MATTEO RIZZI

UNIVERSITÄT ZU KÖLN & FORSCHUNGSZENTRUM JÜLICH

NIQ: NOISE IN QUANTUM ALGORITHMS

WP D: Robust Preparation of Topological Quantum States

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

NiQ Kickoff Meeting

01.04.2022

ForschungsZentrum Jülich: the Team

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Matteo Rizzi (PI)

- Tensor Network Methods for Many-Body Systems (in- & out-equilibrium)
- Synthetic Quantum Matter & Quantum Simulations
- Topological Quantum States

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- Superconducting Qubits

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Tommaso Calarco (Collaborator & Institute Director)

- Quantum Optimal Control
- Quantum Computation with AMO setups
- Quantum Technologies (Flagship initiator & more)

WP D: Robust Preparation of Topological States

NiQ big vision:

- *demonstration of a tech-useful application with a NISQ-device still pending*
- *circuit-based state-preparation is utterly expensive*
- *noise could even be instrumental to escape local minima in a search landscape*

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WP D Objectives*:*

- *understand how to steer into fiducial states via local weak measurements, with the possible aid of feedback loops (QEC-alike);*
- *assess whether such protocols can help to stabilise & accelerate VQE for applicative purposes;*

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Task	Contributing partner	Description
D1	**FZJ, USAAR, FU**	Development of noise- and measurement-assisted preparation of AKLT states.
D2	**FzJ, Qruise, IBM**	Development of codes for noise- and measurement-assisted AKLT states.
D3	**FZJ, USAAR, FU, DESY, Qruise, IBM**	Assessment of the efficiency of noise-assisted quantum state preparation in a quantum computer platform
D4	**FZJ, USAAR, FU, DESY**	Protocols for noise-assisted preparation of non frustration-free topological states

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Timeline	Months 1- 6	Months 7-12	Months 13-18	Months 19-24	Months 25-30	Months 31- 36
Task D1						
Task D2						
Task D3						
Task D4						

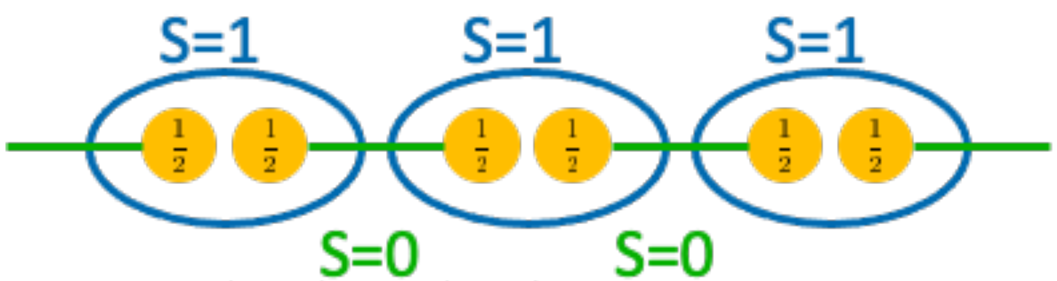
Critical Milestone

Deliverables

WP D: On-Going Work at FZJ & USAAR

Stroboscopic measurement-based non-unitary dynamics towards certain resource states (AKLT & alike)

Affleck-Kennedy-Lieb-Tasaki (1987): paradigmatic (symmetry-protected) topological state



$$H = 2P_2(\vec{S}_i + \vec{S}_{i+1}) = \sum_j \vec{S}_j \cdot \vec{S}_{j+1} + \frac{1}{3}\left(\vec{S}_j \cdot \vec{S}_{j+1}\right)^2$$

