

Emergence of spin entanglement with the pseudogap onset in the Fermi-Hubbard model

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Despite decades of intense theoretical and experimental investigation, the two-dimensional Fermi-Hubbard model still resists a complete microscopic understanding. Conventional approaches typically probe global observables and locally resolved correlation functions. Here, we develop a complementary perspective based on the measurement of entanglement [1]. Using both an ultracold-atom quantum simulator and numerical simulations based on the dynamical vertex approximation, we find that entanglement is closely tied to the onset of the enigmatic pseudogap regime, see Fig.: spin-singlet entanglement emerges only as the pseudogap sets in and, in contrast to classical correlations, remains confined to nearest-neighbour sites in this regime. Our results, therefore, disfavour purely classical-fluctuation theories of the pseudogap and constrain microscopic models to those that develop nearest-neighbour spin-singlet entanglement at the pseudogap onset.

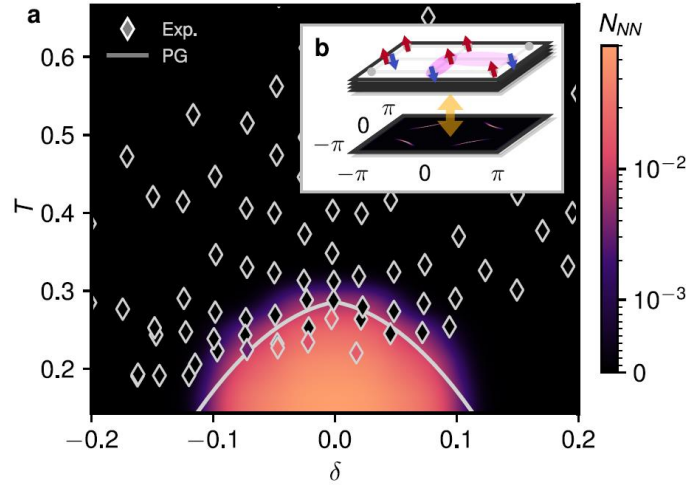


Fig.: Entanglement in the Fermi-Hubbard model between nearest neighbors (NN) as a function of doping δ and temperature T , as measured by the negativity N^{NN} under super selection rules. Diamonds: cold atom experiment; background: DGA; white line: onset of the pseudogap.

[1] F. Bippus, T. Chalopin, G. Bellomia, G. Roósz, T. Franz, A. Georges, A. Kauch, I. Bloch, K. Held, [arXiv:2605.31240](https://arxiv.org/abs/2605.31240)