Dissipative Control of Quantum Dynamics from Biased Trajectory Ensembles

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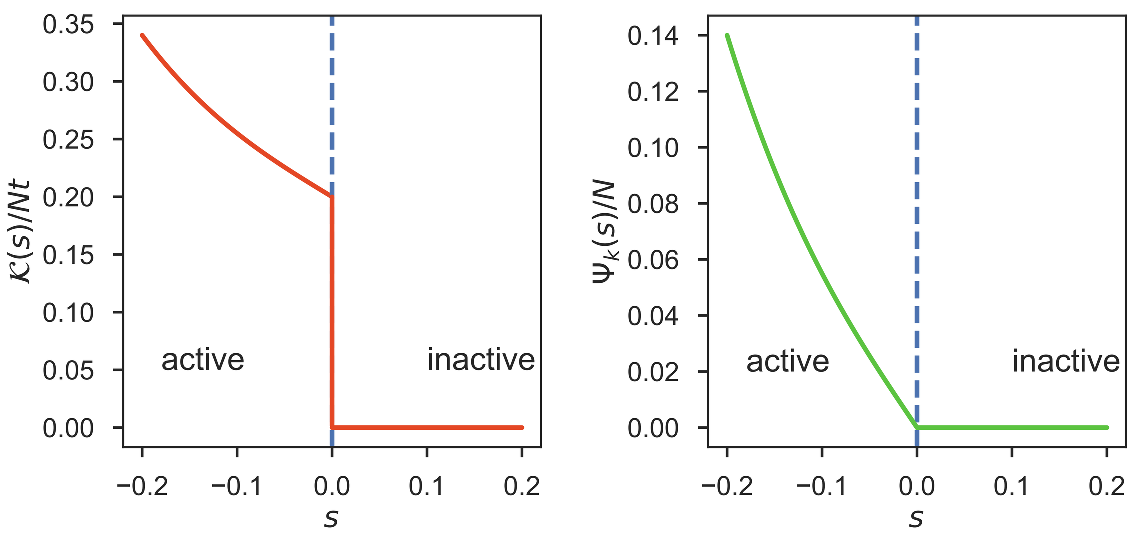
> I: Introduction

- Technological potential of quantum systems due to state space scaling.
- Environmental decoupling a challenge to effective use of quantum technology i.e. in adiabatic quantum computation
- New tools from statistical mechanics?

> II: Aims

- Classical glasses → KCMs → *biased trajectory ensembles*[2]
- Keldysh theory → dissipation → analogy to bias in trajectory ensembles
- Transition from quantum resources to absence as *dynamical phase transition*