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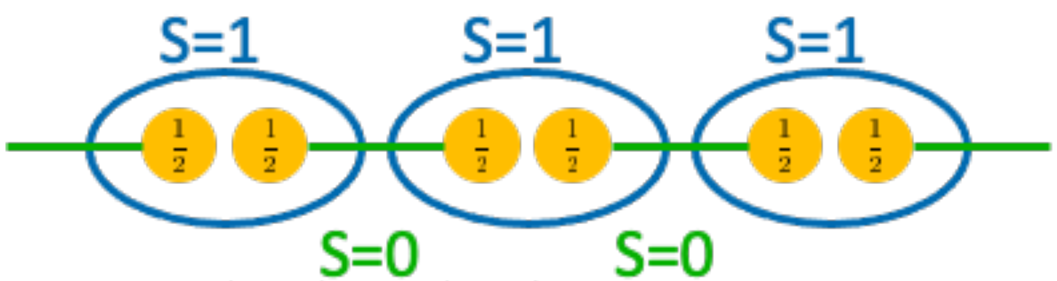

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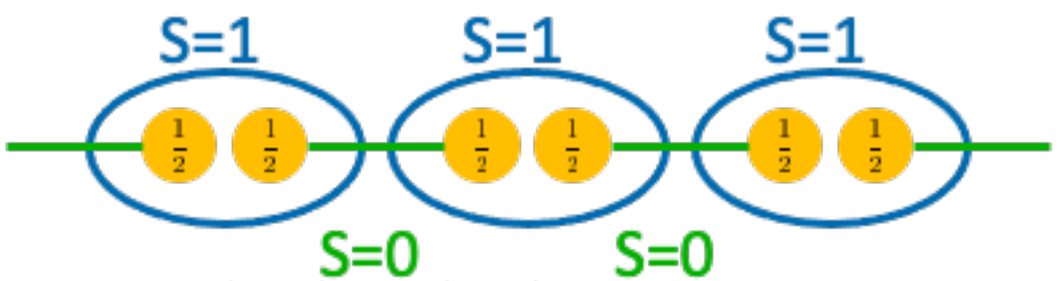

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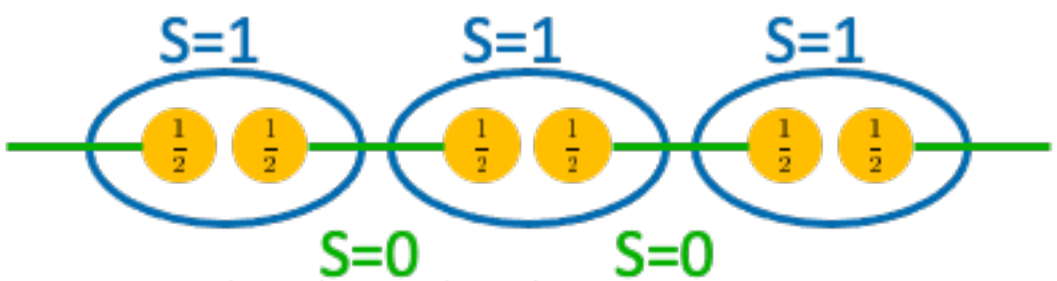

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Roy, Chalker, Gornyi, Gefen, PRR 2, 033347 (2020)

$$\tilde{H} = J \sum_n |\Phi_d^{(n)}\rangle \langle \Phi_d| \otimes U_s^{(n)} + \mathrm{h.c}$$

orthogonal ancilla states *bond isometries*

+ *detector (ancilla) RESET to* $|\Phi_d\rangle$ *every* δt

$\underset{S=2}{|\Psi_{\mathrm{undesired}}\rangle} \rightarrow \underset{S=0,1}{|\Psi_{\mathrm{desired}}\rangle}$

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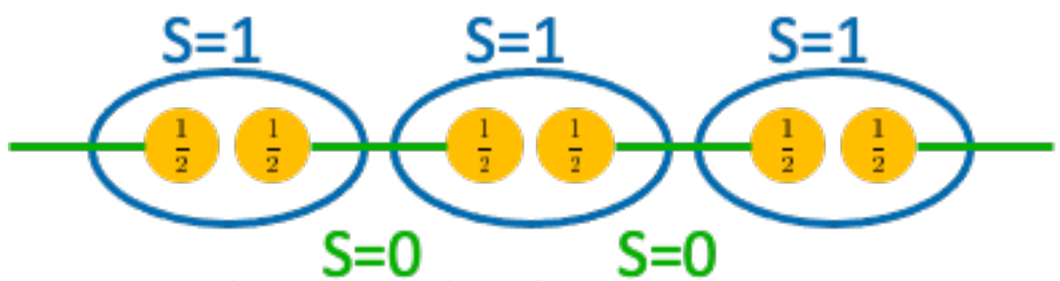

