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Qubit Regularization: Asymptotic Freedom via New Renormalization Group flows

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In order to study quantum field theories on a quantum computer we need to begin with lattice theories with a finite dimensional local Hilbert space. We view this as a new type of regularization of quantum field theories, and refer to it as qubit regularization, which can be explored both in Minkowski and Euclidean spaces. Such a finite dimensional regularization of a quantum field theory was proposed long ago as a general idea for many quantum field theories and was called the D-theory approach. Here the local Hilbert spaces were allowed to grow via an additional dimension if needed. The D-theory approach often provides a very good effective field theory of the original theory with a small additional dimension. However, we have recently discovered examples in $1 + 1$ dimensions where asymptotic freedom seems to emerge exactly even with a strictly finite dimensional local Hilbert space. But the renormalization group flow to the UV fixed point in these examples is quite novel. One starts with a critical quantum field theory which is quite different from the desired continuum asymptotically free quantum field theory. A relevant perturbation then takes us arbitrarily close to the desired theory. These examples implore us to understand if other asymptotically free quantum field theories including Yang Mills theories and QCD can also emerge via similar RG flows within a strict finite dimensional local Hilbert space. Qubit regularized Hilbert spaces of gauge theories do contain both confined and deconfined phases. The challenge is to discover Hamiltonians in the qubit regularized Hilbert space, which may be different from traditional Hamiltonians, but have interesting critical phase transitions between the phases and are governed by novel RG flows.

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