evolution of such local quantum properties?
We aim to tackle these questions by better understanding the role of **temporal and generalized temporal entropies** in out-of-equilibrium dynamics and by building **tensor-network tools** that leverage this understanding.

**Approach.**
We combine analytical methods (field theory, process tensors, influence functionals) with state-of-the-art tensor-network simulations in 1D and 2D. Temporal entropies serve as key quantifiers of quantum complexity and guide the design of scalable algorithms for long-time evolution, thermalization, and transport. Example of our recent works in this direction are: [1–7]

**Your role**

- Develop and apply tensor-network techniques for out-of-equilibrium dynamics in 1D/2D.
- Contribute to the theory of process tensors, influence functionals, and their temporal entropies.
- Help build open-source code and produce publishable results with international collaborators.

**What we're looking for**

- Strong background in quantum mechanics and many-body/field theory.
- Numerical experience (e.g., Python/C++/Julia/MATLAB); exposure to tensor networks is a plus.
- Clear scientific writing in English and good communication skills.
- Motivation to work at the interface of quantum information, condensed matter, and field theory.

**What we offer**

- Training in cutting-edge tensor-network and field-theory methods.
- Opportunities for high-profile publications, conference travel, and open-source contributions.
- A stimulating environment: the QUINFOG group at IFF-CSIC (6 faculty, several postdocs/PhDs) and IFT-UAM/CSIC (including collaboration with Esperanza López).
- A funded PhD position within the **4-year research project**.

**How to apply.**
Send (i) a CV, (ii) a short motivation letter, and (iii) contact details of two referees to luca.tagliacozzo@iff.csic.es and esperanza.lopez@csic.es

The search is restricted to students fulfilling the criteria of the call (European citizens with certification of at least **300 ECTS**, or students from outside the European Union with the **Spanish equivalence of 300 ECTS**). The call is expected to mirror last year's. Selected candidates will apply to the official opening expected in **November**, with PhD start around **January 2026** (exact dates TBA).

**Relevant References from the group**


[1] S. Carignano and L. Tagliacozzo, Loschmidt echo, emerging dual unitarity and scaling of generalized temporal entropies after quenches to the critical point, Quantum **9**, 1859 (2025).

[2] S. Carignano, G. Lami, J. D. Nardis, and L. Tagliacozzo, *Overcoming the Entanglement Barrier with Sampled Tensor Networks*, arXiv:2505.09714.

[3] S. Cerezo-Roquebrún, A. Bou-Comas, J. T. Schneider, E. López, L. Tagliacozzo, and S. Carignano, *Spatio-Temporal Tensor-Network Approaches to out-of-Equilibrium Dynamics Bridging Open and Closed Systems*, arXiv:2502.20214.

[4] C. Ramos-Marimón, S. Carignano, and L. Tagliacozzo, Pauli weight requirement of the matrix elements in time-evolved local operators: Dependence beyond the equilibration temperature, Phys. Rev. B **111**, 094301 (2025).

[5] A. Bou-Comas, C. R. Marimón, J. T. Schneider, S. Carignano, and L. Tagliacozzo, *Measuring Temporal Entanglement in Experiments as a Hallmark for Integrability*, arXiv:2409.05517.

[6] S. Carignano, C. R. Marimón, and L. Tagliacozzo, On temporal entropy and the complexity of computing the expectation value of local operators after a quench, Phys. Rev. Res. **6**, 033021 (2024).

[7] T. Chanda, J. Zakrzewski, M. Lewenstein, and L. Tagliacozzo, Confinement and Lack of Thermalization after Quenches in the Bosonic Schwinger Model, Phys. Rev. Lett. **124**, 180602 (2020).