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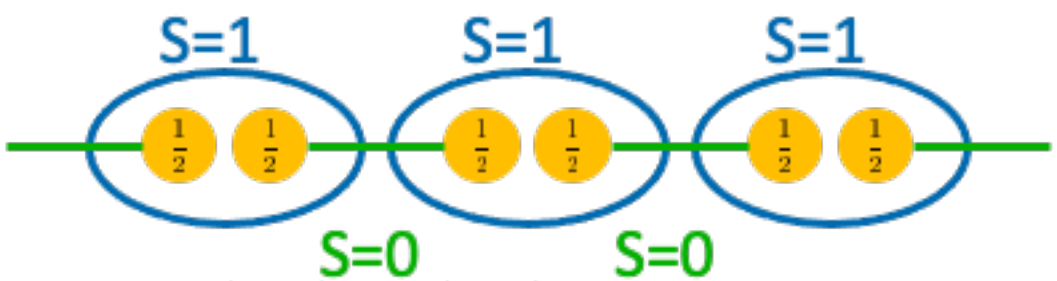

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Lindblad dynamics if $\delta t \to 0$

$$\partial_t \rho_s(tJ) = \delta t J \sum_n \left[U_n \rho_s(tJ) U_n^\dagger - \frac{1}{2}\{U_n^\dagger U_n, \rho_s(tJ)\}\right]$$

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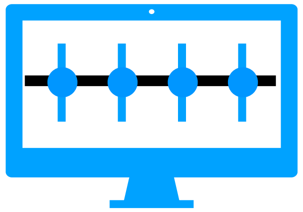

Tensor-Network simulations via Quantum Trajectories (i.e., Monte Carlo)

see works by Daley et al.

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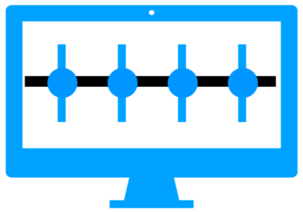

