Mesoscopic physics challenges (in) superconducting quantum devices

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Superconducting quantum bits, or qubits, are at the forefront of quantum computing research. Harnessing the low loss properties of superconductors and the nonlinearity of Josephson junctions, qubits can be engineered to exist in quantum superposition states and they can be entangled, promising a new paradigm in information processing. By controlling and measuring these fragile quantum states, the community eventually aims to implement powerful quantum algorithms, which on some applications have a much more favorable scaling compared to classical counterparts. However, many challenges persist in maintaining coherence, mitigating noise, and enhancing gate fidelity. I will discuss three mesoscopic physics phenomena which significantly complicate the task of engineering coherent superconducting hardware: ionizing radiation interactions with the microelectronic qubit device substrate, long lived and uncontrolled two level systems which imprint a memory in the qubit's environment, and fluctuations in the transparency of aluminum oxide tunnel barriers which are at the heart of Josephson junctions.