Dissipative Control of Quantum Dynamics from Biased Trajectory Ensembles

Fergus Barratt (fergus.barratt@kcl.ac.uk)
Supervisors: Andrew Green & Peter Sollich

EPSRC Engineering and Physical Sciences Research Council

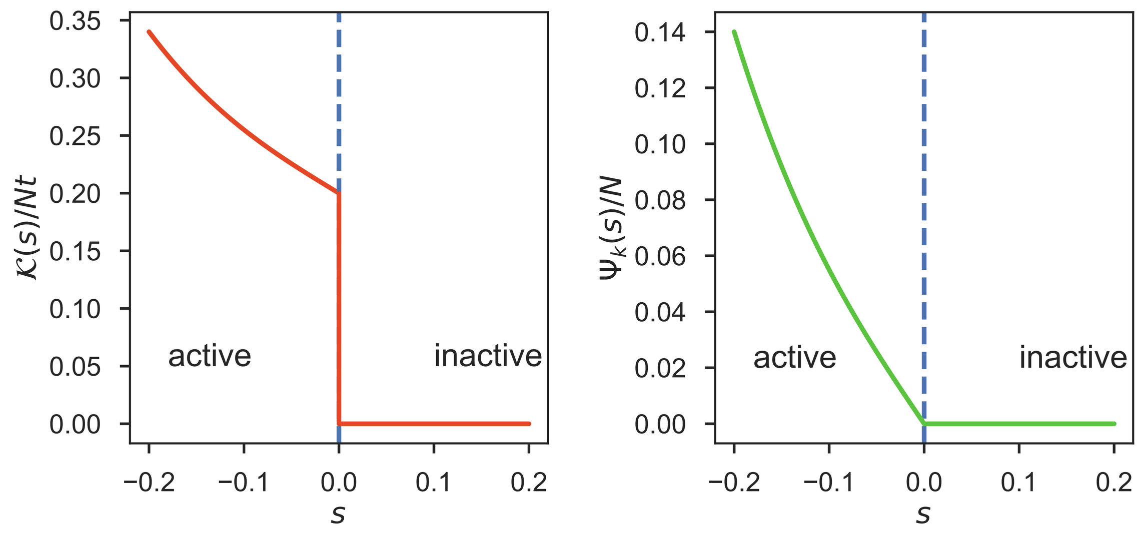
King's College London

> I: Introduction

- Technological potential of quantum systems due to state space scaling.
- Environmental decoupling challenges effective use of quantum technology.
- E.g. Adiabatic quantum computation
- Tools from Statistical Mechanics?

> II: Aims

- Classical glasses $\to$ KCMs $\to$ *biased trajectory ensembles*[2].
- Keldysh theory $\to$ dissipation: analogous to bias in trajectory ensembles?
- Transition from usable quantum resources (i.e. entanglement) to absence.



> 1: Trajectory Ensembles

- Ensembles of trajectories - like thermal ensembles. Partition function: [2].

$$\mathcal{Z}_A(s,t) = \sum_A \Omega_{dyn}(A,t)e^{-sA} \qquad (1)$$

- Markovian, paths biased (like canonical ensemble) by time extensive observable A (E) with strength s (β). $\mathbb{W} \to \mathbb{W}_A$ in

$$\frac{\partial \vec{P}_A}{\partial t} = \mathbb{W}_A(s)\vec{P}_A, \qquad (2)$$

leads to

$$\mathcal{Z}_A(s,t) \sim e^{t\psi_A(s)} \qquad (3)$$

with $\psi_A(s)$ largest eigenvalue of $\mathbb{W}_A(s)$: *dynamical free energy*.