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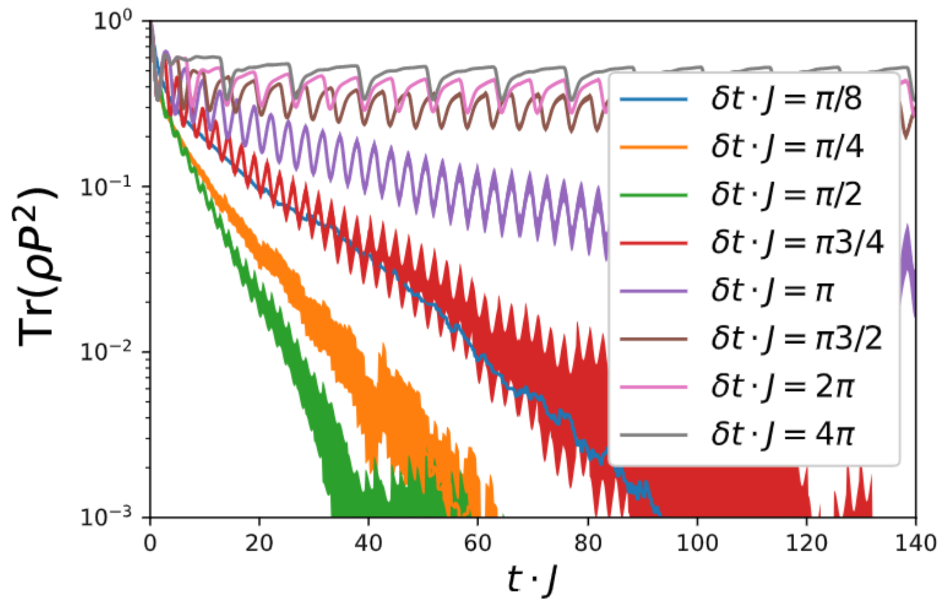
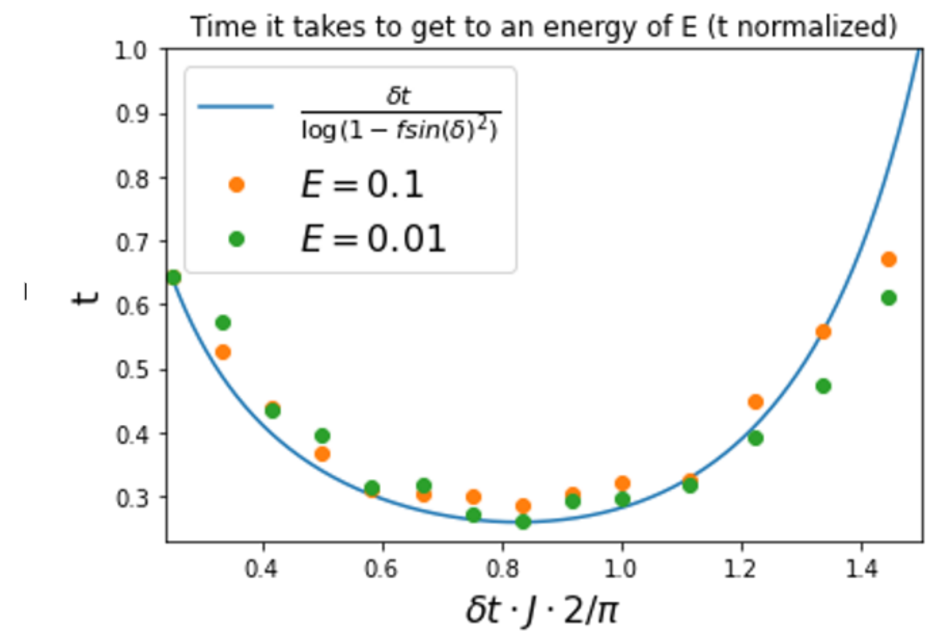
Lindblad dynamics can be beaten by an optimal choice of stroboscopic interval δt





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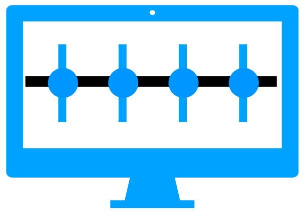

