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Quantum Computational Capability of a Two-dimensional Valence Bond Solid Phase

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Abstract:

I will talk about quantum computation by harnessing many-body correlations of a condensed-matter system. Quantum phases of naturally-occurring systems exhibit rich nature as manifestation of their many-body correlations, in contrast to our persistent technological challenge to build at will such correlations artificially from scratch. Here we show theoretically that quantum correlations exhibited in the two-dimensional valence bond solid phase of a quantum antiferromagnet, modeled by Affleck, Kennedy, Lieb, and Tasaki as a precursor of spin liquids and topological orders, are sufficiently complex yet structured enough to simulate universal quantum computation when every single spin can be measured individually. This unveils that an intrinsic complexity of naturally-occuring 2D quantum systems -- which has been a long-standing challenge for traditional computers -- could be tamed as a computationally valuable resource, regardless of our constraint not to create newly entanglement during computation. Our constructive protocol leverages a novel way to herald the correlations suitable for deterministic quantum computation through a random sampling, and may be extensible to other ground states of various 2D valence bond phases beyond the AKLT state. The main reference is arXiv:1009.3491.