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Probing anomalous two-level systems with a Cooper-pair box[1]

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We have used an Al/AlO_x/Al Cooper-pair box (CPB) qubit to detect coupling to anomalous "two-level" quantum systems. By measuring the excitation spectrum and lifetime of the first excited state from 15 GHz to 50 GHz of the CPB at a temperature of 40 mK, one can identify anomalous levels and ascertain the magnitude of the quantum noise that is coupled to the qubit. It was found that the frequency of a distinct avoided level crossing depends on gate voltage and the size of the splitting depends on the effective Josephson energy. Both the gate voltage and Josephson energy dependence are consistent with coupling to extraneous charged two-level systems formed by point charges that can tunnel between two positions in the oxide of the Josephson junction. By fitting a model Hamiltonian to our data, we are able to extract microscopic information about the charge fluctuator such as the well asymmetry ($\sim$ 130 micro-eV), tunneling rate ($\sim$ 8 GHz) and a minimum hopping distance for the charge fluctuators ($\sim$ 0.8 Angstroms).

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