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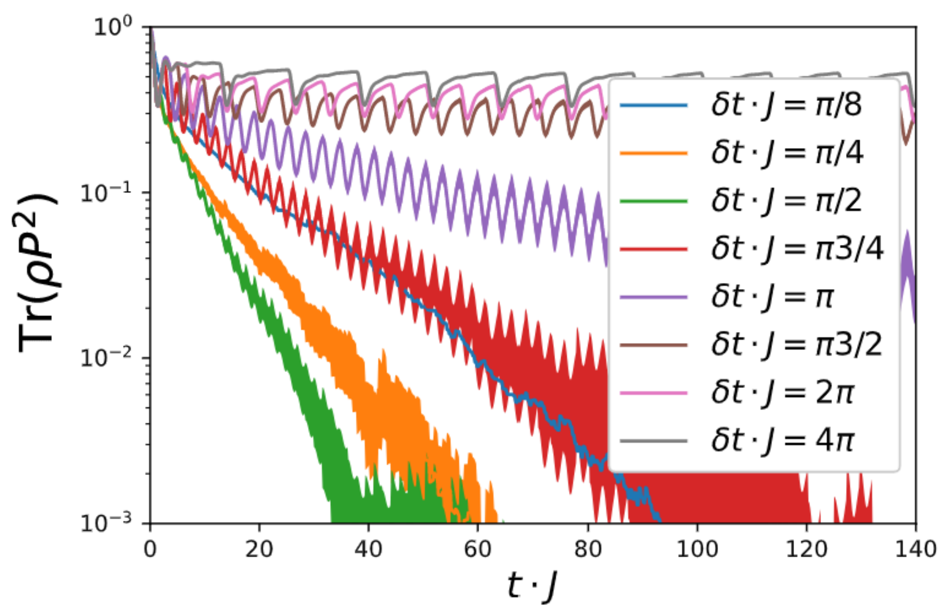
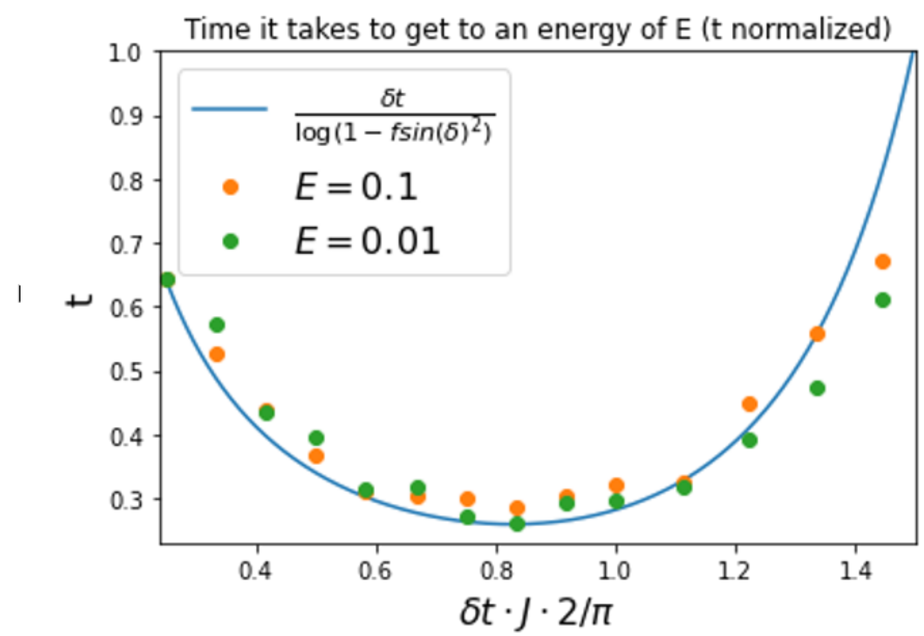
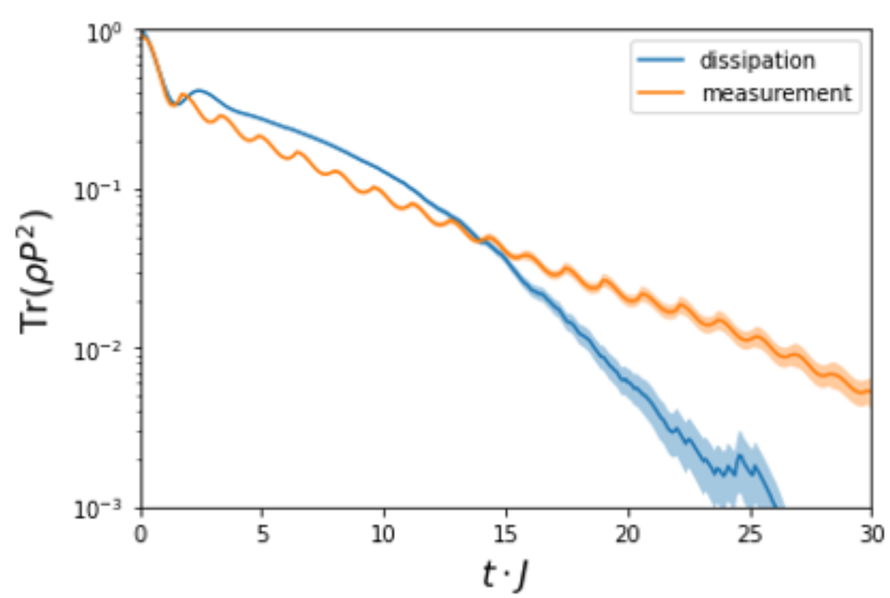




OUR RESULT #2:

Always-on (dissipative) relaxation of the ancillas/detectors even more effective than stroboscopic reset!



