Generalized Pauli channels in the evolution of open quantum systems

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When examining the properties of quantum systems in a laboratory, it is very important to limit the influence of external factors. However, eliminating every type of interaction with the external world is an impossible task. Therefore, one needs to look at the quantum system not as isolated but open. Of course, this results in the need to use more sopohisticated mathematical formalism to describe the changes of the system's state. Instead of undergoing a unitary transformation, the state changes in such a way that its evolution is provided by completely positive, trace-preserving maps, also called quantum channels. My goal is to analyze the generalized Pauli channels, which generalize the random unitary qubit dynamics to higher-level systems.

Evolution of open quantum systems is a very complex and interesting topic that is popular among researchers. In the most common approach, one considers the evolution governed by the (constant-in-time) generator of the Markovian semigroup. In this case, the effects that earlier interactions could have on the current state of the system are neglected. Such an approximation is valid when dealing with most optical systems. However, to describe strong couplings and long-lived interactions with the environment, one has to go beyond the Markovian semigroup approach. There are two ways to include the non-Markovian effects in the evolution equations. One could either use the time-dependent generator or the memory kernel, where the evolution equation becomes integro-differential. Open quantum systems are considered in quantum informatics, quantum communication, quantum processing, quantum cryptography, and many others. Their analysis helps us to better understand many physical phenomena, such as quantum decoherence, dissipation, depolarization, or dephasing.

My research objectives are to analyze the evolution of open quantum systems provided by the generalized Pauli channels. While the channels constructed from the maximal number of mutually unbiased bases have already been characterized, not much is known about the channels in composite dimensions or the ones constructed from noncommutative subalgebras. It would be interesting to characterize these channels and their evolution in terms of the local and non-local master equations. In particular, I would like to find the conditions for admissible generators of evolution and memory kernels that lead to the generalized Pauli channels. I am planning to provide the conditions for Markovianity and non-Markovianity of quantum evolution. I believe that my results will allow for formulating new research hypotheses, finding interesting open questions, and better understanding of the subject.