> 1: Trajectory Ensembles

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

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

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

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

leads to

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

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

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

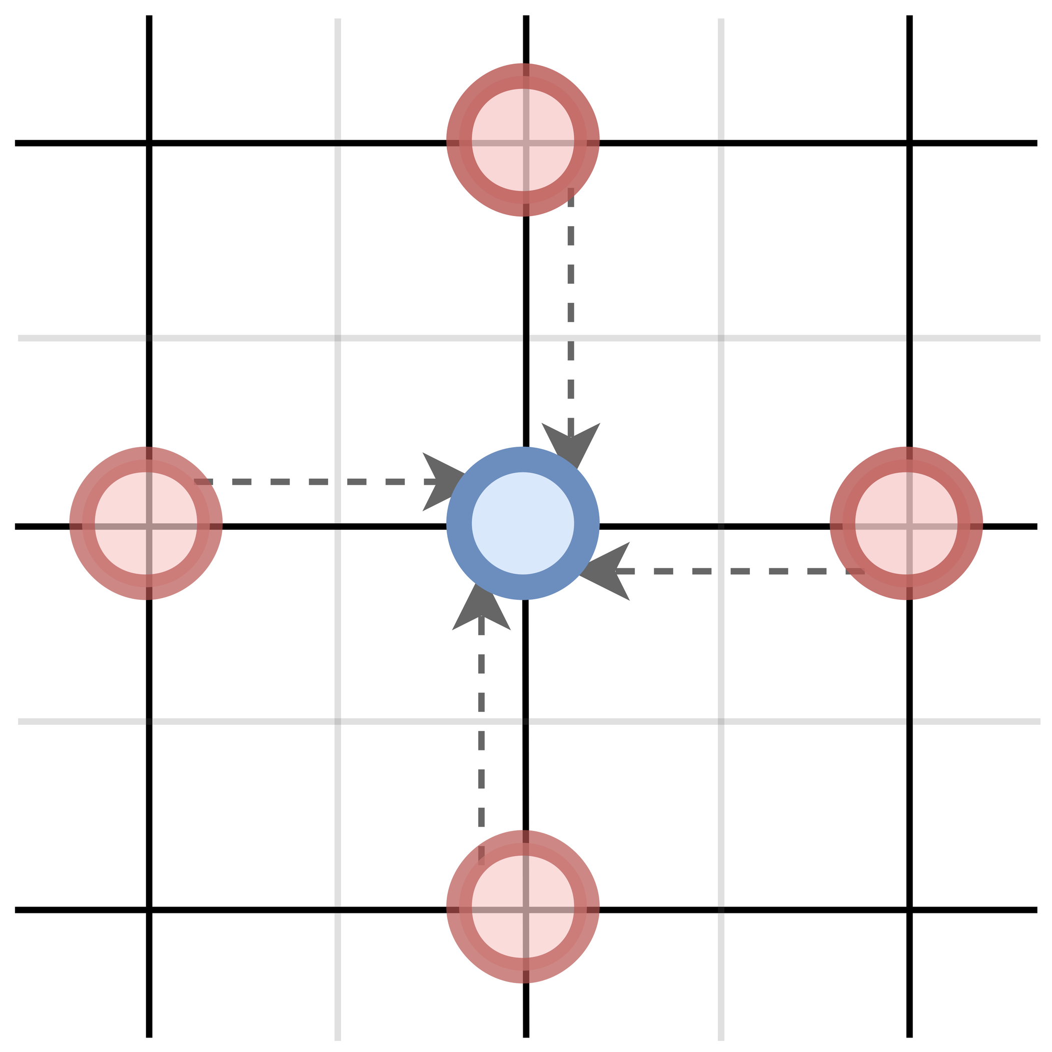
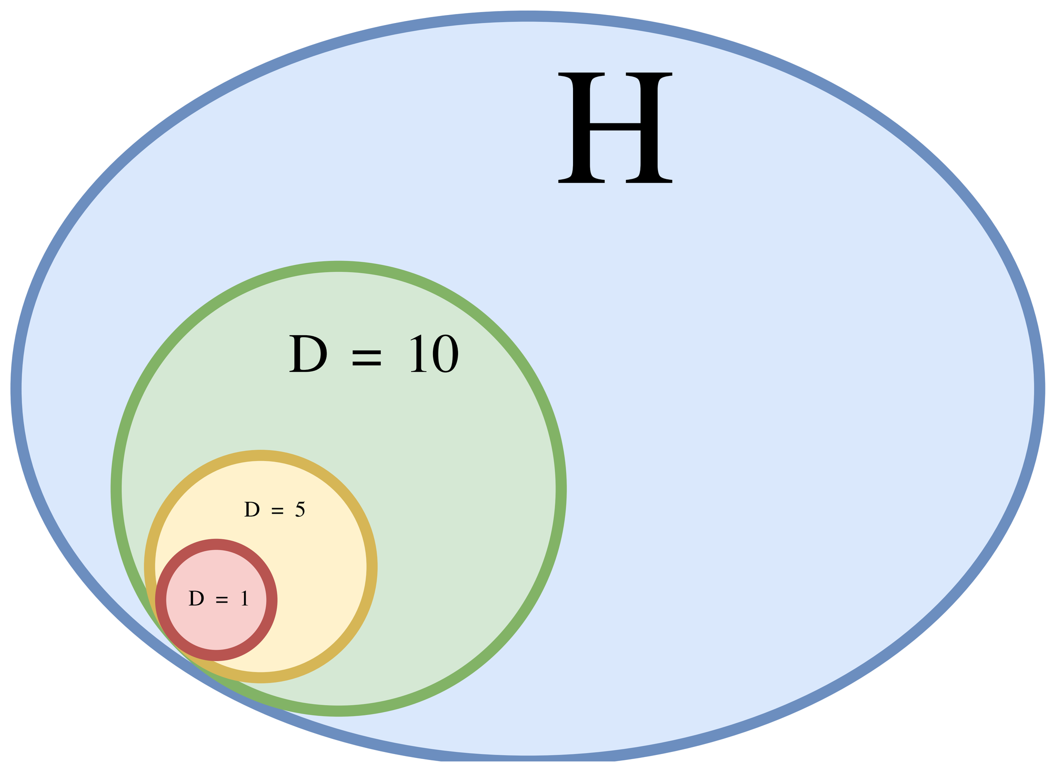


