Quantum Information Processing "Ex Nihil" in Open Systems

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We present a universal comprehensive theory concerning (i) the *spontaneous* (bath-induced) *emergence* of quantum entanglement in multipartite systems immersed in thermal environments ("baths") and (ii) dynamical control aimed at manipulation or protection of this entanglement over times long enough for its applications. The theory allows for bath-enabled quantum computing (QC) protocols in the presence of decoherence and its dynamical control.

Collective coupling to a commonly occurring environment may naturally induce rather than impede the formation of entangled states [1, 2]. Here, we study the intriguing prospects for constructing arbitrary N-qubit gates and N-particle Hamiltonian engineering via dynamically controllable bath-induced entanglement (BIE). Initial estimates lead us to expect the feasibility of high-fidelity entangled states with $N \geq 100$ spins. Such states may be a starting point to the advancement of large-scale quantum information processing by local controls that are not constrained by adiabaticity conditions nor by the strength of coupling to the environment.

Dynamical control methods can protect multipartite entangled quantum states from decoherence and disentanglement by their environment [3, 4]. Such dynamical protection is the key to the coveted quantum computation, but also to better understanding of the transition from quantum to classical behavior.

The theory allows us to tackle intriguing questions regarding the evolution, control and processing of quantum information and thermodynamic properties (entropy) in open, complex systems. Our predicted counter-intuitive bath-induced effects may change our perspective of non-classicality in open quantum systems by identifying an unexpected class of natural entanglement. Progress along these lines may provide new, advantageous opportunities for quantum computing that can harness the environment to its advantage, rather than try to overpower it.

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