- Singularities in dynamical free energy $\to$ *dynamical phase transitions*: different dynamical behaviour i.e. transition to chaos, jamming in glasses.
- Dynamical phase transitions in *kinetically constrained models* (KCMS) of glass formers (fig. 1)

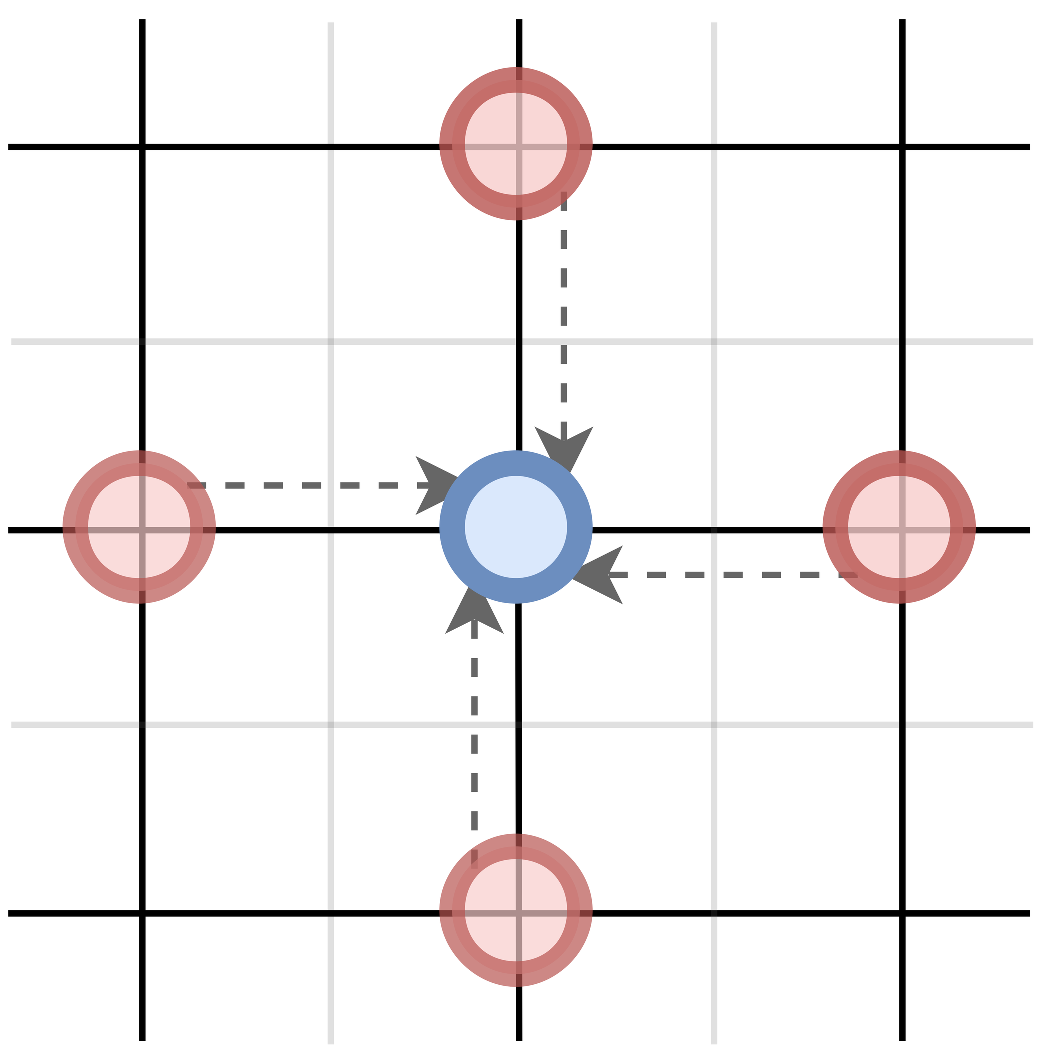


Figure 1: Schematic of site of Kinetically Constrained Model. Site i (blue) transitions from $n_i \to 1-n_i$ with rate $W(n_i \to 1-n_i) = C(\{n_j\})\frac{e^{\beta(n_i-1)}}{1+e^{-\beta}}$, where $C(\{n_j\})$ is a function only of the values of sites n_j (red)