Figure 1: Schematic of site of Kinetically Constrained Model. Site i (blue) transitions from $n_i \to 1-n_i$ with rate $W(n_i \to 1-n_i) = C(\{n_j\})\frac{e^{\beta(n_i-1)}}{1+e^{-\beta}}$, where $C(\{n_j\})$ is a function only of the values of sites n_j (red)

> 2: Matrix Product States

- Interesting bit of most Hilbert spaces small, permits efficient numerics



- Many-body quantum state

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

- MPS decomposition (Λ diagonal)

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

- Important bit of Hilbert space spanned by MPS with Λ truncated to D dims
- D grows with time evolution. Project back to D subspace - classical EOM

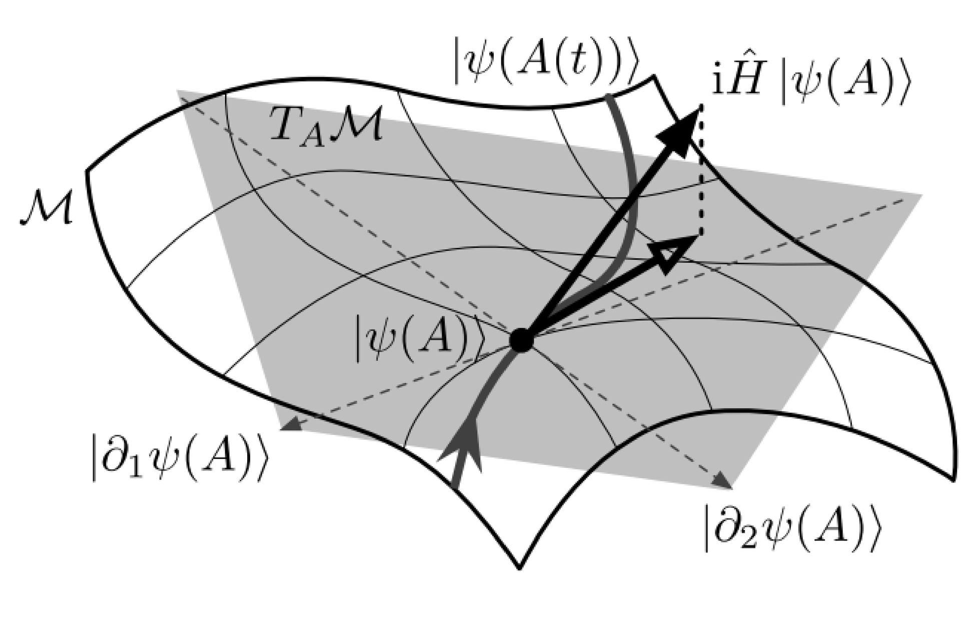


Figure 2: Time-dependent variational principle [3]

