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A cavity quantum electrodynamics implementation of the Sachdev–Ye–Kitaev model

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The search for a quantum theory of gravity has led to the discovery of quantum many-body systems that are dual to gravitational models with quantum properties. The perhaps most famous of these systems is the Sachdev–Ye–Kitaev (SYK) model. It features maximal scrambling of quantum information, and opens a potential inroad to experimentally investigating aspects of quantum gravity. A scalable laboratory realisation of this model, however, remains outstanding.
In this talk, I will discuss our proposal for a feasible implementation of the SYK model in cavity quantum electrodynamics platforms (cQED) [1]. I will motivate how driving a cloud of fermionic atoms trapped in a multi-mode optical cavity, and subjecting it to a spatially disordered AC-Stark shift, can realise an effective model which retrieves the physics of the SYK model, with random all-to-all interactions and fast scrambling. Crucial to this endeavour are the ability to tune the number of cavity modes mediating the long-range interactions, as well as the size of the atomic cloud, as I will demonstrate at the hand of numeric simulations of the effective model's dynamics.
A further milestone in realising the above proposal, is the ability to introduce disorder into the cavity-mediated interactions in a controlled way.
I will discuss results from recent cQED experiments, which demonstrated this ability in the quantum simulation of disordered spin models [2].
Our work demonstrates the increasing capabilities of cQED quantum simulators, showing how these may be leveraged in the pursuit of studying quantum gravity in the lab.

[1] P. Uhrich, S. Bandyopadhyay, N. Sauerwein, J. Sonner, J.-P. Brantut, and P. Hauke, A cavity quantum electrodynamics implementation of the Sachdev–Ye–Kitaev model, arXiv:2303.11343 [quant-ph]

[2] N. Sauerwein, F. Orsi, P. Uhrich, S. Bandyopadhyay, F. Mattiotti, T. Cantat-Moltrecht, G. Pupillo, P. Hauke, and J.-P. Brantut, Engineering random spin models with atoms in a high-finesse cavity, arXiv:2208.09421 [cond-mat.quant-gas]

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