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Signatures of quantum chaos in the Yukawa-SYK model

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The Sachdev-Ye-Kitaev (SYK) model describes a strongly-correlated quantum many-body system consisting of N Majorana fermions with random all-to-all q-body interactions, exhibiting several intriguing properties. Notably, the SYK model displays maximal scrambling of mutual information and maximal quantum chaos. Additionally, the model is of significant interest in the context of the AdS/CFT correspondence, being holographically dual to Jackiw-Teitelboim gravity and sharing much of its interesting features with two-dimensional black holes.

Recently, a proposal has been put forward for the analog quantum simulation of the SYK model in a cavity QED experiment consisting of a cloud of fermionic atoms interacting with the eigenmodes of an optical cavity [1]. The cavity realizes long-range all-to-all fermion-fermion interactions, mediated by the exchange of virtual cavity photons. Furthermore, the interactions are randomized using an optical speckle pattern, approaching the SYK physics. This shows that the SYK model is within the reach of cQED-based experiments and a significant step forward in the search of holographic quantum matter. With this experimental proposal in mind, we investigate a generalization of the SYK model called the Yukawa-SYK model [2], incorporating a boson represented by the cavity photons in the experimental setup. We analyze the chaotic nature of the model by numerically computing the spectral form factor, a typical marker for the spectral statistics and diagnostic tool for quantum chaos.

[1] Philipp Uhrich et al. A cavity quantum electrodynamics implementation of the Sachdev–Ye–Kitaev model. 2023. arXiv: 2303.11343 [quant-ph]

[2] I. Esterlis and J. Schmalian, "Cooper pairing of incoherent electrons: An electron-phonon version of the Sachdev-Ye-Kitaev model,"Physical Review B 100, 1–26 (2019)

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