> 2: Matrix Product States

- Interesting bit of most Hilbert spaces small, permits efficient numerics.
- Many-body quantum state

$$|\psi\rangle = \sum_{\sigma_1,\ldots,\sigma_L} C_{\sigma_1,\ldots,\sigma_L} |\sigma_1,\ldots,\sigma_L\rangle\,,$$

- MPS decomposition (Λ diagonal)

$$|\psi\rangle = \sum_{\sigma_1,\ldots,\sigma_L} \Gamma^{\sigma_1}\Lambda_1 \ldots \Lambda_{L-1}\Gamma^{\sigma_L} |\sigma_1,\ldots,\sigma_L\rangle$$

- Important bit of Hilbert space spanned by MPS with Λ truncated to D dims.

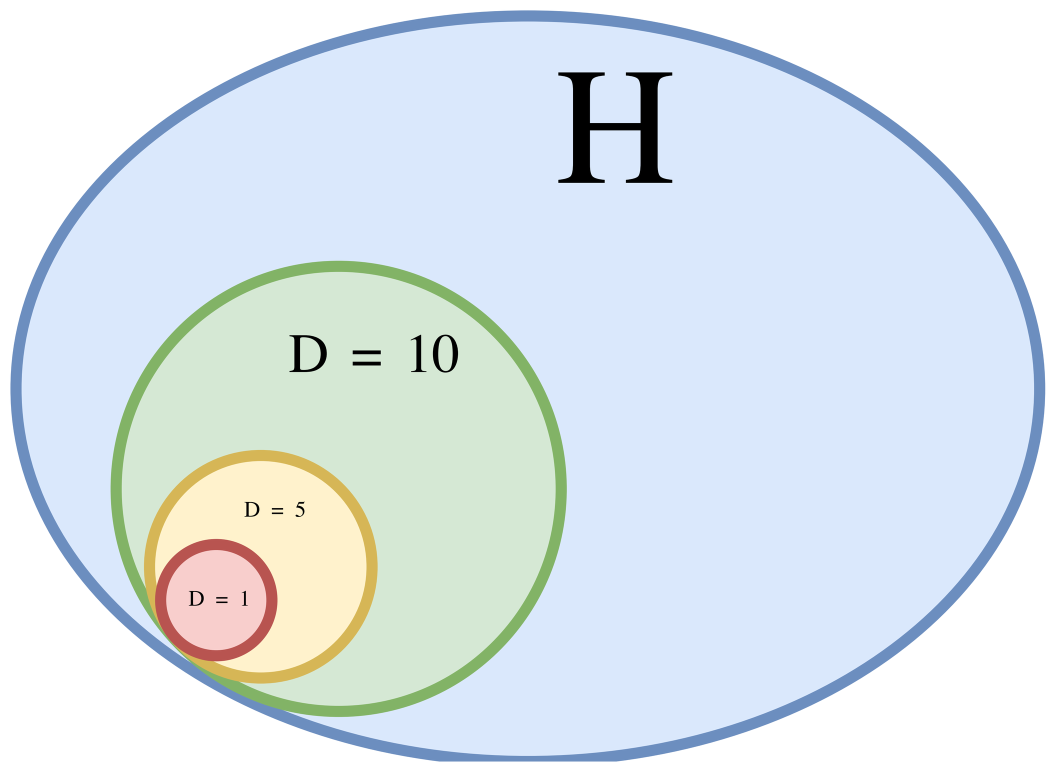
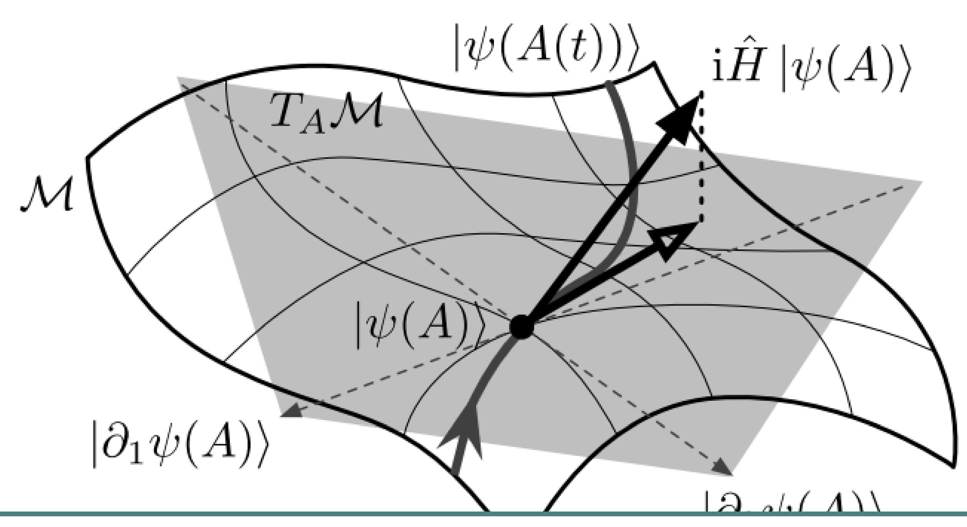


