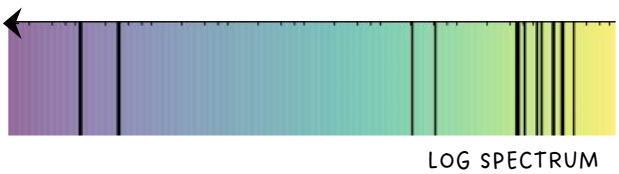
Classicality and Quantumness in Glassy Open Quantum Dynamics

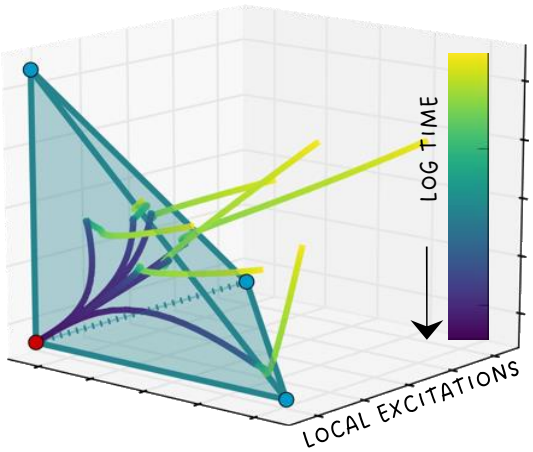
For classical and quantum systems, interactions with external environments are usually detrimental to any information encoded within their configurations. At long times such systems are typically found in stable phases independent from initial conditions. This forms a critical issue for quantum technology applications, with quantum information unavoidably erased over time in experimental platforms.

In classical soft matter featuring glassy dynamics [1], relaxation towards a stable phase can be significantly delayed and preceded by a pronounced time regime when changes are negligible, although the stable phase has yet not been reached. Crucially, this phenomenon enables a part of the initially encoded information to survive for a long time virtually unaffected by external influence.

This project will explore open quantum generalisations of classical kinetically constrained models that are known to feature glassy dynamics, with the goal to discover new physical systems that can store not only classical but also more fragile quantum information [2]. The initial stage will consist of analytical studies of small systems. Those results will then guide adaptations of well-established exact and systematically improvable numerical techniques for efficient simulations of larger systems. Experimentally feasible setups could be the focus in later years, with the outcomes potentially paving a way for a novel type of quantum memories.

The project will be an excellent fit for a student interested in working at the very overlap of quantum mechanics, statistical physics, and soft matter, who is looking to develop both their analytical and numerical skills.





An example of numerical analysis for an open quantum generalisation of East model found to feature long-lived classical information [3].

References:

[1] K. Binder and W. Kob, *Glassy Materials and Disordered Solids: An Introduction to Their Statistical Mechanics* (World Scientific, 2011).

[2] K. Macieszczak *et al*., “Towards a Theory of Metastability in Open Quantum Dynamics”, Phys. Rev. Lett. **116**, 240404 (2016).

[3] D. C. Rose, K. Macieszczak *et al*., “Hierarchical classical metastability in an open quantum East model”, Phys. Rev. E **105**, 044121 (2022).