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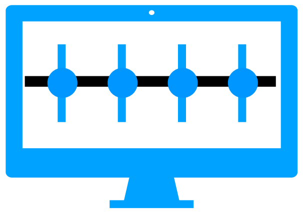

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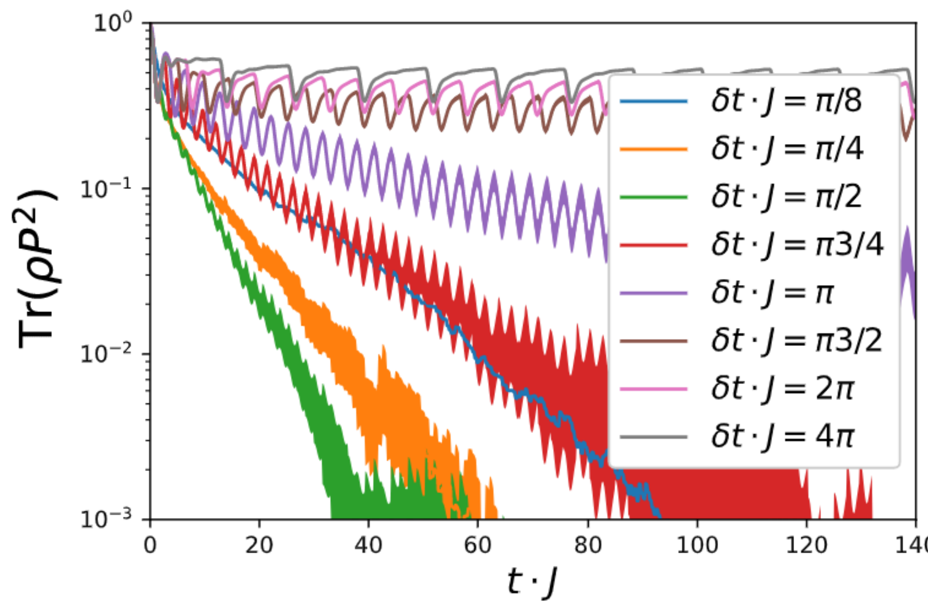