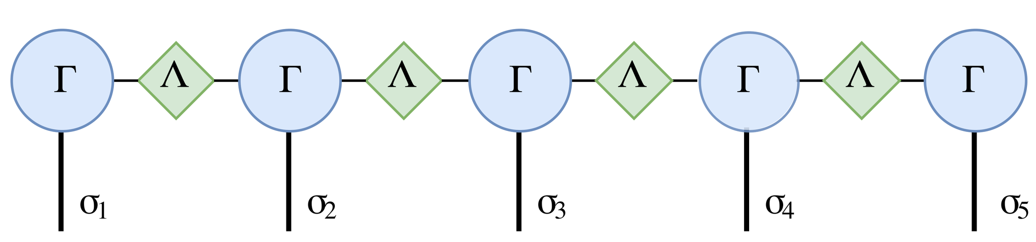


Figure 3: 5-site Open Boundary Condition MPS

> 3: Non-Equilibrium QFT: Keldysh

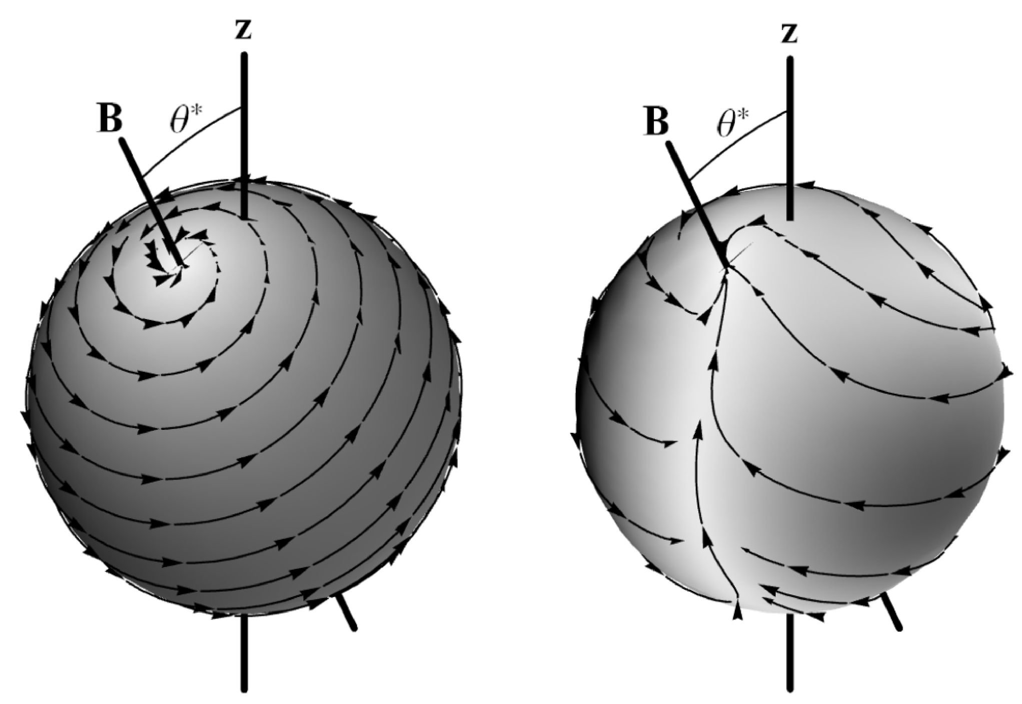


Figure 4: Different dynamical behaviour [1]

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

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

- Introduce a bath interacting with system, integrate out bath, generate semi-classical path integrals for quantum systems
- Classical average over delta function → MSRJD formalism

$$\langle \delta(\dot{x}(t) - f(x) - \xi(t))\rangle$$

- Distribution over paths. Connected to the classical trajectory ensemble?

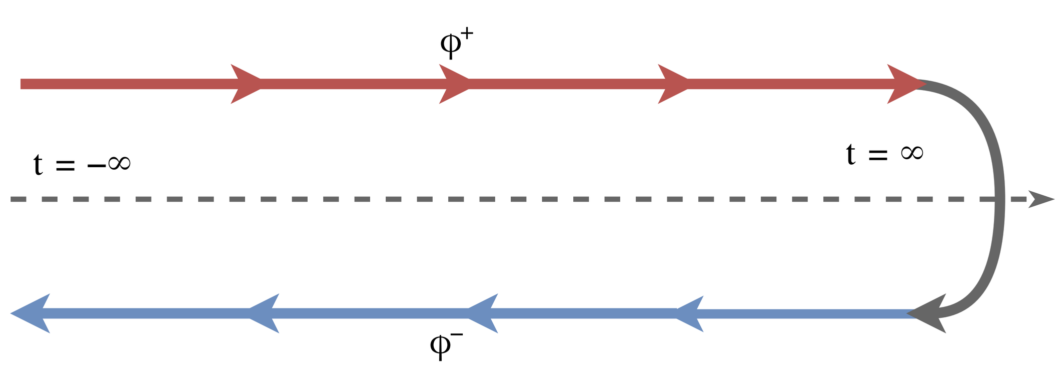


Figure 5: Keldysh Contour

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.

[3] J. Haegeman, J. I. Cirac, T. J. Osborne, I. Pižorn, H. Verschelde, and F. Verstraete. Time-dependent variational principle for quantum lattices. *Phys. Rev. Lett.*, 107:070601, Aug 2011.