Figure 2: Size of subset of Hilbert space H with bond dimension D grows with D

- D grows with time evolution. Project back to D subspace - classical EOM



> 3: Non-Equilibrium QFT: Keldysh

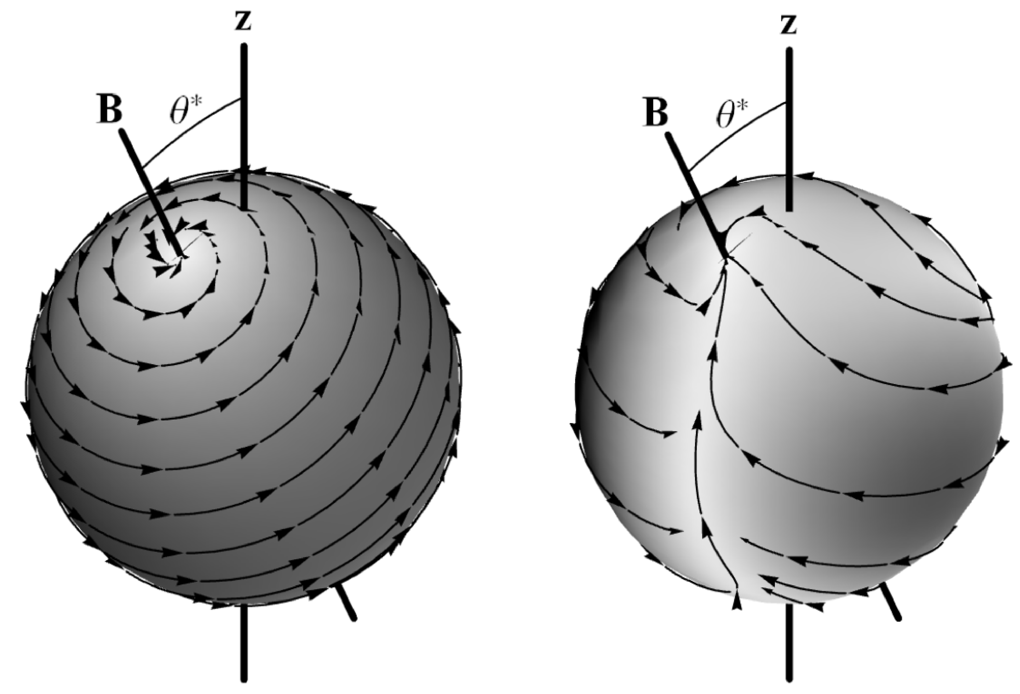


Figure 4: Different dynamical behaviour

- Evolve the state forward in time ($-\infty \to \infty$), rewind $\infty \to -\infty$: fig. 5
- Separate fields on forward and backwards contours (ϕ^+, ϕ^-)
- Construct the path integral $\to$ redundancy in the Green's Functions.
- Combinations such that $\langle \phi^{cl}\phi^{cl}\rangle = 0$

$$\phi^q = \phi^+ - \phi^- \qquad \phi^{cl} = \phi^+ - \phi^- \qquad (4)$$

- Introduce a bath interacting with system, integrate out bath, generate semiclassical path integrals for quantum systems.
- Distribution over paths. Connected to the classical trajectory ensemble?