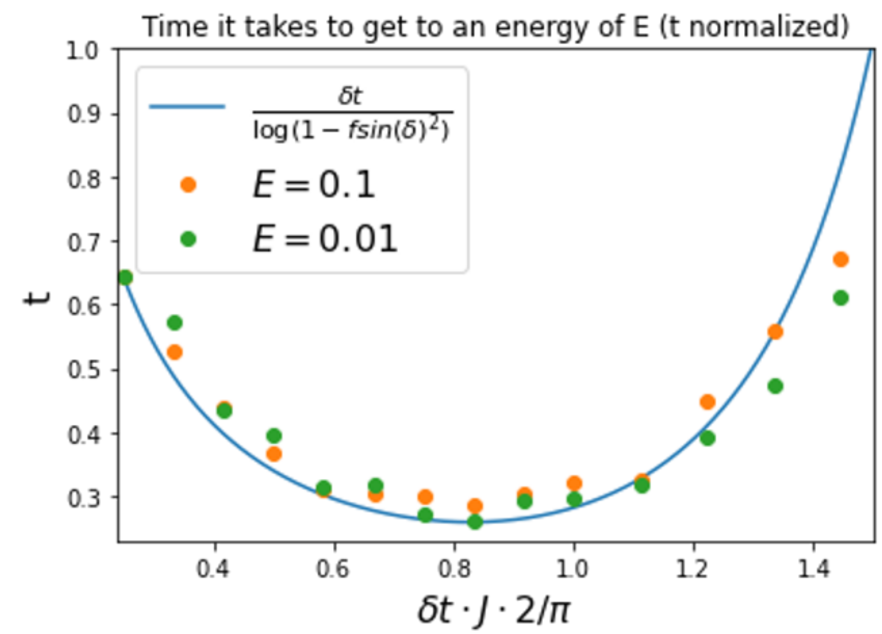

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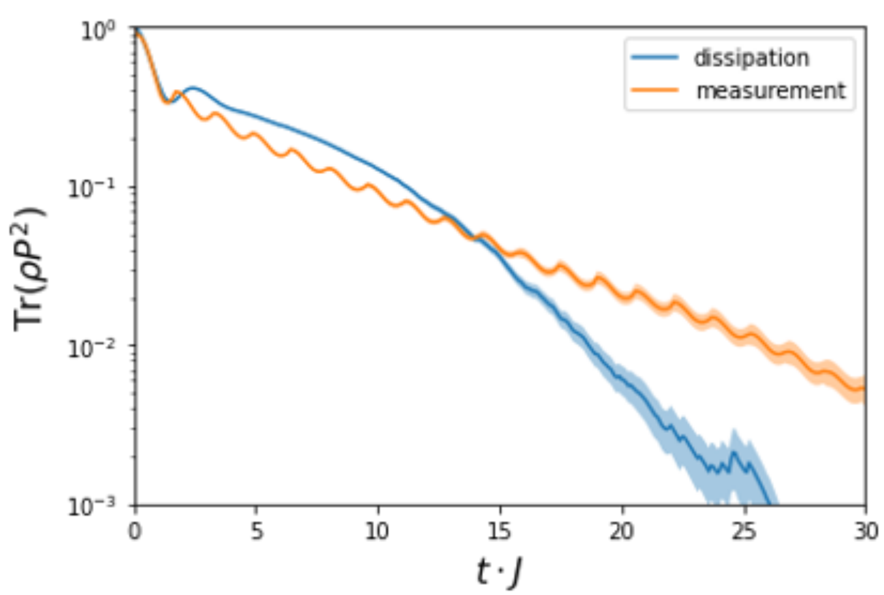

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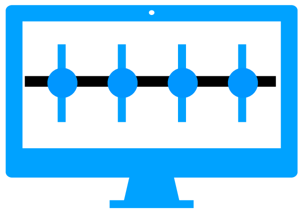

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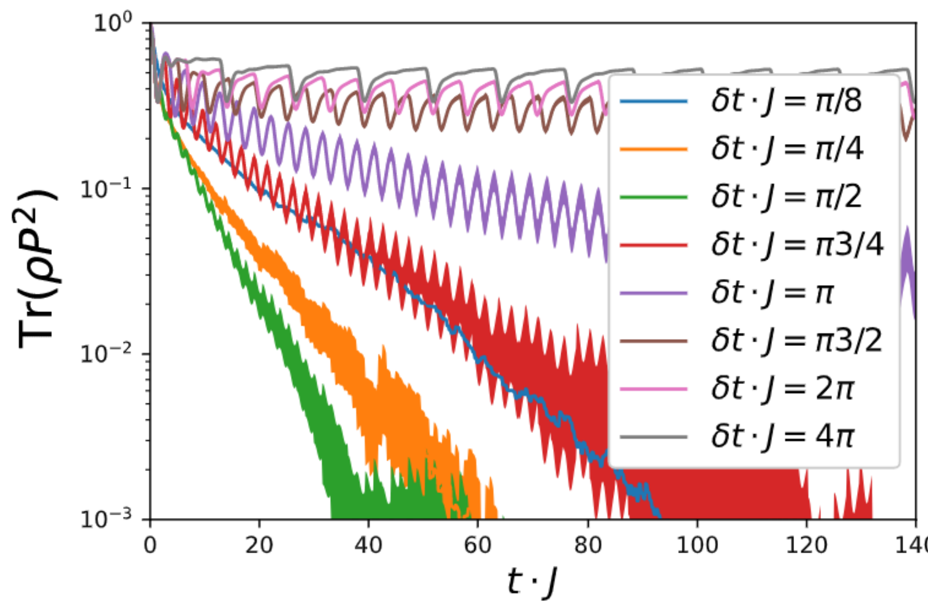

