Quantum mechanics predicts many effects that are counter-intuitive from the point of view of classical physics. In order to observe them, one has to prepare a given physical system in a very precise fashion, and then control it in an equally precise manner. A slightest interaction between the system and its environment („the rest of the world") leads then to a gradual disappearance of its truly quantum-mechanical properties, such as the existence of superpositions of quantum states (e.g. states of the system that cannot be described by ascribing to it well-defined classical parameters). This process of so-called decoherence makes quantum effects absent in every-day life, in which we deal with macroscopic objects that strongly interact with their environment (e.g. with light that falls at them and makes them visible to us). It also hampers the development of quantum computers that could exploit the laws of quantum mechanics to solve problems, which our classical computers cannot solve efficiently.

However, decoherence does not have to be treated as an obstacle. One can exploit the sensitivity of quantum systems to external stimuli. Small and spatially localized systems, such as electrons trapped in semiconductor quantum dots, can be used for characterization of perturbations coming from their environment (the so-called environmental noise) with nanoscale spatial resolution. Experimental works carried out in recent years have shown that spins (magnetic moments) of single electrons in semiconductors can be used as very precise sensors of local magnetic field fluctuations.

The goal of our project is understanding theoretically how much information about an environment of a given quantum nano-system can be gained from manipulation and readout of this system. Currently used methods of such "environmental noise spectroscopy" are based on multiple simplifying assumptions, the applicability of which to real-life situations is not fully understood. We want our research to give a full picture of decoherence of systems currently used as quantum nano-sensors, and to help in interpretation of existing and future experiments.