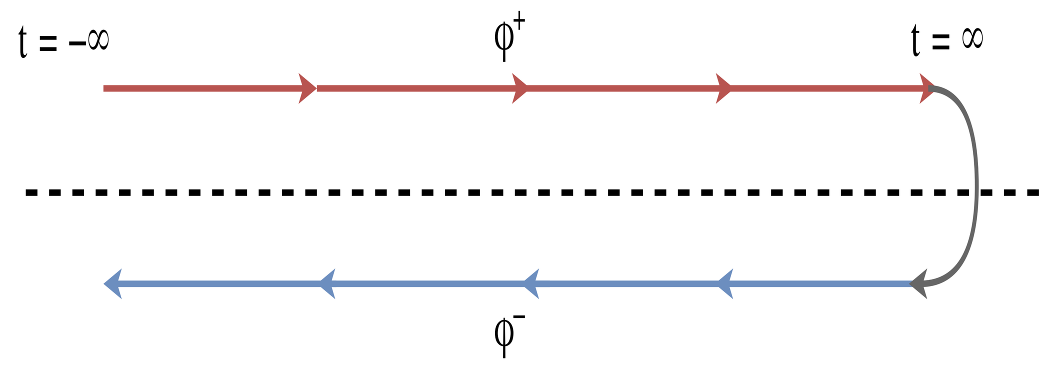


Figure 5: Keldysh Contour

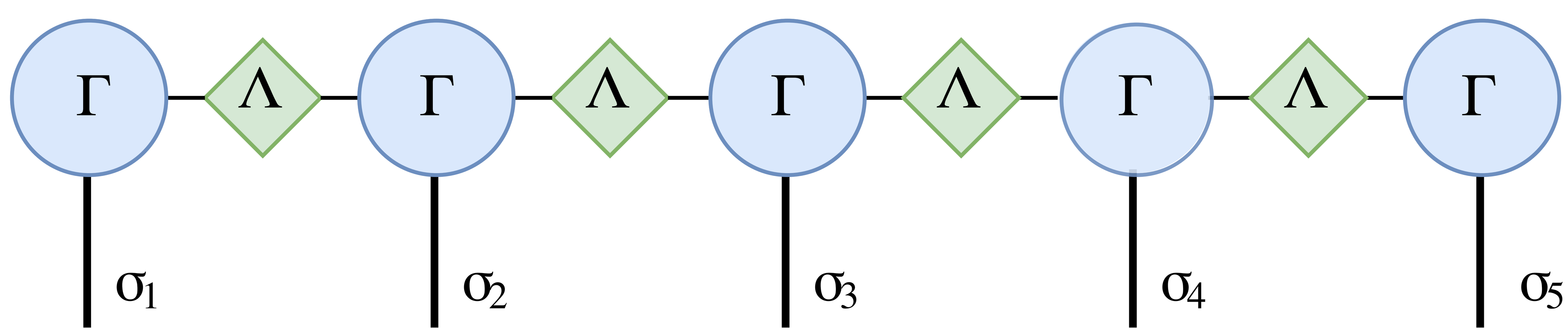


Figure 6: 5-site Open Boundary Condition MPS in $\Gamma\Lambda$ notation

References

[1] P. J. D. Crowley and A. G. Green. Anisotropic landau-lifshitz-gilbert models of dissipation in qubits. *Phys. Rev. A*, 94:062106, Dec 2016.

[2] J. P. G. et al. First-order dynamical phase transition in models of glasses: an approach based on ensembles of histories. *Journal of Physics A: Mathematical and Theoretical*, 42(7):075007, 2009.