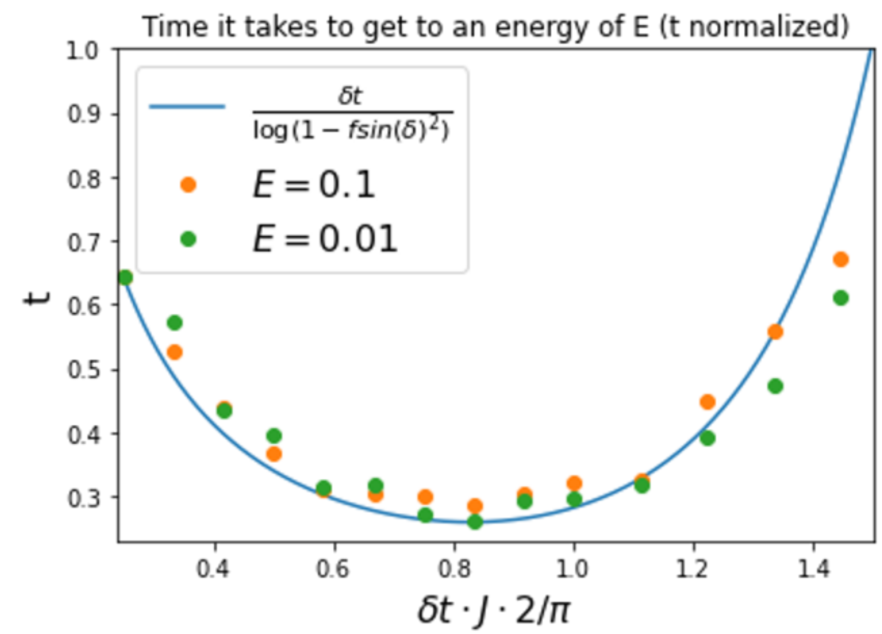

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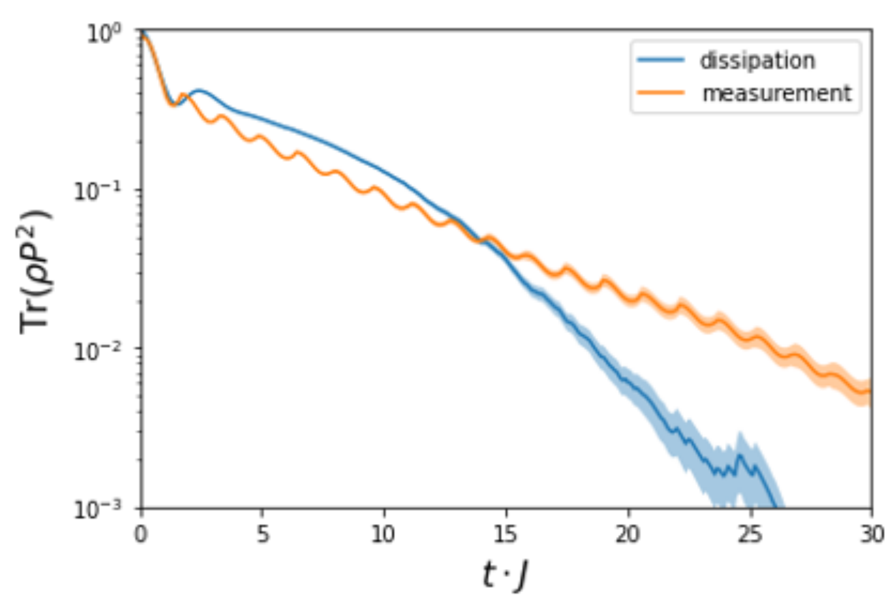

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